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INFLUENCING FACTORS OF THE ACCEPTABLE AMOUNT OF COMPENSATION OF FARMERS FOR CONTROLLING FERTILIZER-INDUCED WATER POLLUTION

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Abstract

This paper aims to identify the influencing factors of the acceptable amount of compensation (AAC) of farmers for controlling fertilizer-induced water pollution, and build a valid ecological compensation mechanism to curb the water impact. To this end, the ecological compensation for farmers is viewed as a good way to reduce fertilizer-induced pollution at drinking water sources, and the opportunity cost is introduced into the discussion of farmers' AAC. To avoid the gaps of previous studies, the economic compositions of the AAC for fertilizer reduction were analyzed in details, and then the IBG was adopted to estimate the respondents' AAC. Meanwhile, a quantile regression model was built for factor analysis on the intensity of the AAC (IAAC). For the two study places, the mean AAC fell between USD 636.51/ha and USD 2,172.51/ha, respectively. The results reveal that the young people demanded the highest IAAC; family income (INC) and rice for sale proportion (FSP) are negatively correlated to the IAAC; the expected production risk played a more important role than production efficiency (PDE) in decision-making; farmers aware of environmental protection requested more reasonable compensation; farmers living in relatively poor place demanded a higher IAAC, but those living in the same place experienced the convergence of the IAAC; the AAC has little to do with environmental or policy awareness. Based on these results, it is concluded that a valid compensation mechanism should guarantee the survival and development of farmers by improving their farmland management ability, lowering the cost of agricultural services and enhancing farmers' awareness of environment responsibility.

Key words: Acceptable amount of compensation (AAC), ecological compensation, fertilizer, water pollution, drinking water sources

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1. Introduction

Water, the essence of life, is critical to agricultural production (Cannistraro et al., 2017; Quist-Jensen et al., 2015). The proper use of agricultural water lays the material and spiritual bases for the sustainable development of the society and ecosystem (Karabulut et al., 2016). Nevertheless, fresh water resources for agriculture are often exploited in a non-sustainable way, such as the abuse of fertilizer near water bodies (Gupta and Nikhil, 2016; Yihdego and Khalil, 2017). The resulting pollution of rivers, lakes and other ecosystems has disrupted the normal supply of fresh water (Kalafatis et al., 2015; Yang et al., 2018). The unsustainable use of agricultural water originates from the wrong perception of water as a freely available or low-cost, inexhaustible public resource (Perry and Berry, 2016). In fact, this flowing, renewable and abundant "public resource" should be managed in a complex manner (Brown et al., 2015; Viola et al., 2016). Otherwise, the safety supply of drinking water sources will be endangered (Ganiron, 2017; Gibellini et al., 2017; Li et al., 2015). In China, the fresh water resources are

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mainly polluted by domestic sources, industrial point sources and agricultural nonpoint sources. Fortunately, the domestic pollution has been diminished by the construction of sewage pipes and other infrastructure, and the industrial point source pollution has been controlled by policies against blind development and irrational exploitation (Fales et al., 2016; Moges et al., 2016; Perez-Vidal et al., 2016). Meanwhile, the agricultural nonpoint source pollution remains as the difficulty of fresh water management, because it is highly random, dispersive and invisible (Jamieson et al., 2004). Currently, the agricultural nonpoint sources concentrate near water bodies, posing great threats to water quality and water safety (Wu and Sun, 2016). As the leading producer of agricultural commodities, China ranks first for fertilizer production and consumption in the world (Huang et al., 2016). However, a staggering proportion of fertilizer (65%) is lost through leaching, volatilization and other means, putting the effective utilization rate at only 35% (Wang et al., 2016; Wu et al., 2016). This calls for an effective means against agricultural water pollution.

The recent decades have seen the emergence of ecological compensation around the world for eco-environment protection at drinking water sources (Wunder, 2015; Ze et al., 2017). It is very meaningful to evaluate the effect of ecological compensation on the ecological awareness and behaviour of stakeholders (Liang et al., 2017). To curb the agricultural nonpoint pollution at drinking water sources, most of the existing measures for ecological compensation have been designed from the economic perspective (Smith et al., 2017). Compared with mandatory measures (e.g. environmental tax), the economic ecological compensation aims to promote voluntary adoption of ecological protection measures among the farmers (Wang, 2017; Zhu et al., 2017). The effectiveness of the compensation depends on whether it can offset the losses incurred in the adoption of these measures (Barrett et al., 2016; Wunder, 2015). After all, the residents living near drinking water sources may suffer from economic losses for the cause of environmental protection. Against this backdrop, it is very meaningful to optimize the ecological compensation mechanism, which is the groundwork of profitable ecological services (Vogl et al., 2017; Xie and Li, 2016).

Segerson (1988) was the first to explore the compensation to farmers for their prevention and control of agricultural nonpoint source pollution, and the creator of an incentive mechanism involving both environmental tax and subsidy. So far, much theoretical and empirical research has been done on this type of pollution (Abler, 2015; Bosch et al., 2013; de Vries and Hanley, 2016; Herriges et al., 1994; Kisaka and Obi, 2015; Lee et al., 2017; Song, 2018; Xu et al., 2013; Yang and Cai, 2012). However, the research focus has always been directed at overall compensation for farmland protection and the farmers' willingness to pay (WTP) for ecological services. When it comes to the prevention and control of fertilizer nonpoint source pollution, most scholars have emphasized on the cost or efficiency of fertilizer (Galati et al., 2015; Rowe et al., 2016; Tamini et al., 2012; Xiao et al., 2014) or the farmer's intention of adopting environment-friendly technologies (Ge, 2010; Emerick et al., 2016; Kaplowitz and Lupi, 2012; Ward and Pede, 2015). Nonetheless, there is few reports on how the changing input structure of production factors affect farmer's agricultural income and their acceptable amount of compensation (AAC).

Currently, the standard for ecological compensation is determined by two issues: investment cost and ecological service value (Zhang et al., 2017; Zhao and Jiao, 2017). In theory, the compensation standard for microscale subjects should depend on opportunity cost and ecological service value (Dai et al., 2013). In most microscale studies and practices, only the investment cost is considered, while the ecological service value is largely overlooked, making it is impossible to reflect the motivations of farmers under the obligations of environmental protection. In this case, freeriding is ubiquitous due to the public nature of water resource (Sun and Sun, 2015), which causes the prisoner's dilemma and the tragedy of the commons. To tackle these problems, the government should adopt rationally coordinate and restrict the use of water resource, and resolve the conflict between individual interest and collective interest (Wang and Li, 2016). One of the best solutions is to incorporate the ecological service value into the motivations of farmers, which ensures that those living at drinking water sources adopt ecological protection behaviours of positive externality and low management cost (Chen et al.,2018;Falconer, 2000).Overall, the focus of the research on ecological compensation for controlling agricultural nonpoint source pollution at drinking water sources has shifted from the compensating protectors and victims towards source control (Savage and Ribaudo, 2016). In China, the government has declared the positive incentives of ecological interests as the basic function of ecological compensation in drainage basins (Xie and Li, 2016). To control the pollution from farmer's individual production, the government should eliminate the pollution of drinking water sources, correct the public understanding of environmental protection, and ameliorate the effect of individual farming on water environment (Orli and Kaufman, 2017; Robins et al, 2017; Zhang and Zhan, 2014). Other governmental measures include collective supervision and environmental tax (Cabe and Herriges, 1992; Segerson, 1998).

At present, China has already implemented the ecological compensation to support the ecological protection of drinking water sources (Zhuang, 2016), but received a poor response from the farmers owing to the following defects. First, the economic compensation lacks stability and transparency, because the funds are appropriated by the central financial budget and allocated as project investment by the local government (Sheng and Webber, 2017; Wen and Tian, 2017; Zhao and Wang, 2010). Second, the compensation policy fails to consider the farmers' AAC, the compensators' ability to pay, or the regional difference, but sticks to a low compensation standard (Wuepper et al., 2016; Zhang, 2011). Third, some subsidies (e.g. the organic fertilizer promotion subsidy) only target the farmers owing a large farm rather than ordinary small farmers (Cerdà et al., 2018; Herrendorf and Schoellman, 2015; Sumner, 2014).

To solve fertilizer nonpoint source pollution of water, it is theoretically and practically significant to improve the ecological compensation mechanism for farmers, especially rationalizing the compensation standard and elevating farmers' satisfaction. Some scholars have applied the contingent valuation survey, a popular, flexible and comprehensive evaluation method, to assess farmers' AAC for controlling fertilizer or other input factors (Cai and Yu, 2014; Yu and Cai, 2015a; Yu and Cai, 2015b). Nevertheless, their studies share some common defects, namely, treating different kinds of farmlands in the same way, ignoring the regional differences, and overlooking the farmers' difference in farmland management ability. To make up for these defects, a contingent valuation survey was performed to examine the famers' intention and compensation demand, and identify the influencing factors of the demand under a certain compensation policy (Norton, 1998).

2. Material and methods

2.1. Economic decomposition of AAC

The conservation tillage measures can be regarded as the farmers' investment on the safety of drinking water. The investment brings benefits to the sustainable growth of their private wealth. In general, there is no essential difference between the investment decision of farmers and that of manufacturers. In China, however, the investment decision of farmers reflects the social, cultural and environmental features of the traditional small peasant economy. In other words, the investment motives are driven by investment habit, family feature, market environment, in addition to investment expectations (McKinley e al., 2017; Jiao et al., 2007).

Farmers' behaviours are motivated by the following four factors. (1) family consumption: meeting the basic survival needs of the families; (2) wealth accumulation: accumulating more and more personal wealth; (3) social service: performing the individual duties to the society; (4) social compliance: submitting to the pressure from the outside world (Chen and Ma, 2007). Therefore, the success of the ecological compensation, aiming to promote conservation tillage among farmers, lies in the fulfilment of these four factors (Ge et al., 2010).

Considering its origins, the *AAC* can be obtained from the crop loss (*CL*) induced by conservation tillage, the opportunity cost (*OC*) of conservation tillage, and the attitude corrected value (*ACV*) (Eq. 1):

$$AAC = CL + OC + ACV \quad (1)$$

where the sum of *CL* and *OC* is the combined effect of family consumption and wealth accumulation; *ACV* is the combined effect of social service and social compliance.

The *CL* reflects the yield loss after conservation tillage. The yield of farmland hinges on the conservation tillage skill, which in turn relies on the farmland management ability of the farmer. If *CL*>0, the farmer losses money after conservation tillage; If *CL*=0, the farmer breaks even after conservation tillage; If *CL*>0, the farmer earns profit after conservation tillage.

The *OC* describes the maximum profit of the farmer by paying additional labour and capital. It can be expressed as (Eq. 2):

$$OC = TCC + OCC + LC \quad (2)$$

where *TCC* is the opportunity cost of technical consultation; *OCC* is the opportunity cost of additional capital (e.g. the adoption of environmental-friendly fertilizer); *LC* is the opportunity cost of additional labour (e.g. the additional labour time spent on conservation tillage).

The *ACV* is an adjustment variable that describes the part of the *AAC* determined by noninvestment factors, such as personal features, family feature, environmental awareness, and so on. The farmers open-minded about conservation tillage have a low to negative *ACV*, while those close-minded about conservation tillage have a positive and high *ACV*.

Obviously, the *CL* is an objective and observable part of the *AAC*, while the other two parts are too random and uncertain to be observed directly. Without considering the economic losses, the other two parts of the *AAC* were combined into a corrected value (*CV*), such that the *AAC* can be rewritten as Eq (3):

$$AAC=CL+OC+AVC=CL+CV \quad (3)$$

The *CV* is harder to estimate than the *CL*. Here, the popular method of contingent valuation survey is performed for *AAC* estimation (Rosa et al., 2016; Van et al., 2012; Wunder, 2015).

2.2. Theoretical analysis on AAC

The *AAC* is a problem about utility in economics. Here, utility is assumed to be separable. Under the economic compensation, the farmers' welfare function can be expressed as Eq. (4):

$$W = TU = \sum_{i=1}^{4} U_i = R = R_1 + R_2 + R_3 + R_4 \quad (4)$$

where R_1 is the agricultural income of traditional tillage and can be expressed as Eq. (5):

$$R_1 = P_1 \cdot Y_1 = P_1 \cdot F_1\left[L_1(X), K_1(Z), FT\right] \quad (5)$$

where L, K and FT are labour input, capital input and fertilizer input, respectively; X are the influencing factors of labour demand, including wage, family feature, etc.; Z is the influencing factors of capital input.

Let R_2 be the agricultural income of conservation tillage, which forbids the use of chemical fertilizer or pesticide, and Y_2 be the magnitude of L and K. Since L and K are affected by both conventional factors and compensation intensity (C), R_2 can be expressed as:

$$R_2 = P_2 \cdot Y_2 = P_2 \cdot F_2\left[L_2(C, X), K_2(C, Z)\right] \quad (6)$$

Hence, the other income (R_3), i.e. the sum of all incomes of non-agricultural operations, can be expressed as:

$$R_3 = P_3 \cdot Q\left[L_3(X), K_3(Z)\right] \quad (7)$$

where $Q[L_3(X), K_3(Z)]$ and P_3 are the yield and price of agricultural commodities of non-agricultural operations, respectively; Both parameters are expressed in average values.

Let R_4 be the compensation income of conservation tillage. In this paper, R_4 is equivalent to C.

Under the labour constraint $TL=L_1+L_2+L_3$, Eq.(1) can be rewritten as Eq. (8):

$$R = P_1 \cdot F_1\left(TL - L_2 - L_3, K_1, FT\right) + P_2 \cdot F_2\left(L_2, K_2\right) +, \; P_3 \cdot Q\left(TL - L_1 - L_2, K_3\right) + C \quad (8)$$

Considering the budget constraint of $I \ge \omega\sum_{i=1}^{3} L_i + \mu\sum_{i=1}^{3} K_i + \gamma FT$, the optimal first-order condition satisfying the utility maximization can be derived as Eq. (9):

$$\frac{\partial L_2}{\partial C} = 1 \Big/ \left(P_1 \frac{\partial F_1}{\partial L_2} - P_2 \cdot \frac{\partial F_2}{\partial L_2} + P_3 \cdot \frac{\partial Q}{\partial L_2}\right) \quad (9)$$

Assuming that $L_2=AC^{\alpha}X^{\beta}$, we have Eq. (10):

$$C^* = \sqrt[\alpha-1]{\left[A\alpha X^{\beta} \cdot \begin{pmatrix} P_1 \cdot \dfrac{\partial F_1}{\partial L_2} -, \\ P_2 \cdot \dfrac{\partial F_2}{\partial L_2} + P_3 \cdot \dfrac{\partial Q}{\partial L_2} \end{pmatrix}\right] \Big/ \begin{pmatrix} 1 + \dfrac{\partial F_2}{\partial K_2} \cdot, \\ \dfrac{\partial K_2}{\partial C} \end{pmatrix}} \quad (10)$$

Since the farmers produce food for self-sufficiency, the agricultural commodities of different farmland management modes can be regarded as the same ($P_1=P_2$). According to Eq. (7), the farmers' willingness to be compensated mainly depends on the marginal output of the labour force. This view can be confirmed by the influence of the marginal output of capital. Comparing the labour input effect between traditional tillage, conservation tillage and other operations, it can be seen that the farmers' expected compensation intensity is related to their production ability through conservation tillage. Their demand for compensation only drops when the output of conservation tillage per unit of labour input is higher than that of the other investment. The other influencing factors of conservation tillage output of labour input also have a certain effect on *AAC*. This conclusion can also be confirmed through the analysis on the conservation tillage output of capital input.

2.3. Research method

2.3.1. AAC valuation

The contingent valuation survey provides four methods to evaluate the *AAC*, including repeated bidding game (IBG), open ended (OE), payment card (PC) and dichotomous choices (DC) (Tang et al., 2012). Considering the completeness of opinion expression, the IBG was adopted to guide farmers to report minimum *AAC* for the prevention and control of fertilizer non-point source pollution. First, the farmers were allowed to report initial bid value by bidding cards. Then, the bidding level was continuously lowered so that the farmers could accept the lowest *AAC*.

Because of the extensive farming, there is a sufficient room for reducing fertilizer. Thus, the conservation tillage was defined as the reduction of fertilizer from the level of the traditional tillage. Based on preliminary survey, the bid values of the farmers' accepted amount of fertilizer reduction were designed as 10%, 20%, 30%, 40%, 50% and 100% to reflect the individual *AAC*. The bid values were not pre-set, but derived from the losses and the bidding card, which contains every multiple of 50 from 0 to 2,000.

2.3.2. Factor analysis

Proposed by Koenker and Bassett (1978), quantile regression was employed for our factor analysis. This method outperforms the traditional linear regression, which only describes the change of conditional mean for dependent variable, in that it captures the change of conditional quantile, achieves robust results, and supports flexible applications. Thus, quantile regression is an ideal tool to estimate the effect of potential tiny changes of covariate on AAC of different quantiles and their change trends.

In quantile regression, the hypotheses are tested and confidence interval is predicted by bootstrap resampling. The resampling frequency is usually selected as 500 times. The quantile regression can be expressed as Eq. (11):

$$y_i = \beta_0^{(p)} + \beta_1^{(p)} x_i + \varepsilon_i^{(p)}, \quad (i = 1 \ldots n) \quad (11)$$

where p ($0<p<1$) is the the proportion of numerical value below p quantile. The *p-th* conditional quantile of a specific value can be expressed as: $Q^{(P)}\left(y_i \mid x_i\right) = \beta_0^{(p)} + \beta_1^{(p)} x_i$. Thus, the *p-th* conditional quantile is determined by specific quantile parameter and specific value.

2.4. Variable descriptions

The intensity of the *AAC (IAAC)* of farmers can be described as the ratio of the *AAC* to the acceptable reduction of fertilizer among the farmers (*ARF*) (Eq. 12):

$$IAAC = \frac{AAC}{ARF} \tag{12}$$

Previous studies (Li et al., 2011; Li and Cai, 2014) have divided the *AAC* into the following variables: individual feature, family feature, farmland management mode, farmers' production ability, environmental awareness, policy cognition and regional variable (Table 1). On this basis, the "time spent on agriculture" was replaced by production efficiency (PDE). Although "time spent on agriculture" is generally adopted to reflect the experience of farmer household, the target crop of our study, a.k.a. rice, is a conventional crop requiring a long period of cultivation.

Thus, it is difficult to identify the farmer's farmland management ability and residence. However, farmland management ability can be described as input and output efficiency, as it is eventually converted to actual income. Thus, the input and output data of the current year were adopted to calculate the PDE, a mirror of the actual production ability in that year. Taking the rice output as the output variable, the PDE was obtained by data envelopment analysis (DEA) on input variables like pesticide cost, land cost, mechanical cost, the volume of nitrogenous fertilizer, the volume of phosphate fertilizer, and the volume of potash fertilizer.

2.5. Survey design

Several surveys were conducted at drinking water sources in Qiaodun reservoir and Siming Lake reservoir, China. Rice farmers were taken as the subjects of our research, considering the following common features of the two places.

First, the two places share a similar catchment area and both provide drinking water to a town nearby. Second, both places suffer from eutrophication resulted from abuse of fertilizer, and lack measures against agricultural nonpoint source pollution. Third, the water supply to local residents is separated from the municipal water supply system, and the polluted water is mainly supplied to urban residents in the downstream. Fourth, rice is the dominant crop in both places. The two places differ greatly in geological condition, economic environment and planting system. In terms of geology, the rice fields around Qiaodun reservoir are fragmented across the hilly region, while those around Siming Lake reservoir are basically flat paddy fields.

Table 1. Statistics of variables

Categories	***Variable***		***Description***	***Mean***	***S.D.***
Individual characteristics	The householder age (AGE)		The real age farmers reported	59.1368	0.4571
	Gender (GEN)		Woman=0, Man=1	0.9630	0.0081
	level of education (EDU)		Illiteracy=1, Primary school or below=2, Above primary school or= 3	1.8226	0.0320
Family characteristics	Annual household income (INC)		The family income in reporting year (Yuan)	5.5174	0.1420
Farmland management ability	The actual management ability	Production efficiency (PDF)	Real values measured with the input and output data	0.6143	0.0074
	Self-reported management ability	Expected production risk (PDR)	Expected output reduction amount to cut-down amount ratio (%)	1.0060	0.0243
Participation willingness	the acceptable reduction of fertilizer (ARF)		The reported ratio of fertilizer farmers willing to cut (%)	0.2886	0.0110
Farmland management characteristics	Rice for sale proportion (FSP)		No=0, Yes=1	0.1388	0.0080
	Farming entirely depends on labor(EDL)		No=0, Yes=1	0.2181	0.0178
environmental awareness	Cognitive impact of fertilizer on water quality (IOF)		Not known=1, No impact=2, Have impact=3	2.6377	0.0261
Policy cognizance	Whether know farmlands within the scope of water source protection area (WPA)		No=0, Yes=1	0.4436	0.0214
Regional variables	Relative village economy (RVE)		Poor=1, Relative poor=2, Relative rich=3, Rich=4	1.7930	0.0383
	The town subordinated to (QDT)		Liangnong town=0, Qiaodun town=1	0.5970	0.0211
Instrumental variable	The mean acceptable reduction of fertilizer (MARF)		The reported ratio of fertilizer the public willing to cut (%)	0.2894	0.0092

In terms of economy, the area near Qiaodun reservoir is featured by backward economic condition, small-scale and scattered agriculture and the severe loss of young labourers. By contrast, the area near Siming Lake reservoir enjoys convenient traffic, developed industry, especially the lighting industry, and the low loss of young labourers. In terms of planting system, the place near Qiaodun reservoir has a low level of mechanization and yield one crop a year, while that near Siming Lake reservoir has a high level of mechanization and yield two crops a year.

The rice farmers living in the two places were investigated via stratified random sampling from July to August, 2014. Then, a supplementary investigation was carried out in the form of one-on-one field trip in January 2015. A total of 360 and 270 copies of questionnaires were released in the place near Qiaodun reservoir and the place near Siming Lake reservoir, respectively. Among them, 323 valid copies were returned from the place near Qiaodun reservoir and 218 valid copies were returned from the place near Siming Lake reservoir. The questionnaire mainly asks about the basic information of the farmers, the farmers' cognition of eco-environment protection and its impact on the environment, as well as *ARF* and *AAC*. The features of our sample are listed in Table 2. Specifically, 91.13% of respondents were males and 80% were over 50 years old. This is because males are decision-makers in most households and the main labour force in rice cultivation, and most young labourers are not enthusiastic about rice planting due to its low economic value.

3. Results

3.1. AAC at different ARFs

80.59% of the farmers chose to reduce the amount of fertilizer by no more than 30%. Thereinto, those with 10% *ARF*, 20% *ARF* and 30% *ARF* accounted for 35.30%, 24.03% and 35.30% of the total number of farmers, respectively (Table 3). The results reveal no special preference to a certain *ARF*, that is, a low *ARF* has a limited impact on output. This feature can be observed in both places.

On average, the *AAC* exhibited an increasing trend with the increase of the *ARF*. The minimum mean *AAC* was RMB 268.57 yuan/mu (≈USD 658/ha) and the maximum mean *AAC* was RMB 916.67 yuan/mu (≈USD 2,245.84/ha). When the *ARF* fell in the range of 10%~30%, the *AAC* remained relatively constant at a low level; when the *ARF* exceeded 30%, the *AAC* fluctuated in a violent manner. In this case, the farmers tended to report a high *AAC*. A possible reason lies in the difficulty of risk estimation and control at a high *ARF*.

Table 2. Sample features

Variable	*Options*	*Frequency*			*Variable*	*Options*	*Frequency*		
		Whole	*Qiaodun*	*Liangnong*			*Whole*	*Qiaodun*	*Liangnong*
Gender	Women	21	8	13	Education level	Illiteracy	264	201	63
	Man	520	315	205		Not finish primary school	29	12	17
Family members	< 3	138	68	70		Finish primary school	146	79	67
	3~5	245	131	114		Finish junior middle school	71	29	42
	> 5	158	124	34		Finish senior high school	28	2	28
Income	<10000 Yuan	13	13	0		Above senior high school	3	0	3
	10000~20000 Yuan	39	31	8	Age	< 40	25	10	15
	20000~30000 Yuan	31	13	18		40~50	76	25	51
	30000~50000 Yuan	137	92	45		50~60	149	86	63
	50000~70000 Yuan	114	90	24		60~70	210	137	73
	>70000 Yuan	178	84	94		> 70	81	65	16

Note: RMB 1 yuan= USD 0.1634 in 2014.

Table 3. *AAC* at different ARFs (unit: RMB yuan/mu; RMB 1 yuan/mu ≈USD 2.45/ha in 2014)

Cut-down amount	*Frequency*	*Range*	*Min*	*Max*	*Mean*	*S.D.*
(0%,10%]	191	600	0	600	268.57	113.43
(10%,20%]	130	700	0	700	255.89	131.78
(20%,30%]	115	600	0	600	357.45	113.40
(30%,40%]	13	900	100	1000	364.15	240.01
(40%,50%]	41	1142	158	1300	477.17	212.06
(50%,100%]	51	1800	200	2000	916.67	315.79

3.2. Factor analysis on IAAC

Ignoring the insignificant variance, eight variables were retained for data analysis, namely, age (AGE), annual household income (INC), working mode (if farming entirely depends on labour, EDL), rice for sale proportion (FSP), production efficiency (PDE), acceptable reduction of fertilizer (ARF), expected production risk (PDR) and the local reservoir (if the place is near Qiaodun reservoir, QDR). The data analysis was performed on a quantile regression model, aiming to disclose the relationship between the *IAAC* and its influencing factors. Estimates and 90% confidence intervals were made for 90th, 80th, 70th, 60th, 50th, 40th, 30th, 20th and 10th regression quantiles.

Considering the interplay of *AAC* and *ARF*, the *ARF* may be endogenous and make the estimation biased. Thus, the instrumental variable (IV) was applied through two-stage estimate to solve the endogenous problem. The mean *ARF (MARF)* was selected as an instrumental variable. It refers to the mean *ARF* of the other respondents reporting the same *ARF*. This variable was adopted because the *ARF* of farmers is the combined result of the herd mentality and local socioeconomic environment. The *MARF* not only reflects the government's crackdown on water pollution, but also the farmers' willingness to join protective activities. In other words, the public *ARF* is positively correlated with the individual *AAC*.

In theory, the *ARF* is not relevant to the error term, because government regulation forces in the model are completely exogenous, and the collective attitude of the other farmers toward protection is also exogenous. Besides, the individual *MARF* has no direct impact on the *AAC* of other farmers.

According to the empirical rule of Staiger and Stock (1997), the instrumental variable is not weak in the case of only one endogenous variable, if F-statistic exceeds the threshold of 10 in the first step of estimation. Here, the F-statistic reached 214.46, which is well above 10, and the instrumental variable coefficient passed the t-test at 1% significance level in the first stage of the two-stage estimation. Thus, the *MARF* is not a weak instrumental variable (Table 4).

Before estimation, the endogeneity was tested by Durbin-Wu-Hausman test through two steps. In the first step, the quantile regression estimate was replaced with ordinary least squares (OLS) estimates, all exogenous variables were subjected to the OLS regression of endogenous variable (*ARF*), and the residual error estimators (RESID) was saved. In the second step, the OLS regression of *IAAC* was performed for all variables and the RESID saved in the first step; If the RESID coefficient was statistically significant, there is an endogenous problem that needs to be solved.

As shown in Table 4, the *ARF* coefficient was statistically significant at 1% significance level. This means the coefficient is an endogenous variable (Table 4). The estimation results after the elimination of endogeneity are shown in Table 5, together with the detailed estimation results of both linear regression and quantile regression.

Table 4. Endogenous test results

Variable	*ModelI(ARF)*		*ModelII(IAAC)*	
	Coef.	*t*	*Coef.*	*t*
Constant	0.0802^{*}	2.0500	9.5143^{***}	5.0800
AGE	0.0017^{**}	3.0900	-0.1211^{***}	-4.7200
INC	-0.0004	-0.2300	-0.2260	-2.8200
EDL	0.0055	0.3800	0.0013	0.0000
FSP	-0.0096	-0.3200	-2.0413^{***}	-1.4200
PDE	-0.0453	-1.3700	2.9850^{*}	1.9100
PDR	-0.1105^{***}	-11.3600	12.1901^{***}	25.4300
ARF			-5.6412^{***}	-4.5600
MARF	0.9996^{***}	38.4100		
QDZ	-0.0626^{**}	-5.0000	6.0587^{***}	10.0800
Resid			-22.3224^{***}	-9.2900
N	541		541	
R^2	0.76		0.70	
F	214.46^{***}		137.46^{***}	

*Note: * is p < 0.1; ** is p < 0.05; *** is p < 0.01.*

Table 5. Quantile regression results

Variable	*LRM*	*QRM*								
		τ=0.1	*τ=0.2*	*τ=0.3*	*τ=0.4*	*τ=0.5*	*τ=0.6*	*τ=0.7*	*τ=0.8*	*τ=0.9*
Constant	9.51***	2.84	2.17	2.86	4.89**	6.48***	9.24***	11.55***	12.82***	9.63*
	(4.38)	(1.51)	(1.22)	(1.51)	(2.49)	(3.16)	(5.06)	(5.92)	(5.06)	(1.71)
AGE	-0.12***	-0.12***	-0.07**	-0.06**	-0.07***	-0.08***	-0.11***	-0.14***	-0.14***	-0.09
	(-4.07)	(-4.03)	(-2.07)	(-1.99)	(-2.83)	(-3.02)	(-3.56)	(-4.26)	(-3.09)	(-1.39)
INC	-0.23**	-0.00	-0.09	-0.12	-0.18*	-0.12	-0.20**	-0.26***	-0.21*	-0.18
	(-2.43)	(-0.03)	(-0.83)	(-1.45)	(-1.88)	(-1.21)	(-2.16)	(-3.87)	(-1.71)	(-1.27)
EDL	0.00	-2.11***	-1.70**	-1.13*	-1.06	-0.46	0.02	-0.37	0.73	1.50
	(0.00)	(-2.86)	(-2.11)	(-1.68)	(-1.19)	(-0.41)	(0.02)	(-0.33)	(0.31)	(0.40)
FSP	-2.04	2.39	1.43	-0.42	-1.87	-2.53*	-4.03**	-4.20**	-8.38***	-3.42
	(-1.22)	(1.45)	(1.33)	(-0.42)	(-1.50)	(-1.66)	(-2.08)	(-2.20)	(-2.95)	(-0.88)
PDF	2.99	3.34*	3.74**	3.46**	3.80***	3.18**	2.13	1.48	0.39	0.97
	(1.64)	(1.96)	(2.06)	(2.27)	(2.86)	(2.32)	(1.23)	(0.67)	(0.12)	(0.27)
PDR	12.19***	10.68***	10.93***	11.96***	12.04***	12.09***	12.74***	13.55***	14.97***	16.46***
	(21.94)	(19.29)	(12.56)	(17.79)	(23.47)	(20.28)	(14.75)	(13.78)	(10.17)	(8.12)
ARF	-5.64***	-3.52***	-4.14***	-5.29***	-5.40***	-6.19***	-5.11***	-3.80**	-3.37*	-5.09***
	(-3.93)	(-3.15)	(-3.87)	(-4.39)	(-3.77)	(-3.65)	(-2.74)	(-2.09)	(-1.94)	(-2.88)
QDT	6.06***	4.54***	4.02***	3.42***	3.88***	4.55***	5.37***	6.76***	9.29***	11.03***
	(8.69)	(7.56)	(6.50)	(5.61)	(6.21)	(8.02)	(5.91)	(5.70)	(6.22)	(9.46)
AR^2 (PR^2)	0.60	0.38	0.37	0.37	0.40	0.40	0.41	0.41	0.42	0.39

*Note: * is p < 0.1; ** is p < 0.05; *** is p < 0.01.*

Comparing the results of linear regression with those of 50th quantile, it is clear that the two models disagreed on the estimated result of any variable, a signal of the asymmetry of conditional density. The results of linear regression are not robust, leading to over- or underestimation of the *AAC*. Then, an analysis was made based on quantile regression.

3.2.1. Individual feature and family feature

The AGE had a significant negative effect on the *IAAC* from the 10th to 80th regression quantiles. With the increase of quantile, the slope of AGE's negative effect on the *IAAC* decreased from -0.12 (P<0.01) to -0.06 (P<0.05) between lower quantiles (0.1<τ<0.3), but increased from -0.07 (P<0.01) to -0.14 (<0.01) between higher quantiles (0.4<τ<0.8). Thus, the *IAAC* is severely divisive for regression quantiles near the two ends of the distribution, but the negative impact of AGE exhibits an increasing trend. This means the older farmers tend to demand lower *AAC* than the younger ones. The *IAAC* of upper level is decided by the young group and the *IAAC* of lower level is decided by the old group. This is because the older people are easier to be persuaded to accept a lower *AAC* if they think it is still reasonable.

The INC was significant only in the 40th, 60th, 70th and 80th regression quantiles, the slopes of which were estimated as -0.18 (P<0.1), -0.20 (P<0.05), -0.26 (P<0.01) and -0.21 (P<0.1), respectively. The negative *IAAC* effects of the INC in these four high quantiles indicate that higher *IAAC* group is more likely to ask for *IAAC* in consideration of household income. The higher the INC, the lower the *IAAC* level. The reason is that the agricultural income takes up a small proportion of the total income of high income households. These households are insensitive to the loss of agricultural production.

3.2.2. Farmland business feature

Contrary to the EDL working mode, some farmers performed farming with cattle or machine. The results show a significant negative effect of the EDL on the *IAAC* from the 10th to the 30th regression quantiles, and the slope of the effect was -2.11 (P<0.01), -1.70 (P<0.05) and -1.13 (P<0.1), respectively, for the three quantiles (0.1<τ<0.3). It can be concluded that the value or cost of EDL farming is lower than that of cattle farming or machine farming, because most small farmers neither hire other labourers nor view their own labour as cost; the lower *IAAC* group wish to receive compensation for the cost of cattle and machine. Nevertheless, the significant negative effect was not observed among the higher quantiles. A possible reason is that high *IAAC* relieves the cost pressure of farmers, such that they tend to think that the compensation is enough to make up for the cost.

The FSP had a significant negative effect on the *IAAC* for 60th, 70th and 80th regression quantiles. The slopes estimated for τ=0.6, 0.7 and 0.8 were -4.03 (P<0.05), -4.20 (P<0.05) and -8.38 (P<0.01), respectively. These results can be explained as follows. The main purpose of rice planting is to meet the self-demand of farmers. Unless the household consumption is threatened, the farmers are not so sensitive to the yield loss caused by the reduction of chemical fertilizer. Obviously, farmers who sell a large proportion of the crop yield have lots of surplus rice after household consumption. These farmers boast a greater ability to resist losses and ask for lower *IAAC*. Of course, this trend only exists in high *IAAC* group. These farmers are more optimistic with a certain degree of loss, because they tend to raise *AACs* above the average level.

3.2.3. Farmland management ability

The PDE exerted a positive effect on the *IAAC*. The estimated slopes from 10th to 50th regression quantiles were 3.34 (P<0.1), 3.74 (P<0.05), 3.46 (P<0.05), 3.80 (P<0.01) and 3.18 (P<0.05), respectively. Under the positive *IAAC* effect of PDE, farmers with greater production ability will demand higher compensation. The positive *IAAC* effect of PDE was not significant for higher quantiles. On the one hand, the results prove that, in pursuit of profit, small farmers tend to make short-term investment, and ask for compensation no lower than normal agricultural income; On the other hand, the results confirm the opportunity cost as the fundamental component of the *AAC*: the farmers demand the reasonable compensation for this cost in their proposed *IAAC*.

By contrast, the PDR had a dominant effect over the *IAAC*. The positive *IAAC* effect of the PDR remained significant between nine quantiles. With the increase of the regression quantile, the estimated slope rose from 10.68 (P<0.01) to 16.46 (P<0.01). It can be seen that the farmers expecting higher production risk call for more compensation. These farmers face greater uncertainty of output loss after reduction of chemical fertilizer. As the key cause of the *IAAC* variation among the farmers, the uncertainty originates from the low degree of specialization and uniformity of management skills among small farmers. It is this uncertainty that generates the individual differences of farmland management level and risk attitude.

Overall, the negative effect of work mode and the positive effect of PDE and PDR demonstrate the farmers' pursuit of breakeven and more income.

3.2.4. ARF

The *ARF* had a negative impact on the *IAAC*. This parameter is positively correlated with the farmers' awareness of their environmental responsibility. The negative *IAAC* effect of the *ARF* indicates that farmers more aware of their environmental responsibility tend to accept a lower *IAAC*. The U-shaped curve of the negative effect peaked at 50th regression quantile, and the slope for $\tau=0.5$ was estimated as –6.19 (P<0.01). In lower quantiles ($\tau\leq0.5$), the negative effect declined with the increase of quantile; In higher quantiles ($\tau>0.5$), the effect increased with quantile. Thus, the promotion of environmental responsibility awareness can lower the *IAAC*.

3.2.5. QDR

The QDR had a positive impact on the *IAAC*. The positive effect increased from 4.54 (P<0.01) to 11.03 (P<0.01) across 9 quantiles. This trend reveals that the farmers near Qiaodu reservoir demand higher *IAAC* than those near Siming Lake reservoir. The tendency is attributable to the wealth of non-agricultural job opportunities near Siming Lake reservoir, which lowers the importance of agricultural income to local farmers.

In addition, *IAAC* is not dependent on relative village economy. It can be interpreted as: the farmers' *IAACs* are convergent between adjacent regions. Given their *IAACs*, the farmers would like to guess others' opinions and take them into account. However, there is little difference in the cognition of agricultural production. Without considering environmental or policy awareness, the lack of dependence may come from the lack of perception of water pollution induced by chemical fertilizer. This is supported by the figure that 70.20% of the respondents thought chemical fertilizer has little impact on water bodies.

4. Conclusions

In this paper, the ecological compensation for farmers is viewed as a good way to reduce fertilizer-induced pollution at drinking water sources, and the opportunity cost is introduced into the discussion of farmers' *AAC*. To make up for the gap of previous studies, the economic compositions of the *AAC* for fertilizer reduction were analysed in details, and then the IBG was adopted to estimate the respondents' AAC. Meanwhile, a quantile regression model was built for factor analysis on the *IAAC*. For the two study places, the mean *AAC* should fall between USD 636.51/ha and USD 2,172.51/ha, respectively. The results reveal that the young people demanded the highest *IAAC*; family income (INC) and rice for sale proportion (FSP) are negatively correlated to the *IAAC*; the expected production risk played a more important role than production efficiency (PDE) in decision-making; farmers aware of environmental protection requested more reasonable compensation; farmers living in relatively poor place demanded a higher *IAAC*, but those living in the same place experienced the convergence of the *IAAC*; the *AAC* has little to do with environmental or policy awareness.

Through the investigation, several suggestions were put forward to build a valid ecological compensation mechanism. First, the compensation should be designed based on opportunity cost. The farmers are willing to join environmental protection activity when their opportunity cost can be fully offset. If the compensation is below the opportunity cost, the farmers will lack the enthusiasm to adopt conservation tillage. Second, the ecological compensation policy should highlight the survival and development of farmers, and the local government should publicize the coexistence of environment protection and economic development. The farmers will ask for rational *AAC*, if they are provided with compensation designed to promote local economy, employment and personal income. Third, the farmland management ability of the farmers should be enhanced to narrow the *IAAC* difference, and the government should provide the farmers trainings on farmland management techniques. Fourth, the agricultural service cost should be reduced to narrow the IAAC difference. For instance, the government can offer more allowances or low-cost agricultural services like low-cost/free farming machine services, free agricultural advisory service, free agricultural training, etc. Fifth, the farmers' awareness of environmental responsibility should be improved to lower the policy cost of ecological compensation. In addition to the traditional publicity, nongovernmental organizations should be encouraged to promote farmers' awareness. Of course, the promotion activities should by no means infringe the interests of farmers.

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