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Short supply chain participation and market performance for vegetable farmers in China*

Xiaoheng Zhang, Ping Qing and Xiaohua Yu †

The fresh food supply chain in China has begun to reduce the number of intermediaries that connect producers and consumers. Using farm-level data, this paper investigates the impacts of short supply chain participation on vegetable farmers' market performance, including profits, productivity, production cost, price and price risk. The results show that the participation in a short supply chain is a profit-maximising strategy and risk management tool for farmers. The increase in profit is attributed to productivity advantages, farm size expansion, and risk reduction rather than because of price premiums or cost savings. A policy implication is that short supply chain promotion has many benefits, but the government should be more concerned about the sustainability of short supply chains.

Key words: farmers' income, market performance, price risk, productivity, short supply chain.

1. Introduction

Fresh food supply chains in China are evolving with a reduction in the number of intermediaries that connect producers and consumers. Motivated by rapid urbanisation and increasing incomes, many new marketing channels have emerged in response to consumers' concerns for food quality and safety (Rao and Qaim 2011; Wang *et al.* 2014a), such as farming-supermarket docking, direct sales to restaurants and canteens, you-pick operations and community supported agriculture. Although the conventional long supply chain efficiently distributes food across the country, consumers know less about the provenance of their food because many intermediaries are involved (Calvin *et al.* 2006). These new marketing channels reduce food miles between farmers and consumers and increase consumer knowledge about the origin of their food, how it was produced, and who produced it.

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† Xiaoheng Zhang is Associate Professor and Ping Qing is Professor at the College of Economics and Management, Huazhong Agricultural University, China. Xiaohua Yu (e-mail: xyu@uni-goettingen.de) is Professor at the Department of Agricultural Economics and Rural Development, University of Goettingen, Germany. Xiaohua Yu is Visiting Professor at the School of Agricultural Economics and Rural Development, Renmin University of China, China.

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Moreover, the closer connection between farmers and consumers has the potential to build trust. Consumers are more likely to trust farmers to produce the food in a safe manner because they can monitor the production process and trace problems to the farmers when the supply chain is short (Hendrickson and Heffernan 2002; Kirwan 2004). These new marketing channels are generally defined as short supply chains, that is, farmers sell their products through one intermediary or directly to consumers. The short supply chains have overlapping characteristics with local food systems and direct marketing, which have been studied in the literature (Uematsu and Mishra 2011; Wang *et al*. 2014b; Mundler and Rumpus 2012). The market share of short supply chains account for approximately 30% of China's total agricultural sales at the end of twelfth 5-year plan[1] (2011–2015).

The development of short supply chains is also consistent with one of the motivations for the Rural Revitalisation Strategy proposed in 2017 by the Chinese government. Short supply chains have potential social and local economic benefits (Hendrickson and Heffernan 2002; Kirwan 2004; Otto and Varner 2005; Kneafsey *et al*. 2013). The development of short supply chains is beneficial to local economic regeneration because of the multiplier effects (Otto and Varner 2005; Kneafsey *et al*. 2013) created by maintaining local employment and retaining a higher share of value added locally. For example, the estimated multiplier effect in Iowa is 1.58 (Otto and Varner, 2005). The short supply chain also has potential to promote interaction and trust between farmers and consumers that may further contribute to inclusive social and behavioural changes (Kneafsey *et al*. 2013).

Whether farmers could achieve additional economic incentives is crucial to the sustainability of short supply chains. The farm-level economic impacts of short supply chains have been extensively studied, but no general conclusion has been reached. One of the most commonly expected economic benefits associated with the short supply chain is increased income for farmers. In theory, the elimination of intermediaries increases farmers' share of the profits. On the other hand, Hu *et al*. (2012), Meas *et al*. (2015) and Lim and Hu (2016) have demonstrated that consumers are willing to pay significantly more for home-province food or food produced locally. Henneberry *et al*. (2009) and Wang *et al*. (2014b) have demonstrated that a short supply chain has a significant positive impact on farmers' incomes. By contrast, Uematsu and Mishra (2011) observed that participation in farmers' markets—one type of short supply chains—is negatively correlated with farmers' gross income. This result may contribute to harsh competition among farms and markets and a low profit margin. Another explanation is the short supply chain reduces the prices in the retail market significantly (Aysoy *et al*. 2015), but there may be no price premium for farmers. In addition, Sage (2003) argued that farmers' low monetary return would be compensated in part by the enjoyment of providing their food to familiar consumers.

[1] Source: http://cpc.people.com.cn/GB/64093/64387/13396631.html.

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The purpose of this study is to provide a comprehensive picture of the impacts of short supply chain participation on farmers' market performance in China. In addition to evaluating the impacts of short supply chains on farmers' profits, this paper identifies the impetus that influences profits. The farmers' profits are determined by yield, average cost, and price. First, this paper investigates how short supply chains affect farms' yield. Second, this study evaluates the impacts of short supply chains on average costs, and prices. Farms' participating in short supply chains may receive price premiums due to reduced transaction costs and consumers' high willingness to pay. Third, lower market risk is also a possible economic incentive for farmers (Uematsu and Mishra, 2011). Thus, this study investigates the link between short supply chain participation and price risk as measured by the coefficient variance of price.

To measure the effect of participation in short supply chains on farmers' market performance, it is necessary to control for self-selection bias. Farmers' participation might be endogenous, because they might have specific characteristics that could also be correlated with market performance. Furthermore, some characteristics correlated with participation decision and market performance might be unobservable. For example, short supply chain farmers are often new entrants with little experience in production but with an emphasis on seeking new market opportunities. Thus, using an ordinary least square (OLS) regression to evaluate the impacts of short supply chain participation could lead to inconsistent estimations. The Heckman-type selection model, instrumental variable method and PSM model have been used to correct self-selection bias (Key and McBride, 2008; Neven *et al.* 2009; Rao and Qaim 2011). In this paper, we use a set of instrumental variables to estimate the impacts of short supply chain participation on farmers' market performances.

Statistics from 2016 indicate that China is the largest vegetable producer and produces 59% of the world's vegetables on 51% of the world's harvest area (Food and Agriculture Organization of the United Nations, 2018). As one of this country's comparative advantage sectors, the vegetable industry plays an important role in the national economy. In China, 150 million people are engaged in vegetable production, processing and marketing (Liu *et al.* 2004). In addition, China's mayors are responsible for the 'vegetable baskets' (vegetable and nonstaple food supply). In 2016 cucumbers and tomatoes were the two dominant vegetable crops and accounted for 37% and 33% of China's total fresh vegetable production respectively. Jiangsu, a province in eastern China, is the third largest vegetable producing region in China, after Shandong and Henan provinces. Jiangsu cultivated approximately 1.43 million hectares of vegetables in 2016, accounting for 6.4% of the total national vegetable harvest areas (NBSC 2017). The data used in this paper was collected from vegetable farmers in Jiangsu. This research on vegetable supply chains in Jiangsu is generalisable to all of China.

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This study contributes to the literature in two ways. First, farm-level data are collected from China to investigate the impacts of short supply chains on farmers' market performances, including profits, yield, average cost, and price. Additionally, price risk is considered an important market performance because China's vegetable prices are volatile (Wang *et al*. 2011). Based on the results, this paper aims to answer how farmers in short supply chains could trade-off between profit and food quality. Second, a set of instrumental variables addresses the possible endogeneity of participation decision.

The remainder of this paper is organised as follows. Section 2 describes the background. Section 3 introduces the methods. Section 4 presents the data and descriptive statistics. Section 5 offers the empirical results, and Section 6 concludes the paper.

2. Background

China has approximately 200 million small-scale farm households. China's conventional agricultural supply chain is characterised by millions of smallholder farmers, traders, and retailers, and an effective distribution of agricultural products across the country to mitigate the impacts of climate and seasons. The fragmented conventional supply chain often uses cash transactions on the basis of oral contracts or no contracts (Calvin *et al*. 2006; Li *et al*. 2012). Because many agents are involved in distribution, the information on agricultural products is untraceable and food safety is not guaranteed (Huang *et al*. 2008; Jia and Huang 2011).

Along with China's increasing incomes and rapid urbanisation, consumers' concerns for food safety and health are also increasing. Many policy measures have been undertaken to reduce the intermediaries and encourage farmers to participate in short supply chains. Therefore, farming-supermarket docking, direct sales to restaurants and canteens, you-pick operations and community supported agriculture have emerged to more closely connect producers and consumers. The market shares of these new emerging short supply chains have increased rapidly from 15% in 2010 to 30% in 2015.

2.1 Farming-supermarket docking

Farming-supermarket docking is a critical mode in short supply chains. The Ministry of Commerce and Ministry of Agriculture in China introduced the farming-supermarket docking strategy in 2007. To standardise products and monitor production practices, the procurement managers of supermarket directly contract with farmers or farmer cooperatives to deliver the products with required quality standards and volumes. The supermarkets inspect the products with their own verification system and reject unqualified products to guarantee food quality.

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2.2 Direct sales to restaurants and canteens

Increasing incomes, rapid urbanisation, and sociodemographic changes have increased the demand for food-away-from-home consumption in China (Liu *et al.* 2015, Yu and Abler 2016). Direct sales to restaurants and canteens operated by schools and factories have, thus, become one of the most important outlets for farmers to sell their products. The managers of restaurants and canteens usually place an order one day in advance and create an oral contract. The managers usually inspect the products on the basis of appearance and choose repeat procurement on the basis of consumers' evaluations. In addition, some factories purchase agriculture products directly from farms as holiday gifts for their workers.

2.3 You-pick operations

You-pick operations are a new mode of short supply chain usually in suburbs with convenient communication conditions. This type of experiential consumption is often enjoyed as family recreation. The consumers enjoy fresh air and choose the best quality products (Detre *et al.* 2011). In addition, you-pick is a learning opportunity for children residing in cities. The consumers monitor the production process and can trace the origins of problems. The most popular you-pick products are high-value and seasonal food, such as strawberries, grapes, and fish. You-pick operations account for a small but growing share.

2.4 Community supported agriculture

Consumers' demand for food quality, safety and convenience has resulted in the increasing popularity of community supported agriculture (Vasquez *et al.* 2017); farmers prepare a box of fresh vegetables weekly and deliver the boxes to the consumers' homes at the appointed time (Oberstein 2016). The consumers can visit the farms and monitor the production process. The farmers usually receive payment early in the season to increase their cash flow.

3. Method

This paper uses a set of instrumental variables to evaluate the impacts of short supply chains on farmers' market performance to overcome possible endogeneity of participation in short supply chains. We consider the urbanisation level for each municipality,[2] county-level short supply chain penetration, agriculture GDP share and distance to Shanghai as instrumental

[2] A municipality is between province and county. Urbanisation level data are not published for the county level.

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variables. Urbanisation level is measured by the percentage of the total population residing in urban areas at the municipal level. China has substantial gaps between its urban and rural regions in terms of employment opportunity, public facilities, and income. Many rural labourers have migrated to urban areas (Cai 2014). Urbanisation would promote the development of short supply chains because of urban consumers' high demand for food quality and safety; thus, farmers' market performance would be indirectly affected. In addition, local urbanisation levels change the balance of supply and demand for local food products, which is linked to short food supply chains, but can be assumed to be exogenous.

Peer effects are usually treated as a valid instrumental variable (Key and McBride 2008; Zhao *et al*. 2014). This paper also uses county-level short supply chain penetration as an instrumental variable. Higher short supply chain penetration indicates that farmers face lower transaction costs in participation in short supply chains and consumers have a higher demand for food quality. Thus, farms in counties with higher short supply chain penetration are more likely to participate. Short supply chain penetration can be assumed to be exogenous and not directly linked to the unobservable factors that affect market performances.

Agriculture GDP shares and distance to Shanghai, one of the most populous cities in the world, may also influence short supply chain participation but are obviously exogenous. As presented in Figure 1, Jiangsu borders Shanghai and is an important vegetable supply base for Shanghai.[3] More than 30% of vegetables in the Shanghai market are from Yancheng,[4] a municipality of Jiangsu. A closer proximity to Shanghai implies a higher demand for food quality, or farmers are more likely to participate in short supply chains. The farmers in counties with lower agriculture GDP shares that are proximal to Shanghai are more likely to participate in short supply chains in response to consumers' high demand for food quality.

A reasonable supposition is that these instrumental variables are exogenous to an individual farm and should not directly affect farmers' market performance. In addition, valid instruments should pass the tests of weak instrumental variables, overidentification, and excludability.

To evaluate the impacts of short supply chain participation on farmers' market performance, we use the following regression specification:

$$\mathrm{MP}_{it} = \beta_0 + \gamma \mathrm{Chain}_{it} + \beta_1 X_{it} + \beta_2 \mathrm{Region}_i + \beta_3 t + e_{it}. \quad (1)$$

The dependent variable is the market performance of farm i in year t. The market performances are measured by the profit, yield, average cost, price,

[3] http://www.joinyuan.com/newsdetail.aspx?newsinfo=d0ad014a-ef43-4d45-a019-16ef8940cd49

[4] The data was obtained from the website: http://www.zgjssw.gov.cn/shixianchuanzhen/yancheng/201512/t2588822.shtml.

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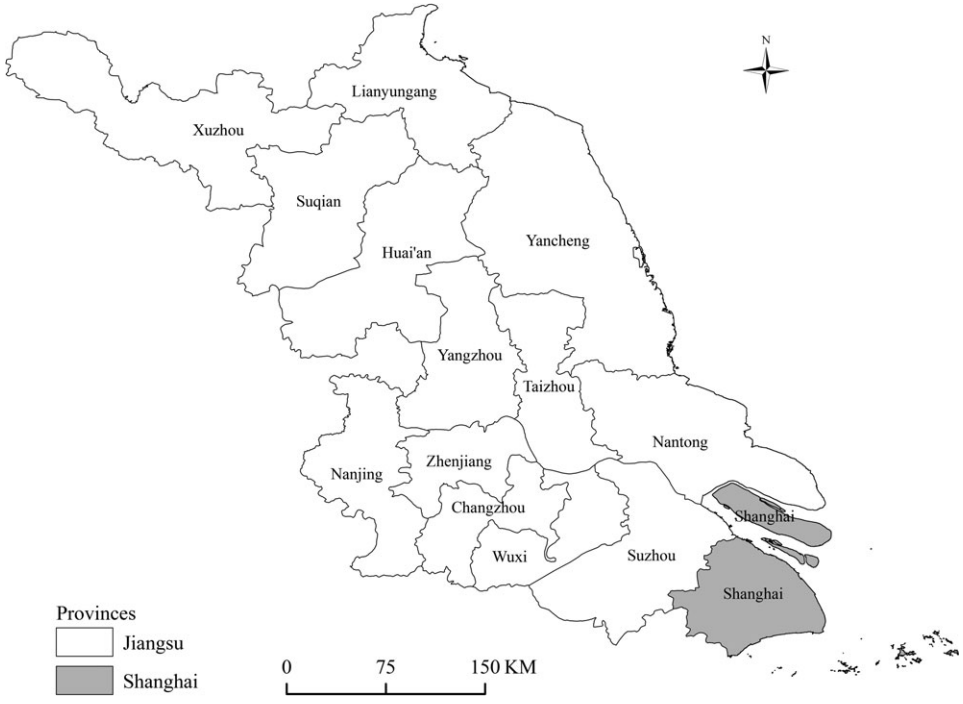

Figure 1 Location of Jiangsu and Shanghai.

profit per kilogram and the coefficient of variation in price. Chain_{it} is the treatment variable and equals 1 if farm i participated in a short supply chain in year t, and 0 otherwise. Because some unobservable characteristics could be correlated with the treatment variable and with market performance, Chain_{it} is possibly endogenous. X_{it} is a vector of exogenous control variables, including the operators' age and education level, farm size, and quantity or price of inputs. Uematsu and Mishra (2011) and Detre *et al.* (2011) demonstrated that operators' age and education level play important roles in market performance. Younger and more educated farmers are more likely to adopt newer technology and to search for information on production and market strategies. We also control for the region-level fixed effects and time trend (1 for 2011, 2 for 2012 and so on). Time trend is used to control for the factors that varies with time. e_{it} is an error term following a normal distribution.

Equation (1) is estimated by using a two-stage least-squares instrumental variable approach. The first stage explains the variation in short supply chain participation by the instruments and the exogenous control variables as follows:

$$\text{Chain}_{it} = \alpha_0 + \lambda Z_{it} + \alpha_1 X_{it} + \alpha_2 \text{Region}_i + \alpha_3 t + \mu_{it} \tag{2}$$

where Z_{it} is a vector of instrumental variables, and μ_{it} is an error term following a normal distribution as well.

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Our data collected from 2011 to 2016 are unbalanced; thus, we treat it as cross-section data by controlling for regional fixed effects and time trends, and allowing for the inherent clustering of the errors.

4. Data

This paper uses the microlevel data on cucumber and tomato farmers from 2011 to 2016, which was collected annually by the Jiangsu Price Bureau. The farm-level dataset is the most authoritative cost-benefit data used to publish the China Agricultural Product Cost-benefit Compilation. A sample of 625 cucumber and tomato farmers from 29 counties[5] were surveyed from 2011 to 2016. In empirical model, the dummy variable of cucumber relative to tomato is included to identify the differences in market performance between cucumber and tomato.

The following stratified random sampling procedure was adopted to determine sample counties, townships, and individual farms to ensure representativeness of the sample. First, all the counties from 13 municipalities[6] were sorted by their vegetable harvest areas, and the top 50% of counties were selected as target counties to guarantee the total harvest areas of the sample counties was greater than half the area of Jiangsu. Next, the proportion of target counties for each municipality was calculated and one to three target counties were randomly selected from each municipality based on the share. Second, two townships were randomly selected from the major vegetable production townships in each sample county. Finally, six to eight households were selected in each township as follows: All households engaging in commercial vegetable production[7] were divided into two groups, small and large farms,[8] and the number of households from each group depended on the number weights of the small and large farms in each township. If one household rejected the survey or stopped producing vegetables, an alternative household would be selected from that group. The original information mainly includes the cost and benefit of vegetable production. We further collected information on whether the farmers sell their products through short supply chains.

As aforementioned, a short supply chain is defined as farmers selling their products through one intermediary or directly to consumers. In our sample, farms selling their cucumbers and tomatoes directly to restaurants and canteens operated by schools, factories, and hospitals are the most prevalent in short supply chain participation. In addition, selling to supermarket and communities households are also two important outlets for short supply chain farmers. Farmers prepare the vegetables according to the orders and

[5] A total of 29 counties were surveyed from 2011 to 2016. Generally, 20 counties were surveyed over each year, and nine counties were surveyed in 2016.
[6] Jiangsu province has 13 municipalities and 106 counties.
[7] China has many self-sufficient vegetable farmers. The survey focuses on commercial farms.
[8] Large farms have a production area >3 mu (15 mu = 1 ha), and small farms have <3 mu.

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deliver the products to the customers by using their own transportation. A you-pick operation is not a major outlet for farmers in our sample. There are 172 farms participating in short supply chains, accounting for 27.5% of the surveyed farms. Notably, farms participating in short supply chain may also sell a small amount of their products through conventional chains.

We deflated the data of product value and input cost by using the producer price index and input price index, respectively. Table 1 shows the mean values and differences in market performances between the short supply chain and conventional chain by using the *t* test. On average, short supply chain farmers have higher profits, but this result is statistically significant for only tomato farms. Conventional chain farmers harvested significantly higher yields of tomatoes and cucumbers. Short supply chain farmers achieved a small of price premium for tomatoes, but no price premium for cucumbers. The average cost of the conventional chain is significantly lower than that of the short supply chain. The profit per kilogram of a short supply chain is lower than that of a conventional chain for cucumber farmers, but no significant difference is observed for tomato farmers. The standard errors are very high for profits, yield and profit per kilogram, and this result implies that many factors could affect market performance. We evaluate the impact of short supply chain participation on market performance by controlling for other factors and using the instrumental variable approach to consider endogeneity. The summary of the statistics of the instrumental variables is also reported in Table 1. The Hausman test is used to compare the results of the IV regression and OLS.

5. Results

Economic incentives are a crucial impetus in the development of short supply chains and the basis for inducing local economic regeneration. Our initial descriptive analysis implies that short supply chain farmers are likely to have higher profits, but no evidence was observed regarding their achievement of a price premium, higher yield, higher profit per kilogram or lower average cost. This paper uses a two-stage instrumental variable approach to investigate the effect of short supply chain participation on farmers' market performance by controlling for other factors as much as possible. The correlation matrix indicates low correlations among most of independent variables (Appendix S1). Hence, multicollinearity might not be an issue in this study.

5.1 Profits

Table 2 presents the impact of short supply chain participation on farmers' profits. Column 1 shows the estimated first stage relationship between the urbanisation level and short supply chain participation. The Pearson's correlation coefficient between urbanisation level and short supply chain participation is 0.32 and significant at the 1% significance level. After

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Table 1 Summary statistics and comparison of market performances

	Tomato			Cucumber		
	Conventional chain	Short supply chain	The differences	Conventional chain	Short supply chain	The differences
Profits yuan	12,691.29	19,534.54	−6,843.25**	11,702.05	13,012.63	−1,310.57
	(13,796.6)	(50,226.8)	(3,828.15)	(15,910.4)	(35,082.9)	(2,739.10)
Yield: kg/mu	4,899.10	3,769.88	1,129.21***	5,700.86	3,697.22	2,003.65***
	(1,340.44)	(1,113.72)	(180.80)	(2,255.63)	(1,354.08)	(236.89)
Price: yuan/kg	2.65	2.91	−0.25**	2.29	2.26	0.03
	(0.86)	(0.92)	(0.13)	(0.86)	(0.69)	(0.09)
Average cost: yuan[1]/kg	1.72	1.96	−0.24***	1.50	1.62	−0.13**
	(0.58)	(0.71)	(0.09)	(0.61)	(0.69)	(0.07)
Profit per kilogram: yuan/kg	0.93	0.95	−0.01	0.79	0.64	0.15**
	(0.72)	(1.17)	(0.12)	(0.70)	(0.94)	(0.09)
Observations	212	67	—	241	105	—

Instrumental variables	Mean	Standard deviation	Min	Max
Urbanisation level (%)	64.00	8.63	49.78	82
Short supply chain penetration	0.19	0.35	−0.5†	1
Agriculture GDP shares	0.28	0.24	0.01	1
Distance to Shanghai (kilometre)	317.68	144.89	90	590

Note: A positive value means the mean value of conventional channel higher than that of the safe vegetable channel.*, **, *** indicate statistically significant at the 10%, 5% and 1% level, respectively. The exchange rates of 100 US Dollars to RMB in 2011–2016 are 645.88 RMB yuan, 631.25 RMB yuan, 619.32 RMB yuan, 614.28 RMB yuan, 622.84 RMB yuan and 664.23 RMB yuan, respectively. †In consideration of peer effects, the model household was deleted when we computed the short supply chain penetration. —, no data.

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Table 2 The impacts of short supply chain participation on profits and yield

Dependent variable	Chain participation	Profits		Chain participation	Yield per mu	
	OLS (first stage) (1)	OLS (2)	IV-2SLS (Second stage) (3)	OLS (first stage) (4)	OLS (5)	IV-2SLS (second stage) (6)
Urbanisation level	−0.039***	—	—	−0.039***	—	—
	(0.00)			(0.00)		
Agriculture GDP share	—	—	—	0.062**	—	—
				(0.03)		
Short supply chain participation	—	−692.551	9,042.338***	—	−193.743	2,733.832***
		(1,065.44)	(3,217.50)		(136.88)	(518.75)
Primary school‡	0.108	−4,078.962*	−6,777.516***	0.099	643.836*	−133.149
	(0.07)	(2,266.24)	(2,061.34)	(0.07)	(379.54)	(507.63)
Junior school	0.152**	−2,462.008	−5,236.122***	0.146**	527.715	−287.228
	(0.06)	(2,155.28)	(1,963.81)	(0.07)	(362.55)	(490.25)
Senior school	0.100	−3,494.895	−4,931.833**	0.082	497.806	102.237
	(0.07)	(2,302.83)	(2,103.47)	(0.07)	(366.26)	(485.44)
College or above	0.397***	−23,536.814*	−29,637.352***	0.398***	18.446	−1,819.367***
	(0.09)	(12,051.78)	(10,490.37)	(0.09)	(492.06)	(661.06)
Age	0.000***	1.169	−2.698*	0.000***	−0.660	−1.799***
	(0.00)	(1.32)	(1.53)	(0.00)	(0.53)	(0.68)
Farm size	0.016***	3,356.116***	3,259.481***	0.016***	24.658***	−3.592
	(0.00)	(375.07)	(362.01)	(0.00)	(5.75)	(8.31)
Price of fertiliser	0.003**	−209.680	−225.628*	—	—	—
	(0.00)	(135.24)	(135.85)			
Seed cost	0.000**	10.567**	7.853	0.000***	1.208***	0.363
	(0.00)	(4.83)	(5.25)	(0.00)	(0.24)	(0.35)
Quantity of labour	−0.000	8.539	33.220	0.000	18.193***	24.182***
	(0.00)	(18.35)	(21.39)	(0.00)	(1.98)	(2.51)
Price	0.024	7,833.621***	7,588.906***	—	—	—
	(0.02)	(674.29)	(702.84)			
Time trend	0.045***	−383.788	−305.197	0.043***	134.344***	158.907***
	(0.01)	(315.66)	(320.36)	(0.01)	(34.12)	(41.09)

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Table 2 (*Continued*)

Dependent variable	Chain participation	Profits		Chain participation	Yield per mu	
	OLS (first stage) (1)	OLS (2)	IV-2SLS (Second stage) (3)	OLS (first stage) (4)	OLS (5)	IV-2SLS (second stage) (6)
Cucumber relative to tomato	−0.005	2,768.640***	2,990.909***	−0.021	914.698***	1,004.054***
	(0.02)	(1,000.05)	(1,035.72)	(0.03)	(114.12)	(139.67)
Quantity of fertiliser	—	—	—	0.000	0.893	1.603
				(0.00)	(1.56)	(1.92)
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
_cons	2.913***	−18,693.641***	−21,108.662***	3.002***	1,042.808***	88.225
	(0.34)	(3,026.58)	(2,898.86)	(0.34)	(387.58)	(520.72)
n	625	625	625	625	625	625
R^2	0.502	0.760	0.743	0.498	0.478	0.202
Hausman Test for Endogeneity (*P* value)	—	—	0.002	—	—	0.000
Under identification	—	—	0.000	—	—	0.000
Weak IV	—	—	70.356†	—	—	33.869†
Overidentification	—	—	—	—	—	0.104

Note: *, **, *** indicate statistically significant at the 10%, 5% and 1%, respectively. Standard errors are in parentheses. †The value of the Stock-Yogo weak ID test critical value at the 15% maximal IV size is 8.96 for Column 3 and 11.59 for Column 6. ‡The education dummy is relative to illiteracy. —, no data.

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controlling for regional fixed effects, urbanisation level negatively affects short supply chain participation at the 1% significance level. Overall, the strong relationship indicates that the instrumental variable is not a weak instrument. All the explanatory variables explain approximately 50.2% of the variation in short supply chain participation. Column 2 reports the OLS regression of profits on the treatment variable and other control variables. Participation in a short supply chain has no significant impacts on profits, but some operation characteristics are statistically significant. This study uses labour quantity instead of wage to avoid the correlation between wage and urbanisation level because the developed regions would have higher wage levels.

The OLS results may not be consistent because of self-selection bias. The Hausman test for endogeneity indicates that short supply chain participation cannot be treated as exogenous. The underidentification test indicates that the null hypothesis is rejected, that is, the excluded instrument correlated with the endogenous variable. Although correlation between the excluded instrument and endogenous variable was observed, the estimators can perform poorly when an instrument is weak. The Kleibergen-Paap rk Wald F statistic to assess if the joint significance of the excluded instrument has a value of 70.356. The Stock-Yogo critical values for the excluded instrument are 16.38 for the 10% level and 8.96 for the 15% level. The result suggests that urbanisation level is a valid instrument. The regression has one instrumental variable; thus, it is exactly identified.

In a comparison with the OLS results, the instrumental variable second stage results indicate that the estimated parameter value for short supply chain is 9,042, which is statistically significant at the 1% significance level. The result indicates that participating in a short supply chain would increase the farmers' profit by 9,042 yuan per mu. The estimated effect on profits is consistent with our descriptive results in Table 2 and the findings of Wang *et al.* (2014b) from Vietnamese vegetable farmers, but contrasts with the findings in Uematsu and Mishra (2011)'s for farmers in the United States. The contrary results may be caused by the differences in supply chain systems across countries.

Notably, the estimated impact of the instrumental variable approach is significantly different from that of OLS regression. This finding confirms our concern that some unobservable factors are correlated with short supply chain participation and profits, and cause an underestimation of the impact. One possible explanation for this phenomenon is that short supply chain farmers are usually new entrants without rich experience in vegetable production. They often do not operate equipment by themselves. Short supply chain farmers highly rely on hired labourers, which accounts for 40% of total labour use, and is 22% higher than that of conventional chain farms. Short supply chain farmers are good at discovering market opportunities and searching for improved seeds.

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A negative but significant coefficient for the variable of age implies that older farmers are less profitable. One possible explanation is older farmers often face social, economic, and technical barriers for new products or business models (Prosperi *et al.* 2019). In addition, additional management time associated with short supply chain may not make it an attractive opportunity for older farmers (Detre *et al.* 2011). We further use product price in the last year instead of current product price to reestimate the impacts, and the results remain unchanged (Appendix S2).

5.2 Yield

Farmers' profits are determined by productivity, cost, and price. Productivity plays a central role in farmers' income, but the impact of a short supply chain on farmers' productivity has not been thoroughly evaluated. Table 2 also presents the impact of short supply chain participation on farmers' yields. We use urbanisation level and agriculture GDP share as the instruments. First, the Hausman tests imply that short supply chain participation is endogenous, and the instruments are neither overidentified nor weak. Second, compared with the OLS results, the impact of short supply chain on vegetable yield becomes positive and statistically significant for the instrumental variable approach when controlling for household and operation characteristics. This result is consistent with the finding in Rao *et al.* (2012); participation in supermarket channels could increase farm productivity, namely, technology progress. Due to the restricted use of specific inputs, Mayen *et al.* (2010) and Kumbhakar *et al.* (2009) have demonstrated that organic farms are less productive in an economic sense, and this result is similar for green food in China (Yu *et al.* 2014). Similarly, a negative and statistically significant coefficient for age in the yield function may have similar reasons with the results in the above profit function. Older farmers often face social, economic and technological barriers to adopt new products, new technologies or new business models (Prosperi *et al.* 2019).

5.3 Inputs

We analyse the difference in inputs between a short supply chain and conventional chain. Substantial differences are observed in terms of seeds, fertiliser, pesticide, labour, and land. First, short supply chain farmers have significantly higher seed costs for tomatoes and cucumbers. The observed difference in seed costs may reflect differences in quality. Short supply chain farmers are more likely to buy improved tomato seeds from more formal companies at a higher price. High-quality seeds often have high yields as a return. Second, short supply chain farmers use significantly less fertilisers and pesticides, which may be because of consumers' concern for food quality but result in lower yields in short supply chains. Third, short supply chain farmers use less labour. Finally, the operation scales of short supply chain farmers are

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on average twofold larger than conventional chain farms, which contradicts the findings of Wang *et al.* (2014b) and Uematsu and Mishra (2011). In China, short supply chain farmers usually specialise in agricultural production and consider farming their main occupation and main income source. Overall, short supply chain farmers use less fertiliser, pesticides, and labour but the improved seed and capital-intensive technologies may compensate for the loss of yield and even contribute to higher yield and profit (Table 3).

5.4 Price

Price is another important determinant of farmers' profit. Whether farmers can achieve a price premium has been hotly debated (Hu *et al.* 2012; Aysoy *et al.* 2015; Meas *et al.* 2015; Lim and Hu 2016). Table 4 presents the estimated effects of a short supply chain on price. First, the Hausman test for endogeneity implies the evidence is insufficient to reject the null hypothesis by using urbanisation level and short supply chain penetration as instruments. Thus, the OLS result is consistent, and it makes sense that farmers in China usually have no negotiation power regarding their prices because their scale is too small.

Column 2 in Table 4 shows that the coefficient of short supply participation is not statistically significant and implies there is no price premium for short supply chain farmers. The possible explanation for this phenomenon is that short supply chain farmers sell their products with the price no higher than the market price to gain competitiveness. Aysoy *et al.* (2015) demonstrated that removing intermediaries cannot reduce the retail market price. In addition, imperfect market mechanisms may not rate in terms of obtaining a higher price for high quality.

5.5 Profit per kilogram

Although we do not observe a price premium, the impact of short supply chain participation on profit per kilogram is positive and statistically significant when using urbanisation level and distance to Shanghai as instruments. Column 6 in Table 4 presents that short supply chain farmers can obtain a 0.663 yuan higher profit per kilogram. Productivity and cost could jointly contribute to the higher profit per kilogram with no price premium. If there is no difference in cost between a short supply chain and conventional chain, we may attribute the higher profit per kilogram only to productivity advantage.

5.6 Costs

Table 5 reports how short supply chain participation affects production cost per mu and per kilogram. Column 3 in Table 5 shows that short supply chain participation is not exogenous and short supply chain penetration is a valid

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Table 3 Summary statistics and comparison of inputs

	Tomato			Cucumber		
	Conventional chain	Short supply chain	The differences	Conventional chain	Short supply chain	The differences
Seed: yuan/mu	152.00 (92.71)	386.51 (400.49)	−234.51*** (29.65)	204.14 (133.18)	254.78 (201.13)	−50.64** (30.08)
Fertiliser quantity: kg/mu	52.49 (23.67)	47.37 (30.44)	5.12* (3.57)	65.27 (53.17)	34.34 (27.01)	30.94*** (5.48)
Pesticide: yuan/mu	194.03 (100.14)	175.69 (190.62)	18.35 (17.89)	272.46 (196.53)	127.82 (76.76)	144.64*** (19.82)
Labour: day/mu	71.74 (29.12)	45.99 (30.04)	25.74*** (4.11)	59.84 (28.13)	37.54 (19.88)	22.30*** (3.03)
Land: mu	2.68 (2.36)	4.93 (11.82)	−2.25*** (0.86)	2.10 (1.76)	5.15 (11.96)	−3.05*** (0.79)

Note: A positive value means the mean value of conventional channel higher than that of the safe vegetable channel.*, **, *** indicate statistically significant at the 10%, 5% and 1% level, respectively. The exchange rates of 100 US Dollars to RMB in 2011–2016 are 645.88 RMB yuan, 631.25 RMB yuan, 619.32 RMB yuan, 614.28 RMB yuan, 622.84 RMB yuan and 664.23 RMB yuan, respectively.

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Table 4 The impacts of short supply chain participation on price and profit per kilogram

Dependent variable	Chain participation	Price per kilogram		Chain participation	Profit per kilogram	
	OLS (first stage)	OLS	IV-2SLS (Second stage)	OLS (first stage)	OLS	IV-2SLS (second stage)
	(1)	(2)	(3)	(4)	(5)	(6)
Urbanisation level	−0.006	—	—	−0.039***	—	—
	(0.01)			(0.00)		
Short supply chain penetration	0.885***	—	—	—	—	—
	(0.08)					
Distance to Shanghai	—	—	—	−0.001***	—	—
				(0.00)		
Short supply chain participation	—	0.140	0.177	—	−0.074	0.663***
		(0.09)	(0.16)		(0.08)	(0.16)
Primary school	0.003	−0.386*	−0.396*	0.081	0.115	−0.089
	(0.07)	(0.23)	(0.23)	(0.07)	(0.16)	(0.14)
Junior school	0.089	−0.271	−0.282	0.129*	0.053	−0.157
	(0.06)	(0.22)	(0.22)	(0.07)	(0.16)	(0.15)
Senior school	0.024	−0.400*	−0.406*	0.074	−0.050	−0.158
	(0.07)	(0.22)	(0.22)	(0.07)	(0.17)	(0.15)
College or above	0.305***	−0.229	−0.253	0.323***	0.067	−0.395*
	(0.09)	(0.34)	(0.34)	(0.09)	(0.19)	(0.20)
Age	0.000***	−0.000**	−0.000**	0.000***	−0.000	−0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Farm size	0.017***	−0.013***	−0.014***	0.018***	0.009***	0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Quantity of fertiliser	−0.000	0.002**	0.002**	—	—	—
	(0.00)	(0.00)	(0.00)			
Seed cost	−0.000	−0.000	−0.000	0.000**	−0.000	−0.000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Quantity of labour	−0.001	0.014***	0.014***	−0.000	−0.006***	−0.004***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cucumber relative to tomato	−0.005	−0.364***	−0.363***	−0.008	0.113**	0.130**

Table 4 (*Continued*)

Dependent variable	Chain participation	Price per kilogram		Chain participation	Profit per kilogram	
	OLS (first stage)	OLS	IV-2SLS (Second stage)	OLS (first stage)	OLS	IV-2SLS (second stage)
	(1)	(2)	(3)	(4)	(5)	(6)
	(0.02)	(0.06)	(0.06)	(0.02)	(0.05)	(0.05)
Time trend	0.001	0.026	0.026	0.044***	−0.042***	−0.036***
	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Price of fertiliser	—	—	—	0.005***	−0.027***	−0.028***
				(0.00)	(0.00)	(0.00)
Price	—	—	—	0.041*	0.849***	0.831***
				(0.02)	(0.03)	(0.03)
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
_cons	0.409	2.410***	2.398***	2.948***	−0.812***	−0.995***
	(0.42)	(0.24)	(0.23)	(0.33)	(0.19)	(0.17)
n	625	625	625	625	625	625
R^2	0.584	0.284	0.284	0.510	0.606	0.512
Hausman Test for Endogeneity (*P* value)	—	—	0.865	—	—	0.000
Under identification	—	—	0.000	—	—	0.000
Weak IV	—	—	123.94†	—	—	47.382†
Overidentification	—	—	0.203	—	—	0.568

Note: *,**,*** indicate statistically significant at the 10%, 5% and 1%, respectively. Standard errors are in parentheses. †The value of the Stock-Yogo weak ID test critical value at the 15% maximal IV size is 11.59. —, no data.

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Table 5 The impacts of short supply chain participation on average cost and price risk

Dependent variable	Chain participation	Cost per mu		Chain participation	Cost per kilogram	
	OLS (first stage)	OLS	IV-2SLS (second stage)	OLS (first stage)	OLS	IV-2SLS (second stage)
	(1)	(2)	(3)	(4)	(5)	(6)
Urbanisation level	—	—	—	−0.039***	—	—
				(0.00)		
Short supply chain penetration	0.945***	—	—	—	—	—
	(0.06)					
Short supply chain participation	—	111.873	1,046.110***	—	0.091	−0.628***
		(153.09)	(275.26)		(0.08)	(0.17)
Primary school	0.012	−656.571	−909.563	0.102	−0.158	0.037
	(0.07)	(596.26)	(655.54)	(0.07)	(0.17)	(0.16)
Junior school	0.097	−660.511	−923.632	0.149**	−0.078	0.125
	(0.07)	(594.23)	(653.08)	(0.07)	(0.17)	(0.16)
Senior school	0.025	−239.230	−372.805	0.096	0.020	0.122
	(0.07)	(604.32)	(658.43)	(0.07)	(0.18)	(0.17)
College or above	0.314***	−802.170	−1385.781*	0.395***	−0.089	0.360*
	(0.09)	(729.54)	(781.00)	(0.09)	(0.20)	(0.22)
Age	0.000***	−0.614***	−0.978***	0.000***	0.000	0.000
	(0.00)	(0.17)	(0.18)	(0.00)	(0.00)	(0.00)
Farm size	0.017***	−1.374	−10.374	0.016***	−0.011***	−0.004
	(0.00)	(8.03)	(8.39)	(0.00)	(0.00)	(0.00)
Price of fertiliser	0.001	47.914***	45.521***	0.004***	0.032***	0.034***
	(0.00)	(16.00)	(15.91)	(0.00)	(0.00)	(0.00)
Seed cost	−0.000	2.664***	2.411***	0.000**	0.000	0.000**
	(0.00)	(0.29)	(0.28)	(0.00)	(0.00)	(0.00)
Quantity of labour	−0.001*	82.816***	84.889***	0.000	0.008***	0.007***
	(0.00)	(4.74)	(4.95)	(0.00)	(0.00)	(0.00)
Cucumber relative to tomato	−0.008	509.141***	537.785***	−0.013	−0.160***	−0.182***
	(0.02)	(144.52)	(146.50)	(0.02)	(0.05)	(0.05)
Time trend	−0.005	303.967***	310.755***	0.046***	0.047***	0.042***

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Table 5 (*Continued*)

Dependent variable	Chain participation	Cost per mu		Chain participation	Cost per kilogram	
	OLS (first stage)	OLS	IV-2SLS (second stage)	OLS (first stage)	OLS	IV-2SLS (second stage)
	(1)	(2)	(3)	(4)	(5)	(6)
	(0.01)	(38.70)	(39.29)	(0.01)	(0.01)	(0.01)
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−0.002	685.542	404.269	2.966***	1.125***	1.342***
	(0.08)	(606.96)	(659.18)	(0.33)	(0.19)	(0.18)
n	625	625	625	625	625	625
R^2	0.582	0.714	0.702	0.500	0.332	0.185
Hausman Test for Endogeneity (*P* value)	—	—	0.000	—	—	0.000
Under identification	—	—	0.000	—	—	0.000
Weak IV	—	—	70.052†	—	—	242.380†
Overidentification	—	—	—	—	—	—

Note: *,**,*** indicate statistically significant at the 10%, 5% and 1%, respectively. Standard errors are in parentheses. †The value of the Stock-Yogo weak ID test critical value at the 15% maximal IV size is 8.96. —, no data.

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Table 6 The impacts of short supply chain participation on price risk

Dependent variable	Chain participation	Price risk	
	OLS (first stage) (1)	OLS (2)	IV-2SLS (second stage) (3)
Short supply chain penetration	0.946***	—	—
	(0.06)		
Short supply chain participation	—	−0.020***	−0.043***
		(0.01)	(0.01)
Primary school	0.011	−0.013	−0.007
	(0.07)	(0.03)	(0.03)
Junior school	0.098	−0.016	−0.010
	(0.07)	(0.03)	(0.03)
Senior school	0.026	−0.015	−0.012
	(0.07)	(0.03)	(0.03)
College or above	0.319***	0.001	0.016
	(0.09)	(0.04)	(0.04)
Age	0.000***	−0.000***	−0.000***
	(0.00)	(0.00)	(0.00)
Farm size	0.017***	0.000	0.001*
	(0.00)	(0.00)	(0.00)
Quantity of fertiliser	−0.000	−0.000**	−0.000**
	(0.00)	(0.00)	(0.00)
Seed cost	−0.000	0.000**	0.000***
	(0.00)	(0.00)	(0.00)
Quantity of labour	−0.001*	0.000	0.000
	(0.00)	(0.00)	(0.00)
Cucumber relative to tomato	−0.005	0.004	0.003
	(0.02)	(0.00)	(0.00)
Time trend	−0.006	0.020***	0.019***
	(0.01)	(0.00)	(0.00)
Region fixed effects	Yes	Yes	Yes
_cons	0.004	0.287***	0.294***
	(0.08)	(0.03)	(0.03)
n	625	625	625
R^2	0.583	0.289	0.273
Hausman Test for Endogeneity (*P* value)	—	—	0.027
Under identification	—	—	0.000
Weak IV	—	—	245.854†
Overidentification	—	—	—

Note: *,**,*** indicate statistically significant at the 10%, 5% and 1%, respectively. Standard errors are in parentheses. †The value of the Stock-Yogo weak ID test critical value at the 15% maximal IV size is 8.96. —, no data.

instrument. The results imply that the short supply chain farmers have significantly higher production cost per mu. Column 6 in Table 5 also shows the impact of short supply chain participation on production cost per kilogram when yield and production scale is considered. The average production cost of short supply chain farms is 0.628 yuan per kilogram lower than that of conventional chain farms. The reduction in average production cost is closely linked to the increase in the profit per kilogram. Therefore, we

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conclude that the increase in profit per kilogram is mainly attributed to productivity advantage and scale effect rather than a price premium or cost saving. Once again, a negative but significant coefficient for age in the cost function shows that older farmers have lower cost per mu due to the adoption of conventional cost-saving production pattern, as well as lower opportunity cost of labour.

5.7 Price risk

The direct marketing strategy is an important risk management tool (Uematsu and Mishra 2011). Gibson and Kim (2012) showed that stock held by consumers may play important roles in food market equilibrium. A direct marketing strategy could reduce consumers' stock and possibly make market price adjust rapidly and efficiently. Thus, we use the variance of price to measure the price risk and investigate how short supply chain participation affects the price risk. The endogeneity test shows insufficient evidence regarding the treatment of short supply chain participation as an exogenous variable. Column 3 in Table 6 presents that participating in a short supply chain can significantly reduce the price risk by using short supply chain penetration as the instrument. The reduction in price risk could have explanatory power for the expansion of farm size for short supply chain farmers. In addition, the coefficient of the time trend variable, which is positive and statistically significant, shows that the price risk increases significantly in our research period.

Gibson *et al.* (2014) indicated that individual producers' behaviours may be affected by their neighbours in rural household surveys. Chinese vegetable producers tend to cluster in the suburbs of cities because vegetables are perishable and inconvenient to transport. Thus, we must recognise the clustering of households in our empirical model. This paper also reports that the households cluster at a county level and by farm size (Appendices S3–S6). The empirical results of the robust standard errors are consistent with that of cluster-corrected standard errors. Cluster-corrected standard errors may still not be enough for dealing with these location and spillover effects. Thus, we should collect location data and estimate spatial error models in further research.

6. Conclusions

Fresh food supply chains in China have been reducing the number of intermediaries that connect producers and consumers. This paper defines a short supply chain as farmers selling their products through one intermediary or directly to consumers. Promoting a short supply chain has the potential to facilitate responsiveness to consumers' demand for food quality and safety because consumers have better knowledge about the origins of the food, how it was produced, and who produced it. In addition, the development of short

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supply chains benefits local economic regeneration. Whether farms can achieve additional economic benefits is crucial to the sustainability of a short supply chain. This study provides a comprehensive picture of short supply chain participation impacts on farmers' market performance in China. In addition to our evaluation of the impacts of a short supply chain on farmers' profits, this paper also identifies the impetus that affects profits.

Given farm-level data collected from China, this paper uses a set of instruments to address the possible endogeneity problem and investigate the impacts of a short supply chain on farmers' market performances, including profits, productivity, production cost, price, and price risk. The empirical results show that participating in a short supply chain is a profit-maximising strategy and risk management tool for farmers. The increase in profit is attributed to productivity advantage and farm size expansion rather than as a result of price premiums or cost savings. The reduction in price risk could explain the expansion of farm size for short supply chain farmers.

The implications of our research are potentially important from the public policy perspective; promoting short food supply chains benefits local economic regeneration, increases farm-level income, and reduces fluctuations in vegetable prices. To promote sustainable development of short supply chains, long-term economic benefits for short supply chain farmers should be considered. Due to the spillover effects of improved seeds and capital-intensive technologies, conventional chain farmers can learn and adopt these technologies to increase their productivity. Thus, to realise high prices for high-quality short supply chain food in functional markets is important for China.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Correlation Matrix.

Appendix S2 The impacts of short supply chain participation on profit and profit per kilogram - products price of last year.

Appendix S3 The impacts of short supply chain participation on profits and yield.

Appendix S4 The impacts of short supply chain participation on price and profit per kilogram.

Appendix S5 The impacts of short supply chain participation on average cost per mu and cost per kilogram.

Appendix S6 The impacts of short supply chain participation on price risk.

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