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Factors affecting farmers' willingness to pay for adopting vegetable residue compost in North China

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ABSTRACT

The random disposal of vegetable residues in north China has become an important obstacle for the sustainable development of vegetable industry. The composting treatment technology has been transformed into organic fertilizer by high temperature fermentation, which has become a widely promoted agricultural clean production technology. However, due to the voluntary nature of farmers' adoption and their reluctance to adopt, this study aimed at assessing the factors that influence their adoption will and evaluate the value of willingness to pay (WTP) for composting technology. Data were collected from 142 respondents through a household survey in Gaocheng District by using structural questionnaire of contingent valuation method (CVM). Some qualitative response models (Probit, Logistic and multiple linear regression models) were applied for examining the main factors influencing the vegetable residue compost adoption and estimating the WTP value. The findings showed that social resource factors play an important role in the respondents' behaviors toward composting technology adoption. The empirical results indeed highlighted that subsidy policy, top dressing time, age, scale, investment of irrigation and net income have significant positive influences on the WTP of compost, while work time and information sources have a negative impact. Government subsidy is a necessary premise for implementing the composting program. The governments should subsidize the remaining 97% of the construction costs to ensure the smooth implementation of composting technology. The findings specifically mentioned that the subsidy object should be the disadvantaged peasant groups with lower household income but more environmentally conscious. This paper is believed to not only assess the technical externality of vegetable residues for the first time but also provide decision reference for policymakers, especially in the background of rapid development of agricultural clean production technology, the accuracy and efficiency of subsidies should be improved.

1. Introduction

With the rapid development of facilities vegetables industry in China, waste products such as root, stem, leaf, and rotten fruit are largely dumped at will, causing serious environmental pollution problems. Composting technology for vegetable residue, which can convert waste into organic fertilizer has recently become an important cleaner production technology [11,52]. Within the limited fund support and service scope, the application of technology cannot benefit all farmers. Composting technology has achieved “quasi-public good” status [31,55], and has significant positive externalities on farmland's ecological environment [5,14]. However, adopting vegetable residue compost may lead to profit losses, farmers are reluctant to adopt and adopt it only when they can obtain additional profits through government's incentive policy [32]. As the marginal private income of technical activities is less than the marginal social benefits, farmers should be encouraged and remunerated for the economic losses incurred by these practices [19,35,39,59].

There are a large number of studies to investigate the farmers' participation in agricultural environmental measures. These studies are largely based on the contingent valuation method (CVM) to obtain the willingness to pay (WTP) and willingness to accept (WTA) of households' contingent behavior, which can be categorized into two fields. The first category is to assess the determinants of the acceptance of agricultural, ecological, or environmental protection measures. For instance, CVM method was used to obtain the WTP and WTA of households in the contiguous area of the Garonne River for habitat preservation and to estimate visitors' willingness to pay for the conservation of Paya Indah Wetlands in Malaysia, and to explore the willingness of farmers to participate in two voluntary agricultural environmental policies which were plants in yard and extension of field margins [3,45,48]. In addition, some studies aimed at assessing the factors that influence farmers' participation in crop intensification program in Rwanda,

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determining the adoption levels of environmentally friendly practices in Turkey, and discussing consumer acceptance of cultured meat in Belgium [10,37,49].

The second category aims to evaluate the WTP and WTA for agricultural nonpoint source pollution prevention and control technology. Some studies are focused on crop production and have analyzed the farmers' WTP and WTA for conservation tillage in Iowa and Canada, composted municipal solid and fecal waste in Ghana and cooperative pest control in North American [17,18,32,46]. The willingness to adopt agricultural waste recycling technology mainly involves the biogas technology, manure separation technology and green fertilizer technology [1,22,29]. These studies have provided valuable insights on how to guide farmers to adopt environment-friendly production techniques and raise awareness of environmental protection. A few studies have assessed the value of farmers' WTP for pollution prevention and control technology and the utilization of agricultural waste resources [23,26,47,54]. There are some other studies conducted in vegetable production to understand how farmers' attitudes, characteristics, perceptions, and other control variables influence their willingness to adopt an innovation, or to participate in an ecological security management program [27,28,33]. There are also a few studies on the willingness to adopt composting technology. Such as analyzing the determinants for compost adoption by farmers in French West Indies and valuing the environmental impacts associated with the operation of landfills for residues following waste treatment in Ikaria of Greece [21,41]. Empirical studies have confirmed that subsidies could be used by governments to induce additional adoption and reduce the cost of premiums for farmers' production practices.

Because of low level of production in the agricultural industry and differences in farmers' cognitive levels has led to many problems and perplexities in the existing research. The CVM method depends on a hypothetical market establishment [36,40]. Due to hypothetical characteristics of bias, the deviation of research methods and investigation of the implementation of bias and so on will inevitably occur in the assessment of the CVM [58]. At present, the empirical research on improving the effectiveness and reliability of this method is limited. The current literature focuses on the mechanisms influencing technical adoption behaviors, yet rarely accounts for the value of the WTP. The limitations of CVM lead to a questioning of the accuracy of the assessment results, thus the existing research does not provide sufficient technical support for decision-making of government.

This study aims to apply the CVM for valuing the composting technology externalities attributed to the recycling of vegetable residue in the North China Plain. It focuses mainly on the behavioral driving mechanism for the vegetable residue composting technology and the value evaluation of the WTP concept from the perspective of farmers. We use probit, logit binary selection models to analyze the determinants of the WTP, and linear regression models to estimate the cumulative utility value and the WTP. This paper is organized as follows. We describe the data sources and econometric models in Section 2. In Section 3, the econometric models are estimated to identify the determinants of the WTP and further assess farmers' WTP. Section 4 contains a general discussion of the research approach and limitations of the analysis. The final section presents our conclusion.

2. Approach and application

2.1. The contingent valuation method

The contingent valuation method (CVM) is a typical appraisal method for statement preference. It directly asks the respondent's willingness to pay (WTP) for certain environmental goods or resource protection measures or their willingness to accept (WTA) compensation for environmental damage and resource loss in a hypothetical market environment, and evaluates the economic value of environmental services on both WTP and WTA scales [34,36]. CVM is based on the theory of welfare economics with constant consumer utility, and establishes an indirect utility function model under restricted conditions [56,57]. CVM is not only an important method used by the international community to measure the value of non-market environment items, but also an effective means for quantitative behavioral research [4,50].

The CVM method has not yet become an officially recognized method of determining ecological compensation standards because there are questions about the validity and reliability of data acquisition [25]. The major limitation of CVM is that the respondents may not answer the WTP questions accurately, and hence the willingness value elicited from the questionnaire may not be an expression of their true intentions [17]. Generally, the biases affecting the accuracy of CVM research results in the field of agricultural ecological compensation mainly include the following: hypothetical market bias, questionnaire design bias, core estimated value problem bias, and interviewer bias [6,12,58]. Therefore, it is necessary to avoid possible deviations in practical application and to improve the validity and accuracy of measurements from the CVM method.

2.2. Application of CVM in composting technology assessment

Research work evaluating the willingness to pay for adopting residue composting technology is rather limited. In addition, none of the previous studies used vegetable residue composting, an important environmentally friendly technology, to assess external value. Instead, to date research has focused on farmers' adoption of agricultural waste disposal and recycling technology, and other eco-friendly practices. Although the relevant literature is scare, the available studies have applied the contingent valuation method (CVM) to measure the values of practices by using survey questions to elicit farmers' stated preferences for intermediate environmental goods such as compost and technology that comprehensively utilize agricultural waste, while others used the two WTP/WTA evaluation criteria with CVM, focusing on the factors influencing farmers in their adoption of these advanced technologies, and estimated the monetary values of WTP/WTA through econometric methods [17,44,53].

First, we review the main researches on the willingness to adopt composting treatment technologies. Paul et al. [41] conducted a survey at Guadeloupe Archipelago in the Caribbean region, with a sample of 520 farmers. They used a logit regression model to assess the impact of 14 biophysical and socio-economic variables on compost adoption. The experience of the farmers and their level of education had a positive effect on adoption, whereas farmer age and a lack of professional organization had a negative effect. The innovation of the research was using the farm typology to estimate the probability of adoption and it was very helpful in identifying the interactions between the two categories of variables. Danso et al. [17] focused on the analysis of perceptions and willingness-to-pay (WTP) for composted municipal solids and stool waste among urban farmers, peri-urban farmers, and other potential compost users in Ghana. The probit statistics indicated that farmers with a higher ability to pay and a higher comprehension of the benefits and risks of compost showed a higher WTP, and that the age and education factors significantly affected the farmers' purchasing decisions for compost. In addition, the participation of the construction sector could effectively increase the production of organic waste by approximately 25%, and public subsidies appear necessary to cover major cost aspects such as transport and disposal. Gaglias et al. [21] devised an application of CVM in estimating in monetary terms the environmental impacts of a landfill for solid waste residues following waste treatment, which was conducted in Ikaria, Greece, a medium-sized island in the northern Aegean Sea. The results showed that the mean willingness to pay per household to create a fund for financing programs that would host the landfill in question was estimated at €6.5–6.7 bimonthly per household, taking into account all households of the sample.

Second, we present the representative researches on the willingness to adopt technologies for the utilization of agricultural wastes. Gebrezgabher et al. [22] analyzed the effect of farms and farmers' characteristics on their attitudes toward the different attributes of manure separation in the Netherlands. The analysis used survey data collected from 111 Dutch dairy farmers, and utilized a multi-step approach. Results from the ordered probit model showed that young farmers with a low level of education and bigger farm size were more likely to adopt manure separation technology. Additionally, farmers' attitudes toward the different attributes of manure separation technology significantly affected the likelihood of their adoption. These key factors for explaining the likelihood of adoption had to be considered by policy makers, technology developers, and distributors when designing an appropriate marketing strategy. Wang et al. [53] evaluated the perceptions of eco-friendly soil-management practices and the adoption attitudes of small farmers in Shandong Province, China by applying a logit model. In this study the factors affecting the adoption of the technology were grouped into farmers' characteristics, the farms' biophysical characteristics, and the farms' financial and social characteristics. The findings indicated that the perception of practices and adoption attitudes were the most important in positively influencing farmers' decisions, and that the availability of farming funds had a significantly negative impact on adoption. In China, scholars have also tried to use the CVM method to assess the willingness to adopt environmentally friendly technologies and their economic value. Guan et al. [23] used CVM to evaluate the economic value of water-saving irrigation system services in three irrigation areas of Qingdao in Shandong Province, China, and found the average WTP of each household for a water-saving irrigation system was 117.93 Yuan, varying from 117.93 to 153.26 Yuan. He et al. [24] analyzed farmers' willingness to pay for the prevention and control of agricultural waste pollution and its influencing factors, and the non-market value was estimated with the application of CVM. Farmers' annual average WTP was 130.08 Yuan to 189.84 Yuan per household per year, the total present value of which is 1.39 to 2.04 billion Yuan in Hubei Province. Wei et al. [54] conducted a field survey for 400 farmers in the three Chinese provinces of Shandong, Hubei, and Shanxi, with questionnaires concerning the cognition of resource agro-waste and the willingness to pay for it. The sample's total average willingness to pay for straw was 186 CNY/year/person, for livestock and poultry manure was 310.8 CNY/year/person. The research conclusions provided a reference for relevant government policy making and decision-making.

3. Materials and methods

3.1. Study area

Gaocheng District is located on the eastern side of Shijiazhuang City in the south west of Hebei Province, and has a total area of 836 km^2. It is a national agricultural production demonstration base for large counties producing pollution-free vegetables. The cultivated area is 54,400 ha or 0.07 ha per capita. The region has complete water conservation facilities with an effective irrigation rate of 100%. Gaocheng has chosen 16 villages to build vegetable standard garden. However, low utilization of vegetable waste and unreasonable disposal methods are important obstacles to further development of vegetable industry. Because composting technology is relatively mature and construction costs of the reactor are relatively high, farmers must pay a high price to adopt the technology. Thus, the internalization of positive technology externalities is still not possible and therefore, farmers' willingness to adopt this technology is not high.

3.2. Data sources

In this study, the related problems of obtaining eigenvalue data were designed from the perspective of building a model. The questionnaire consists of four parts: individual characteristics, labor intensity, production costs, and social resources. We used a CVM payment card in calculating the WTP for the construction fee. First, we asked respondents if they accepted subsidies for vegetable residue compost facilities (Q1 in Appendix A). Second, we asked the following question (Q2 in Appendix A) if a subsidy was accepted: ① We introduced the subsidy policy to the farmers, that is, the government subsidizes most of the construction costs of the pool, and then asked "Would you like to pay for the remaining construction costs?" ② If yes, how much would you be willing to pay? The respondents selected one of the values on the payment card (Q3 in Appendix A). Third, we designed the selection table for the subsequent deterministic problem. In the selection table, the number 1 represents very uncertain, whereas 10 represents very certain. The certainty threshold was set at 9 and respondents who chose a number less than or equal to 9 were deemed to be unwilling to pay (Q4 in Appendix A), thereby effectively improving the accuracy of the data on the WTP. We conducted face-to-face interviews in March 2015, and also obtained 142 valid survey responses from a total of 144 questionnaires from five villages (Fig. 1). The interviews were conducted by the authors and trained researchers.

3.3. Economic models

We controlled for as many variables as possible, redefining and assigning 15 variables on the basis of defining principles for variables and the transformation experience rule in Table 1. This table contains four categories of explanatory variables: ① Individual characteristic variables: age, education, and income; ② Labor intensity variables: worktime, planting area, irrigation times, and top dressing times; ③ Production costs variables: includes fertilizer, pesticides, irrigation, organic and seeds costs; ④ Social resource variables: selected information source and policy cognition respectively, which are binomial selection variables.

In the first stage, we use a limited dependent variable that can take only one of two values for the econometric estimation. The objective

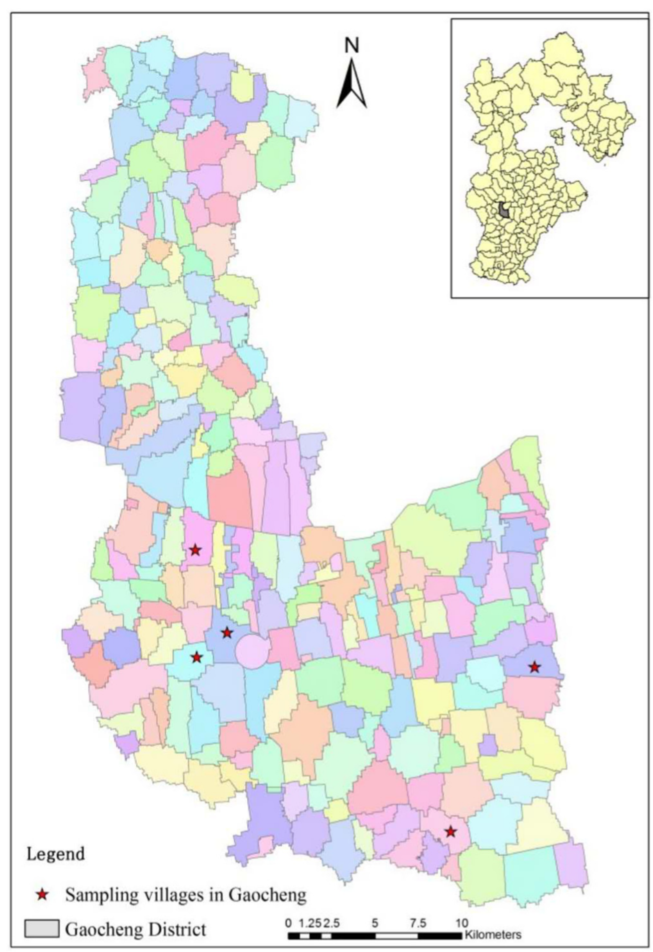

Fig. 1. Villages included in the survey.

Table 1
Summary of the explanatory variables used in the probit models.

Variable	Explanation and definition of variables	Average	Standard deviation
Individual characteristics			
Age	Actual age of respondents	47.39	9.241
Education	Illiteracy = 0, PS = 6, MS = 9,HS = 12, college above = 16	8.49	2.741
Income-capita	Household incomes per capita. (CNY/person/year)	12,851.63	11,596.62
Income-net	Net income from vegetables production (CNY/0.067 ha/year)	9446.539	8706.783
Labor intensity			
Time	Square of labor time group level	18.612	5.7450
Area	Square of greenhouse planting area	31.000	59.068
IR	Total times of irrigation (times/year)	19.55	9.873
TD	Total times of top dressings (times/year)	18.22	6.189
Production costs			
Fertilizer	Fertilizer costs per unit area (CNY/0.067 ha)	1495.243	1024.358
Pesticides	Pesticide costs per unit area (CNY/0.067 ha)	899.662	722.324
Irrigation	Irrigation costs per unit area (CNY/0.067 ha)	162.647	94.920
Organic	Organic fertilizer costs per unit area (CNY/0.067 ha)	419.438	305.156
Seeds	Seedling costs per unit area (CNY/0.067 ha)	1887.183	508.862
Social resources			
Information	Not rich = 0, rich = 1	0.49	0.502
Policy	Do not accept = 0, accept = 1	0.96	0.202

Note: 1. Planting scale and production cost variables are reference "mu" as the unit of measurement for calculations, which is commonly used in agricultural production in China.1 mu = 0.067 ha.
2. Abbreviations: PS-primary school, MS-junior middle school, HS-senior high school, IR-irrigation, TD-top dressing.

is to estimate the probability that respondents are willing to pay conditional upon their individual characteristics and external factors. For this kind of discrete binary choice problem, the most appropriate technical tools are probit and logit models [2,38,48]. Following previous studies [30,42,43], the cumulative distribution function for the error term follows the cumulative normal distribution in the probit model, and follows the logistic distribution in the logit model. The probability of the investigated event occurring can be defined as:

$$\begin{aligned} &Prob(WTP_i = 1) \\ &= f(Age_i, Education_i, Incomecapita_i, Incomenet_i, Time_i, Area_i, Fertilizer_i, Pesticides_i, \\ &\quad Irrigation_i, Organic_i, Seeds_i, IR_i, TD_i, Information_i, Policy_i, \mu) \end{aligned} \tag{1}$$

The parameters can be estimated by maximum likelihood methods [7,20]. We expect that: ① An increase in household income will increase farmers' WTP for the construction of the reactor. ② As fertilizer, pesticide, irrigation, and other obvious production costs increase, it is expected that farmers will pay more attention to agricultural production investment and better understand the advantages of composting and pay for it. ③ Farmers with rich information sources on compost or other agricultural clean technology are expected to pay more than others with less or no relevant information. ④ Reflecting the benefits of agriculture, we assume that farmers who accepted subsidies have a greater WTP than those who did not.

In the second stage, we estimate the WTP for the construction fee. Some of the arithmetic means are calculated by the SPSS statistical software, and the estimation of the mean WTP was done by econometric estimation. Cobb−Douglas (CD) production function is used to calculate the WTP values. The quantitative variables are logarithmically transformed and the dummy variable is directly in the form of a horizontal value. We estimate the following multivariate logarithmic linear model to calculate the respondent's WTP for the construction fee:

$$\begin{aligned} &WTP_i \mid PAY_i = 1 \\ &= EXP(lnA + \beta_1 Age_i + \beta_2 Education_i + \beta_3 lnIncomecapita_i + \beta_4 lnIncomenet_i + \beta_5 lnTime_i \\ &\quad + \beta_6 Area_i + \beta_7 lnFertilizer_i + \beta_8 lnPesticides_i + \beta_9 lnIrrigation_i \\ &\quad + \beta_{10} lnOrganic_i + \beta_{11} lnSeeds_i + \beta_{12} lnIR_i + \beta_{13} lnTD_i + \beta_{14} Information_i \\ &\quad + \beta_{15} Policy_i + \mu_i) \end{aligned} \tag{2}$$

4. Results

4.1. Willingness to pay responses

The frequency distribution of the bidding value is shown in Table 2. Twenty-three respondents, or 16.2% of the total, expressed zero WTP. This reluctance to pay is because of the small scale of greenhouse cultivation and the small yield of vegetable residues, which is not worth piling. Twenty-six respondents, or 18.3%, selected the tender value of 10 CNY/person. Fifteen respondents, or 10.6%, selected the tender value of CNY 11–20/person. Nineteen

Table 2
Distribution of WTP of the respondents ($n = 142$).

Bidding (CNY/person)	Number of people	Effective frequency	Cumulative frequency	Bidding (CNY/person)	Number of people	Effective frequency	Cumulative frequency
0	23	0.162	0.162	51–60	5	0.035	0.669
10	26	0.183	0.345	61–70	0	0.000	0.669
11–20	15	0.106	0.451	71–80	5	0.035	0.704
21–30	13	0.092	0.542	81–90	7	0.049	0.754
31–40	2	0.014	0.556	91–110	19	0.134	0.887
41–50	11	0.077	0.634	111–150	16	0.113	1.000

Table 3
Mean of WTP for five explanatory variables with grouped data.

Variables/group.	Group 1	Group 2	Group 3	Group 4	Group 5
① Gender	50.99 (0.53)	48.08 (−2.38)			
② Age	64.00 (13.54)	54.44 (3.98)	44.51 (−5.95)	55.37 (4.91)	51.76 (1.3)
③ Education	62.86 (12.4)	43.21 (−7.25)	53.71 (3.25)	45.75 (−4.71)	17.50 (−32.96)
④ Income structure	56.67 (6.21)	45.48 (−4.98)	56.62 (6.16)	49.15 (−1.31)	
⑤ Area	47.02 (−3.44)	61.19 (10.73)	31.25 (−19.21)	40.45 (10.01)	76.07 (25.61)
⑥ Policy	50.00 (−0.46)	50.48 (0.02)			

Notes: ① Gender: male, female. ② Age: ≤29, 30–39, 40–49, 50–59, ≥60. ③ Education: Illiteracy (=0), primary school (=6), junior high school (=9), senior high school (=12), Bachelors or above (=16). ④ Income structure: <25%, 25–49%, 50–74%, ≥75%. ⑤ Area: <0.2, 0.2–0.32, 0.33–0.46, 0.47–0.59, ≥0.6 (hectares). ⑥ Policy: Do not accept, accept.
Difference is in parentheses.

respondents, or 13.4%, selected CNY 91–110/person and sixteen respondents, or 11.3%, selected CNY 111–150/person. This shows that despite some respondents expressing a strong WTP and environmental awareness, nearly half of the respondents expressed a lower WTP under the premise of unknown production efficiency. This implies that farmers want to pay as little as possible, thus the more subsidies provided, the better. The mean WTP of the total valid sample was CNY 50.46/person. We compared the difference between the overall mean and the mean WTP for the six grouping variables which is showed in parentheses of Table 3. It can be seen from Table 3 that the WTP average of some grouping variables is close to the WTP average of the sample, and the difference between the two is smaller such as male, 60 years of age, junior high school culture, vegetable production income higher than 75% and accept the subsidy policy.

Table 4
Probit and logit analysis of the determinants affecting respondents' willingness to pay.

Variable	Expected sign (1)	Probit		Logit	
		Coefficient (2)	z-Statistics (3)	Coefficient (4)	z-Statistics (5)
Con		−5.0677 (1.9841)[a]	−2.5542	−8.7794 (3.8722)	−2.2673
Age	−	0.0722*** (0.0245)	2.9418	0.1298*** (0.0466)	2.7850
Edu	−	−0.1058** (0.0526)	−2.0110	−0.1830** (0.0857)	−2.1354
Inc. capita	+	−5.59E-05 (3.70E-05)	−1.5107	−9.89E-05 (7.64E-05)	−1.2958
Inc. net	+	7.82E-05* (4.72E-05)	1.6548	0.0001 (9.50E-05)	1.4435
Time		−0.0862* (0.0453)	−1.9010	−0.1619* (0.0905)	−1.7884
Area	−	0.0259** (0.0126)	2.0619	0.0450* (0.0261)	1.7239
IR		0.0156 (0.0552)	0.2831	0.0100 (0.1099)	0.0909
TD	−	0.0889** (0.0393)	2.2628	0.1456** (0.0694)	2.0998
Fertilizer	−	0.0002 (0.0003)	0.8009	0.0004 (0.0006)	0.7434
Pest	+	−0.0005* (0.0003)	−1.8069	−0.0009 (0.0005)	−1.6138
Irrigation	+	0.0109*** (0.0041)	2.6513	0.0204** (0.0087)	2.3383
Org	+	−0.0008 (0.0006)	−1.3210	−0.0013 (0.0011)	−1.2657
Seed	−	0.0002 (0.0004)	0.7090	0.0006 (0.0007)	0.8040
Info	−	−1.0983** (0.4265)	−2.5753	−1.9597** (0.8279)	−2.3672
Pol	+	2.7808*** (0.7095)	3.9196	4.8282*** (1.3421)	3.5974
McFadden R-squared		0.4059		0.4030	
LR statistic		51.4882(0.0000)[b]		51.1228(0.0000)	
Log likelihood		−37.6832		−37.8659	
# of observations		129		129	

Abbreviations used in Table 5 and all following tables: Con = constant, Edu = education, Inc. capita = income per capita, Inc. net = net income from vegetable production, IR = irrigation times, TD = top dressing, Org = organic, Info = information, Pol = policy.
Note:
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
a Standard errors are in parentheses.
b Probability of LR statistic.

4.2. Willingness to pay determinants

The results are reported in Table 4. For the individual characteristics variables, older farmers are mainly vegetable growers and their net income from vegetables is higher. They usually pay more attention to the protection of the production environment and are willing to pay the construction fee. In contrast, education level has a significant negative impact on the WTP, which may be because of more opportunities for nonagricultural employment by highly educated farmers, so less attention is paid to investment in agricultural production. Regarding the production cost control variables, irrigation and pesticides are deemed to be indispensable agronomic measures in vegetable cultivation. The more farmers invest in these agronomic measures, the more they attach importance to agricultural production, and the higher their WTP for the construction fee becomes. In addition, planting area and top dressing significantly affect the WTP, because large-scale cultivation produces more debris, and therefore the cost of composting can be effectively shared, so that large farmers are more willing to accept this measure. The innovation point is the social resource control variables. From columns 2 and 4, it can be seen that farmers who accept the subsidy policy have a higher WTP, and information has the greatest negative impact on WTP.

In particular, the results in Table 5 show the factors that influence the information sources of farming households. We found that farmers with insufficient sources of information have the following characteristics: low level of education, low per capita income of family, low cost of seed production, and less top dressing. It can be seen that these farmers mainly live by planting vegetables, and the family is not rich. However, it is this group of farmers who are more concerned about the ecological environment of farmland and their own resource conditions and are more willing to participate in the government's agricultural environmental policy projects. Agricultural environmental protection measures are a strong guarantee of ecological and environmental security, and the safety of the ecological environment is the lifeline of most farmers. Therefore, subsidy policy for agricultural environmental protection should be more focused on the disadvantaged groups with low cultural level and low household income.

We conduct our analysis with models that include net income from vegetables, irrigation costs, and top dressing times, and end with all the explanatory variables (Table 6). We found that the higher the per capita income of the family is, the higher the net income is. As greenhouse vegetables are the main source of income for farmers, they are more willing to use composting techniques to reduce fertilizer application. The most significant influencing factors for irrigation costs are irrigation times and top dressing times. An increase in the number of irrigation and top dressing hours indicates that the labor intensity of farming has increased. The greater the labor intensity of farmers' vegetable cultivation, the higher the level of production management and the more they were willing to adopt the composting technology. The determinants that affected top dressing times were explicit production costs (fertilizer cost and irrigation cost) and information sources. As the cost of fertilizer and irrigation increases, vegetable production and agricultural income will increase accordingly, and they are therefore willing to increase

Table 5
Probit and logit analysis of the determinants of respondents' information sources.

Variable	Probit		Logit	
	Coefficient	z-Statistics	Coefficient	z-Statistics
Con	−1.3941 (1.2549)[a]	−1.1109	−2.3636 (2.0795)	−1.1366
Age	0.0031 (0.0153)	0.1997	0.0067 (0.0252)	0.2674
Edu	0.0918* (0.0541)	1.6965	0.1502 (0.0916)	1.6413
Inc. capita	6.20E-05** (2.41E-05)	2.5743	0.0001** (4.06E-05)	2.4863
Inc. net	−5.27E-05** (2.39E-05)	−2.2052	−8.50E-05** (3.92E-05)	−2.1686
Time	−0.0374 (0.0265)	−1.4136	−0.0620 (0.0444)	−1.3960
Area	−0.0082** (0.0036)	−2.2839	−0.0132** (0.0060)	−2.2226
IR	0.0164 (0.0268)	0.6124	0.0251 (0.0449)	0.5581
TD	0.0681** (0.0305)	2.2311	0.1144** (0.0525)	2.1819
Fertilizer	−0.0005*** (0.0002)	−2.6841	−0.0008** (0.0003)	−2.5469
Pest	−0.0005** (0.0002)	−2.2081	−0.0009** (0.0004)	−2.0789
Irrigation	0.0016 (0.0021)	0.7621	0.0023 (0.0034)	0.6708
Org	−0.0005 (0.0005)	−0.9977	−0.0009 (0.0009)	−0.9967
Seed	0.0009*** (0.0003)	2.9794	0.0015*** (0.0005)	2.9069
Pol	−0.2921 (0.5935)	−0.4922	−0.4568 (0.9607)	−0.4755
McFadden R-squared		0.2328		0.2288
LR statistic		41.6069(0.0001)[b]		40.8933(0.0002)
Log likelihood		−68.5777		−68.9345
# of observations		129		129

Note:
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
[a] Standard errors are in parentheses.
[b] Probability of LR statistic.

Table 6
Statistical analysis of the determinants affecting main influencing factors of willingness to pay.

Variable	Model (1)	Model (2)	Model (3)
	Income net (+)	Irrigation (+)	Top dressing (+)
Con	0.8418	−0.8764	0.6240
	(1.5887)[a]	(0.9262)	(0.9210)
Age	−0.0167**	−0.0020	−0.0052
	(0.0081)	(0.0048)	(0.0048)
Edu	0.0119	0.0232	−0.0019
	(0.0272)	(0.0158)	(0.0158)
Inc. capita	0.7613***	−0.0093	−0.0015
	(0.0865)	(0.0655)	(0.0650)
Inc. net		0.0861	−0.0636
		(0.0542)	(0.0540)
Time	0.1636	0.1354	0.0362
	(0.2213)	(0.1290)	(0.1286)
Area	−0.0035***	−0.0002	0.0007
	(0.0013)	(0.0008)	(0.0008)
IR	−0.5798**	0.8720***	0.2155
	(0.2854)	(0.1489)	(0.1674)
TD	−0.1890	0.2275**	
	(0.1605)	(0.0919)	
Fertilizer	0.0290	0.0886	0.3638***
	(0.1491)	(0.0868)	(0.0795)
Pest	0.0082	0.1175*	−0.0591
	(0.1129)	(0.0651)	(0.0653)
Irrigation	0.2521		0.2241**
	(0.1585)		(0.0906)
Org	0.0215	−0.0670	0.0192
	(0.1081)	(0.0629)	(0.0627)
Seed	0.2741	0.0814	−0.2882**
	(0.2097)	(0.1233)	(0.1196)
Info	0.1672	−0.0512	0.2864***
	(0.1559)	(0.0915)	(0.0869)
Pol	−0.4597	0.0750	0.1580
	(0.3546)	(0.2087)	(0.2067)
Adjusted R-squared	0.4717	0.4811	0.3641
Log likelihood	−144.6394	−75.3752	−74.4096
F-statistic	9.1633(0.0000)[b]	9.4779(0.0000)	6.2351(0.0000)
# of observations	129	129	129

Note:
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
[a] Standard errors are in parentheses.
[b] Probability of F statistic.

their investment in environmental protection technology to improve production conditions. Information resource had a significant negative impact on WTP, but in our study, it had a positive effect on top dressing times while top dressing times had a positive effect on WTP. Because of these inconsistencies, we do not develop a specific hypothesis for all information source channels used by farmers.

4.3. Willingness to pay values

The estimation results are reported in Table 7. Three variables are statistically significant, including information ($P \le 0.01$), planting area ($P \le 0.01$) and seed cost ($P \le 0.1$). The estimation results of the model show the following. ① F-statistic is 2.76 and the probability is 0.002, which is less than the 0.05 level of significance, therefore not all of the coefficients of the explanatory variables in the model are zero. ② Adjusted R-squared is 15.1%, which is better than in similar studies. ③ Models pass the residual autocorrelation and the White heteroskedasticity tests.

Therefore, the expected mean of WTP is CNY 44.65/person using OLS with Eq. (3).[1] The mean WTP of the 129 valid samples is CNY 768.0/person/ha. To sum up, the mean value of WTP estimated by the multi-log linear model is below the arithmetic mean. In summary, we used different statistical methods to estimate the WTP value. The results

Table 7
Statistical results of willingness to pay values by the ordinary least squares method.

Variables	Coefficient	Standard error	t-Statistics	Probability
Con	−2.5635	2.4302	−1.0549	0.2937
Inc. capita	−0.1427	0.2007	−0.7110	0.4785
Inc. net	0.1331	0.1585	0.8397	0.4028
Time	−0.5810	0.3778	−1.5379	0.1268
Area	0.0038***	0.0014	2.6520	0.0091
IR	−0.2005	0.6129	−0.3271	0.7442
TD	0.4689	0.3366	1.3929	0.1663
Fertilizer	0.2543	0.2731	0.9311	0.3538
Pest	−0.0539	0.2205	−0.2444	0.8074
Irrigation	0.1746	0.3484	0.5011	0.6173
Org	−0.1401	0.1810	−0.7741	0.4405
Seed	0.6615*	0.3537	1.8702	0.0640
Info	−1.2158***	0.2819	−4.3135	0.0000
Pol	1.1752	0.7280	1.6143	0.1092
Adjusted R-squared		0.1514		
Log likelihood		−227.1257		
# of observations		129		

Note: * significant at 10%, **significant at 5%, *** significant at 1%.

[1] In Eq. (3): n_i is the sample number of $E(WTP)_i$ in the effective sample, and N is the total number of valid samples.

are showed in Table 8 and Eq. (3). The mean WTP of the 142 samples is CNY 756.9/person/ha. The mean WTP of the 129 valid samples is CNY 669.75/person/ha using the Eviews logarithmic model estimation method. The error between the expected and the sample mean is 11.51%, and the error between the expected and the valid sample mean is 12.79%. These errors are close to the limits of 8–10%, and thus the statistical analysis results of this study are both reliable and representative.

$$E(\overline{WTP}) = \sum_{i=1}^{n} EXP(-2.5635 + 0.0038Area + 0.6615lnSeeds - 1.2158Information + \mu)_i \frac{n_i}{N} = CNY44.65/person/mu = CNY669.75/person/ha \tag{3}$$

5. Discussion

5.1. Avoidance of CVM deviation

Compared with other studies, we adopted the following measures to avoid any possible deviation in the CVM. First, a 30-yuan subsidy was granted to each respondent to thank them for participating in the survey. Subsidizing farmers after the investigation not only simulates the real market in which the government provides subsidies, but also encourages the farmers to answer the questions accurately. In practice, it has been proven that most farmers have expressed great gratitude to the investigators after receiving the 30-yuan subsidy. They are certain to answer the questions seriously and be more fully aware of the facts.

Second, subsequent deterministic issues were designed after the core valuation issue to quantify the true likelihood of a willingness to act [13,51]. The more the willingness of respondents to pay for composting technology, the greater the number he chooses. We could exclude those farmers who were unwilling to adopt composting technology to ensure that the willingness to pay data is more accurate. This study demonstrates that subsequent deterministic issues can help improve the effectiveness of CVM, but the main issue is how to determine its threshold, especially when using a 10-point scale [9]. In the existing literature on the use of subsequent deterministic issues, some research results have been proposed in which a respondent who answers yes in the contingent valuation and gives a value of at least 8 on 10-point scale can be considered to have afforded an expression of true will [8,51]. Whereas in our survey, the determinant threshold was set at 9, and all respondents who chose a value of 9 or greater were considered “willing to pay”. This provides an important reference for peers to explore threshold values for subsequent deterministic issues that suit China's national conditions, and also provides an effective method for avoiding deviations from influencing the core valuation issues.

5.2. Impacts of individual characteristics variables

This study is of great practical significance for developing and improving the subsidy policy for vegetable residue composting technology in North China, and in guiding the environmental production behavior of farmers. This paper differs from previous studies in that it examines the factors affecting the adoption of composting technology in the rural areas of North China. We found that the age of farmers had a positive effect on vegetable residue compost adoption at the 1% level, and that education level had a significant negative effect at the 5% level, thus suggesting that farmers with an older age and lower education do have a more positive attitude toward vegetable residue compost technology. This result is in contrast to the results already reported by several authors [22,41], who they concluded that younger farmers are more knowledgeable about innovation and more likely to adopt compost technology in the future, and that older farmers may be unwilling to change their traditional planting practices. It has been found through many years of research projects, in the rural areas of China, that young and highly educated people are willing to work in urban areas. Therefore, the current vegetable farmers are generally older and have lower education levels. However, these farmers are extremely concerned about the cultivation environment of the vegetables and the cultivation measures. Given the premise of being provided with subsidies, they are more intense in adopting composting technology than farmers who are young and highly educated. We found that farmers who grow vegetables as their main source of income are usually more accepting of agricultural technology subsidy policies, and have a significantly higher WTP for adopting composting technology [17,26].

5.3. Impacts of labor and production variables

We found that the labor and production variables had significant effects on the farmers' WTP for compost technology, and the impact directions involved both positive and negative effects on compost technology adoption. The planting area variable had a significantly positive relationship with compost adoption, which is acceptable when compared with other studies related to environmental agriculture measures or practices [18,48]. For each farmer, the larger the vegetable planting areas, the greater the amount of vegetable residues are. As a result, since the cost of raw materials will be greatly reduced, the probability of adopting composting technology increased [15,23].

In view of the large amount of chemical fertilizers used to produce vegetables in Hebei Province [16], a special variable, top dressing frequency, was introduced in labor intensity. When respondents were asked carefully and stated the number of top dressings applied during the vegetable growing season, they would naturally realize that their application of fertilizer was too frequent, which may increase soil salinization and soil consolidation in the shed. The application of composting technology can increase the content of organic matter in the soil and prolong the service life of the shed, which is what farmers expect. This research has proven that the selection of the top dressing frequency variable is effective. It passed the 5% significance level test and positively affects the willingness to pay. In addition, lower pesticide costs and higher irrigation costs make farmers more focused on the safety of the farm environment, and thus make them have a significantly higher WTP for adopting composting technology.

5.4. Impacts of social resources variables

The most significant innovation of this study is the information source control variable which was introduced in the measurement model. We found that to some extent, the source of information directly reflects the farmers' concern and dependence on agricultural production. Because these information source variables have negative effects, farmers who have less production information are concerned about protecting agricultural production and the environment, and thus are more willing to participate in agricultural environmental protection policy projects. However, the per capita household income of farmers is not high, which is a problem for policymakers. The analysis of the effect of the information variable had a strong negative impact on the probability of adoption. It is interesting to compare the results of this study with similar work, such as that already presented by Danso et al. [17], concerning farmers' willingness to pay for municipal waste compost in Ghana, and Paul et al. [41] for compost adoption in the Caribbean. These studies showed that the information variable is significant at the 1% or 5% level in explaining the preferences of farmers toward the attribute of composting technology, and it is worth to note that the influence direction of the information variables were contrary to this study.

Table 8
Summary of mean willingness to pay based on different estimation methods.

Estimation method	Samples size (Overall/valid)	Willingness to pay values (CNY/person/ha)	Error with overall sample (%)	Error with valid sample (%)	Error with model (%)
Statistical calculation	142	756.90	0.00	1.45%	13.01%
	129	768.00	−1.47%	0.00%	14.67%
Regression model	129	669.75	11.51%	12.79%	0.00%
Average estimation	129	735.30	2.85%	4.26%	9.79%

We expected that the richer the information sources, the more positive farmers' attitudes would be toward composting technology. Our results indicated that information has a significant negative effect. This study further proves that if farmers have abundant channels to understand new agricultural technologies, their cultural level tends to be higher, and they will have more opportunities to engage in non-agricultural production. Thus, technical costs are the biggest obstacle to their adoption. On the contrary, farmers who do not have rich information channels are more willing to increase investment in agricultural production to gain more economic and ecological benefits.

The limitations of this study are as follows: There is a need to further improve the guidance technology of CVM. We can use the international double-bounded dichotomous choice theory, which is easier to use to simulate pricing behavior in the market. Not only is it easier for respondents to answer such a questionnaire, but it also overcomes the issue of zero WTP in open questionnaires. In the future, we can try to use the closed questionnaire method (binary selection method) to guide the WTP to improve the effectiveness of data acquisition using the CVM method. Another objective is to further develop the feature variables in the model design. In this study, the variable set is not comprehensive, and could be improved by including variables such as the expected income from residual composting, the ratio of vegetable income to household income, and the distance between the greenhouse to the village, which may affect the WTP but were not included in the questionnaire. Therefore, we should add more alternative variables and improve the accuracy and directivity of the effective data. In the future, we will focus on the above-mentioned problems to analyze the factors influencing the behavioral intentions of farmers, and further develop the quantitative design of the CVM method when applied to compensation mechanisms for cleaner vegetable production technology.

6. Conclusion

The results suggest that age, net income, planting area, top dressing time, irrigation costs, and subsidy policy are the key drivers of technology adoption behavior. The estimates of the drivers of WTP are as follows: subsidy policy (2.7808),[2] top dressing time (0.0889), age (0.0722), planting area (0.0259), irrigation cost (0.0109), and net income (0.0000782). We also removed four factors that had negative coefficients: information sources (−1.0983), education (−0.1058), labor time (−0.0862), and pesticide costs (−0.0005).

Subsidy policy is an important incentive for WTP. The most important factor in determining the environmental preferences of farmers is that of the economic benefits rather than the environmental impact. Subsidy policy compensates for the economic losses caused by application of the technology, and motivates farmers to protect the environment. The source of information is an innovative variable chosen by this study. Especially information sources, is a somewhat scarce resource. It can be regarded as perceived social pressure on producers while a particular action is carried out, and has different degrees of hindrance relating to producers' behavioral intentions, thus affecting their WTP. Farmers with higher cultural levels have more opportunities to engage in nonagricultural industries and earn money from them. With the richness of their information and the openness of vision, they are not willing to adopt composting technology unless they obtain extra benefits. Therefore, to promote additional adoption, subsidies should be used.

The labor intensity variables affect the WTP in different ways. Only by reducing the individual labor time can benefits be increased. If the production efficiency can be improved, it is possible for farmers to be more willing to additionally invest in production efficiency. Top dressing times and planting area are important indicators of workload density. A greater workload density indicates that farmers rely more on agricultural production, and they are more likely to maintain a good farmland production environment in order to achieve better productivity. Therefore, farmers want to process vegetable residue in time to arrange the next cycle of planting tasks. The various production cost variables have different effects on WTP. Irrigation cost is a main determinant of WTP. Vegetables are water-intensive horticultural crops, local vegetable cultivation using water-saving irrigation technology and irrigation water and vegetable production are closely related. Therefore, increasing irrigation can improve the yield and quality of vegetable production, which clearly enhances the power of environment-friendly production. Pesticides represent considerable additional costs, but increase the quality and safety of vegetable products. Therefore, in order to save production costs, farmers naturally do not want to pay the additional construction costs of pools.

Finally, we calculated the mean of WTP to be CNY 44.65/person. In summary, if local governments want to further promote composting technology for vegetable residues in Hebei Province, they need to increase the subsidies for the construction cost of the reactor, given the fact that local farmers are only willing to pay about 3% of the total cost. The government must have sufficient preparation to cover the remaining 97% of the technical application costs. The results also provide a scientific basis for the formulation of subsidy policies in the North China Agricultural District.

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[2] The numbers in parentheses are the estimated coefficients. The other numbers in this paragraph have the same interpretation.

Appendix A. Willingness to pay and willingness to adopt: survey questions

Q1 If the government intends to promote the composting technology of vegetable residues in Gaocheng, do you accept it?

(1) Yes

(2) No

[If the respondent answers "Yes", continue to ask the second question. If he/she answers "No", proceed to the next section.]

Q2 If the government provided heap retting pool construction fee subsidies and farmers paid the remaining costs, would you pay the construction fee?

(1) Yes

(2) No

Q3 If you agree to pay for the construction fee, could you tell me the amount you are willing to pay?

Please draw a "√" over one of the following option values.

10	15	20	25	30	35	40	45	50	55	60	65
70	75	80	85	90	95	100	110	120	130	140	150

Q4 If we introduce the technology subsidies in 2015, could you please tell me how likely it is that you will be willing to pay for the construction cost?

The number "1" means "very uncertain", saying that you are highly unwilling to pay.
The number "10" means "fairly certain", saying that you are quite willing to pay for the cost.
Please draw a "√" over the appropriate number.

Very uncertain	1	2	3	4	5	6	7	8	9	10	Fairly certain

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