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Does certified food production reduce agrochemical use in China?

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Abstract

Purpose – The purpose of this paper is to examine the effect of adopting certified food production on chemical fertilizer and pesticide use in China.
Design/methodology/approach – The authors estimate fixed effect models to track the changes in agrochemical consumption at household level over time and evaluate the effect of certified food production, using an unbalanced panel data set covering 4,830 households in six provinces over the period 2005–2013.
Findings – On average, the authors do not find significant effects of certified food production on either chemical fertilizer or pesticide consumption among Chinese farmers. The effects are heterogeneous across villages, but the heterogeneous effects show no clear pattern that is consistent with different types of certification. The findings are robust to the use of alternative panel structure and certification indicators. The lack of knowledge about certification among farmers, the price premium and differences in regulation enforcement across regions may explain why the authors do not find negative effects on agrochemical use.
Practical implications – This study suggests that careful inspections and strong enforcement of certified food production is needed to ensure that the environmental goals of certified food production can be achieved and the reputation of certification in China can be improved. The inspection of certification producers and the enforcement of current regulations should be stricter for the further healthy development of certified food production in China.
Originality/value – This study is the first attempt to systematically evaluate the impact of food certification on the use of agrochemicals in Chinese agriculture.

Keywords China, Food certification, Fertilizer, Pesticide
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1. Introduction

Agricultural production in China experienced rapid growth during the past few decades. The widespread adoption of chemical fertilizer and pesticide has made an important contribution to this growth. Yu and Zhao (2009) provide a literature review on the source of

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agricultural growth and identify that "fertilizer is the largest contributor in physical inputs to agricultural growth in China." China now is the largest chemical fertilizer and pesticide consumer in the world[1]. Chemical fertilizer consumption has increased from 25.90m tons in 1990 to 59.12m tons in 2013, while pesticide use has risen from and 0.73 to 1.80m tons during the same period (NBS, 2006-2014). According to World Bank data, the average chemical fertilizer consumption in China increased from 325.8 kg to 364.4 kg per hectare of arable land between 2005 and 2013. In France and the USA, and even in (densely populated) Japan after 2008, fertilizer consumption per hectare was considerably lower than in China. Moreover, fertilizer consumption either declined or remained stable in those countries while it increased steadily in China. Pesticide use per hectare is also high in China. According to FAO statistics, pesticide consumption in China is much higher than pesticide consumption in major crop exporters such as the USA and France and has surpassed pesticide consumption in Japan since 2007. In contrast to the slightly declining or stable trends in those countries, China has experienced a steady increase in pesticide consumption per hectare in recent years.

The relatively high, and increasing, multiple cropping index in China can at least partly justify the large consumption of agrochemicals[2]. But the high input intensity *per se* could cause environmental problems and threaten long-term land productivity. In China, chemical fertilizer use efficiency is only around 33 percent (Cheng *et al.,* 2010; Wu, 2011; MOA, 2015a), while pesticide use efficiency is estimated at 35 percent (MOA, 2015b). Chemical fertilizers and pesticides have been identified as the major source of rural non-point source pollution in China. MOA (2004) claims, "the area of farmland suffering from agricultural chemical contamination has reached 136m mu[3]." Nitrogen and phosphate washed from agricultural fields are identified as the major source of eutrophication of surface waters and shallow groundwater in China (Le *et al.,* 2010; Qu *et al.,* 2011; Sun *et al.,* 2012). Use of large quantities of agrochemicals also contributes to the acidification of farmlands (Guo *et al.,* 2010). Intensive application of pesticide has caused contamination of soil, surface water, groundwater and farm products (Sun *et al.*, 2012).

Researchers and policy makers in China have become aware of the downside of the increasing agrochemical consumption, and are seeking ways to promote sustainable agricultural development. For instance, in February 2015, the Ministry of Agriculture launched the "Chemical Fertilizer and Pesticide Consumption Zero-Growth Operation," aiming at reducing the growth rate of chemical fertilizer and pesticide consumption to zero, and improving the use efficiency to at least 40 percent, by the year of 2020 (MOA, 2015a, b).

The general public has also become increasingly aware of the danger of heavy agrochemical use as well, which has resulted in a rising demand for environmental friendly and safe food (e.g. Yin *et al.,* 2010; Yu *et al.,* 2014; Thogersen *et al.,* 2015; Ortega *et al.*, 2015; Yin *et al.*, 2017). However, consumers cannot observe the agricultural practices that are used to produce the food that they consume. One way to bridge this information gap is certification. Green Food, Organic Food, Non-hazard Food and Geographic Indication Product are the typical types of certified products in China. Food certificates are issued and controlled by government agencies or qualified third parties. Production of certified food in China aims to meet consumers' demand for high-quality food, increase farmers' incomes through the price premium they receive for high-quality food and to reduce agricultural pollution through lower agrochemical consumption. Restrictions on chemical inputs use are usually the crucial farm-level requirement for food certification.

Starting in the 1990s, certified food production has developed into an increasingly important segment of China's agricultural sector. For example, in 2014, the environmental monitoring area of crop land under Green Food certification was 207.85m mu (CGFDC, 2015), equal to 10.25 percent of the total arable land area in China[4].

Despite the growing popularity of certified food production in China, the available international scientific literature on its development and impact is limited and mainly qualitative, reviewing the development of certified food production, pointing out existing problems and providing policy advices (e.g. Sanders, 2006; Sheng *et al.,* 2009; Lin *et al.,* 2010; Oelefse *et al.,* 2010; Scott *et al.,* 2014). The available Chinese scientific literature is relatively rich, but largely focuses on marketing strategies, value chain management and development strategies, using evidence from either macro-level data or specific case studies (e.g. Han, 2010; Wang *et al.*, 2009). Changes in actual production practices and the environmental outcomes of certified food production have not yet received adequate attention. Much of the certified food production in China is carried out by smallholders. Since it is hard to observe and control the behavior of large numbers of small farmers, it remains unclear to what extent certified food production has actually reduced farmers' chemical fertilizer and pesticide consumption and what environmental benefits it has brought so far.

The available literature on other countries is limited as well. Among the studies that did examine production practices of organic farming, Kleemann and Abdulai (2013) found that organic farming increased agro-ecological practices among pineapple producers in Ghana; Blackman and Naranjo (2012) observed that organic farmers use less agrochemicals than conventional farmers in Costa Rica; Beuchelt and Zeller (2011) reported zero chemicals use among organic farmers in Nicaragua. On the other hand, Gambelli *et al.* (2014) found evidence of non-compliance occurring in Italy and Germany. Given the weak enforcement ability in low- and middle-income countries, it is likely that non-compliance also exists and may be even more prevalent in such countries. We certainly should not take lower chemical input use among certified food producers for granted. This also holds for China, where the restrictions posed on agrochemical use differ between different categories of food certificates (as will be discussed in Section 2).

A few Chinese studies provide some evidence that farmers do not fully conform to the certification requirements. For example, Zhang (2012) examines the quality control behavior of green vegetable farmers in Sichuan province and finds that farmers' pesticide use often differs from the level required by the contracting firms. Zhou and Xu (2008) find that pesticide overuse and use of forbidden pesticides is quite common among farmers engaged in Non-hazard Food production in the city of Nanjing. And Li *et al.* (2007) find that Non-hazard Food certification has no impact on farmers' levels of pesticide use in Nanjing. The evidence of non-compliance in these studies is obtained for relatively small regions. It points to the urgent need for a more systematic examination of the issue.

In this study, we use panel data from six provinces to examine the impact of certified food production on chemical fertilizer and pesticide consumption in China. Our sample covers different agro-ecological regions across the country and therefore provides a relatively complete picture of certified food production in China. On average, we do not find evidence of lower agrochemical use in certified food production. The effects are heterogeneous across villages, but the heterogeneous effects show no clear pattern that is consistent with different types of certification. Our results are robust to the use of alternative panel structure and certification indicators. Our findings suggest that the current product certification system is not very successful in reaching its environmental goals. Stricter inspections and enforcement may be needed in the near future to make a contribution to the reduction of non-point source pollution.

The rest of the paper is organized as follows. Section 2 reviews the development of different types of certified food products and presents our hypotheses. Section 3 introduces our empirical strategy and Section 4 describes the data set; Regression results and their interpretation are presented in Section 5; Section 6 provides some discussion about our findings; and Section 7 concludes.

2. Food certification in China and hypotheses to be tested

In China, different types of certified products have different requirements in terms of chemical fertilizer and pesticide use. Non-hazard Food has the lowest requirements, while Organic Food has the highest. Green Food lies in between. Geographic Indication Product certification is not introduced to reduce agrochemical consumption, but it complies with at least the Non-Hazard Food standards.

In 2001, MOA launched the "Non-hazard Food Project" and the formal certification was introduced in 2003. Non-hazard Food certification is created as a way to provide basic food safety. Use of highly toxic pesticide is forbidden and pesticide residuals, heavy metals and microorganism contents need to be below national standards.

Green Food certification started as early as 1990. The China Green Food Development Center was founded in 1992 to oversee the certification process. There used to be two different types of Green Food certificates: Green Food AA and Green Food A. Green Food AA has very similar standards to organic food, requiring that no chemical fertilizers, pesticides and other chemical inputs are used. It is not widely recognized as organic food and was abolished in 2008, shortly after the official introduction of Organic Food certification. Green Food A is the normally recognized green food, allowing limited use of chemical fertilizer, pesticide and other chemicals; in this study, the term "green food" refers to Green Food A. The Green Food certificate is also valid for three years, and there are random inspections every year.

The export of organic food from China started in the early 1990s, with certification by foreign agencies. The national organic food standards and certification were introduced in 2005. Consistent with the common practice around the world, no agrochemical inputs are allowed in the production process. The certificates are valid only for one year and thus need to be renewed annually.

Geographic Indication Product certification was introduced in 2005 to protect high-quality products from certain specific regions. The certification is managed by the Agricultural Products Quality and Safety Center. Although this certificate does not directly aim to reduce the use of agrochemical inputs, the inspections and tests follow the same national standards as Non-hazard Food. The Geographic Indication Product certificate is also valid for three years with annual random inspections.

From the technical requirements on limiting agricultural chemical inputs in order to obtain ecological certificates, we can derive a number of hypotheses. Our main hypothesis is as follows: on average, certification of food production has a negative impact on chemical fertilizers and pesticides consumption. Based on this main hypothesis, we further form two sub-hypotheses. Our first sub-hypothesis is that the impacts of certifications are stable over time. This requires that the annual inspections are effective and that producers do comply with the chemical input restrictions. And our second sub-hypothesis that will be tested is that Organic Food certification has the strongest negative impact on agrochemical use, followed by Green Food certificates, and the impact of Non-hazard Food and Geographic Indication Product certification is the smallest. In the next section, we explain how these hypotheses are tested in this study.

3. Empirical strategies

To identify the impact of food certification on farmers' agrochemical use, we utilize the panel structure of the data set (see next section) and estimate fixed effects models. A fixed effect model helps to control for potential endogeneity problems related to unobserved time-invariant household-specific effects (u_i).

The main reduced form models we use in this study can be formulated as:

$$Y_{ijt} = \beta_0 + \alpha_1 Cer_{jt} + \alpha_2 CerDur_{jt} + \beta_2 \mathrm{X}_{ijt} + u_i + \theta_t + \varepsilon_{ijt}, \quad (1)$$

where Y_{ijt} is the indicator of fertilizer and pesticide consumption of household i in village j in year t; Cer_{jt} the certified food production dummy and $CerDur_{jt}$ stands for the duration of certified food production in year t; X a vector of covariates; u_i the unobserved household-specific fixed effects; θ_t the year-specific effects and ε_{ijt} the error term.

The dependent variable Y_{ijt} is the chemical fertilizer (pesticide[5]) consumption (in kg/mu), which can be interpreted as chemical fertilizer (pesticide) use intensity. It equals the quantity of fertilizer (pesticide) used in a year divided by the total sown area. Since we do not have crop-level agrochemical consumption information for the years before 2010, we use the household as the observation unit. The quantity purchased by a household is used as a measure of total household fertilizer (pesticide) consumption. We use the physical quantity rather than nutrients (active ingredients) content due to incomplete information about the latter[6]. Total sown area was calculated by summing data on the sown areas of 16 different types of crops obtained through the household survey. We use sown area rather than arable land area because it takes multiple cropping practices into account.

Village-level certified food production indicators are used as key explanatory variables. The certified food production dummy variable, Cer_{jt}, indicates whether village j had certified food production in year t. The dummy equals 1 for all villagers in a village if this village has certified food production in year t, and 0 otherwise. The duration variable, $CerDur_{jt}$, indicates the duration (in years) since certification started. We first include only the dummy indicator, Cer_{jt}, to test the main hypothesis that certified food production reduces agrochemical use. Then we further test the sub-hypothesis that the impact of certified production on agrochemical use is stable over time by adding the duration indicator $CerDur_{jt}$. We expect α_1 to be significantly negative and α_2 to be equal to zero.

We choose to use village-level indicators instead of household-level certification indicators for two reasons. First, beside the direct effect of certification on the participants, there might be spillover effects on the non-participants as well. Village-level indicators will take the potential spillover effects into account. Second, participation in certified food production is a self-selection process. Farmers' decisions of joining or quitting and the timing of these decisions are all endogenous. Given the data we have, these decisions are untraceable and we are not able to deal with these endogeneity issues. One concern is that using village would cause biased estimate as not all farmers in certified village participate into certification food production. However, if certification reduces agrochemical consumption of participants and there is no spillover to non-participants, we should still expect to find a statistically significant negative effect of the village-level certification variable despite potentially underestimating the size. If there is a spillover effect that also reduces agrochemical use of non-participants, then our estimates capture the overall effect at the village level. Therefore, if certification affects agrochemical use in the hypothesized direction, the potential bias only affects the magnitude, but not the sign of our estimates.

We also use time leads of Cer_{jt} as alternative key explanatory variables. The underlying logic is that, to obtain certification, farmers may have to make preparations in advance. If they already reduce their chemical consumption before getting certified, results from Equation (1) may underestimate the negative impacts. We use 1-year and 2-year leading variables, respectively. Replacing Cer_{ijt} in Equation (1) with Cer_{jt+1} or Cer_{jt+2}, we have the following model:

$$Y_{ijt} = \alpha_0 + \alpha_1 Cer_{jt+1(2)} + \alpha_2 X_{ijt} + u_i + \theta_t + \varepsilon_{ijt}. \tag{2}$$

Furthermore, to test heterogeneous effects of different types of certification, we construct village-specific certified food production indicators and test whether the coefficients of villages with different certificates follow the pattern described in the second sub-hypothesis. Instead of having one overall indicator, there are seven variables for each of the seven villages:

$$Y_{ijt} = \beta_0 + \beta_{11}Cer_{j1t} + \beta_{12}Cer_{j2t} + \cdots + \beta_{17}Cer_{j7t} + \beta_2 X_{ijt} + u_i + \theta_t + \epsilon_{ijt}. \quad (3)$$

In all specifications, the vector of control variables X consists of other factors besides certification that may affect farmers' fertilizer/pesticide input decisions. It includes household head characteristics, agricultural assets and endowments, other household characteristics, agrochemical prices, crop structure, village characteristics and year dummies. Specifically, household head characteristics include self-evaluated health and agricultural training dummy; agricultural assets and endowments include sown area and its squared term, household labor force[7] per mu, draft animals per mu, large agro tools per mu, machinery power per mu, proportion of land covered with greenhouses in arable land and proportion of irrigated land in arable land; other household characteristics include computer and television ownership dummies, agriculture as the main income source (dummy variable) and amount of non-cropping income; agrochemical prices include fertilizer price and pesticide price (yuan/kg); the fractions of each type of crops in the sown area are used as indicators of crop structure[8]; village characteristics include two dummy variables: whether the village administration spent money on providing extension services and whether the village administration provides any monetary support for grain production.

Although we hypothesize in Section 2 that certification reduces agrochemical use, we test the null hypothesis of no effect in the analysis. In principle, the effect of certification could go in both directions. Producers could increase agrochemical use if proper monitoring by regulation bodies is missing and if the prices of certified products are higher. We therefore test the null hypotheses of zero effect in the econometric analysis.

4. Data

The basic data set used in this study is the Rural Fixed Observation Points (RFOP) survey data set collected by the Research Center for Rural Economy (RCRE), Ministry of Agriculture. The RFOP survey is a national-wide longitudinal survey of rural households and villages. The first survey started in 1986; it is conducted annually except for a few interruptions. The latest available wave in 2013 covers 23,000 rural households living in 360 villages in 30 provincial level administrative units. The survey provides information on rural household characteristics, land use, labor use, agricultural production, income, expenditure, etc. Its panel nature allows us to track the changes in fertilizer and pesticide use over time. For a more detailed discussion on the sampling method, see Benjamin *et al.* (2005, Table AI) and Yao (2011).

The regular RFOP survey does not provide any information on certified production. To collect relevant information, the RCRE added a questionnaire specifically focusing on certified production to the regular survey in a six-province subsample in the summer of 2014[9]. The additional survey provides information on which village has adopted certified food production at the time of survey and when it started. The questions on certified food production refer to Green Food, Organic Food and Geographic Indication Product. Since Geographic Indication certification only started in 2005 and none of our sampled villages adopted certified production before 2007, we restrict the research period to 2005–2013. We build our certified food production indicators in a retrospective way, based on whether they had certification in 2014 and when it started.

We confine our analysis to the villages that were included in the additional six-province survey held in 2014, and combine the information from that survey with information collected for the same villages in earlier RFOP surveys held by the RCRE. After dropping observations with incomplete information and households that were interviewed for the RFOP survey in less than three years, we have 34,569 observations from 4,830 different households in 72 different villages in our working sample. Out of these 72 villages, 7 villages had certified food production at the time of the additional survey. Among these seven villages, two started certified production in 2007, one in 2008, one in 2009, two in 2010 and one in 2011. The certified products they were producing include staple food (rice), vegetables (Chinese yam), tea and fruits (apples and kiwi fruits). The number of households in our sample in each year ranges from 3,477 to 3,996 (see Table I). Only 1,757 households were interviewed in all nine years, but there are many households that are missing for only one or two years. To make maximum use of the available information, we use an unbalanced rather than a balanced panel in our main analysis. We check the robustness of our results in section 5.3 for the balanced panel[10].

Table I shows the mean values of the most important variables for the purpose of this research in the nine waves of the survey (see Table AI for the complete table). The proportion of certified food producers in our sample grew steadily from zero to about 10 percent in 2013. The chemical fertilizer consumption per mu in our sample shows a fluctuating but slightly increasing trend over the period under study. It increased proximately at rate (12 percent from 2005 to 2013). Pesticide consumption per mu increased more rapidly over time. The consumption in 2013 is 69 percent higher than in 2005.

The mean values of household head characteristics and most of the endowment and input variables are relatively stable over time. The sown area fluctuates around 11 mu per household, which is consistent with data presented in China's national statistics[11]. The steady increase of household labor force per mu after 2008 is probably due to the combined effects of more and more younger persons reaching labor force ages and declining mortality rates. Plastic mulching use is more volatile, without a clear time pattern. The share of land occupied by greenhouses in the total arable area is very small in all years. The share of land under irrigation in our sample declined despite an increase from 45.2 percent in 2005 to 52.1 percent in 2013 at the national level (NBS, 2006-2014). It is mainly caused by that fact

Table I. Mean values of most important variables, 2005–2013

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Certified producers (%)	0.00	0.00	4.12	5.20	5.78	9.68	11.17	10.22	9.92
Fertilizer (kg/mu)	67.33	71.19	70.02	66.48	72.34	75.99	74.64	76.88	75.44
Pesticide (kg/mu)	1.14	1.27	1.28	1.58	1.7	1.53	1.85	1.99	1.93
Sown area (mu)	10.59	13.60	10.60	10.51	10.85	11.09	10.45	10.31	10.99
Household labor per mu	0.62	0.65	0.75	0.78	0.95	0.99	1.11	1.21	1.19
Agro tools per mu	0.19	0.18	0.22	0.22	0.25	0.34	0.23	0.22	0.24
Machinery power per mu	0.23	0.23	0.28	0.25	0.23	0.29	0.44	0.86	0.78
Greenhouses (% of arable land)	0.59	0.71	0.18	0.22	0.33	0.96	0.20	1.04	0.22
Irrigation (%)	50.87	51.20	55.19	54.61	50.61	49.13	48.90	47.16	46.19
Share of major crops in sown area (%)									
Wheat	16.08	16.55	15.88	14.69	14.06	14.38	14.23	13.72	14.30
Rice	20.05	19.83	20.30	20.07	19.60	18.22	20.28	16.55	17.08
Maize	23.31	23.73	23.27	22.65	26.38	28.97	30.10	33.75	33.08
Soybean	5.85	4.93	4.43	4.71	4.54	3.82	3.07	2.19	2.35
Vegetables	5.28	5.56	5.39	5.87	5.96	5.91	6.69	6.96	6.64
Fruits	8.03	6.66	8.35	9.15	8.59	8.41	8.69	9.14	9.43
Non-cropping income (1,000 yuan)	12.02	13.72	17.19	17.29	18.69	21.31	24.42	25.22	27.98
Fertilizer price (yuan/kg)	1.51	1.5	1.53	1.94	1.78	1.69	1.91	2.03	1.93
Pesticide price (yuan/kg)	23.28	24.67	25.58	26.21	26.92	27.11	27.15	28.34	26.66
No. of villages	70	70	69	70	72	72	69	71	67
No. of observations	3,943	3,909	3,936	3,959	3,996	3,813	3,689	3,847	3,477

Note: All price and income variables have been deflated to 2005 prices, using national consumer price index data
Source: Calculated by authors from the RCRE surveys and the 2014 additional survey

that sample attrition relatively concentrated in Anhui and Yunnan where the shares of irrigation land are higher. The data on crop structure show an expansion of the area grown with maize from 23 percent in 2005 to 33 percent in 2013. Partly as a result, the area shares of other major crops decline over time, except for fruits and vegetables. Given the growing importance of migration and other forms of off-farm employment in rural China, it is no surprise that income from non-cropping activities has more than doubled during the period 2005–2013. The two price variables are calculated from dividing total cost by the total quantity of fertilizers or pesticides for each household. They therefore partly reflect changes in the composition of fertilizers and pesticides bought by farmers. The price of chemical fertilizers increased about 28 percent over the entire 2005-13 period. Its annual changes closely resemble fertilizer price changes reported in the *China Statistical Yearbooks* (NBS, 2006-2014). Mean pesticide prices increased more slowly and showed less variation than fertilizer prices for the farm households in our sample.

5. Results and analysis

5.1 Effects on household fertilizer and pesticide consumption

We estimate Equation (1) with fixed effect regressions. All standard errors are clustered at the village level. The regression results of key explanatory variables are shown in Table II. Columns (1) and (2) present the results for chemical fertilizer consumption. Column (1) includes only the certified production dummy in order to test the average effect of certification, while column (2) includes both the certification dummy and its duration to

		Fertilizer		Pesticide
	(1)	(2)	(3)	(3)
Certified production				
Certified production	18.57 (1.580)	4.566 (0.548)	0.413 (0.865)	−0.215 (−0.537)
Certified duration		5.041 (1.418)		0.226* (1.864)
Selected explanatory variables				
Sown area	−0.448*** (−2.688)	−0.454*** (−2.754)	−0.00849* (−1.729)	−0.00873* (−1.804)
Sown area squared	0.000493** (2.510)	0.000498** (2.556)	1.01e-05 (1.644)	1.03e-05* (1.692)
Household labor per mu	−0.500 (−0.645)	−0.520 (−0.670)	0.120** (2.427)	0.119** (2.403)
Agro tools per mu	−0.624 (−0.760)	−0.647 (−0.792)	0.0106 (0.189)	0.00961 (0.171)
Machinery power per mu	0.194** (2.588)	0.188*** (2.664)	0.00568*** (2.842)	0.00541*** (2.654)
Green house %	0.349*** (3.084)	0.354*** (3.184)	0.0209* (1.861)	0.0211* (1.858)
Irrigation %	−0.0634 (−1.642)	−0.0643 (−1.662)	−0.000777 (−0.275)	−0.000813 (−0.289)
Agricultural as main income source	4.063* (1.676)	3.768 (1.641)	0.190 (1.278)	0.176 (1.188)
Non-cropping income	−0.0585* (−1.720)	−0.0563 (−1.627)	−0.00143 (−1.348)	−0.00132 (−1.273)
Fertilizer price	−14.28*** (−4.246)	−14.30*** (−4.257)		
Pesticide price			−0.0414*** (−7.543)	−0.0415*** (−7.493)
Extension service	0.138 (0.0295)	0.385 (0.0821)	−0.861 (−1.606)	−0.850 (−1.590)
Staple crop subsidy	−9.759* (−1.773)	−9.288* (−1.771)	−0.214 (−0.644)	−0.193 (−0.604)
Crop structure	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Constant	87.73*** (6.176)	88.51*** (6.214)	1.328* (1.773)	1.364* (1.807)
Observations	34,569	34,569	34,569	34,569
R^2	0.101	0.103	0.034	0.034

Notes: *t*-statistics in the parentheses. Standard errors are cluster-adjusted at the village level. *,**,***Significant 10, 5 and 1 percent level, respectively

Table II. Certified food production and agrochemical use: fixed effects regression results examine whether the certification effect changes over time. Although the coefficients are large in magnitude (as compared to the mean values in Table I), they are not statistically significant. Since we expect to find a significantly negative impact, the insignificant results along with the positives signs show no support for our hypothesis that certified food production reduces fertilizer consumption. Nor do the results support the sub-hypothesis that the (negative) impact of certification on fertilizer use remains stable over time.

As for the control variables, it is worth noting that the relation between sown area and fertilizer exhibits a U-shape pattern. Fertilizer consumption per unit area decreases as the sown area increases until it reaches about 450 mu (about 30 hectare). Since the average sown area in our sample is only 11 mu per household, the vast majority lie on the left side of the U-shape curve, suggesting a negative correlation between farm size and chemical fertilizer input. The use of agricultural machineries seems to be complementary to fertilizer use. We find a slightly negative effect of irrigation, probably because given the household fix effects and crop structure, irrigation helps improve fertilizer use efficiency and thus slightly reduce fertilizer input. And farmers in villages that provide staple crop subsidies seem to use less chemical fertilizer. The fertilizer price is negatively related to fertilizer use as expected. Coefficients of the crop structure variables are largely consistent with our expectations that cash crops and horticultural crops usually need heavier fertilizer input than staple crops, although they are not shown in Table II[12]. Year dummies show a rising trend of fertilizer use, when controlling for other factors included in the model, during the period under study.

The results for pesticide use are reported in columns (3) and (4). The values of the R^2 are smaller than those in the fertilizer regressions, suggesting that the explanatory variables have less explanatory power in explaining pesticide use. This is plausible since pesticide use may be more related to certain climate conditions, biological features of crops and outbreaks of diseases or insects, and thus less dependent on other inputs or household characteristics. The average effect of certified food production on pesticide use intensity in column (3) seems to be zero, while column (4) suggests that certified food production has a positive effect on pesticide consumption, although only significant at 10 percent level. These results imply that having certification either has no impact on pesticide use or even slightly increased pesticide use over time. The hypotheses that certified food production reduces pesticide consumption and that the (negative) impact of certification is stable over time should therefore both be rejected.

In Table II, we assume that gaining certification at certain year affects agrochemical use in that year and afterwards. However, farmers that plan to obtain a certification may make preparations before applying for it. Therefore, the effect of certification may happen before actually gaining the certification. If this is the case, leading indicators are the more appropriate explanatory variables. Thus, we estimate Equation (2) with one- or two-year leading certification dummy as the key variable and report the coefficients of the certification in Table III. Again, the estimated coefficients are not significantly different from zero. The hypothesized negative impact of certification on agrochemical use is therefore not supported by the results even when we take the possibility that farmers reduce their agrochemical input before getting the certification into account.

Table III. Certified food production and agrochemicals use: fixed effects regression with leading indicators

	(1) Fertilizer, 1-year	(2) Fertilizer, 2-year	(3) Pesticide, 1-year	(4) Pesticide, 2-year
Certified production	6.568 (0.793)	0.0990 (0.0162)	0.117 (0.369)	−0.240 (−1.044)
Observations	28,048	23,549	28,048	23,549
R^2	0.114	0.108	0.037	0.033

Notes: Control variables are the same as in Table II. Full regression results are available upon request. *t*-statistics in the parentheses. Standard errors are cluster-adjusted at village level

5.2 Heterogeneous effects of certified food production

Different types of certificates could have different effects on input use due to the differences in the standards and requirements of each certificate. These heterogeneous effects might be hidden underneath the insignificant impact found in the previous section. Since organic food certification requires using no chemical inputs, green food certification requires limited chemical inputs use and geographic indication certificate exerts no legal constraint on fertilizer use and only forbids the use of highly toxic pesticides, we expect that organic food production has the strongest negative impact, green food weaker and geo-indication food has the smallest impact on agrochemical use (as specified in the second sub-hypothesis).

For this purpose, we construct certified food production indicators for each village and run fixed effects regression as in Tables II and III to identify village-specific effects of certified food production for each of the seven villages. Since we can identify which kind of certification each village holds, we can compare the effects of different certifications and test the aforementioned sub-hypothesis. The estimation results are given in Table IV. Only the coefficients for the seven village indicators are shown in the table for conciseness (see footnote 12). We mark the type of certification for each village-specific certification indicator in the parenthesis.

The coefficients for the seven village indicators vary a lot. There is only one village in which both fertilizer and pesticide use significantly declined after the certificate was obtained. Four villages experienced increased fertilizer consumption after getting certification, and the magnitudes are quite large in some cases (e.g. in vill1302 and vill6110). Certified food production has no significant effect in two villages and only in one village, we find a negative effect of certified food production on fertilizer consumption as it is supposed to be. Results for pesticide are similar. There are one village with significantly positive coefficients, five with insignificant coefficients and one with significantly negative coefficients.

For the four villages with Green Food certification, the estimated coefficients for both fertilizer and pesticide use are quite diverse, ranging from large and significant positive values, to insignificant and significant negative values. Therefore, we cannot assess the direction of the impact of green food certification on fertilizer and pesticide input use. The same holds for Geographic Indication certification. Surprisingly, Organic Food certification seems to increase fertilizer use, and have no significant effect on pesticide use, in the two villages that obtained the certification. However, since we only have two villages in our sample and the effects may be case-specific, we do not want to over-interpret these results as evidence against organic food production. To sum up,

Dependent variable	(1) Fertilizer	(2) Pesticide
Certified production		
Vill1302 (Green)	72.05*** (11.61)	3.615*** (16.59)
Vill3404 (Green)	0.110 (0.0474)	−0.0158 (−0.0952)
Vill3415 (Green)	−6.861 (−1.171)	−0.388 (−0.889)
Vill3511 (Geo and Green)	−26.36*** (−9.173)	−0.665*** (−4.284)
Vill5302 (Organic)	7.086* (1.875)	−0.141 (−0.899)
Vill6110 (Geo)	90.47*** (11.03)	0.645 (1.519)
Vill6118 (Geo and Organic)	11.13*** (2.790)	−0.339 (−1.562)
Observations	34,569	34,569
R^2 overall	0.117	0.037

Notes: Control variables are the same as in Table II. Full regression results are available upon request. *t*-statistics in the parentheses. Standard errors are cluster-adjusted at village level. *,**,***Significant at 10, 5 and 1 percent level, respectively

Table IV. Detailed village-specific effects on fertilizer and pesticide consumption we find heterogeneous effects across different villages but we do not find evidence supporting the sub-hypothesis that negative effects on agrochemical use increase with the degree of stringency in the type of certificates.

5.3 Robustness checks

We use unbalanced panel data in the previous analysis. As a robustness check we also run the same regressions as in Table II using a balanced panel for the 1,757 households with complete information in all the nine waves of the survey, leaving us 15,813 observations. The regression results, which are shown in panel (A) of Table V, are consistent with our main conclusions on the effects of certification on fertilizer and pesticide consumption.

Another concern is that large farmers may act differently from small farmers when facing the same production and market conditions. Although the average land holding size is rather small, there are some households that have relatively large land holdings. For example, there are 60 observations with sown area larger than 150 mu (10 hectare) in our sample. Relatively many of these observations are concentrated in the year 2006, which explains the relative peak of average sown area in 2006 shown in Table I. As another robustness test we restrict our sample to farmers whose total sown area is smaller than 30 mu (= 2 hectares) and redo all the regressions in Table II. Less than 4 percent (1,309 out of 34,569) of observations are dropped by this criterion. Yet, our conclusions about the (lack of) impact of certified production on agrochemical consumption do not change when large farmers are excluded from the sample (see panel (B) in Table V).

In the previous analysis, we use village-level certified production indicators. This means that all households in villages with certified production are regarded as producers of certified crops. When not all agricultural households in a village participated, using

	(1) Fertilizer	(2) Fertilizer	(3) Pesticide	(4) Pesticide
(A) Balanced panel				
Certified production	10.63 (1.065)	10.49 (1.415)	0.367 (0.838)	−0.188 (−0.516)
Certified duration		0.0495 (0.0320)		0.198*** (2.745)
Observations	15,813	15,813	15,813	15,813
R^2	0.130	0.130	0.044	0.044
(B) Smallholding farmers				
Certified production	18.38 (1.632)	4.995 (0.590)	0.388 (0.847)	−0.225 (−0.557)
Certified duration		4.843 (1.416)		0.222** (2.047)
Observations	33,260	33,260	33,260	33,260
R^2	0.120	0.122	0.037	0.037
(C) Household level				
Certified production	26.90* (1.673)	3.785 (0.371)	0.839 (1.220)	−0.113 (−0.230)
Certified duration		8.044 (1.494)		0.331 (1.545)
Observations	34,569	34,569	34,569	34,569
R^2	0.104	0.108	0.034	0.035
(D) Without crop structure				
Certified production	21.44 (1.616)	4.871 (0.603)	0.581 (1.074)	−0.253 (−0.663)
Certified duration		5.885 (1.511)		0.296* (1.873)
Observations	34,569	34,569	34,569	34,569
R^2	0.081	0.084	0.030	0.031

Notes: Control variables in each panel are the same as in Table II (except for Panel D, which exclude crop structure variables). Full regression results are available upon request. *t*-statistics in the parentheses, based on standard errors cluster-adjusted at village level. *,**,***Significant at 10, 5 and 1 percent level, respectively

Table V.
Robustness checks

village-level indicators may underestimate the negative impact on agrochemicals. Although we do not have household-level information on certified crop production, we may use household-level information on crop production to construct a household-level certified production variable. It equals 1 for households who lived in a village that had adopted certified production in a certain year and whose revenues from the certified crop was positive in that year, and equals 0 otherwise. The household-level duration variable indicates how many years the household had engaged in certified production. These household-level indicators could help reduce the classification error by excluding seeming non-participants. We rerun the same specifications as in Table II and present the key coefficients in panel (C) of Table V. The duration variable is no longer statistically significant (though larger in value) in the pesticides equation, but the positive impact on fertilizer becomes significant at 10 percent level. Again, our results do not support the hypothesis that certified food production reduces agrochemical use. Our results are robust to the potential underestimation of negative effects due to using village-level indicators.

To address the same concern, we also use information collected in the additional village survey held in 2014 about how many households participated in certified food production. Combining this information with the total number of households in each village derived from RFOP data, we calculated the participation rates in the seven villages with certification. We received valid participation rate information for six of these villages. Their participation rates are 23 percent (vill5302), 37 percent (vill3511), 57 percent (vill6118), 62 percent (vill1302), 80 percent (vill6110) and 81 percent (vill3404), respectively. The average participation rate is 57 percent. If food certification reduces agrochemical use, we expect to find larger and more statistically significant negative effects in villages with higher participation rates. However, when we combine the participation rates of each village with the village-specific effects presented in Table IV, we do not see such a pattern. Interestingly, the only village showing a significant decrease in agrochemical use has a relatively small participation rate (vill3511: 36.5 percent), while large increases in the use of agrochemicals can be observed in two villages with a higher share of participants (vill1302: 62.1 percent; vill6110: 80 percent). These results suggest that a bias due to differences in participation rates between villages cannot explain our main findings.

So far, we have controlled for crop structures in the regression specifications to assess the impact of certification while taking crop-specific demands for agrochemicals into account. However, as food certification applies to specific crops, crop choices could change as a result of obtaining certification and thereby also indirectly affect agrochemical consumption. Comparing the villages that adopted certified food production (C-villages) with those that never adopted (N-villages) we find that crop structures in C-villages not only were different from crop structures in N-villages in 2005, but also changed in different patterns from 2005 to 2013 (see Table AII, the shares of certified products such as fruits and rice increased in C-villages while decreased in N-villages). Therefore, in Panel D of Table V, we exclude crop structure from our regression specifications and compare these results with the results in Table II to check whether the indirect effect of certification through changes in crop structures could influence our main findings. Yet, the results here are very similar to our main findings in Table II. We do not believe that the indirect effect through crop structure changes affects our findings.

6. Discussion and possible explanations

We do not find support in our empirical analysis for the hypothesis that producing certified food reduces fertilizer and pesticide consumption. The average impact on fertilizer use is not significantly different from zero and the average impact on pesticide use is even weakly positive. When looking into the heterogeneous impacts of different types of certifications, there are great variations in the direction and magnitude of the effects across villages, with more villages that use more agricultural chemicals in certified production than villages that use less. But there is no clear pattern fitting the different requirements on agrochemical inputs of different certificates to the variation across villages.

One possible explanation for our counterintuitive findings is that villages that adopted certified food production are villages that already used less agrochemicals than other villages. If farmers started with low agrochemical input, they do not have to change their farming practices much. To test this, we compared the average fertilizer and pesticide consumption in 2005 between villages that never adopted certified production and villages that adopted certified production at some point of time during our period of observation in Table VI.

As can be seen from the table, villages that obtained certificates did not have lower levels of fertilizer and pesticide use in 2005. On the contrary, they actually had significantly higher levels of fertilizer use just a few years before they obtained their certificates. Therefore, in the case of China, we have reasons to expect that certification of crop production does not reduce agrochemical inputs use and does not generate environmental benefits.

What may be the reasons that certified production does not reduce chemical fertilizer and pesticide use in China? Farmers' awareness about certified production is one potential explanation. In the additional household questionnaire in 2014[13] , we asked the respondents about their knowledge of each type of certification, using a 1–5 scale: 1 = "never heard of," 2 = "only heard of the name," 3 = "know somewhat," 4 = "know well" and 5 = "know very well." The distribution of the answers is given in Table VII. All respondents were asked to answer these questions no matter whether they were producing certified food or not. Geographic Indication Product is the least well-known certificate. In total, 87 percent of surveyed households answered that they "never heard of" it or "only heard of the name." Green Food is relatively better known, as the corresponding proportion is 72 percent. Furthermore, even among the certified producers, the self-reported knowledge still seems to be limited. Over 50 percent of Green Food producers barely know anything about it (1 and 2) and the numbers for Geographic Indication Production and Organic Food are even higher. With limited awareness of what they are producing, farmers are unlikely to reduce their agrochemical consumption.

Table VI. Comparison of fertilizer and pesticide consumption in 2005

	(1) Fertilizer (kg/mu)	(2) Pesticide (kg/mu)
Non-certified villages	66.35	1.12
Certified villages	75.36	1.26
t-statistics	−3.261***	−0.900

Notes: Figures are the average consumption of households in each type of villages. *t*-tests are for the mean comparison of the two types of villages. *,**,***Significant at 10, 5 and 1 percent level, respectively
Source: Calculated from the RCRE surveys and the 2014 additional survey

Table VII. Knowledge of different types of certification

	All sample (%)			In certified villages (%)		
	Geo indication	Green	Organic	Geo indication	Green	Organic
1 = "never heard of"	69.6	36.4	49.0	63.9	38.2	54.1
2 = "only heard of the name"	17.9	35.8	26.7	11.5	19.7	21.9
3 = "know somewhat"	8.9	20.6	19.7	17.2	37.9	16.4
4 = "know well"	1.6	5.4	3.3	7.1	4.0	7.3
5 = "know very well"	2.0	1.8	1.3	0.3	0.2	0.3
No. of obs.	4,368	4,364	4,209	366	422	329

Source: Calculated by the authors from the 2014 additional survey

The price premium coming along with certification may provide farmers with incentives to actually increase agricultural chemical use to obtain higher yields. We have some evidence showing that farmers are not particularly loyal to their cooperators. In the survey, we asked a question about side selling: if there are other firms/individuals that offer 10 percent higher prices for your certified products, will you sell to them? All Organic Food producers answered "definitely will not" but most of the Green Food (155 out of 214) and Geo-Indication producers (35 out of 66) answered "definitely will." Meanwhile, the average price premium reported in the survey is around 30 percent, compared with prices of regular crop products. Along with the fact that farming practices of individual farmers are hard to observe and monitor, it is likely that even farmers who know exactly what they sign up for, may not comply.

To formalize this idea, we test how relative importance of certified production affects farmers' agrochemical use. We use the share of the revenues from the certified crop in the total revenues from crop production as a proxy of the relative importance of certified production and add this proxy to the regression specification as an interaction term with certified production dummy. The key results are shown in Table VIII. It reveals that certified production reduces agrochemical consumption only for those farmers whose revenues from certified production are just a small share of their total cropping revenues[14]. The more important certified production is for farmers, the more chemical fertilizer and pesticide they use. In our sample, for more than 80 percent of certified producers, certified production is important enough to incentivize them to use more agrochemicals, rather than less.

Differences in regulatory enforcement may explain the heterogeneous results across villages. Some villages are doing better in reducing agrochemicals than others. Although we do not have first-hand data on this issue, certification scandals in the news might shed some light on this. One recent example is a report by *The Beijing News* (*The Beijing News*, June 23, 2015) on the traceability code system that allows consumers to look up the origin of the products through the code online, which is particularly relevant to Geo-Indication Products. According to the report, tracing information may be faked and the codes can be purchased at a low price, or even customized at will[15]. Another example is a report on organic certification in 2012 (China News Service, August 28, 2012)[16]. In some places, an organic certificate could be bought for less than a hundred thousand yuan from a certification agency; government inspection and supervision were loose due to unclear jurisdiction or overlapping jurisdiction of different agencies; farmers interviewed admitted not conforming to the production protocols and conforming relied more on self-discipline. Such anecdotal stories may imply that differences in regulation enforcement are a possible explanation for the observed heterogeneous effects of certified production across villages. For villages located in regions with stronger regulation enforcement, certified food production may reduce agrochemical inputs use as it is intended to do. However, for villages in regions with weaker certification enforcement, certified food production may not reduce the use of agrochemicals but merely contribute to larger farm incomes.

Dependent variable	(1) Fertilizer	(2) Pesticide
Certified production	−38.37* (−1.718)	−1.657** (−2.228)
Certified production × relative importance	1.116** (2.367)	0.0427** (2.395)
Observations	34,569	34,569
R^2	0.118	0.037

Notes: Control variables are the same as in Table II. Full regression results are available upon request. *t*-statistics in the parentheses. Standard errors are cluster-adjusted at village level. *,**,***Significant at 10, 5 and 1 percent level, respectively

Table VIII. Impact on agrochemical consumption and relative importance of certified production

7. Conclusion

The excessive agricultural chemical consumption in China has drawn more and more attention from the general public and from policy makers in recent years. Certification has been used as an important tool to promote sustainable agricultural development in China. Certified production practices started in the early 1990s, but only began to boom in mid-2000s. Now, it has become an important part of agriculture production in China. However, little is known about the extent to which certified food production brings environmental benefits by reducing the use of chemical fertilizers and pesticides.

Using data from the RFOP survey conducted by RCRE, and an additional survey specifically focusing on certified food production, we explore the empirical evidence on this question. Using the panel nature of the data, our analysis reveals that certified food production might not be very effective in reducing chemical fertilizer and pesticide consumption. On average, certified food production does not have a significant impact on chemical fertilizer use, while there is weak evidence suggesting that it even increases pesticide use. The effects are found to be heterogeneous across villages. In some villages with certified production the use of agrochemicals does show a decline, but the impacts on both chemical fertilizer and pesticide use in most of villages are significantly positive.

Limited awareness and knowledge about certified food production might be a potential explanation. Little knowledge could easily translate into little change in agricultural practices. Even knowing exactly what they are supposed to do, the price premium could lure farmers to use more agrochemicals to secure or increase yields. Another possible explanation is the weak enforcement of relevant regulations, which may explain the heterogeneous effects across villages that we observed. In regions with careful inspections and strong enforcement, certified food production is more likely to reduce chemical inputs as expected, while in regions with loose inspections and weak enforcement, the price premium of certified food may even stimulate a higher use of agrochemical inputs.

Given the findings of this study, we suggest that further measures should be taken to make sure that the environmental goals of certified food production can be achieved and the reputation of certification in China can be improved. However, the evidence presented in this study should be considered as preliminary evidence that may guide future research in this field. Our study is limited in scale, not able to distinguish between agrochemical use on certified and non-certified crops and only made an explorative analysis of the potential factors explaining the results. Future research is needed to examine the validity of our counterintuitive conclusions through using, for example, data from large-scale surveys specifically designed for this purpose and to rigorously test the potential explanations that we give in our study.

Notes

1. Data source: FAO data base.
2. The MCI is defined as the total annual sown area of crops/the total cultivated area × 100 percent. It increased from 120.1 in 1998 to 134.3 in 2012 (Xie and Liu, 2015).
3. 15 mu = 1 hectare.
4. The arable land area equals 135.1634m hectare (2.027bn mu), according to recent statistics released by the Ministry of Land and Resources (2015).
5. Pesticides include insecticides, herbicides, fungicides, bactericides and other chemicals meant to reduce potential yield losses.
6. Information on the nutrient content of fertilizers and percentage active ingredient of pesticides is not available in the RFOP survey data sets. We use the price of fertilizer (pesticide) per kg as an explanatory variables in the regressions to control for differences in quality of fertilizer and

pesticide, assuming that the price is an appropriate indicator of the nutrients (effective ingredients) content level. The price per kg is calculated by dividing the total cost of fertilizer (pesticide) by the total physical quantity. We also ran regressions with the monetary value of fertilizer (pesticide) as dependent variable. The results, which can be obtained from the first author upon request, are very similar and do not lead to different conclusions.

7. Household labor force is defined as household members who are 16 or older, not disabled and not students.

8. The RCRE survey divides crops into three main categories: staple crops, cash crops and horticultural crops. Staple crops include six subcategories: wheat, rice, corn, soy bean, tuber, other staple crops. Cash crops include eight subcategories: cotton, oil crops, sugar crops, flax, tobacco, mulberry, vegetable and other cash crops. And horticultural crops comprise fruit and other horticultural crops.

9. The six provinces are Hebei, Liaoning, Anhui, Fujian, Shaanxi and Yunnan. Due to our budget constraints and existing regulations at the Research Center for Rural Economy (RCRE), it was not possible to do the survey in all 30 provinces in the RCRE Fixed Observation Point Survey. In consultation with the RCRE, we selected six provinces that represent different agro-ecological and socio-economic conditions prevailing throughout China and where the quality of the RCRE survey data is known to be relatively good.

10. Information about 969 households (20 percent) is missing for only one year, and for 638 household (13 percent) it is missing for only two years. This means that about 70 percent of the households appear at least seven times in our nine-year time span. In the main analysis we include households that have information for at least three different years so that we can capture a time trend. The number of observations in each year is rather stable, as can be seen from Table I. Sample attrition does not monotonically reduce the sample size over time. This means that the panel is unbalanced mainly due to accidently missing information, instead of systematic sample attribution, and that our sample should be able to capture the changes over time well.

11. In 2006, the total sown area equaled 152.1m ha, while number of agricultural production households stood at 200.16m at the end of 2006 according to the second Agricultural Census (NBS, 2008). The average sown area per household therefore equaled 11.4 mu (= 0.76 ha) at the end of 2006. The relatively large mean sown area in 2006 as compared to the other years reported in the RCRE survey data is probably caused by changes in the sample composition over time.

12. Full regression results are available upon request.

13. Here we use the information collected from the additional household survey in 2014. The data are collected in the same villages as the village survey. However, due to some coding issue, we were not able to match the 2014 additional household survey data with 2005–2013 RFOP survey data well. And the data quality in term of certified food production is quite poor. Thus, we did not use this household survey in the main analysis and only use it in the discussion section to provide some descriptive evidence.

14. The turning point in the share of revenues where the impact of certification on use becomes positive is 34.4 percent (= 38.37/1.116) for fertilizer and 38.8 percent (= 1.657/0.0427) for pesticide.

15. http://epaper.bjnews.com.cn/html/2015-06/23/content_583285.htm?div=0

16. www.chinanews.com/jk/2012/08-28/4137759.shtml

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(The Appendix follows overleaf.)

Appendix 1

Table AI.
Summary statistics of relevant variables used in analysis

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fertilizer (kg/mu)	67.33	71.19	70.02	66.48	72.34	75.99	74.64	76.88	75.44
Pesticide (kg/mu)	1.14	1.27	1.28	1.58	1.70	1.53	1.85	1.99	1.93
Certified producer (%)	0.00	0.00	4.14	5.24	5.83	9.66	11.18	10.38	9.61
Household head features									
Agro-training	0.06	0.07	0.08	0.08	0.07	0.07	0.09	0.08	0.08
Health: very good	0.47	0.48	0.49	0.49	0.50	0.50	0.50	0.48	0.48
Health: good	0.37	0.36	0.36	0.36	0.33	0.32	0.34	0.34	0.34
Health: normal	0.11	0.10	0.10	0.10	0.10	0.11	0.09	0.11	0.11
Health: bad	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06
Health: disabled	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Endowment and assets									
Crop sown area	10.59	13.60	10.60	10.51	10.85	11.09	10.45	10.31	10.99
Labor per mu	0.62	0.65	0.75	0.78	0.95	0.99	1.11	1.21	1.19
Draft animals per mu	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.03
Tools per mu	0.19	0.18	0.22	0.22	0.25	0.34	0.23	0.22	0.24
Machinery power per mu	0.23	0.23	0.28	0.25	0.23	0.29	0.44	0.86	0.78
Green house (%)	0.59	0.71	0.18	0.22	0.33	0.96	0.20	1.04	0.22
Irrigation (%)	50.87	51.20	55.19	54.61	50.61	49.13	48.90	47.16	46.19
Crop structure (%)									
Wheat	16.08	16.55	15.88	14.69	14.06	14.38	14.23	13.72	14.30
Rice	20.05	19.83	20.30	20.07	19.60	18.22	20.28	16.55	17.08
Maize	23.31	23.73	23.27	22.65	26.38	28.97	30.10	33.75	33.08
Soybean	5.85	4.93	4.43	4.71	4.54	3.82	3.07	2.19	2.35
Potato	3.40	3.47	3.63	3.53	3.38	3.33	3.11	3.20	2.91
Other staple crops	2.44	2.68	2.46	3.18	2.92	2.77	3.23	2.76	1.97
Cotton	2.10	2.81	3.55	3.37	2.51	1.80	1.20	0.86	0.56
Oil crops	6.91	6.51	6.41	7.16	6.37	5.93	3.94	4.02	4.14
Sugar crops	1.07	1.59	1.34	0.85	0.95	0.82	0.90	0.67	0.43
Flax	0.05	0.01	0.00	0.00	0.01	0.02	0.05	0.01	0.01
Tobacco	0.98	0.89	0.62	0.63	0.63	0.65	0.55	0.46	0.43
Mulberry	1.27	1.38	1.30	1.04	0.72	0.53	0.33	0.45	0.34
Other cash crops	1.65	1.87	1.91	1.63	2.04	2.72	2.02	2.55	3.46
Vegetables	5.28	5.56	5.39	5.87	5.96	5.91	6.69	6.96	6.64
Fruits	8.03	6.66	8.35	9.15	8.59	8.41	8.69	9.14	9.43
Other horticultural crops	1.53	1.53	1.16	1.47	1.34	1.72	1.61	2.71	2.87
Other household features									
Agriculture as main Income source (%)	0.82	0.80	0.80	0.80	0.78	0.76	0.77	0.76	0.75
Non-crop income	12.02	13.72	17.19	17.29	18.69	21.31	24.42	25.22	27.98
Computer	0.01	0.01	0.01	0.02	0.04	0.07	0.09	0.14	0.16
Television	0.91	0.90	0.93	0.95	0.94	0.97	0.95	0.97	0.97
Fertilizer price (yuan/kg)	1.51	1.50	1.53	1.94	1.78	1.69	1.91	2.03	1.93
Pesticide price (yuan/kg)	23.28	24.67	25.58	26.21	26.92	27.11	27.15	28.34	26.66
Extension service dummy	0.23	0.20	0.15	0.14	0.19	0.16	0.20	0.16	0.11
Subsidy dummy	0.08	0.05	0.03	0.03	0.06	0.02	0.06	0.03	0.02
No. of observations	3,943	3,909	3,936	3,959	3,996	3,813	3,689	3,847	3,477

Notes: The unit of non-crop income is 1,000 yuan. All price and income variable have been deflated to 2005 level

Appendix 2

Crop structure (%)	2005 C-villages[a]	2005 N-villages[a]	2013 C-villages	2013 N-villages
Wheat	22.90	15.23	15.07	14.22
Rice	33.79	18.33	35.30	15.08
Maize	16.98	24.20	15.34	35.04
Soybean	1.95	6.34	0.86	2.51
Potato	0.00	3.82	0.40	3.18
Other staple crops	2.63	2.42	0.95	2.08
Cotton	0.00	2.36	0.00	0.62
Oil crops	1.55	7.58	2.28	4.34
Sugar crops	0.23	1.18	0.08	0.47
Flax	0.02	0.06	0.00	0.01
Tobacco	0.27	1.07	0.00	0.48
Mulberry	0.95	1.31	0.16	0.36
Other cash crops	1.36	1.69	3.08	3.50
Vegetables	5.15	5.23	5.29	6.77
Fruits	11.38	7.61	19.28	8.35
Other horticultural crops	0.84	1.57	1.91	2.99

Notes: Share of each type of crops in total sown area calculated from RFOP data. [a]C-villages are villages that adopted certified food production at some point, and N-villages are village that never adopted certified food production

Table AII. Crop structure of villages with and without certification, 2005 and 2013

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