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Direct farm, production base, traceability and food safety in China



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Abstract

With the rapid growth of China's economy, rising demand for safety food has been accompanied by frequent food safety scandals. Given that China's farming is dominated by millions of small-scale farms, ensuring food safety is a major challenge facing the public and private sectors. The direct farm (DF) program, initiated in 2008, represents one of the government's major initiatives to modernize the distribution of fresh fruit and vegetables (FFV) and improve food safety. Under the DF program, participating national and international retailers are expected to establish more direct procurement relationships with farm communities. While it is often claimed that greater participation by retailers in the production and post-harvest processing implied the DF program will lead to improved quality, safety and traceability, systematic evidence remains elusive as existing studies are largely narrative, based on case studies, or theoretical inference. Little empirical evidence is available for a broader evaluation of the DF program. This paper aims to fill this gap by assessing the overall performance of a single retailer's DF experience with respect to the procurement and food safety of FFV. We use data from a survey of production managers of 35 DF production bases (PBs) spread across 11 provinces, 3 cities and 1 autonomous region in China. The results show a mixture of opportunities and challenges. On one hand, the DF program improves production practices and distribution channels of FFV produced on its PBs, thus facilitating the move of China's food system towards improved food safety compliance. On the other hand, significant heterogeneity in the traceability of food and the ability of DF to meet higher safety standards is evident both across major product categories and across household-operated vs. firm-operated PBs. The paper concludes with policy implications.

Keywords: direct farm, production base, marketing chain, traceability, food safety

1. Introduction

Rapid and sustained growth in the three decades since China's market-oriented economic reforms has placed China squarely in the group of upper-middle income countries, with a corresponding large and growing middle class that is increasingly concerned about and willing to pay for high quality, safe fresh produce. Unfortunately, a series of

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food safety scandals in recent years suggests that China's domestic supply side has failed to keep pace with this increased demand for food safety (Gale and Buzby 2009; Gale and Hu 2012). For instance, the illegal and carcinogenic chemical additive Sudan IV was detected in eggs in 2006, while adulterated infant formula led to six infant deaths and more than five thousands babies sickened in 2008 (Lam *et al.* 2013). In 2012, thousands of food safety related incidents were reported by the Ministry of Health of China (Lam *et al.* 2013).

The frequent reports of food scandals have caused significant concern by the Chinese public about food safety, prompting the government to accelerate the restructuring and modernization of the agri-food system. In 2007, the *Law of Professional Farmers' Cooperatives* was passed to facilitate cooperative members' access to key production services and further promote vertical coordination along the agri-food chain (Deng *et al.* 2010; Jia and Huang 2011). The Chinese government has also provided substantial subsidies for investment in cold chain and logistics, land consolidation, and production inputs for specific high-value sectors, including fresh fruits and vegetables (Niu and Xia 2000; Waldron 2009).

In recent years, much of these government resources have been channeled to promote the development of production bases (PBs, the special form of farm organizations that coordinate the choice and timing of crops planted and utilizes) and the direct farm (DF) program (a PB with direct-procurement relationships with downstream retailers who introduced DF procurement relationships in the mid-2000s) in order to promote the standardization of food production and to improve efficiency and traceability in the food supply chain. Among the many initiatives to modernize the agri-food system in China, PB development and the DF program are considered as key tools to tighten food safety management. With agricultural production dominated by millions of small-scale farms¹ and farm-gate marketing dominated by a large number of small brokers, ensuring the delivery of safe and traceable food represents an enormous challenge.

One might imagine that the "supermarket revolution" may be an important driver of change in the agri-food system in China. Yet while the supermarket sector in China has grown rapidly since the late 1990's, by 2007, this downstream retail revolution did not lead to significant upstream changes in either production practices or the structure of the supply chain (Huang *et al.* 2008). Farmers are essentially free of accountability after selling their products, and food traceability is almost impossible.

The location of PB may consist of the farms of all or a

subset of villagers from one or more villages or a land area leased by an outside agri-business firm. In the former case, the PB is run by the villagers themselves in a contract farming or outgrower scheme, while in the latter case the base is run by the outside firm using either wage labor or through sub-leasing or sharecropping arrangements with local residents or migrant farmers.

Seeing its potential to enhance food safety and improve supply-chain efficiency, in 2008, the Ministry of Agriculture of China (MOA) and Ministry of Commerce of China (MOC) launched a government sponsored DF program that tries to directly link supermarkets with producers by procuring fresh produce directly from farmers or farmers' cooperatives (Gale and Hu 2012). The DF program is expected to promote traceability and to increase farmers' income by eliminating intermediaries. A handful of large supermarkets including Carrefour, Lianhua, Metro, Nong Gong, and Walmart participated as "pioneer enterprises" in the initial pilot stage of the DF program.

While the emergence of PBs and DFs in China has potentially important implications for food safety, little systematic evidence exists about the new institutions; existing studies are either narrative with little empirical evidence or based on one or a few qualitative case studies. For example, a number of papers published in Chinese journals have stated that DFs can or should improve food safety, but lack rigorous supporting (Hu *et al.* 2006; Zhang and Hu 2009; Li 2013). To our knowledge, only two papers in English-language journals address the food safety implications of the DF program in China (Miyata *et al.* 2009; Gale and Hu 2012), yet again, the insights are largely descriptive and narrative. Case studies in Chinese-language journals often focus either on describing the degree of traceability of food procured by supermarkets through DF programs (Gu *et al.* 2011; Hu 2012) or understanding food quality control within farm cooperatives (Hu *et al.* 2006; Hu 2010; Shi *et al.* 2012; Niu 2014). In sum, relatively little systematic data are available to explore the implications of emerging DF programs on food safety in China. To fill this gap in the literature, data from a larger and more representative sample of PBs participating in DF programs are essential.

This paper provides an in-depth examination of the DF program of a specific retailer, namely Walmart-China, and the implications of the DF program on food safety. Our analysis utilizes data collected from nearly all of fresh fruit and vegetable (FFV) PBs participating in Walmart's DF program in 2012 to answer the following questions: How is production and marketing organized DF PBs? Have PBs improved the traceability of FFV? To what degree are PBs

¹ The average farm size in China is 0.6 hectares (NBSC 2013).

able to comply with standards of food production and thus eventually strengthen food safety?

This study makes three distinct contributions. First, while existing studies are typically based on case studies or theoretical conjecture, our analysis is based on data from 35 PBs across 11 provinces, 3 cities and 1 autonomous region, representing nearly the universe of PB's supplying to Walmart's DF program. Second, we examine performance of the DF program across different product categories (fruits, leafy green vegetables, fruit/root vegetables) and across different land tenure and organizational structures of PBs. Third, Walmart facilitated our access the full set of intermediaries that (directly or indirectly) coordinate production and procure from the upstream PBs. This allows us to successfully trace the stakeholders upstream back to the farm gate, thereby enabling a better understanding of the application of food safety standards and traceability along the fragmented agri-food chain for FFV in China.

We acknowledge the scope of the study is limited given the complexity of the research topic. While the Chinese government tracks the retailers participating in the government-supported DF program, it does not maintain a registry of PBs. As such, quantitative data collection on PBs and other potentially sensitive aspects of FFV supply chain governance requires active cooperation with retailers. A fortunate collaboration with Walmart provided us access to key agents involved in the initial DF pilot program including Walmart purchase officers, private supply companies that coordinate and manage production of FFV on the PBs and farm managers of the PBs themselves. Although this study focuses solely on PBs where Walmart's pilot DF program operated (and the practice of DF might be different for other retailers), we believe that it offers a valuable contribution as one of the first in-depth, quantitative descriptions of DF procurement relationships, which may hold key insights for enhancing food safety in China.

The rest of the paper is organized as follows. The next section presents the data collection and field survey method. Section 3 investigates the organization of production and marketing in PBs for the DF program. Section 4 discusses safety, traceability and standards of vegetables and fruits produced in PBs. The last section concludes with a discussion of potential policy implications.

2. The sample and data

With the rapid rise of supermarkets in China, DF programs of major retailers have emerged steadily since the mid-2000s. Walmart began its DF (WDF) program in 2007 and was one

of the earliest DF programs in China. In 2008, the Chinese government officially initiated its program to support retailers' adoption and expansion of DF programs. In October 2009, Walmart signed a memorandum to promote DF cooperation with the MOA and MOC. One year later, Walmart had established relationships with 56 PBs with a total cultivated area of about 500 000 Mu (15 Mu=1 ha) across 18 provinces. The number of PBs increased to 80 by 2012, of which 44 specialized in vegetables or fruits. Walmart established a number of key criteria for a PB to be eligible to supply to its DF program including: a minimum area planted in specific fruits or vegetables, sufficient managerial and coordination capacity to understand and meet Walmart's quality and safety requirements, and access to high quality transportation infrastructure. With respect to food safety, PBs were expected to meet standards for maximum levels of soil and water contaminants, minimum distance from major urban or industrial sites and appropriate use of pesticides.

The data used in this study were obtained from a survey on WDF's fruit and vegetable PBs. During the fall of 2012, we were able to visit 38 of the 44 PBs supplying FFV to the WDF program². Of these 38, we collected full data for 35 PBs which are used in this study. These 35 PBs are located in 31 counties in 11 provinces, 3 cities and 1 autonomous region throughout China. Of the 35 PBs, 20 primarily produced fruit and the remaining 15 PBs primarily produced vegetables. Table 1 shows the location of these PBs by region. As far as we know, the size and geographical coverage of our sample significantly exceed those of existing studies about DFs in China and the related management of food safety.

For each PB, we interviewed both a leader of the local PB and a manager of the supply company that links the flow of produce from the PB to Walmart. PBs, in turn, can be divided into two broad categories: those managed by village households who cultivate their own landholdings and those directly managed by the supply company which coordinates production on the base using wage labor and/or sub-leasing arrangements. We refer to the former category as household-operated PBs and the latter as firm-operated PBs. For household-operated PBs, we interviewed both the supply company manager and the leader of village or farmers' cooperative as he/she often was typically also the leader of the PB. For firm-operated PBs, we interviewed the employee of the supply company responsible for managing production on the farm base. The data collected and used in this study include the history, size and organizational structure of the PB, as well as the base's crop portfolio, pesticide use, marketing channels, and the presence of any government or private certifications of food safety and quality.

² The six production bases were not visited because of difficulties to find the managers of supply companies during our surveys.

Table 1 The regional distribution of sample production bases¹⁾

Region ²⁾	All	Vegetables	Fruits
North and Northeast China	14	4	10
East China	5	2	3
Southwest and Northwest China	7	3	4
South and Central China	9	6	3
Total	35	15	20

¹⁾ Source: Authors' survey. The same as below.

²⁾ North and Northeast China include Beijing City, Hebei, Liaoning and Shandong provinces. East China includes Shanghai City, Jiangsu and Fujian provinces. Southwest and Northwest China includes Chongqing City, Sichuan Province and Xinjiang Autonomous Region. South and Central China includes Guangdong, Hubei, Hunan, Jiangxi and Yunnan provinces.

3. Production base: formation, operation and marketing

The structure and composition of the supply chains that connect fresh produce from PBs to retail outlets in Walmart's DF program are complex and heterogeneous. In this section, we first examine the timing of the formation of PBs. We then analyze and compare the organization of production and modes of marketing of the two classes of PBs. Through this analysis, we seek to understand the nature of DF and how production and marketing are organized under Walmart's DF program.

To structure our analysis, we classify and compare the 35 sample PBs along two axes. First, we divide the sample into firm-operated PBs, of which there are 18, and household-operated PBs, of which there are 17 (Table 2). The second axis of classification is the primary crop type grown on the PB. The survey identified the five most important crops in terms of value of production sold to Walmart during the previous 12 months. We classified each PB into one of the following crop categories based on these top five crops: fruit (20 PBs), leafy green vegetables (6) or fruit/root vegetables (9). We distinguish between the two broad vegetable categories to acknowledge the potential differences in organization and production patterns for highly perishable leafy greens, such as lettuce and spinach vs. less perishable fruit/root vegetables such as tomatoes, peppers

and radishes. When the top 5 crops included crops from more than one category (i.e., spinach and radishes), we classified the PB according to the category with the highest value among the top five.

3.1. Production base formation

More than half of the sample PBs were established before 2008, the year the DF policy was first launched by Chinese government and also before Walmart started its DF program. For firm-operated PBs, about 56% (10 of 18) were set up before 2008 (Table 2). The number was slightly higher for household-operated PBs (10/17 or nearly 60%). Similar patterns were found by product category (columns 3–7, Table 2). These results suggest that Walmart's DF program started with already-existing production bases that could meet the food safety suggest and quality criteria established by Walmart's DF program.

3.2. Production organization

In general, fruit PBs are much larger than vegetables PBs. The average size of the fruit PB was 120 ha for a firm-operated PB and 183 ha for a household-operated PB (Table 2). The average size of an individual farm on household-operated PBs was small, 0.33 ha (183/559) for fruit PBs and 0.17 ha (50/299) for fruit/root vegetable PBs (Table 2), suggesting that the expansion of household-operated PBs may be more inclusive than firm-operated PBs in term of farm size. It is interesting to note that all six of the leafy green vegetables PBs in our sample were firm-operated.

We also collected information on the total number of different crops grown commercially (i.e., for sale as opposed to home consumption) on each PB. As seen in Table 2, fruit PBs typically specialized in a single crop. This is explained, in part, by the fact that the fruits grown on the PBs were primarily perennials including: apples, peaches, pears, sweet pomelos, navel oranges, jujubes, blueberries and grapes. Production on fruit/root vegetable PBs was significantly more diversified, with an average of 7 distinct crops grown

Table 2 Characteristics of sample production bases (PBs) in 2012

	All		Fruits		Leafy vegetables	Fruit/Root vegetables	
	Firm ¹⁾	HH ²⁾	Firm ¹⁾	HH ²⁾	Firm ¹⁾	Firm ¹⁾	HH ²⁾
Number of PBs	18	17	5	15	6	7	2
Set up before 2008	10	10	2	9	3	5	1
Size of PBs in 2012 (ha)	96	168	120	183	87	86	50
Number of households	n.a.	527	n.a.	559	n.a.	n.a.	299
Number of crops	7.8	1.7	1.4	1.0	11.8	9.2	7.0

¹⁾ Firm represents the firm-operated production bases. The same as in Table 3.

²⁾ HH represents the household-operated production bases. The same as in Table 3.
n.a., not applicable.

on household-operated PBs and 9.2 on firm-operated PBs (Table 2). The number of different crops produced on leafy green vegetables PBs was even higher, at just under 12. Major leafy vegetables includes baby bok choy, Chinese flowering cabbage, spinach, cabbage mustard, lettuce, and amaranth leave. Tomato, cucumber, eggplant, broccoli and radishes were commonly grown on fruit/root vegetable PBs, as well as small amounts of garlic and bitter melon.

Production on fruit and vegetable PBs was organized in distinct ways. For fruit PBs, the supply companies typically opted for a conventional contract-farming relationship with individual households who produced on their own land. These household-operated PBs accounted for 75% (15/20) of the 20 fruit PBs, vs. only 22% (2/9) of fruit/root vegetable PBs and, interestingly, none of the leafy green vegetable PBs (Table 2). The relative importance of household vs. firms in the operation of farm bases is reversed for vegetable PBs; 100% (6/6) of leafy vegetable and 78% (7/9) of fruit/root vegetable PBs were operated by firms (Table 2). This finding is consistent with Eswaran and Kotwal's (1985) dual-sided moral hazard model of agrarian organization that predicts that the supply company would directly provide managerial expertise under wage labor arrangements of those crops whose quality requires significant coordination regarding the timing of planting, crop rotation and harvest, as well as those crops with the most demanding food safety requirements, such as leafy vegetables due to their strict pesticide residual requirements. In contrast, for crops for which managerial decision making and interaction with complex markets is less important, such as apples and other tree crops, the supply company is more likely to choose a more conventional contract farming relationship with household farmers using their labor-supervision advantage under direct owner-operation based production.

3.3. Marketing channels of production bases

In the previous section we saw that there exists an interesting heterogeneity of organizational structure across the PBs supplying to Walmart's DF program. We now turn to the question: "To whom are these PBs selling their fresh produce?" We identify the primary marketing channels and examine whether the relative importance of the channels varies by crop category and organizational form (i.e., household-operated vs. firm-operated). Our survey included questions about marketing and distribution from the PB that were directed separately to the local PB manager and the supply company manager responsible for procuring from the PB. We asked the local PB manager about the relative importance of modern (supermarkets and export firms, direct sales to consumers and agro-processing companies)

and traditional (wholesalers and local brokers) outlets for the total value of sales from the PB in the last 12 months. We asked the supply company manager about the relative importance of procurement from PBs vs. other sources, such as wholesale markets in their overall fresh produce portfolio.

It is worth noting that the contractual relationship between the supply company and PB is not exclusive as the PB can sell its produce to multiple outlets, including other supply companies. While owner-operated PBs are more diversified in the sales outlets, some firm-operated PBs also sold to multiple outlets. This occurred in those PBs in which land was acquired by the outside firm and sub-leased back to farmers who, in turn, were required to sell some, but not all, of their production to the firm.

Marketing patterns are presented in Table 3 and Fig. 1. We find that modern channels were the major sales outlets for all types of PBs. Even before 2008, among the 35 sample PBs, 57% (20/35) had experience with direct sales to supermarket and/or export firms, and 20% (7/35) had already begun a formal DF relationship (column 1, Table 3). In 2012, the year covered by our survey, the percentage of the value of PB produce sold to modern channels reached 79%, with 67.8% to supermarkets and export firms, 8.8% direct sales to consumers and 1.6% to processors (Fig. 1). In the case of vegetable-growing PBs, the proportion of products sold to modern channels was even higher (columns 4–6, Table 3). A smaller percentage, although still the majority, of the sales value from fruit PBs went to modern outlets. A closer examination of our data shows that firm-operated PBs sold more of their fruit through modern marketing channels than household-operated PBs (columns 2–3, Table 3). Among household-operated PBs, farmers sold 31% of their produce to wholesalers and 4% to small brokers. Even for the household-operated PBs, however, the relatively high importance of modern marketing channels is a distinguishing features of DF PBs and suggests that this new institutional arrangement is quite different than the typical marketing situation of fresh produce producing households in rural China. For example, in their survey of fruit producing villages in China, Huang *et al.* (2008) found that only 9% of fruit was sold through modern channels, while the rest was sold through traditional marketing channels such as small wholesalers and small, local traders and brokers.

4. Food safety, traceability and standards

4.1. Pesticide use and acquired services

Chemical pesticides are intensively used in China's agricultural production and the ensuing high levels of pesticide residues has become one of major food safety concerns in

China (Huang et al. 2003). Among crops, vegetable and fruits have the highest pesticide application.

The level of use and types of pesticides used on PBs associated with DF programs is a particularly interesting question. One may imagine that retailers' concerns with providing safe food to consumers would imply that participating PBs would use pesticides in ways that would reduce food safety concerns. Yet relatively little is known about pesticide use in crop production associated with DF programs. To our knowledge, only a few case studies have investigated the use of pesticides on DF PBs in China. Niu (2014) showed that pesticide use reduced in vegetable and fruit PBs in Liaoning Province. Hu et al. (2006) show that the percentage of farmers of apple PB in Shandong Province using non-toxic pesticide has already reached 75.4%.

In this section, we add to the scarce empirical evidence on pesticide use on vegetable and fruit DF PBs. During our survey we asked the following questions related to pesticide use that can be used to infer food safety implications: "Who decides the types of pesticide used in your PB?" "Does the

supply company directly provide any pesticide to your PB?" While we did not collect quantitative pesticide use data, our field surveys suggest that if the supply company provided advice and technical assistance regarding pesticide use, lower quantities and less toxic types of pesticides were used with likely positive implications for food safety. Major results are summarized below.

On about 60% of sample PBs, pesticide types and level of use were determined and pesticides were provided by supply companies. This number varied somewhat across vegetable and fruit PBs. Overall, supply companies determined pesticide use for 57% of the PBs (column 1, Table 4). This percentage was higher for PBs specializing in fruit/root vegetables (78%) than those specializing in fruit (45%). This might be due to the fact that fruit PBs are typically much more specialized in one or a small number of fruit varieties while vegetable PBs are much more diversified and therefore require greater knowledge of pesticides, which farmers may not possess. Similar results are found regarding the provision of pesticides to PBs; 60% of all sample PBs received

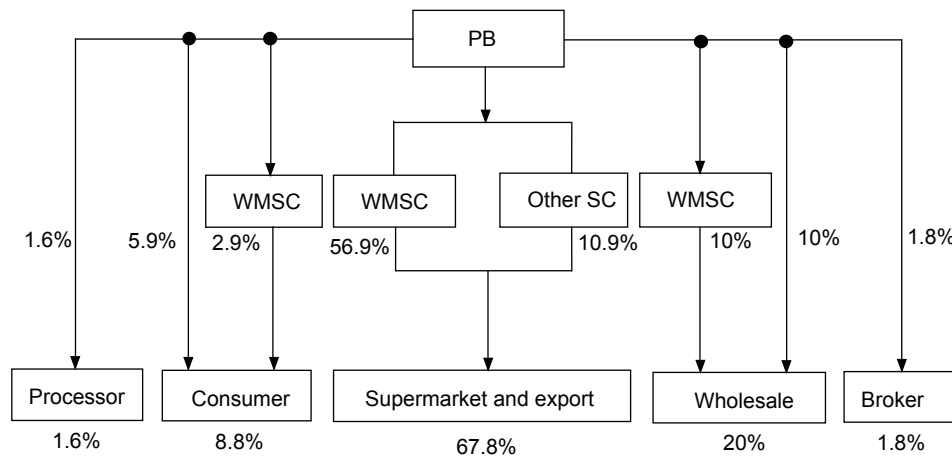


Fig. 1 Marketing channels of all 35 production bases in 2012. PB, production base; WMSC, Walmart's supply company. SC, supply company.

Table 3 Marketing of vegetables and fruits by type of production base

	All	Fruits		Leafy vegetables	Fruit/Root vegetables	
		Firm	HH	Firm	Firm	HH
Number of PBs in 2012	35	5	15	6	7	2
Sell to supermarket & export before 2008	20	3	8	3	5	1
DF started before 2008	7	1	1	1	4	0
Marketing channels in 2012 (%)						
Supermarket & exporters	68	64	58	92	77	73
Consumer ¹⁾	9	20	6	2	11	15
Processor	2	10	0	0	0	0
Wholesaler	20	6	31	6	12	13
Broker	2	0	4	0	0	0

¹⁾ Consumer means the products of production bases are directly sold to consumers such as restaurants, online sales, and local consumers.

some pesticides from a supply company. This percentage ranges from 45% for fruit PBs to 78% for fruit/root vegetable PBs (column 1, Table 4).

The role of supply companies in determining pesticide use also differs across firm-operated and household-operated PBs. The supply company made decisions over pesticide use and provided pesticides to 72 and 78% respectively of firm-operated PBs (column 2, Table 4). This high importance of supply companies is not surprising because a large proportion of the firm-operated PBs were directly set up and operated by the supply company. Supply companies did not determine pesticide use on all firm-operated PBs. This may be explained by the fact that, as mentioned above, some firm-operated production sub-leased land to individual households who then directly managed production, making it more difficult for supply companies to control for pesticide use.

Compared with firm-operated PBs, household-operated PBs were less likely to receive technical support on pesticide use from their supply companies, although at 41%, the share is non-negligible (column 3, Table 4). This lower degree of control of pesticide by outside supply companies on household-operated PBs may have important implications for food safety because, in the absence of information and supervision from an outside agent such as a supply company, the typical Chinese farmer obtains inputs from the market based on their own decisions and applies large quantities of pesticides to maximize yields with minimal understanding or concern for food safety implications (Huang *et al.* 2008).

4.2. Food traceability

The ability to track fresh produce from retail back to its farm origin allows firms and governments to identify sources of contamination and other potential causes of accidents and,

depending on the nature and enforcement of liability laws, provides incentives to producers and suppliers to comply with food safety regulations. Thus, although traceability of fresh produce throughout the supply chain is not a direct measure of food safety, it is critical to ensure food safety (FMRIC 2008). Several studies provide insights into efforts taken by major supermarkets in China to increase traceability in their food supply chains (Gu *et al.* 2011; Hu 2012). To our knowledge, however, no study provides empirical evidence on food traceability under DF programs.

To examine the traceability of fruits and vegetables in Walmart's DF program, we asked the supply companies that procure fresh produce for Walmart's DF program to identify the relative importance of difference sources, including contracts with DF PBs, spot market transactions with other farmers, other traders and wholesale markets. If the produce was sourced exclusively from the DF PBs, we consider the produce as potentially traceable³. If the produce was instead sourced from wholesale markets or simultaneously from both DF PBs and other farmers outside (and often nearby) the PBs, then it is very difficult to trace the produce back to the farm. As such, we consider produce procured under this situation as non-traceable.

Our data suggest that while Walmart's DF program improved the traceability of fresh produce relative to traditional procurement through wholesale markets, traceability was far from complete. Just over half (51%) of sample supply companies sourced exclusively from their PBs (Table 5), while just under half (49%) procured at least some fruits and vegetables from farmers outside of PBs. Conversations with supply company managers suggest that one of the major reasons for the above phenomenon is the inability of many PBs to meet certain quality standards. In order to fulfill purchase orders from Walmart, these supply companies often

Table 4 The roles of supply companies in pesticide use by types of production base, 2012 (%)

	All	Firm	Household
PBs with pesticide use decided by supply company ¹⁾			
All	57	72	41
Fruits	45	60	40
Leafy vegetables	–	67	–
Fruit/Root vegetables	78	86	50
PBs with pesticides provided by supply company			
All	60	78	41
Fruits	45	60	40
Leafy vegetables	–	83	–
Fruit/Root vegetables	78	86	50

¹⁾ The decision includes the type and the quantity of pesticide uses. –, no sample in this group. The same as below.

³ Of course traceability also depends on how the retailer manages produce after delivery from the supply company. We focus only on traceability in the supply chain until delivery to Walmart.

had to procure from farmers growing the same crops nearby the PBs. An additional reason to source from non-DF PBs is that Walmart was increasing pressure for supply companies to provide fresh produce year-round. This obliged some supply companies supplying seasonal products to source from regions where they had not yet established PBs.

Turning from crop to organizational-based differences, the degree of traceability differed significantly across firm-operated vs. household-operated PBs. Recall that we asked supply company managers about how they met purchase orders for Walmart's DF program, and specifically if they met the demand solely through the DF PBs or if they also relied on spot transactions with outside farmers or wholesalers. The percentage of supply companies that sourced produce exclusively from firm-operated PBs was 61%; ranging from 57% for fruit/root vegetables to 60% for fruits and 67% for leafy green vegetables (column 2, Table 5). In contrast, a significantly lower percentage of supply companies were able to source solely from household-operated PBs; 47% for fruits and 0% for fruit/root vegetables (column 3, Table 5). The higher incidence of sole reliance by supply companies on firm-operated vs. household-operated PBs suggests that the traceability of produce coming from firm-operated PBs is higher than from household-operated PBs. This is not surprising since, when farm-land is consolidated by an outside firm, the firm can directly coordinate and manage production *via* wage labor or sub-leasing arrangements. The greater control over production, including the crops and specific varieties planted, the timing of planting and rotation of crops, and specific production practices such as weeding, fertilization, and pesticide application that make it more likely that the PB will meet the quantity, quality and food safety requirements of retailers, such as Walmart, without the need to turn to untraceable outside, spot market transactions.

4.3. Standards of food safety and quality

In this final section, we examine the acquisition of formal certifications of quality and safety by PBs. In China, both public and private certifications of food quality and safety at the farm level exist. We use the acquisition of certifications as an additional indicator of food safety across DF PBs in our sample.

The Chinese government established three separate levels of farm-based certification, each of which is enforced by the MOA (Zhou *et al.* 2011). The minimum and obligatory level "no-harm" or "hazard-free" food. This "no-harm" standard seeks to limit the presence of toxic residues, heavy metals and nitrates by banning the use of certain chemical inputs and limiting the intensity of use of permissible inputs according to a set of national standards (Huang *et al.* 1999). "green food" is a voluntary and more restrictive standard that

Table 5 Percentage of the DF suppliers that procured fruits and vegetables only from their production bases (or no procurement from farmers outside of production bases) in 2012

	All	Firm	Household
All	51	61	41
Fruits	50	60	47
Leafy vegetables	–	67	–
Fruit/Root vegetables	44	57	0

establishes tighter restrictions on the types and amounts of chemical inputs. This standard also focuses more on environmental protection and sustainable development, and every stage of the "green food" production process must meet specified standards of environment protection (Liu *et al.* 2013). Finally, the most rigorous and restrictive standard is "organic food", which conforms to international norms for organic certification and prohibits the use of chemical inputs such as artificially synthesized fertilizers and pesticides. Because "no-hazard" standard is the required standard for PB in our sample, we thus focus our analysis on "green food" and "organic food".

In addition to public standards, a number of private standards exist in China and are certified through third parties. These private standards, which include Good Agricultural Practices (GAP); Hazard Analysis and Critical Control Point (HACCP); International Standardization Organization 9000 (ISO 9000); Good Manufacturing Practice (GMP); Quality Safety (QS), are designed to assure consumers and especially retailers that products are produced and handled following specific practices to maintain consistent safety and quality standards as well as to meet other objectives related to labor and environmental standards (Zhou *et al.* 2011). Among our sample of PBs, GAP was the only private certification acquired and we thus restrict attention to it in this study.

The results of our survey show that percentages of PBs with either public or private food standard certificates differed among fruit, leafy green vegetable, and fruit/root vegetable PBs (Table 6). By and large, both fruit and fruit/root vegetable PBs met food standards much better than leafy green vegetable PBs. There were 45 and 30% of fruit PBs had the public "green food" and "organic food" certificates, respectively (column 1, Table 6). Meantime, more than one third (35%) of fruit PBs obtained the private GAP certificate. These findings should be considered as a great step forwards food safety. For example, according to the official data, nationwide less than 5% of China's fruits were produced with green food certificates in 2012 (CGFDC 2012). However, the leafy green vegetable PBs were exception, none of them obtained any public (green food and organic food) or private (GAP) certificates (column 2, Table 6). The nature of fruit and vegetable production

may help to explain the above variations. For example, leafy green vegetables cover much wide range of products within a single PB (Table 2), resulting in more complicated farm management. While one fruit PB normally produced only one of major fruits such as apple, grape, peach and orange. Average number of vegetables produced in leafy green PBs (11.8) was also more than that (about 7–9) in fruit/root vegetable PBs (Table 2).

Interestingly, firm-operated PBs had more likely to have food safety standard certificates than household-operated PBs. For firm-operated fruit PBs, 60% of them received green food certificates and 40% of them had organic food certificates (column 2, Table 6). While the corresponding numbers were much lower (40% for green food and 27% for organic food; Column 3, Table 6) in household-operated fruit PBs. The most significant difference was observed in meeting the requirement of GAP. There were as high as 80% of firm-operated PBs that had obtained GAP certificate by 2012, the number was only 20% for household-operated PBs (Table 6). This difference can be explained by the fact that, on average, there were 559 households within a fruit PB (Table 2), their production decisions and practices could differ largely and therefore are difficult to follow the same standard of fruit production. For fruit/root vegetable PBs, percentages of firm-operated PBs that had green food, organic food and GAP were 71, 29, and 14%, respectively. While these numbers were zero for household-operated fruit/root vegetable PBs (Table 6).

5. Discussion and conclusion

China's recent ascension to the tier of "middle-income" countries and the accompanying emergence and rapid expansion of China's middle class has led to a rising demand for high quality and safer food. Domestic supply has struggled to keep pace as evidenced by the frequent occurrences of food safety threats. Given the fact that farm production in China is dominated by millions of small-scale households and fresh food supply chains are comprised of large numbers of traders, small brokers and wholesalers, ensuring food safety along the food supply chain represents a major challenge. Since 2008, the government has provided strong support to supermarkets to establish DF programs to create more direct relationships between modern retailers, their suppliers and farm communities and, in so doing, improve food quality and safety. Although the government's support for DF programs in China has existed for nearly a decade, little empirical data exist to evaluate the food safety implications.

Using a unique data set collected in collaboration with Walmart-China, this study shows that the relationship between the supply companies and the PBs from which they source fresh fruit and vegetables is complex. About

Table 6 Percentage of production bases with public and private certification in 2012 (%)

	Average	Firm	Household
Fruits			
Green food	45	60	40
Organic food	30	40	27
GAP	35	80	20
Leafy vegetables			
Green food	–	0	–
Organic food	–	0	–
GAP	–	0	–
Fruit/Root vegetables			
Green food	56	71	0
Organic food	22	29	0
GAP	11	14	0

GAP, Good Agricultural Practices.

half of the PBs supplying to Walmart's DF program are household-operated, i.e., organized and managed by large numbers of small, owner operated family farmers in one or more villages. The other half consists of firm-operated PBs in which the supply company acquires land from farmers and villages and directly coordinates and manages production via wage labor and/or sub-leasing arrangements.

This study provides empirical evidence on the roles that the DF program has played on food safety for vegetables and fruits. We examine the degree to which the greater vertical integration and coordination implied by DF programs positively influences production practices and distribution in ways that contribute to improving food safety.

Our first key finding is that the supply companies that linked PBs to Walmart retail stores in 2012, provided technical assistance regarding pesticide use (the types, quantities and timing) to about 60% of sample PBs. A similar percentage of PBs directly received pesticides from the supply companies. We also found that the frequency of providing pesticide-related services was significantly higher on vegetable than fruit PBs. This is likely a result of the greater complexity of pest management on vegetable PBs that are characterized by highly diversified portfolios of short-cycle crops. The provision of pesticide management services by specialized outside firms (supply companies) who are likely better informed about pest management techniques and food safety regulations than villagers represents a significant step that may reduce the risk of food-safety related insecurity caused by uninformed pesticide use by millions of small farmers.

Second, a strong majority of production from PBs is distributed through modern channels associated with the outside supply companies who either contract with or directly manage the PB. About 80% of vegetables and fruits produced in PBs were sold through modern channels in 2012, which stands in stark contrast to the general situation

of farmers in China who rely on traditional marketing channels such as small wholesalers and brokers. Among PBs in our sample, the share of production sold through these modern channels gradually increases with the move from PBs specializing in fruits, to fruit/root vegetables to leafy green vegetables. Similar to the trend in production, the firm-operated PBs more intensively sell produce through modern channels than the household-operated PBs. But even for household-operated PBs, about 65% of fruits and more than 80% of vegetables were also sold through modern channels in 2012.

Third, although the DF program has the potential to significantly improve food traceability, realizing this potential will require overcoming several challenges. Currently, about half of the supply companies procure their fruits and vegetables exclusively from the DF PBs. The remaining half procured from the PBs and through spot transactions with other farmers outside the PBs and local traders. This outside procurement makes it virtually impossible to trace food back to the source and seriously compromises overall traceability of the DF program. Expanding PBs to cover more farmers and villages in order to reduce the need for intermediaries to turn to outside sources thus seems essential to meet the demand for the DF program.

Finally, a number of PBs have acquired public and/or private certification for voluntary quality and safety standards, providing a strong indication of a commitment to improving food safety among some supply companies/PBs. The incidence of certification, however, varies widely across types of PBs, with a much higher incidence of certification among firm-operated than household-operated PBs. In particular, no household-operated fruit/root vegetable PB in our sample had acquired any voluntary certification.

The findings of this study have several policy implications. First, the DF program should be further promoted in broader areas. A recent study shows that despite the expansion of DF programs, the percentage of villages with at least one government-recognized DF PB associated with any retailer was only about 3% in 2012 in the counties where Walmart's DF program operated (Huang *et al.* 2014). There would thus appear to exist a large potential to expand the DF program to cover many more villages in rural China. Second, our findings also suggest that the potential to improve production practices and marketing arrangement for ensuring food safety in the existing PBs is still high. For example, our results show that the traceability of food and the ability to reach higher standards of food safety differ across product type and across firm-operated and household-operated PBs. Improving the current DF program to reach higher safety standards of production and marketing should be one of policy priorities in the future. Finally, in its current form, the DF is not truly a direct linkage between supermarkets

and farmers on the PBs. The relationship between retailers and farm communities is intermediated by supply companies who provide a range of specialized services including land consolidation, production management and technical assistance, packaging, transportation and storage. Given the extremely small farm-size and relatively low levels of human and financial capital of farm households in China, these intermediaries may be necessary to provide both the capital and scale required to modernize supply chains for fresh produce. Yet one wonders if well-organized producer cooperatives would represent an alternative path in which retailers such as Walmart could contract directly with farmers. Identifying the conditions that would favor success for this type of DF program that truly directly links supermarkets and farmers on PBs would be well worth exploring as the elimination of additional layers of intermediation may have strong, positive implications for meeting goals for traceability and food safety.

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