Nonparametric Estimation of Farmers' Willingness to Accept: Implication for Calculating Crop Insurance Amount

WAN Chunli, WU Dongli

(College of Economics and Management,
Shenyang Agricultural University, Shenyang 110866, China)

Abstract

Scientific and reasonable setting of agricultural insurance amount is one of the important ways to realize the high-quality development of agricultural insurance. Based on the data of 465 insured farmers in Liaoning Province, this paper fitted the distribution of farmers' WTA (Willing to Accept) by the nonparametric kernel density method. The crop insurance amounts satisfying farmers' WTA were calculated under various levels of insurance participation rates. The results show that: (1) There is heterogeneity in farmers' WTA. The WTA of large farmers who rent land is higher. (2) Large farmers need higher insurance amount to realize consistent participation rate with small farmers. For example, to meet the policy requirement of a 70% participation rate, it is necessary to provide at least 647 and 564 CNY (about 102 and 89 USD) of insurance amount for large and small farmers, respectively. (3) Participation rate and farmers' WTA are the key factors for setting multi-level insurance coverage of crop insurance. It is necessary to identify the difference of farmers' WTA, construct the differentiated coverage system of agricultural insurance and make it dynamic adjust, which could further meet the differentiated insurance demand of farmers and promote the high-quality development of agricultural insurance in China.

Keywords: crop insurance; insurance coverage; willing to accept; production cost; nonparametric kernel density method

WAN Chunli is a PhD student in the College of Economics and Management, Shenyang Agricultural University, Email: 1203543694@qq.com; WU Dongli is a professor and PhD tutor in the College of Economics and Management, Shenyang Agricultural University, Email: wdl@syau.edu.cn

Introduction

China's agricultural insurance expanded rapidly in last fifteen years with the implementation of policy on insurance subsidies. Indeed, the total agricultural insurance premium increased from 5.3 billion CNY (about 0.8 billion USD) in 2007 to 81.5 billion CNY (about 12.8 billion USD) in 2020. China is now the largest agricultural insurance market in the world. Farmers purchasing crop insurance can receive an average of 183.6 CNY (about 28.9 USD) risk protection by paying 1 CNY (about 0.16 USD) premium. Agricultural insurance has become an important instrument to help farmers diversify the risk in agricultural production, smooth farm income, and increase the enthusiasm of agricultural production. Consequently, to promote the modernization of agriculture and ensure national food security, it is necessary to improve the product system and strengthen the risk prevention function of agricultural insurance.

However, China's crop insurance is still facing the development situation of 'wide coverage and low protection'. The main driving force for the improvement of the coverage level is the insurance coverage rather than the insurance depth (the ratio of unit insurance amount to unit output value). The setting form of insurance amount is simplistic, most of them lack dynamic adjustment based on the change of production cost. The crop insurance amount cannot completely cover the direct physical and chemical costs of crop production for a long time. There is a large difference between low indemnity of crop insurance and the actual loss of farmers because of the simplistic setting form of insurance amount (Meng *et al*. 2011; Zhao *et al*. 2015). These problems ultimately lead to insufficient effective demand and lower participation rate for China's crop insurance. In addition, as the continuous promotion of land transfer policy, the proportion of land rent and labor cost to total agricultural production cost is gradually increasing. Scale farmers' demands for the coverage level of crop insurance is increasing accordingly. In this context, how to set the amount of crop insurance scientifically based on the demand of farmers? Whether there is heterogeneity in the demand of farmers? How to construct a corresponding differentiated coverage system of crop insurance scientifically? These are the focus of this paper.

In recent years, the issue of improving the coverage level of crop insurance has aroused widespread concern in academia (Xiao *et al*. 2020). However, there are few studies on the scientific setting of multi-level coverage of crop insurance. The analysis of this problem is of great significance for crop insurance to meet the differentiated demands of farmers and realize the function of risk diversification. In October 2019, China's Ministry of Finance proposed to

improve the agricultural insurance system with expanded coverage and functions to allow it to better serve farmers. The agricultural insurance system that meets farmers' demand for risk protection should be constructed, and the coverage of insurance for rice, wheat, and corn should reach over 70%. Based on this, the article established a framework to set crop insurance amount and aimed to set the multi-level coverage of crop insurance according to farmers' differentiated demand for risk protection through empirical research.

There are two questions that this paper solves. (1) What level of crop insurance coverage should be increased to meet farmers' demand for risk protection and the requirement of a 70% participation rate; (2) How to set the coverage level of crop insurance to meet farmers' differentiated demand for risk protection. Compared with the extant research, the contributions of this paper are as follow: (1) The method of setting crop insurance amount scientifically was proposed based on the perspective of meeting farmers' demand for risk protection. We fitted the distribution of farmers' WTA (Willing to Accept) using the nonparametric kernel density method and calculated the crop insurance amount satisfying farmers' WTA at various levels of insurance participation rates. (2) Farmers' heterogeneity was considered in this paper. We divided the farmers into two groups according to whether they rent land, and set the coverage level for the two groups of farmers. Finally, a multi-level and differentiated guarantee system of crop insurance was constructed.

The rest of this research is structured as follows. The next section summarizes the search status of China's crop insurance demand and the improvement in coverage level. The third section elaborates the framework for how to set the coverage level of crop insurance to meet farmers' demand for risk protection. The fourth section presents the data and the estimation strategy, followed by the empirical findings and the interpretations. The concluding remarks are offered in the last section of this article.

Literature Review

The issue of insufficient demand for crop insurance has been widely discussed by scholars (Sherrick *et al*. 2004; Goodwin and Smith 2013). Goodwin (1993) found that producers with differing levels of loss-risk have different demand elasticities. Coble *et al*. (1997) concluded that the higher the expected return to insurance, the higher the adoption rate. Just *et al*. (1999) found that farmers participate in crop insurance primarily to receive the subsidy while risk aversion appears to be a minor part of the incentive. Vandeveer *et al*. (2001) implied that farmers prefer higher yield guarantee level. Sherrick *et al*. (2004) showed that midwestern farmers who are more highly leveraged, less wealthy, risker, and operate larger acreages engage more

extensively in insurance and are more likely to choose revenue insurance versus yield and hail protection. However, the characteristics of crop insurance programs are not homogeneous across countries, the demand for crop insurance is different within China. Ning *et al*. (2005) earlier analyzed the influencing factors of demand for crop insurance based on theoretical and empirical analysis. Sun (2008) and Zhang (2018) measured farmers' WTP (Willingness to Pay) to estimate insurance demand based on the CVM (Contingent Valuation Method) and DBDC (Double-Bounded Dichotomous Choice) experiment. Taking 'willingness to insure' or 'purchase decision' as the two-valued variable, Hou *et al*. (2010), Li (2014) and Liu (2014) analyzed the influencing factors of insurance demand. However, these studies mainly analyzed the insurance demand according to the initial insurance behavior without distinguishing the differences between insurance behavior and insurance demand (Niu *et al*. 2020; He *et al*. 2020). Few studies have focused on farmers' risk protection demand for crop insurance.

The influencing factors of demand for crop insurance can be classified into three aspects: individual characteristics, family characteristics and agricultural insurance product characteristics. Zhang *et al*. (2005), Wang *et al*. (2008), and Guo *et al*. (2019) found that education, risk preferences, and insurance cognition affect the demand for crop insurance. The magnitudes of household assets and debts, agricultural income, crop acreage, and losses are the main household characteristics that affect the demand for crop insurance (Yong *et al*. 2001; Vandeveer *et al*. 2001; Nie *et al*. 2017). The characteristics of insurance products, such as expected indemnity payments, high insurance premiums, low premium subsidies, and coverage levels, are the major challenges in improving farmers' demand for crop insurance (Makki *et al*. 2001; Ozaki *et al*. 2008; Wang *et al*. 2010; Li *et al*. 2019). To transform potential demand into effective demand for crop insurance, Zhou *et al*. (2012) and Xie *et al*. (2017) implied that risk division and actuarial insurance rating are effective methods. In addition, the authors found that setting multi-level premium rates and coverage, enriching the forms of subsidies, and accelerating the design of crop insurance products are also effective (Meng *et al*. 2011; Luo *et al*. 2011; Zhang *et al*. 2018; Zhang, 2018; Xu *et al*. 2018). However, how to design the differentiated crop insurance products according to farmers' risk protection demand is still an urgent need to resolve.

The issue of improving the coverage level of crop insurance also has been widely discussed by scholars. Tuo (2019) suggested that increasing the amount of agricultural insurance and achieving full coverage of materialized costs is the primary goal of agricultural insurance at this stage. Yu (2013) and Tuo *et al*. (2016) argued that extending the coverage level from productive cost to yield and revenue and expanding the pilot scope of total cost insurance and agricultural

income insurance. Insurance depth is inferior to insurance breadth, which restricts the further improvement of crop insurance coverage level (Zhang *et al*. 2019). Huang *et al*. (2013) and Liu *et al*. (2020) suggested that the key to improving the coverage level include setting multiple risk units and coverage levels, establishing the dynamic adjustment mechanism of coverage level according to the price change, and innovating insurance productions with higher coverage level for new agricultural enterprises. However, few of these studies suggested the method of setting crop insurance amount scientifically based on farmers' demand for risk protection.

The previous literature shows abundant research results based on insufficient demand for crop insurance and innovation of crop insurance products. Nevertheless, the existing literature ignores whether the risk protection demands for farmers are met and how to set the amount of crop insurance based on heterogeneity in the risk protection demands. Although some researchers have suggested that set multiple coverage levels to meet farmers' differential demand and expand the pilot scope of new insurance products to increase the amount. Whether the setting of the insurance amount for these products is reasonable? Could they provide effective risk protection for farmers? And how to set up a multiple guarantee system of crop insurance? These are problems to be further solved.

Theoretical Analysis

The risk diversification function of crop insurance can be measured in three ways. The first is by diversifying the relevant natural and price risks (Ning *et al*. 2006). In accordance with the requirements of expanding the scope of application, increasing the insurance category and improving the coverage level, China's crop insurance has improved since 2019. Various pilots programs have been promoted continuously, such as weather index insurance, total cost insurance, revenue insurance, and 'insurance + futures'. Such insurance products can basically cover natural risk and price risk in crop production. The second is by ensuring that the premium is affordable for farmers (Ye *et al*. 2017). Chinese central government subsidies approximately 45% of the crop insurance premium, while local governments offer a subsidy equal to approximately 35% of premium (Feng *et al*. 2021). For traditional yield insurance, which is currently widely implemented, farmers pay approximately 5 CNY/mu (about 12 USD/hm^2) for premium. The premium is affordable for farmers (Liu *et al*. 2019).

The third is by guaranteeing the income of farmers (Ye *et al*. 2018). However, the lower coverage level of current crop insurance cannot significantly stabilize the crop income by compensating for the loss (Shi 2016; Zheng *et al*. 2019). The most common form of crop insurance in China is traditional yield insurance, which guarantee the physical and chemical

costs of crops. Although the pilot of full cost insurance and revenue insurance has been expanded in 2021, it will only cover about 500 grain-producing counties in 13 major grain-producing provinces[1]. In the case of protecting production cost, the average indemnity received by insured farmers after the loss occurred is 234 CNY (about 37 USD), accounting for only 2.42% of family crop income (Liu *et al*. 2019). Crop insurance with low coverage levels and limited compensation cannot meet farmers' demand for risk protection, especially for scale farmers (Tang *et al*. 2021; Ma *et al*. 2020). Therefore, it is necessary to improve coverage levels to further exploit the role of crop insurance as a "stabilizer" of crop production income.

Meeting the risk protection demand of farmers should be the basis for improving coverage level of crop insurance. In the context of affordable premium, the expected insurance indemnity under extreme risks can be used to measure farmers' risk protection demand. When the extreme risk leads to a large loss, the expected insurance indemnity is farmers' WTA. Furthermore, the heterogeneity of farm size may lead to differences in farmers' risk protection demand (Chao *et al*. 2017). Compared with small farmers, scale farmers, such as family farmers and large grain farmers, accumulate greater risks in agricultural production due to the significant increase in production costs, resulting in higher risk protection demands. Therefore, it is necessary to set differentiated insurance amounts based on the heterogeneity of farmers' risk protection demand.

Improving the coverage level should also be based on the overall policy objectives of current crop insurance development instead of meeting the risk protection demand of all farmers. As rational economic men, farmers will participate in crop insurance due to the increase of expected utility after their risk protection demands are met (Baquet *et al*. 1996; Ning *et al*. 2005). This paper set crop insurance amount based on the requirement of 'the coverage rate of crop insurance reaching over 70%' proposed by China's Ministry of Finance, which can meet the risk protection demands of 70% of farmers. Multiple participation rates and the heterogeneity of farmers' demand for risk protection should be considered at the same time. Then, a multi-level system of crop insurance that meets farmers' demand for risk protection can be constructed.

In addition, factors such as the characteristics of crop insurance product and relevant provisions of the WTO Agreement on Agriculture should also be considered. Crop insurance is

[1] Data sources: Related documents of China's Ministry of Finance (http://jrs.mof.gov.cn/zhengcefabu/phjr/202106/t20210629_3726782.htm)

a property insurance that provides risk protection rather than an investment insurance. Therefore, the insurance amount should not exceed the output value of the insured crop. To meet the requirement of the WTO Agreement on Agriculture that 'the compensation provided by agricultural insurance for farmers cannot exceed 85% of the corresponding output value when risks occur', the insurance amount should not be higher than 85% of the output value of the insured crop.

Based on this, this paper comprehensively considers farmers' WTA and its heterogeneity, multi-level participation rates, crop insurance product characteristics, and WTO Agreement on Agriculture, etc., to construct a multi-level and differentiated system of setting crop insurance amount.

Data and Methods

To test the feasibility of setting crop insurance amount based on farmers' demand for risk protection, the empirical analysis is as follow. We divide the samples into two groups according to whether they rent land. The probability density function of farmers' WTA is estimated by the nonparametric kernel density method. And then, the crop insurance amounts which meet differential farmers' WTA are calculated by solving the integral in multiple participation rates.

Nonparametric modeling of WTA distribution

There are two methods commonly used to fit the sample distribution, parametric and nonparametric approaches. Considering that the distribution pattern of farmers' WTA is unknown, nonparametric kernel density estimation is used in this paper. Large farmers renting land were divided into group A and the remaining small farmers were divided into group B. Farmers' WTA can be represented as the fraction which have the sum of direct physical and chemical costs and land rent as the denominator, then the probability density functions of farmers' WTA are fitted:

$$f(x_a) = \frac{1}{n_a h_a \sqrt{2\pi}} \sum_{i=1}^{n_a} exp\left[-\frac{1}{2}\left(\frac{x_a - x_{ai}}{h_a}\right)^2\right] \quad (1)$$

$$f(x_b) = \frac{1}{n_b h_b \sqrt{2\pi}} \sum_{i=1}^{n_b} exp\left[-\frac{1}{2}\left(\frac{x_b - x_{bi}}{h_b}\right)^2\right] \quad (2)$$

$$x_a = \frac{WTA}{DPCC+LR} - 1 \quad (3)$$

$$x_b = \frac{WTA}{DPCC} - 1 \quad (4)$$

where n and h are the number of samples and the window of probability density estimation in groups A and B[2]. As mentioned in the third section, farmers participate in crop insurance when the insurance amount meets their risk protection demand. We take multiple insurance participation rates as the integral result, and calculate the magnitude of insurance amount that meets farmers' WTA by solving the upper limit of the integral g:

$$F(x) = \frac{1}{nh\sqrt{2\pi}} \sum_{i=1}^{n} \int_{e}^{g} exp\left[-\frac{1}{2}\left(\frac{x-x_i}{h}\right)^2\right] \quad (5)$$

Date description

Our research data came from the questionnaire surveys of the College of Economics and Management of Shenyang Agricultural University in 2015. The survey adopted the stratified random sampling method and first divided Liaoning province into five regions: Central Liaoning, eastern Liaoning, northern Liaoning, southern Liaoning, and western Liaoning. Second, 3 counties, 3 townships, and 3 villages were selected from each region based on the economic development of each region in the province. Finally, 9 households were selected from each village according to their economic status. The survey obtained 1,233 valid samples, covering agricultural production, farmers' lives, village appearance, democratic management, and other aspects of data. The production cost and yield data of corn were obtained from the compilation of national agricultural product cost and benefit data.

Our empirical analysis makes use of the data of agricultural insurance and agricultural production in the questionnaire. Considering the characteristics of agricultural production and the current situation of crop insurance in Liaoning Province, we take the yield insurance for corn as an example to set the amount of crop insurance. First, we select the observations from samples who plant corn and participate in yield insurance for corn. Second, because of provisions of the WTO Agreement on Agriculture, we exclude the observations whose WTA exceed 952 CNY[3] (about 149 USD). Finally, we obtain 465 observations. There are 64 large farmers and 401 small farmers, respectively. The average planting area for corn is 55.60 and 8.53 mu (about 3.71 and 0.57 hm^2) in groups A and B, the average WTA is 492.94 and 434.07 CNY/mu (about 1156.26 and 1018.21USD/hm^2). It's obvious that the large farmers renting land

[2] Window calculation formula in nonparametric kernel density estimation$h = 1.06\sigma n^{-0.2}$

[3] The 'compilation of national agricultural product cost and benefit data' shows that the output value of corn production in Liaoning Province in 2014 was 1120.12 CNY (about 176.04 USD), and the direct physical and chemical cost was 357.47 CNY (about 56.18 USD).

have higher WTA and need higher crop insurance amount to meet their demand for risk protection. Furthermore, we estimate the probability density function of WTA to calculate the insurance amount for farmers in two groups.

Empirical Results

Based on MATLAB software to estimate samples by nonparametric kernel density, we obtain the probability density function of farmers' WTA in groups A and B. The insurance amount satisfying the two groups of farmers' WTA under various participation rates is further discussed. And then, we constructed a matching multiple guarantee system of crop insurance.

The distribution of farmers' WTA

The probability density functions of farmers' WTA in groups A and B are fitted by MATLAB software:

$$f(x_a) = \frac{1}{26.1824}\sum_{i=1}^{64} exp\left[-\frac{1}{2}\left(\frac{x_a - x_{ai}}{0.1632}\right)^2\right] \quad (6)$$

$$f(x_b) = \frac{1}{199.7390}\sum_{i=1}^{401} exp\left[-\frac{1}{2}\left(\frac{x_b - x_{bi}}{0.1987}\right)^2\right] \quad (7)$$

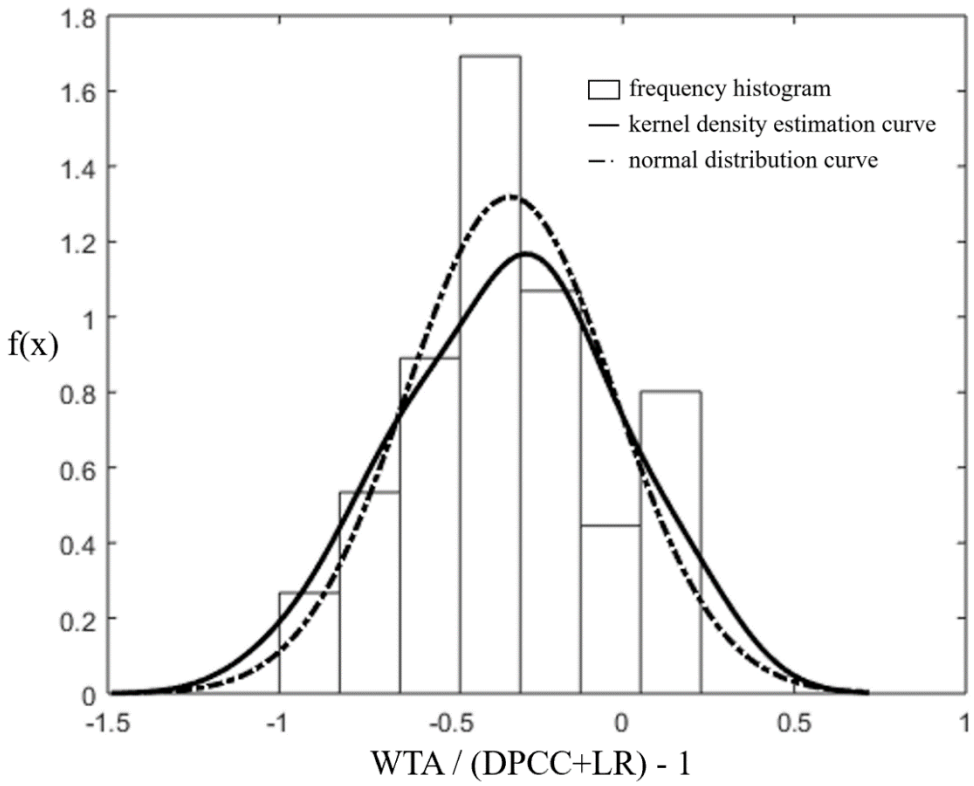

Figure 1. The distribution image of farmers' WTA in group A

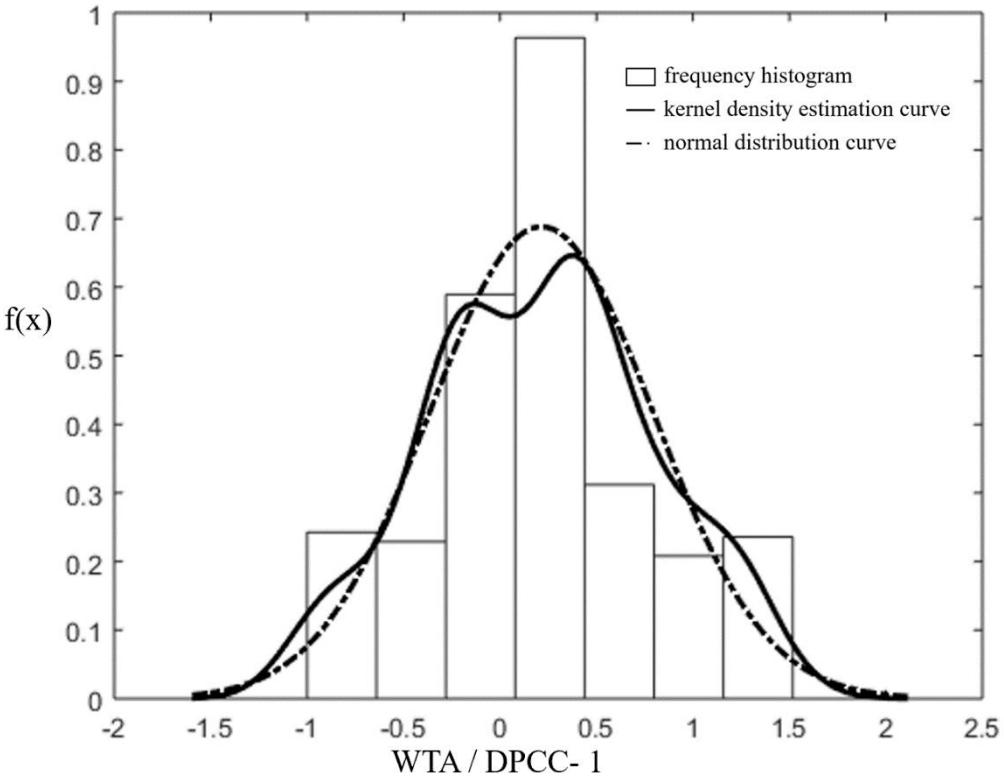

Figure 2. The distribution image of farmers' WTA in group B

where the window h_a and h_b are 0.1632 and 0.1987. Fig 1 and 2 show the distribution image of farmers' WTA in group A and B, including frequency histogram, kernel density estimation curve, and normal distribution curve. The kernel density estimation curve has the same trend as the normal distribution curve. It shows that the probability density distribution of farmers' WTA in two groups fits well. Based on three distribution images, we find that data in group A has the largest probability of distribution in the interval of [-0.5, -0.17]. That means the WTA of large farmers is more concentrated in the range of [366.4694，608.3392]. Data in group B has the largest probability of distribution in the interval of [0, 0.5]. That means the WTA of small farmers is more concentrated in the range of [366.4694，608.3392]. The land rent increases farmers' WTA. Compared with small farmers, large farmers have a higher demand for crop insurance amount. Thus, it is necessary to set differentiated amounts of crop insurance according to different farmers' demands for risk protection. However, the current amount of corn yield insurance in Liaoning Province is 300 CNY/mu (about 703.70 USD/hm^2), which can only satisfy the WTA of 28% and 36% of large and small farmers. The form of setting insurance amount is single which cannot provide differentiated insurance services for farmers. Most farmers' demand for risk protection cannot be met.

Multi-level crop insurance coverage

After fitting the distribution of farmers' WTA in two groups, we derive their cumulative distribution functions to set crop insurance amount based on farmers' WTA. Then, we construct a differentiated system for insurance coverage that meet different farmers' demand for risk protection under multiple participate rates. The cumulative distribution functions of farmers' WTA are as follow:

$$F(x_a) = \frac{1}{26.1824}\sum_{i=1}^{64}\int_{-1}^{0.2990} exp\left[-\frac{1}{2}\left(\frac{x_a - x_{ai}}{0.1632}\right)^2\right] \quad (8)$$

$$F(x_b) = \frac{1}{199.7390}\sum_{i=1}^{401}\int_{-1}^{1.6634} exp\left[-\frac{1}{2}\left(\frac{x_b - x_{bi}}{0.1987}\right)^2\right] \quad (9)$$

where the value range of independent variables x_a and x_b is [-1，0.2990] and [-1，1.6634] respectively. We take multiple participation rates as the result of the cumulative distribution function and solve the corresponding upper limit of the integral by MATLAB software. Then, the insurance amount satisfying farmers' WTA under multiple participation rates is obtained. We calculate the upper limit of the integral of the cumulative distribution functions at 0.70, 0.75, 0.80, 0.85, and 0.90. In Table 1 and 2, we show the results of insurance amount under these participation rates in two groups. Comparing the two Tables, one can realize that insurance amounts for large farmers are higher than that for small farmers, about 13.72% higher on average under multiple participation rates. To realize 70-90% participation rates, the insurance amount for large and small farmers should be in the range of [647, 858] and [564, 763]. It implies that crop insurance should provide differentiated insurance amounts based on farmers' heterogeneity to achieve the same participation rate. Take whether to cover land rent as an example, the difference in insurance amount should be about 13%. In Table 1 and 2, we calculate the proportion of insurance amount in the output value of corn per unit area as coverage level to construct the guarantee system of corn yield insurance (Ren *et al*. 2021). Under the participation rates from 70% to 90%, the coverage level of corn yield insurance for group A is in the range of [57.77%, 76.59%] while the coverage level for group B is in the range of [50.34%, 68.10%]. Large farmers need higher coverage level, about 7.92% higher on average under multiple participation rates, to achieve the participation rate consistent with small farmers. However, the coverage level of corn yield insurance in Liaoning Province is just 27%. To achieve more than 70% of the participation rate, the amount of corn yield insurance should be at least 647 and 564 CNY (about 102 and 89 USD) for large and small farmers. The corresponding coverage level is 57.77% and 50.34%, respectively. In addition, we calculate the proportion of insurance amount in the physical and chemical cost of corn production to provide

a standard for setting crop insurance amount. The results show that the proportion of groups A and B are in the range of [1.81, 2.40] and [1.58, 2.13] respectively, the former is 0.25 higher than the latter on average under multiple participation rates. It implies that multiple amounts of crop insurance could be set according to the multiple proportions of physical and chemical costs. Based on farmers' differentiated demand for risk protection, calculating the proportion of insurance amount in physical and chemical cost under multiple participation rates, which could build the standard of setting a multiple and differentiated crop insurance guarantee system.

Table 1 Group A: Setting insurance amount for large farmers renting land

Participation rate (%)		70	75	80	85	90
Upper Limit of Integral		-0.1271	-0.0630	-0.0006	0.0744	0.1705
Insurance Amount	(CNY)	647.1115	686.5761	732.4988	787.4692	857.9046
	(USD)	101.6991	107.9013	115.1185	123.7575	134.8271
Coverage Level (%)		57.7716	61.2949	65.3947	70.3022	76.5904
Proportion		1.8103	1.9207	2.0491	2.2290	2.3999

Table 2 Group B: Setting insurance amount for small farmers

Participation rate (%)		70	75	80	85	90
Upper Limit of Integral		0.5773	0.6771	0.7989	0.9511	1.1339
Insurance Amount	(CNY)	563.8374	599.5129	643.0528	697.4597	762.8052
	(USD)	88.6119	94.2186	101.06126	109.6118	119.8814
Coverage Level (%)		50.3372	53.5222	57.4093	62.2665	68.1003
Proportion		1.5773	1.6771	1.7089	1.9511	2.1339

Conclusion

Taking corn yield insurance in Liaoning Province as an example, this paper calculated the crop insurance amount based on farmers' risk protection demand. We fitted the probability density function of farmers' WTA by the method of nonparametric kernel density. The amounts of crop insurance satisfying farmers' differentiated demand for risk protection were calculated

by solving for integrals under multiple participation rates. Finally, we constructed a multi-level guarantee system for crop insurance. The main conclusions of this paper are as follows. (1) Farmers' demand for risk protection have heterogeneity. Large farmers renting land have higher WTA. The key to effectively realize the risk prevention function of crop insurance is paying attention to farmers' demand for risk protection. Increasing insurance amounts according to farmers' WTA and their heterogeneity can provide effective risk protection for farmers and improve the participation rates further. Crop insurance should provide higher insurance amounts for large farmers to achieve the participation rate consistent with small farmers. (2) It is necessary to set differentiated amounts of crop insurance based on the heterogeneity of farmers' risk protection demand. Setting crop insurance amount should be a process of dynamic adjustment, whether it guarantees the physical and chemical cost, complete cost, part income, or all income of crop production. Farmers' WTA should be the basis and the key of the dynamic adjustment process in addition to the consideration of production costs and the provisions of the WTO Agreement on Agriculture. The insurance amount for large farmers that meet their demand for risk protection should be 13.72% higher than small farmers under multiple participation rates. To realize a 70% of the participation rate, the crop insurance amount should be at least 647 and 564 CNY (about 102 and 89 USD) for large and small farmers. (3) It is feasible to construct the multi-level setting system for crop insurance amount based on the participation rates, farmers' demand for risk protection, and their heterogeneity. The process of setting crop insurance amount scientifically should be carried out in the principle of meeting farmers' differentiated demand for risk protection. The key to further improve crop insurance products and provide multiple choices for farmers is constructing a multiple guarantee system with participation rates as the target.

In addition, this paper puts forward the following suggestions: (1) Expand the insurance depth further by setting crop insurance amount scientifically based on farmers' demand for risk protection. Taking multiple participation rates as the standard, crop insurance amounts should be set to satisfy farmers' differentiated WTA. Transform the potential demand for crop insurance into effective demand and improve the strength and scope of risk prevention. (2) Combined with a multi-level setting system of crop insurance amount, the corresponding setting of premium rates and subsidies should be gradually improved to achieve the diversification of crop insurance productions. (3) The process of setting crop insurance products should consider farmers' heterogeneity. Based on farmers' demand for risk protection, setting multiple coverage levels of crop insurance can provide various options to farmers. In particular, the setting should focus on serving scale farmers, such as raising premium rates or reducing premium subsidies

appropriately, providing insurance production with higher coverage, and so on. (4) The standard and supervision of crop insurance compensation should be improved and strengthened. The promotion of effective compensation can further meet farmers' demand for risk protection based on improving crop insurance coverage level, which realizes the risk management function of crop insurance.

References

Baquet A E, Smith V H. 1996. "The demand for multiple peril crop insurance: Evidence from Montana wheat farms." *American Journal of Agricultural Economics* 78(1): 189-201.

Chao N N, Hu L X, Yang R H, et al. 2018. "Comparison of cotton insurance policy between the US and China." *Research of Agricultural Modernization* 39(1): 71-79.

Chao N N, Yang R H. 2017. "Cultivated land scale, cognition of agricultural insurance and diversification of potential demand of agricultural insurance products—Based on the survey of 6492 grain growers in China." *Finance & Economics* (5): 67-79.

Coble K H, Knight T O, Pope R D, et al. 1997. "An expected‐indemnity approach to the measurement of moral hazard in crop insurance." *American journal of agricultural economics* 79(1): 216-226.

Goodwin B K. 1993. "An empirical analysis of the demand for multiple peril crop insurance." *American Journal of Agricultural Economics* 75(2): 425-434.

Goodwin B K. 2001. "Problems with market insurance in agriculture." *American Journal of Agricultural Economics* 83(3): 643-649.

Goodwin B K, Ker A P. 1998. "Nonparametric estimation of crop yield distributions: Implications for rating group‐risk crop insurance contracts." *American Journal of Agricultural Economics* 80(1): 139-153.

Goodwin B K, Smith V H. 2013. "What harm is done by subsidizing crop insurance?." *American Journal of Agricultural Economics* 95(2): 489-497.

Guo J, Tan S, Kong X Z. 2019. "Regional differences in farmers' agricultural insurance exclusion: Inadequate supply or inadequate demand—Investigation and analysis of crop insurance in twelve counties of six north provinces in North China." *Journal of Agrotechnical Economics* (2): 85-98.

He J. 2020. "China's agricultural insurance participation situation and promoting measures: From the perspective of behavioral economics." *Insurance Studies* (11): 19-31.

Hou L L, Mu Y Y, Zeng Y Z. 2010. "Empirical analysis on the farmers willing of buying insurance effects and subsidies policy of agricultural insurance." *Issues in Agricultural Economy* 31(4): 19-25+110.

Huang Y X, Li W Y. 2013. "Speed up institutional innovation and promote the sustainable development of agricultural insurance." *Issues in Agricultural Economy* 34(2): 4-9.

Just R E, Calvin L, Quiggin J. 1999. "Adverse selection in crop insurance: Actuarial and asymmetric information incentives." *American Journal of Agricultural Economics* 81(4): 834-849.

Li Q Y. 2014. "An empirical analysis on farmers' willingness to demand for agricultural insurance policy." *Henan Social Sciences* 22(12): 73-77+124.

Li Q Y, Chen K, Chen L P. 2019. "Policy prominence, premium subsidy and farmers' willingness to participate in insurance." *Rural Economy* (7): 72-79.

Liu H C, Tao J P. 2020. "Policy-oriented agricultural insurance in China: Development trend, international comparison and path optimization." *Journal of Huazhong Agricultural University (Social Sciences Edition)* (6): 67-75+163-164.

Liu J. 2014. "Empirical study of the factors influencing the intention of buying agricultural

insurance." *Dongyue Tribune* 35(10): 159-163.

Liu Y Z, Zhong F N. 2019. "Risk management vs income support: A research about the police target selection of police agricultural insurance in China." *Issues in Agricultural Economy* (4): 130-139.

Luo X M, Zhang W, Ding J F. 2011. "Regional subsidy differences, farmers' differentiated decisions and redistribution of agricultural insurance welfares." *Insurance Studies* (5): 11-17.

Ma B, Zhang C, Peng C. 2020. "A research on function realization of agricultural insurance under the background of rural-household differentiation." *Insurance studies,* (9): 77-91.

Makki S S, Somwaru A, et al. 2001. "Farmers' participation in crop insurance markets: creating the right incentives." *American Journal of Agricultural Economics* 83(3): 662-667.

Meng D F, Li C Y. 2011. "The investigation into demand and supply of policy-oriented agricultural insurance." *Economic Review Journal* (10): 73-76.

Nie R, Shen D J. 2017. "Study on influencing factors of farmers' agricultural insurance decision and production." *Journal of Northwest A&F University (Social Science Edition)* 17(1): 106-115.

Ning M X, Miao Q, Xing L, et al. 2006. "An empirical analysis of farmers' willingness to pay for agricultural insurance: A case study of Mass River Basin in Xinjiang." *Chinses Rural Economy* (6): 43-51.

Ning M X, Xing L, Zhong F N. 2005. "Factors influencing farmers' decisions to purchase crop insurance: A case study on Manas Valley." *Issues in Agricultural Economy* (6): 38-44+79.

Niu H, Chen S W, An K, et al. 2020. "Does agricultural insurance meet the protection needs of new agricultural operators—Evidence based on 422 provincial demonstration family farmers in Shandong Province." *Insurance Studies* (6): 58-68.

Ozaki V A, Goodwin B K, Shirota R. 2008. "Parametric and nonparametric statistical modelling of crop yield: Implications for pricing crop insurance contracts." *Applied Economics* 40(9): 1151-1164.

Ren T C, Zhang H Z, Yang R H. 2021. "How does the level of agricultural insurance security affect agricultural production efficiency: Evidence from the survey data of Hubei, Jiangxi, Sichuan and Yunan Province." *China population, resources and Environment,* 31(7): 161-170.

Sherrick B J, Barry P J, Ellinger P N, et al. 2004. "Factors influencing farmers' crop insurance decisions." *American journal of agricultural economics* (2): 103-114.

Shi H. 2016. "Hedging effect of hog insurance on farmer's revenue." *Journal of Zhejiang University (Humanities and Social Sciences)* 46(2): 126-135.

Sun X Y. 2008. "Crop insurance knowledge, trust on government and demand for crop insurance—An empirical study of peasant households' willingness-to-pay in Huai'an, Jiangsu Province." *Journal of Nanjing Agricultural University (Social Science Edition)* (1): 48-54.

Tang Y M, Xu T. 2020. "Weather index insurance and farmers' technology choice preference from the perspective of scale heterogeneity—Experimental method based on field

economics." *Insurance studies* (8): 18-34.

Tuo G Z. 2019. "China's agricultural insurance policy and possible trend of evolution." *Insurance studies* (1): 3-14.

Tuo G Z, Zhu J S. 2016. "Revenue insurance: An important means to perfect the farm produce price formation mechanism reform." *Insurance studies* (6): 3-11.

Vandeveer M L. 2001. "Demand for area crop insurance among litchi producers in northern Vietnam." *Agricultural Economics* 26(2): 173-184.

Wang A X, Zhang Q. 2008. "Empirical analisis on the demand for agricultural insurance in Erdos City, Inner Mongolia." *Issues in Agricultural Economy* (S1): 101-106.

Wang B L, Sun J, Jiang C G. 2017. "Research on the economic effect of introducing agricultural income insurance in China." *Insurance studies* (3): 71-89.

Wang W, Tian J, Du J, et al. 2010. "Empirical study on farmers' willingness to participate insurance in selected province of policy agricultural insurance: A case of Henan Province." *Financial Theory & Practice* (1): 35-38.

Xiao Y G, Wang K, He X W, et al. 2020. "The impact of indemnity scheme on the risk protection of government subsidized agricultural insurance." *Insurance Studies* (7): 63-76.

Xie F J, Wu D L, Zhao S Z. 2017. "The measurement of the rate of soybean income insurance based on copula method: Theory and demonstration." *Journal of Agrotechnical Economics* (2): 111-121.

Xu M B, Wang M H, Li X G. 2018. "The opportunity, challenge and reform path of agricultural insurance development under the background of rural revitalization—Take Jilin Province as an example." *Economic Review Journal* (8): 121-128.

Ye M H, Zhu J S. 2017. "Correlation between micro-effect of agricultural insurance and grain security." *Reform* (9): 76-86.

Ye Z H. 2018. "Research on improving China's agricultural insurance system." *Journal of Financial Research* (12): 174-188.

Young C E, Vandeveer M L, Schnepef R D. 2001. "Production and price impacts of U.S. crop insurance programs." *American Journal of Agricultural Economics* 83(5): 1196-1203.

Yu Y. 2013. "Research on the differentiated policy of premium subsidy for agricultural insurance based on the coverage level: The experience of America and the choice of China." *Issues in Agricultural Economy* 34(10): 29-35+110.

Zhang Q, Wang K, Li Y, et al. 2019. "On the current situation and problems of risk protection of agricultural insurance in China and relevant suggestions." *Insurance studies* (10): 3-18.

Zhang R J. 2018. "The incentive effect of agricultural insurance subsidy." *Journal of South China Agricultural University (Social Science Edition)* 17(6): 31-41.

Zhang W, Huang Y, Li C C, et al. 2018. "Research on the reform of agricultural insurance supply side based on demand evolution." *Issues in Agricultural Economy* (11): 123-134.

Zhang Y H, Gu H Y, Shi Q H. 2005. "One explanation on the lacking demand of agricultural insurance from the view of utility." *The Journal of Quantitative & Technical Economics* (4): 83-92.

Zhao Y, Fu Z P. 2015. "Research on the development of agricultural insurance in China."

Economic Review Journal (12): 64-67.

Zheng J, Fang T. 2019. "Effect of agricultural insurance protection level on anti-poverty." *Journal of Shanxi Agricultural University (Social Science Edition)* 18(4): 41-48.

Zhou X H, Fan Q Q, Zhou M, et al. 2012. "A comparative study on cases of crop insurance products in China and the U.S.." *Insurance Studies* (7): 50-58.