Factors Affecting Reduction of Fertilizer Application by Farmers: Empirical Study with Data from Jianghan Plain in Hubei Province

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Abstract: non-point source pollution arises from fertilizer application in China. This paper empirical test the major factors which affect fertilizer application amount using econometric models and micro-level data from Jianghan plain in Hubei province by year 2006. The results demonstrate that housemaster's education level, family's management scale, land fragmentation are major factors affecting farmer's decision-making process. When farmers have consciousness of scientific fertilization, higher agricultural labor proportion, farther land distance, longer production period could decrease fertilizer application amount. In the field of agricultural public policy, training for technical generalization is helpful in reducing fertilizer consumption.

Key words: non-point source pollution; farmer; fertilizer application; influence factors

I. Introduction

In the 1980s, farmers has used more fertilizers in agricultural production because of the increasingly scarce land resources, declining prices of inputs and relatively free trade policy environment[1-2]. Since the reform and opening-up, a large number of rural labors transferring have made farmers reduce the use of organic manure and switch to apply fertilizer. These factors prompted China to become one of the countries which have the highest intensity of fertilizer application. The total fertilizer consumption increased rapidly from 1980s. However, the utilization ratio of fertilizers is low that the one quarter utilization ratio of nitrogen fertilizer is only 30%. The remaining nutrient has lost into the atmosphere, ground or surface water, leading to environmental pollution [3-6]. In 2004, China's agricultural nitrogen fertilizer (25,830,000 tons) losing into the environment up to 4,934,000 tons, among which, there were 1,291,000 tons lost into the surface water and 517,000 tons lost into the ground water through leaching and run-off. This problem not only caused nutrient nitrogen loss, but also led to the surface water eutrophication and the increase in the amount of groundwater nitrate enrichment. In the amount of nitrogen flew into the Yangtze River and Yellow River in each year, there are about 92% and 88% respectively come from agriculture. Especially, the nitrogen of fertilizer accounts for about 50%. This problem resulted in the heavy pollution of surface water and

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groundwater. This situation has become the main cause of China's water pollution [7].

Agriculture depends heavily on the natural environment. Farmers are the most direct victims in the economic losses and ecological damage caused by the pollution of water resources. However, farmers use lots of fertilizer to improve production outputs driven by the market economy, resulting in a vicious circle. If fertilizer and pesticide application used by farmers is indeed excessive and leads to a further deterioration of ecological environment, farmers adopt scientific fertilization technologies to improve the utilization ratio, which will not only be able to reduce production costs, but also can reduce the negative externalities caused by the use of fertilizer. At this point, the analysis of the farmers' decision-making and willingness of fertilizer application is of great significance. What factors influence the decision-making in farmers' application of fertilizer? What is the direction and degree of these influences? What kinds of role do these factors in effecting the amount of fertilization when farmers have the willingness to fertilize scientifically? This article will be to resolve and analyze these problems.

II. Theoretical Hypothesis

The previous researches of other scholars studied the farmers' act of using fertilization from three type's factor: market environment, personal characteristics and public policy. Zhang Hong-yu (2004) and Nunez, et al. (2004) examined the impact of the fertilizer prices, agricultural products prices, expected earnings and regional market environment factors on the farmers' decision-making of using fertilizer [8]. LU Bo-xiang, et al. (2000), MA Ji and CAI Xiao-yu (2007) analyzed the impact of the individual characteristics of farmers and public policy, and influencing factors included: the cultural quality of farmers, the farmers' awareness of whether there is excessive use and pollution in using fertilizer, whether the famers have received fertilizer guidance provided by Agricultural Extension Station, farmers' attitude towards risk [9-10].

Based on the economic assumptions of "rational economic man" and "risk aversion", this paper inspected the impact on reducing fertilizer made by the family factors endowment, in addition to estimate three types of factors: the market environment, the individual characteristics and the public policy, including the following factors.

Age of householder. The age of householder is an important factor which influencing the decision-making of pollution emissions. The younger the householder is, the more willing to reduce pollution emissions and use organic fertilizers. Many scholars have found that younger farmers tend to use more sustainable agriculture technologies characterized modern technology (Adesina and Zinnah, 1993; Souza et al., 1993; Goodwin et al., 1997; Arellanes, 1994; Huang Jikun, 1998).

Education. In terms of the producers, education have a role in the promotion of carrying out environment-friendly production [11-12].The higher the educational level of farmers have, the stronger sense of environmental protection, and the more preference to use fertilizer and pesticides rationally.

Number of agricultural labor. The actual number of labor in family is an essential element in agricultural production. The labor noted in this study is referred to a group of people, whose age is more than 16 years old and be able to participate in the production and operation activities to obtain money or in-kind income, including the people who can often participate in work no matter whether his age is within the working-age or over the working-age. Using organic fertilizer and scientific fertilizer application technology is a labor-intensive technology. Assumed that the number of labor in family is positively correlated with the probability of scientific fertilization, the more the number of agricultural labor a family hold, the better it is to reduce pollution.

Scale of operation. The greater operating scale usually helps farmers to adopt more advanced technology and scientific means to product, and there is positive relationship between the scale and the amount of pollution emission reduction. ZHANG Yun-hua and MA Jiu-jie(2004) regarded the survey data of 15 counties (cities) in Shanxi, Shanxi, Shandong as basis, coming to the conclusion that the number of labor and the scale of arable land is important factors influence farmers to adopt pollution-free and green pesticides [13].

Fragmentation of land. The household contract management has caused fragmentation in arable land. LI Hai-peng (2006) thought that because the land is fragmented, and farmers cannot use the land in large-scale and take the land quality as the basis to use the fertilizer and pesticides targeted, farmers often judged the amount of fertilizer based on their subjective experience, resulting in excessive fertilizer inputs and the unbalanced proportion of soil nutrients[14].

Distance of arable land away from residence. In general, farmers always think that there is a high alternative between fertilizer and manure. The farther arable land away from farmers residence is, the more inconvenient to use manure. As a result, farmers tend to use manure to replace fertilizer.

Transfer of information. Agricultural technology popularization systems and agencies are important technical director in the link of agricultural production. New technology information basically came from agricultural technology popularization agents [15]. The more the number of guidance from agricultural technology popularization personnel is, the more opportunities of obtaining advanced technology and production methods for farmers, which will be beneficial to promote scientific fertilization and pollution abatement.

Production experience. The farmers' production experience is difficult to quantify. It is assumed that the longer period existed in agricultural production, the more rich experience will be obtained. The uncertainty in direction of the impact made by famers' production experience on the fertilizers amount, one possibility is that the farmers refused to give up their experience easily, although the local knowledge passed from generation to generation is not necessarily in line with the "scientific rationality" standard, another possibility is that some more experienced and older farmers feel the negative effects on the quality of the environment caused by excess fertilizer, so they tend to use green manure or fertilize scientifically.

Willingness of farmers. Farmers' awareness to the importance of scientific fertilization is judged by the attitude that whether farmers are willing to adopt scientific technology to fertilize.

III. Data Description and Model Specification

(ⅰ). Data description - selection of investigation point and data collection

The data referred in this study came from the household survey in the summer of 2006 in Jianghan Plain which is the most important grain production base in Hubei Province. By Stratified Sampling, we got 300 samples of household drawn from nine villages, twenty-seven counties in three regions: Jingzhou, Hong Lake, East and west Lake. In this survey, there were 285 valid questionnaires were reclaimed, so the recovery rate was 95%. The main contents of the questionnaire include: the basic situation of farmers' family, the fixed assets in agricultural production, the use of fertilizer in 2005 and 2006, the brand and price in buying seed and fertilizer, as well as the farmers' basic viewpoints and attitudes on the use of fertilizer.

Through the descriptive statistics of sample data (Table 1), we can found that the average age of householder in the samples is about 45 years old, mainly middle-aged male. The average length of education accepted by household is 7.68 years, which is relatively low and less than the level of education in junior high school. The average length spent on farming by householder is 23 years. Every household owns 13.66 mu lands, which is higher than the national level. The degree of fragmentation in family arable land is indicated by the area per piece of arable land. The smaller the index value is, the higher the degree of fragmentation of arable land will be. On the contrary, the lower the degree is. In the survey sample, the area per piece of arable land, which is the highest degree of fragmentation, is 0.2 mu. The distance of arable land away from residence is indicated by the average time spent on walking from every piece of arable land to home. In the survey sample, the walking from the farthest arable land to home takes 45 minutes, the closest arable land is in the front of farmer house. The average level of arable land is 1.78, close to 2, indicating that the average quality of most family arable land is middle. The average value of irrigation in arable land is 2.88, which reflects that irrigation can cover almost all of the farmland. After the conversion, the application rate per mu of nitrogen, phosphorus and potassium is 51.08, 91.19, 42.55 catties respectively, and the total is 184.82 catties, far beyond the safe upper limit of fertilizer application rate in developed counties, which is 30 catties per mu. These data reflected that the main agricultural producing area also is the pollution-stricken area.

Table 1.Descriptive Analysis of the Survey Data

Variable	Unit	Average	Standard deviation	Maximum	Minimum
Householder age	Year	45	8.98	78	25
Householder gender	-	0.9397	0.24	1	0
Householder education life	Year	7.68	2.88	12	0
Householder farming life	Year	23.27	10.56	50	2
Total family arable land area	Mu	13.66	4.09	90	0.2
Average family arable land area per piece	Mu	5.44	12.06	22.5	0.2
Distance of arable land away from residence	Minute	9.57	6.31	45	0
Rank of arable land	-	1.78	0.61	4	1
Irrigation of arable land	-	2.88	0.36	3	1
Application intensity of Nitrogen fertilizer	Catty	51.08	19.19	151.16	9
Application intensity of Phosphate fertilizer	Catty	91.19	37.22	375	10
Application intensity of Potash fertilizer	Catty	42.55	18.62	110	15
Receiving technical training or guidance about fertilization	-	0.25	0.43	1	0

Note: In the "Householder gender","1" stands for "Male","0" stands for "Female". The distance of arable land away from residence is indicated by the average time spent on walking from every piece of arable land to home. The rank of every arable land is divided into 4 grades: 1 (excellent), 2 (middle), 3 (low), 4 (poor) and each household's rank is indicated by the average rank of all arable land. Irrigation of arable land is divided into three levels: 1 (relying on rain), 2 (cannot guarantee irrigation), 3 (ensure irrigation), which is indicated by average irrigation level of all arable land in each family. In the "Receiving technical training or guidance about fertilization","1" stands for "Yes","0" stands for "No".

(ⅱ). Model specification

We use regression model to test the impact of influencing factors in the theoretical hypothesis made on the application amount. In general, the optional econometric model includes multiple linear regression model, Log-log-linear model and Semi-linear model. In the Log-log-linear model, flexibility is the coefficient of explaining variable [16]. The Log-log-linear model established in this article is as follows:

$$\ln Y = a_0 + a_1 \ln X_1 + a_2 \ln X_2 + a_3 X_3 + a_4 \ln X_4 + a_5 \ln X_5 + a_6 \ln X_6 + a_7 D_1 + a_8 \ln X_8 + \varepsilon \quad (1)$$

In the Model (1), D_1 stands for the information transfer variable, and $\ln Y$, $\ln X_1$, $\ln X_2$, $\ln X_4$, $\ln X_5$, $\ln X_6$ respectively stands for nitrogen fertilizer application intensity, age, years of education, proportion of agricultural labor in family, scale of operation, fragmentation of arable land, distance of arable land away from residence, production experience in the log form. Logarithm is taken to dependent variables and some of the independent variables. a_1, a_2, a_4, a_5, a_6, a_7, a_8 are the flexibility of their variables, a_3 is a half-flexibility. The reason why not takes logarithm to X_3 be that the proportion of agricultural labor in family is a ratio and its estimated value is equivalent to the usual flexibility [17].

From this survey, we found that most of the farmers do not want to reduce fertilizer input for the purpose of risk aversion, but they agree on and are willing to adopt some technology, which can keep the same level of output and has a high utilization ratio. This shows that inducing farmers to adopt scientific fertilization technology seems more feasible than blindly persuading farmers to reduce fertilizer use. This paper introduced a dummy variable to represent the farmers' willingness in order to measure the impact on the decision-making of fertilization made by every variable in model (1), when farmers have the willingness to fertilize scientifically. The variable is "1"as farmers have the willingness to use scientific fertilization technology in the future, and the variable is "0" as farmers haven't this willingness. After the cross-multiplication between dummy variable and every explaining variable, the re-estimated coefficient represents the difference of impacts on fertilizer application amount made by farmers' willingness of scientific application. The model is as follows:

$$
\begin{aligned}
\ln Y = {} & \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 \\
& + \beta_8 \ln X_8 + \beta_9 D_2 \ln X_1 + \beta_{10} D_2 \ln X_2 + \beta_{11} D_2 X_3 + \beta_{12} D_2 \ln X_4 \\
& + \beta_{13} D_2 \ln X_5 + \beta_{14} D_2 \ln X_6 + \beta_{15} D_2 \ln X_8 + \varepsilon
\end{aligned} \tag{2}
$$

Table 2.Definitions and Values of Variables

Variable	Definition	Values
Nitrogen fertilizer（$\ln Y$）	Nitrogen fertilizer Amount is a commutation	Catty/Mu, Conversion factors：46% of nitrogen in urea, 15% of nitrogen in fertilizer,17.7% ammonium bicarbonate in nitrogen[1]
Age（$\ln X_1$）	The age of householder	Year，18～
Education years（$\ln X_2$）	The education years of householder	Year，0～
Proportion of agricultural labor （X_3）	The proportion of the farming labor with the age between 16-65 years old in the family population[2]	Proportion，0.1～1
Scale of family management（$\ln X_4$）	The total area of arable land in family management	Mu，0.1～
Fragmentation of the arable land（$\ln X_5$）	The average arable land area per piece	Mu，0.1～
Distance of arable land away from residence（$\ln X_6$）	The average walking time	Minute，0.1～
Information transfer（D_1）	Whether contract with agricultural officials	0=no contact, 1=contact
Production experience（$\ln X_8$）	The years spent by farmers who is responsible for engaged in agricultural production	Year，1～

[1] Gong Qianwen, Research on Utilization Rate of Agricultural Fertilizers and Farmers Fertilization Conducts [D], Wuhan: Huazhong Agricultural University, 2005.

[2] He Haoran, Zhang Linxiu, Li Qiang, Study on farmers Fertilization Conducts and the agricultural non-point source pollution [J], Agro-technical Economics, 2006 (6) :2-10.

Farmers' willingness（D_2）	Whether farmers want to adopt scientific fertilization technology or not	0 = don't want to, 1 =want to

Table 3.Assumption of Variable Coefficient Symbols

Independent variable	Age $\ln X_1$	Education year $\ln X_2$	Proportion of agricultural labor X_3	Scale of management $\ln X_4$
Coefficient Symbols	+	-	-	-
Independent variable	Fragmentation of arable land $\ln X_5$	Distance of arable land away from residence $\ln X_6$	Message transfer D_1	Production experience $\ln X_8$
Coefficient Symbols	-	+	-	-

According to the above-mentioned theoretical assumption and general judgment, influencing tendency of every independent variable is assumed. "+" indicates that the greater the value of independent variable is, the more fertilizer application amount will be, which has a positive effect. "-" indicates that the greater the value of variable is, the more farmers tend to reduce the amount of fertilizer, which has a negative effect (Table 3).

IV. Results

Data used in the estimation of Model (1) and (2) are from questionnaires of household survey and 285 are valid for empirical purpose. After rejecting 109 lacking of critical data relevant to this study, we finally have 176 cross-sectional samples. In Table 4, the first column is the results of model (1) using OLS, and the results are statistically insignificant. Due to heteroscedasticity that is common in cross-section data [18], we choose to re-estimate Model (1) using WLS and the White test, and results are listed in the second column and the statistical significance is improved obviously. Results of intersection terms of dummy variable D_2 with other variables are listed in the third column; we can use them to study the differences between with and without farmer's willing to apply fertilizer scientifically. Model (2) is also estimated using WLS and the White test.

Table 4.Estimation Result of model

Variable	①	②	③
$\ln X_1$	0.295	0.385*(9.041)	-1.020*(-32.446)
$\ln X_2$	0.004	0.090*(4.720)	-0.021*(-3.305)
X_3	0.145	0.238*(4.519)	0.083*(8.302)
$\ln X_4$	-0.047	-0.126*(-3.883)	-0.082*(-3.122)
$\ln X_5$	-0.032	-0.030**(-1.311)	0.060*(4.563)
$\ln X_6$	-0.083	-0.073*(-12.085)	-0.079*(-10.995)
$\ln X_8$	0.006	-0.035(-0.875)	0.109*(4.065)
D_1	-0.050	-0.085*(-3.834)	—
$D_2 \ln X_1$	—	—	0.264*(32.297)
$D_2 \ln X_2$	—	—	0.005*(3.170)
$D_2 X_3$	—	—	-0.021*(-7.947)
$D_2 \ln X_4$	—	—	0.022*(3.128)
$D_2 \ln X_5$	—	—	-0.016*(-4.540)
$D_2 \ln X_6$	—	—	0.020*(10.726)
$D_2 \ln X_8$	—	—	-0.028*(-4.035)
调整 R^2	0.072	0.724	0.999
D.W	1.690	1.928	2.116

Note: the numbers in bracket are t values. * stands for 1% significance level and ** stands for 5% significance level.

Results in the second column from model (1) indicate that, variables contradicting to our assumption or uncertain are $\ln X_2$, X_3, $\ln X_6$ (totally different from previous assumption) ; $\ln X_8$ (results are uncertain). The rest variables are significantly consistent with theoretical assumptions.

(ⅰ). Results from model (1)

The coefficient of $\ln X_1$ in the second column is significant, which is in accord with expectation, indication that age of householder has great impact on fertilizer application. Whenever the age increases by 1%, fertilizer application per mu will increase 0.385% accordingly. Coefficients of operation scale ($\ln X_4$) and fragmentation ($\ln X_5$) are also significant, which indicate that they both have great impact on nitrogenous fertilizer application. With expansion of operation scale and reduction of fragmentation, farmer will be more willing to adopt new technology and apply modern on-site management to improve productivity and therefore reduce fertilizer use. Result of D_1 is consistent with our expectation, when farmer has access for training or relevant technology information, they will probably reduce use of fertilizer.

Coefficients of $\ln X_8$ are statistically insignificant, showing that production experience of householder in our survey area has little impact on fertilizer use.

Because Hubei province is in the middle of China, awareness of farmers lag far behind the social progress, and the survey area are characterized by traditional grain and cash crop production, the development of green agriculture and agricultural industrialization are both in the early stage. Therefore, it is difficult for him to change his way of production even the householder engage in agriculture production for a very long time.

Result of $\ln X_2$ is contrary to our expectation. Reasons are as follows: (1) people in our survey area mostly receive education in elementary or high school, effects of education differences on fertilizer use are not obvious; (2) most farmers engage in production with traditional style, and those with small scale of operation are more likely to imitate others about fertilizer use [19]. Result of X_3 is contrary to our expectation. Obviously, reduction of fertilizer application will be dependent upon modern technology, training, or adoption of other manure as substitution. However, much money will be needed for all these input. The higher the ratio of agricultural labor, the lower is the number embarking non-agriculture sectors. Furthermore, profit gaining from agriculture production is far less than non-agriculture activities and low income per capita imply investment in agriculture is in the low level. If family strongly relies on agricultural revenue, it will be unlikely to reduce use of fertilizer as well as maintain the same output. Coefficient of $\ln X_6$ (distance of arable land away from home) is significant, but is not consistent with our expectation, which is negative correlated with fertilizer use per mu. This implies that the longer arable land away from home, the less is the application of fertilizer.

(ⅱ). Results of model (2)

In the third column, we can see how variables affect use of fertilizer with farmer’s awareness of willing to apply fertilizer scientifically. Contrary to the results when farmer has no willingness, we now find proportion of agricultural labor and distance arable land away from home have impact on fertilizer use, which is consistent with our expectation.

With farmer’s willingness, proportion pass significance test under level of 1%, whenever the proportion increases by 1%, fertilizer application will by 0.021% per mu. This indicates that, with householder’s willingness, when agricultural labor increases, it will be more probably for them to produce intensively with modern technology, and use less fertilizer or other substitute. Coefficient of $D_2 \ln X_6$ is positive, which indicates that arable distance is positive correlated with fertilizer application. When arable land is long from home, it is convenient to use fertilizer; when land is close to home, the farmyard manure will be used. Coefficient of

$D_2 \ln X_8$ is significantly negative, indicates that more experienced farmer will be inclined to reduce fertilizer input.

Ⅴ. Conclusion

(ⅰ). Characteristics of the householder

This paper proves again that the greater the age of householder is, the less willing to reduce the amount of fertilizer. On the contrary, the condition for the younger farmers is different. In Jianghan Plain, the householders' level of education has not significantly impact on reducing fertilizer use. Only if farmers have the willingness of adopting scientific technology to fertilize, the richer production experience is, the more the farmers tend to reduce the amount of fertilizer inputs.

(ⅱ). Household endowment

The variables of scale of operation, fragmentation of arable land and agricultural labor proportion are important variables which have the impact on use of fertilizer. The larger the scale of operation is, the lower the fragmentation of arable land is, and the more obvious scale benefit is. Based on the long-term interests, the farmers pay attention to the importance of soil fertility restoration and conservation, which is helpful to reduce agricultural non-point source pollution and the quality of water could be protected to a certain extent. The higher the proportion of agricultural labor in family is, the farmers mainly rely on the agricultural income so as to form short-sighted act under the absence of scientific awareness of the fertilizer. Therefore, the farmers tend to increase the amount of fertilizer, which could cause rivers and groundwater pollution.

(ⅲ). Policy environment

The role of public service policy is very significant, effective measures should be taken to improve use efficiency and reduce pollution by increasing opportunities that farmers access to scientific and technical training for fertilization.

(ⅳ). Willingness of Scientific fertilization

It shows that, under the willingness of scientific fertilization, the influencing trends of two indexes, that are the ratio of agriculture labor in family and the distance of arable land away from residence, are opposite from the trends without willingness of scientific fertilization. The influencing trends under the willingness are in line with the expectation. The higher the ratio of agricultural labor in a family is, the farther the distance of arable land away from residence is, the much probability the farmers reduce the input amount of fertilizer.

VI. Discussion

This paper studies environmental consequence of fertilizer application. We then make empirical test about factors affecting fertilizer application. Finally, we analysis different results when farmer's have the willingness to apply fertilizer scientifically. Due to data limitation, we only analysis the different impact of whether or not the technique training exit. Information access and training times are not considered. Some people argue that great difference of fertilizer application do exist between vegetable and grain, however, this article do not analysis fertilizer application decision based on classified varieties. Apart from nitrogen, phosphor is one of factors causing eutrophication. It should be included in further analysis.

Reference:

[1] Stone, B. Basic Agricultural Technology under Reform [M]. Oxford, England, 1993.

[2] Huang, J. K. and Rozelle, S. Environmental Stress and Grain Yields in China [J]. American Journal of Agricultura Economics, 1995, 77: 337-369.

[3] Cai, G. X., Fan, X. H. and Yang, Z. Gaseous loss of nitrogen from fertilizers applied to wheat on a calcareous soil in North China Plain [J]. Pedosphere, 1998, 8(1): 45-52.

[4] Zhu, Z. L. and Chen, D. L. Nitrogen fertilizer use in China-contributions to food production, impacts on the environment strategies [J]. Nutrient Cycling Agroecosystems, 2002, 63(2): 117-127.

[5] YANG Lin zhang，SUN Bo，LIU Jian．Progress in translocation and transformation of nutrients in agroecosystems and its optimized management[J]．Advance In Earth Sciences，2002，17（3）：441~445．

[6] Cao Zhihong．Effect of fertilization on air quality—effect of fertilization on environment quality[J]．Soils，2003，35（4）：265~270．

[7] ZHU Zhaoliang， Norse David， SUN Bo． Control measures of China's agricultural non-point pollution[M]．Beijing：China Environment and Scientific Press，2006．

[8] Nunez, J. and Mccann, L. Crop farmers' willingness to use manure [C]. Denver, Colorado, 2004.

[9] LU Bao xiang，JIANG Wen hua，SHI Qin hua．Investigation and analysis on use efficiency of pesticide in Zhejiang province [J]．China Rural Survey，2000（5）：62~70．

[10] MA Ji，CAI Xiao yu．Analysis on farmer's willingness of reduce nitrogen fertilizer and influencing factors[J]．China Rural Economy，2007（9）：9~17．

[11] Bosch, D., Cook, Z. and Fuglie, K. Voluntary versus Mandatory Agricultural Policies to Protect Water Quality:Adoption of Nitrogen Testing in Nebraska [J]. Review of Agricultural Economic, 1995(17): 13-24.

[12] Gould, B. W., Saupe, W. E. and Klemme, R. M. Conservation Tillage: The Role of Farm and Operator Characteristics and the Perception of Soil Erosion [J]. land Economics, 1989, 85(5): 167-182.

[13] ZHANG Yuhua，MA Jiujie．Analysis on influencing factors of farmer's using no pollution and green pesticide [J]．China Rural Economy，2004（1）：41~49．

[14] LI Haipeng．The Agricultural Non-point Source Pollution in China: an Economic Analysis and Policy Studies[D]．Wuhan：Huazhong Agricultural University，2006．

[15] JIANG Taibi．Study on agricultural technology extension and farmer decision behavior[J]．Journal of Agrotechnical Economics，1998（1）：1~6．

[16] Jeffrey M. Wooldridge．Econometrics Introduction: modern viewpoint[M]．Beijing：Tsinghua University Press，2004．

[17] FAN Ziying，MENG Lingjie．New explanations and test to Sen s entitilements: evidence from China[J]．Economic Research Journal，2006（8）：104~113．

[18] Gujarati．Basic Econometrics[M]．Beijing：China Renmin University Press，2000.

[19] LI Yueyun，LAN Haitao，FANG Xiaojun．Study on household economic behavior for different management scale[J]．China Rural Economy，1999（4）：39~45．