An Empirical Study on the Moderating Effect of Agricultural Insurance Against Natural Disasters

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Abstract: Agricultural producers face agricultural disasters that cause serious negative impacts on agricultural production. Hence, agricultural producers and the government need to use risk management tools to control these agricultural risks. This paper focuses on one of the most important risk management tools in agriculture, i.e., agricultural insurance. Specifically, we study whether agricultural insurance can mitigate the negative impact of natural disasters on the primary industry. We firstly establish a theoretical macroeconomics model that combines agricultural risk, agricultural insurance, and moral hazard. The theoretical model shows that agricultural insurance can effectively reduce the negative impact of agricultural risks on primary industry production only when the moral hazard is not severe. Next, we use provincial data in China to empirically test the predictions of the theoretical model. The empirical results indicate that agricultural insurance promotes primary industry production. An increase of 1 RMB in agricultural insurance premium income can increase the primary industry production by 15 RMB. The purchase of agricultural insurance does not significantly change the production behavior of agricultural producers, indicating no significant moral hazard. This paper adds moral hazard to the traditional macroeconomics model, which allows a more reasonable role for agricultural insurance. The conclusions of this study give important implications for agricultural producers and governments.

Keywords: Agricultural Risk, Agricultural Insurance, Moral Hazard, Primary Industry

1. Introduction

Agricultural producers face agricultural disasters such as droughts, floods, and hail. These natural events cause serious negative impacts on agricultural production. It is estimated that adverse natural events reduce yields of wheat and rice by 2.5% and 3.8% (Moore and Lobell, 2015) [1], and that impact of these adverse events on agricultural markets would amount to a 0.26% reduction in global GDP [2]. Hence, agricultural producers and the government need to use risk management tools to control these agricultural risks [3, 4]. Also, researches on this issue have essential implications for economic development and people's well-being [5].

This paper focuses on the agricultural economy and agricultural insurance market in China. China's binary economic structure has not changed, the proportion of the rural population is still high, and the problems of agriculture, rural and farmers are still serious [6]. Besides, the system of managing agricultural catastrophe risks has not been well-established. The agricultural risks cannot be well assessed and responded to in China [7]. Thus, the issue of how to use risk management tools for the agricultural economy's development is of great importance and urgency for China, especially for poverty alleviation in rural China [8].

Theoretically, agricultural insurance would have two opposing effects on the agricultural economy. On one hand, agricultural insurance compensates agricultural producers if losses. It stabilizes their income and thus ensures a smooth reproduction process. On the other hand, agricultural insurance may also present moral hazard problems. The insured may cause an increase in the probability or degree of loss through action or inaction. It may result in additional damage to the agricultural economy [9, 10]. Therefore, whether agricultural

insurance promotes the agricultural economy depends on the combined effects of these two opposing forces.

Several studies have theoretically analyzed the impact of agricultural insurance on the agricultural economy [11, 12]. Yet these theoretical studies do not consider moral hazards in a dynamic environment. The positive effects of agricultural insurance would be overestimated if the moral hazard were not considered. Meanwhile, empirical studies' conclusions are ambiguous. Some studies found that agricultural insurance significantly increases agricultural output and farmers' income [13, 14], but others found no significant effect [15, 16]. These ambiguous results may reflect the tradeoff between two opposing effects of agricultural insurance.

This paper uses theoretical and empirical analysis to study this issue. First, it constructs a stochastic dynamic model that incorporates agricultural risk and agricultural insurance. The model considers both the compensatory function of agricultural insurance and the moral hazard in the agricultural insurance market. The model predicts that agricultural risk reduces the primary industry production and that agricultural insurance can mitigate the negative effects of agricultural risk only when the moral hazard is small.

Subsequently, this paper tests these predictions using provincial data in China. Empirical results show that agricultural risk reduces primary industry production. Results also show that agricultural insurance can reduce the negative effects of agricultural risks, thus promoting the production of primary industry. To be more specific, an increase of 1 RMB in agricultural insurance premium income could reduce the loss of primary industry production due to agricultural risk by about 15 RMB on average. The results are robust under various specifications of regressions and driven by the endogeneity problem.

According to the model's predictions, the precondition of the above conclusion is that the moral hazard problem in the agricultural insurance market is not severe. So, this paper next is to verify whether agricultural insurance significantly increases the level of moral hazard. The results show no significant change in the usage of fertilizers and pesticides with the development of the agricultural insurance market. It indicates that the moral hazard problem in the agricultural insurance market is not that severe at least at the province level. This corroborates the precondition of the main conclusions in this paper and completes the verification of the hypotheses of this paper.

The rest of the paper is as follows. The second section introduces the risk and insurance model with moral hazard. The third section presents the data and empirical models. The fourth section reports empirical results. The fifth section is the discussion on moral hazards. The last section concludes and gives the implications of this study.

2. Risk and Insurance Model with Moral Hazard

This section shows how the agricultural risk and insurance

affect the agricultural economy by using a theoretical model. The model considers both the compensatory function of agricultural insurance and the moral hazard in the agricultural insurance market.

2.1. Model Setup

The basic assumption is the representative producer can live permanently. A representative producer has one unit of labor and initial capital. Representative producer maximizes the lifetime utility by selecting consumption and savings for each period

$$U = \sum_{t=1}^{\infty} \beta^t u(c_t) \qquad (1)$$

where the c_t is the consumption in period t, and the β is the discount factor of utility. The $u(\cdot)$ is the monotonically increasing concave utility function.

The production function is $y^b = f(k)$, where the $f(\cdot)$ is the monotonically increasing concave. The y^b is the output without agricultural risk and insurance. The k is the capital inputs, including the fixed-assets investment (e.g., agricultural machines) and the consumable inputs (e.g., fertilizer utilization). For simplicity and without loss of generality, the model takes these two parts together and assumes that the average depreciation rate is d.

The agricultural risk ultimately affects agricultural output, so this paper incorporates it into the model by altering the output. Following Xu and Liao (2014) [12], this paper uses a random variable X to measure the loss caused by objective agricultural risk. The production function taking risks into account is $y^r = (1 - X)f(k)$. The X is between 0 and 1, and it is identical and independent among periods, i.e. $X_1 = X_2 = \cdots = X$. The expectation of the risk loss ratio is EX. Accordingly, the expectation of the output is $Ey^r = (1 - EX)f(k)$.

Agricultural insurance's effects on the output are much more complicated. First, the representative producer has to pay premiums for "purchasing" agricultural insurance to ensure the output. This paper uses the α_t, the insured proportion, to measure the demand for agricultural insurance in period t. Its value is from 0 to 1. If $\alpha_t = 0$, it means that the producer does not have any insurance, and $\alpha_t = 1$ means full insurance. Because of the asymmetric information, the moral hazard cannot be priced actuarially. Hence, the actuarially fair price for the agricultural insurance is $\alpha_t f(k_t)EX$. Besides the actuarially fair price, the premium also includes a loading factor (θ) representing the risk premium or the premium subsidy. The representative producer is charged with an excessive risk premium if $\theta > 0$, and the insured get a premium subsidy if $\theta < 0$. Notably, it is assumed that producers share risks by paying premiums and getting payment among each other through an "invisible insurer", so no need to take the insurance companies or governments into the model l (Xu and Liao, 2014; Ahsan et al., 1982) [12].

Second, the model should consider the moral hazard. The insured (representative producer) has the incentive to reduce its efforts on risk management after purchasing the agricultural insurance. It will increase the probability of loss.

On the other hand, the insured may obtain more insurance compensation by exaggerating the loss value or not preventing further loss in time. It increases the loss severity. This model uses the actual loss ratio, $g(X, \alpha_{t-1})$, to measure the combined effects of objective risks and moral hazard in period t. When the agricultural risk rises, the loss will increase, i.e. $g_X(X, \alpha_{t-1}) \geq 0$. When the insured gets a higher insurance level, the loss probability increases due to moral hazard, i.e. $g_a(X, \alpha_{t-1}) \geq 0$. Now the production is

$$(1-d)k_{t-1} + (1 - g(X, \alpha_{t-1}))f(k_{t-1}) + \alpha_{t-1}g(X, \alpha_{t-1})f(k_{t-1}) = c_t + k_t + \alpha_t(1 + \theta)f(k_t)EX \quad (2)$$

It means that the current consumption (c_t), capital (k_t) and the agricultural insurance premium [$\alpha_t(1 + \theta)f(k_t)EX$] equal to the capital after depreciation [$(1 - d)k_{t-1}$] plus the output after loss [$(1 - g(X, \alpha_{t-1}))f(k_{t-1})$] and the compensation [$\alpha_{t-1}g(X, \alpha_{t-1})f(k_{t-1})$] in the previous period.

2.2. Equilibrium When Considering Moral Hazard

For simplicity but without loss of generality, this paper assumes that the effects of the objective agricultural risk are scaled by the moral hazard, i.e. $g_a(X, \alpha_{t-1}) = (1 + \mu\alpha_{t-1})X$. This assumption will not alter the existence and convergence of the optimal path. In the steady-state, the capital k^m is determined by

$$f'(k^m) = \frac{1 - \beta(1-d)}{\beta - A(1+\theta)EX} \quad (3)$$

where

$$A = \frac{(1+\mu a^2)}{(1+2\mu a - \mu)}$$

Equation (3) shows that the capital in the steady-state is determined by the discount factor (β), the depreciation rate (d), the objective risk level (EX), the loading factor (θ), the insurance level (a), and the moral hazard effect (μ). This paper focuses on the impacts of risk and insurance on the steady-state output. When the expectation of loss ratio increases, the $f'(k^m)$ will go up. Because of the $f'(\cdot)$ is monotone decreasing, the capital and the output in the steady-state will decrease when the $f'(k^m)$ increases. Economic intuition is clear here. As we measure the impact of risk by changing the production function, the increasing objective risk level causes the expectation of production to decline.

Agricultural insurance affects the equilibrium output through three parameters in equation (4). First, other things equal, a greater loading factor (θ) will reduce the output. A larger θ means a larger premium compared to the actuarial price, thus reducing the capital input for agricultural production. In other words, if the producer is provided with more premium subsidies, he will have more capital input. Second and third, the insurance level and moral hazard affect the equilibrium output. Analyzing their effect by differentiating A on the a,

$$A'(a) = \frac{2\mu(1+\mu a)(a-1)}{(1+2\mu a-\mu)^2} \quad (4)$$

and on the μ,

$y^m = (1 - g(X, \alpha_{t-1}))f(k_{t-1})$.

Last but not least, the insured can get compensation for the loss. This allows the agricultural producer to have sufficient money to purchase inputs and thus stabilizes the process of agricultural reproduction. The compensated value in period t is $\alpha_{t-1}g(X, \alpha_{t-1})f(k_{t-1})$. If the producer has full insurance ($\alpha = 1$), then the agricultural insurance will cover the total loss. All in all, this paper then gets the budget constraint of the utility maximization problem for the representative producer

$$A'(\mu) = \frac{(a-1)^2}{(1+2\mu a-\mu)^2} \quad (5)$$

As $0 \leq a \leq 1$, the $A'(a)$ is always no more than zero. Hence, when the a increases, the A will go down, and so will the $f'(k)$, thus promoting the production. The intuition is quite clear. With insurance coverage, the producer will get more compensation when occurring losses. Compared to the premium fees paid to the "invisible insurer", the compensated money is much more. Thus, increasing the insurance level means more expectation of capital input in the next period, which stimulates the primary industry production.

According to the equation (5), the $A'(\mu)$ is always no less than zero. When the μ increases, the A will go up, and so will the $f'(k)$. The production in steady-state, therefore, will decline. As the μ measures the level of moral hazard, the large the μ is, the higher the actual loss will be. With other things being equal, it causes production to decrease.

2.3. Equilibriums in Other Cases

To further analyze the effects of moral hazard, insurance, and risks on production, this paper considers the equilibriums in the other two cases and compares them with equation (3). First, it investigates the situation where there is risk and insurance but no moral hazard. If there is no moral hazard, the actual loss ratio is only influenced by the objective risk, i.e. $g(X, \alpha_{t-1}) = X$. In the steady-state, the representative producer purchases the full insurance ($a = 1$), and the capital level k^r is determined by

$$f'(k^i) = \frac{1 - (1-d)\beta}{\beta - (1+\theta)EX} \quad (6)$$

where

$$(1 + \theta)EX = \beta\frac{E[Xu'(c^i)]}{E[u'(c^i)]}$$

This paper further considers two cases: (a) there is a risk but no insurance, and (b) there is neither risk nor insurance. Referring to existing literature [12], the steady-state capital k^r in case (a) and the steady-state capital k^b in case (b) is determined by the following equations,

$$f'(k^r) = \frac{1 - (1-d)\beta}{\beta - \beta E[Xu'(c^r)]/E[u'(c^r)]} \quad (7)$$

and

$$f'(k^b) = \frac{1-(1-d)\beta}{\beta-\beta EX} \qquad (8)$$

The intuition for equations (6) to (8) is clear. Because the $f'(\cdot)$ is monotone decreasing, when the expectation of loss ratio increases, the capital, and production in the steady-state will decrease. When the level of risk premium increases, the cost of the agricultural insurance increases, and the capital input decreases, so the production will decrease. In contrast, when the insured gets more subsidy, there will be more capital input, so the production will increase. The consumption is equivalent to the production after loss exposure and the payment from the insurer minus the depreciated capital and the expenditure of premium. When $(1+\theta)EX < \beta E[Xu'(c^r)]/E[u'(c^r)]$, i.e. the cost of transferring the risk is lower than the individual's subjective loss of the uncertainty, the agricultural insurance can promote the production.

I summarize the results for all the cases and emphasize the effects of risk and insurance on the primary production by the following proposition.

PROPOSITION 1. *Suppose that (a) the representative producer is under the classical RCK model, and (b) the actual risk loss ratio is determined by the agricultural risk and insured proportion. Then,*

$$f'(k^r) > f'(k^b) \qquad (9)$$

i.e., the capital and production in the steady-state decrease after introducing the uncertainty of loss.

$$f'(k^r) > f'(k^i) \qquad (10)$$

i.e. the steady-state capital and production increase when there is insurance but no moral hazard.

$$f'(k^m) > f'(k^i) \qquad (11)$$

i.e. the moral hazard will reduce the positive effects of agricultural insurance on production.

And when the moral hazard is very severe,

$$f'(k^m) > f'(k^r) \qquad (12)$$

i.e. the output with insurance may be less than the output without insurance when the moral hazard is very serious. The dynamic process of the capital converges to a steady-state when the expectation of loss is very large or the moral hazard is very small.

Proof. See Appendix.

2.4. Hypotheses

The model generates predictions about the effects of agricultural risks and agricultural insurance on the primary industry production. According to equation (9), this paper generates the Hypothesis 1 (*H1*). The Hypothesis 2 (*H2*) is based on equations (10), (11) and (12). This paper tests these hypotheses in the following sections:

H1: Other things equal, higher agricultural risks will reduce the production of primary industry.

H2: Other things equal, agricultural insurance can mitigate the negative effects of agricultural risks and promote agricultural production only when the impact of moral hazard is not severe.

3. Empirical Model and Data

In this section, I first introduce the empirical models. The empirical specifications are based on the theoretical model and are used to verity those hypotheses. I then describe the data and summary statistics of variables.

3.1. Empirical Model

This paper uses aggregated province-level data in China to test hypotheses derived from the risk and insurance model. Assuming that the effects of the objective agricultural risk are scaled by the moral hazard, the production of primary industry is

$$EY_t^r = [1-(1+\mu a_{t-1})EX_t)]F(K_{t-1}, L_{t-1}) \qquad (13)$$

Assuming that $F(K,L) = K^\alpha L^\beta$, and taking the logarithm of both sides of equation (13) and making it as a regression model, then get the following estimation equation,

$$Pri_{i,t} = \alpha Risk_{i,t} + \beta Ins_{i,t-1} + \gamma Ins_{i,t-1} \times Risk_{i,t} + \delta C_{i,t} + \theta_i + \lambda_t + \epsilon_{i,t} \qquad (14)$$

where $Pri_{i,t}$ represents the primary industry production of province i in year t. $Risk_{i,t}$ is the agricultural risk. This paper uses the ratio of the area occurs loss and total farmland area to measure the agricultural risk. $Ins_{i,t-1}$ is the development of agricultural insurance in province i in year $t-1$. This paper uses both premium income and payment to describe the development of agricultural insurance. $C_{i,t}$ is a set of control variables; θ_i is province fixed effects, and λ_t is year fixed effects; $\epsilon_{i,t}$ is the error term.

Control variables are to address the omitted variables problem. Control variables include the labor force, farmland acreage, agricultural machinery power, and usage of fertilizers, and pesticides. The labor force is a direct input of agricultural production. Farmland is an important input in agricultural production. Machine power is a measure of fixed assets investment in production. The utilization of fertilizers and pesticides is used to control the heterogeneity of nondurable inputs among provinces. Those variables not only affect the primary industry production but also are correlated with the agricultural risks and agricultural insurance. Hence, adding them into the regressions can address the omitted variables problem.

This regression also controls for province-fixed effects and year-fixed effects following the prior works [17-19]. Province fixed effect δ_i can absorb the influence of provincial characteristics that do not change with time. Year fixed effects θ_t can absorb the impact of regional common trends, making the results reflect the agricultural risk and the

impact of agricultural insurance in various regions.

3.2. Data

This study utilizes two administrative data sets. The *China Insurance Yearbook* provides yearly premium income and payment of agricultural insurance for each province. The data of the disaster area, the production of the primary industry, and its sub-industries and control variables are from the *China Rural Statistical Yearbook*. These two datasets are matched by the year and province. Our data covers the period from 2002 to 2017 for 31 provinces on China's mainland.

Table 1 presents the summary statistics of the variables. The variables are expressed in logarithmic except for the "loss area". The explained variable of interest is primary industry production (*Pri*). Its mean is 16.42 with a standard deviation of 1.15. The primary industry consists of four sub-industries, namely agriculture, forestry, husbandry, and the fishery. The productions of agriculture (*Agr*), forestry (*For*), husbandry (*Hus*), and fishery (*Fis*) have mean values of 15.76, 13.11, 15.23, and 13.07.

The explanatory variables of interest are loss area (*Los*), agricultural insurance, and their interaction. The mean loss area is 0.14 with a standard deviation of 0.10. It means that about 14% of the farmland occurred lost during the sample period. In the baseline regression, agricultural insurance premium income *(Pre)* is used to measure the development of the agricultural insurance market. It has a mean of 8.920, and its maximum and minimum values are 12.897 and 0. This shows obvious variations in agricultural insurance development across provinces and years. In robustness check, I also use the agricultural insurance payment to measure the development of the agricultural insurance market. It has a mean of 8.438, and its maximum and minimum values are 12.977 and 0. Table 1 also reports summary statistics of control variables. For instance, the mean value of the agricultural land area is 17.14 with a standard deviation of 1.07.

4. Empirical Results

I present the empirical results in this section. First, I report the baseline results for primary industry production. Second, I do some robustness checks of the baseline results. Then, I present the results of subsample analysis. Next, I emphasize the endogeneity problem. Last is the discussion on the moral hazard in agricultural insurance market.

4.1. Baseline Results

Table 2 reports the fixed effects regression for primary industry production. Column (1) is the baseline result. The coefficient on agricultural risk *(Risk)* measured by the loss area is -0.630 which is statistically significant at the 1%. This coefficient is also economically significant. All other things equal, an increase of 1% in loss area would reduce primary industry production by 0.63%. The coefficient on agricultural insurance (*Insurance*) measured by premium income is -0.013.

It is statistically and economically significant. An 1% increase of agricultural insurance premium income reduces the output by 0.013% without agricultural risk. This is because agricultural insurance premium would become deterministic cost but this cost would not bring any benefit in a world without any risk. Specifically, if there was no agricultural risk, then there should be no agricultural insurance.

In column (1), the coefficient on the interaction between insurance and risk is 0.059 with a standard error of 0.021. It indicates that agricultural insurance can more significantly mitigate the negative effects of agricultural risks in areas with higher risks. For example, if at the average agricultural risk level (loss area = 0.14), a 1% increase in agricultural insurance would reduce the loss of 0.0083% (0.059*0.14%). The absolute value of this reduction is

$$\Delta = \frac{exp(16.42) \times 0.0083\%}{exp(8.92) \times 1\%} \approx 15 \qquad (15)$$

That means an increase of 1 RMB in agricultural insurance premium income could reduce the loss of primary industry output due to agricultural risk by about 15 RMB on average.

In brief, the baseline result shows that agricultural insurance can mitigate the negative effects of agricultural risks and thus promotes the production of primary industry. This verifies the predictions of the theoretical model and indicates that the moral hazard problem is not that severe. I will discuss the moral hazard later.

4.2. Robustness Check

I conduct several robustness checks of the baseline in this sub-section. All results show that the baseline result is robust.

Robustness Check 1: using agricultural insurance payment to measure agricultural insurance. Column (2) of Table 2 reports the result when using insurance payment to measure the development of agricultural insurance market. The coefficient on *Risk* is -0.570 which is statistically significant at the 5%. All other things equal, an 1% increase in *Risk* (loss area) reduces primary industry production by 0.57%. This is consistent with the baseline result. The coefficient on *Insurance* is -0.008 but not statistically significant. The coefficient on the interaction is 0.053 with a standard error of 0.023. It is statistically and economically significant. At the mean agricultural risk (loss area = 0.14), an 1% increase in agricultural insurance reduces the loss of primary industry production by 0.0074% (0.053*0.14%). This means that a 1 RMB increase in premium income reduces the loss by about 13.4 RMB on average.

Robustness Check 2: using samples after 2007. The agricultural insurance market in China changed significantly around 2007. In 2007, the government began to gradually select pilot provinces and provide agricultural insurance premium subsidies for them. This has led to an acceleration in the growth of China's agricultural insurance market after 2007. To be more specific, the agricultural insurance premium income was 850 million RMB in 2006 and 5.19 billion RMB in 2007, and the growth rate is 510.6%. This paper limits the sample after 2007 to see if the results change

after that. The result is reported in column (3) of Table 2. The coefficient on *Risk* is -1.160 which has statistical significance at the 5%. The coefficient on agricultural insurance is -0.010 which is not statistically significant. The coefficient on the interaction is 0.099 with a standard error of 0.052. This means that a 1 RMB increase in agricultural insurance premium income reduces the loss of primary industry output due to agricultural risk by about 25.1 RMB on average. In short, the estimation result using the sample after 2007 is consistent with the baseline result.

Robustness Check 3: Use a sample without four municipalities. The four municipalities (Beijing, Tianjin, Shanghai, and Chongqing) are different from other provinces in many aspects. So, I drop these observations and rerun the regression. The result is reported in column (4) of Table 2. The coefficient on *Risk* is -0.436 with a standard error of 0.173. The coefficient on agricultural insurance is -0.009, which is not statistically significant. The coefficient on interaction of *Risk* and *Insurance* is 0.041, which is statistically and economically significant. Consider the case at the mean agricultural risk as before. A 1% increase in agricultural insurance could reduce the loss of primary sector output by 0.0057%. Thus, the regression results after dropping the observations of the four municipalities still show that agricultural insurance reduces negative impacts caused by agricultural risk.

4.3. Analysis of Endogeneity Problem

One concern is that the agricultural insurance variables may be correlated with the error term due to the two-way causation and the omitted variable. This paper needs to solve this endogeneity problem carefully. Otherwise, it cannot get the unbiased coefficients on the *Insurance* and the interaction of *Insurance* and *Risk*.

Endogeneity problems arise from two-way causation. Agricultural insurance can reduce the losses from agricultural risks, thus promoting the development of the primary industry. Meanwhile, the higher the output of primary industry, the higher the demand for agricultural insurance, so it is more likely to have a higher development of the agricultural insurance market. To address this problem, this paper uses the lag term of agricultural insurance premium income to measure the development of insurance as shown in equation (14). The lag item for agricultural insurance can affect primary sector output, but current primary sector output cannot affect the previous period's agricultural insurance. Hence, it is good for addressing endogeneity problem resulted from two-way causation.

Endogeneity problem caused by omitted variables. There may be unobservable variables that can affect both agricultural insurance and primary industry production. I address this problem using a falsification test. I rerun the regression in equation (14) for the secondary and tertiary industries. Theoretically, the agricultural insurance market should not significantly affect the secondary and tertiary industries. If coefficients on the interaction of agricultural insurance and risks for these two industries are also statistically significant, then there may be unobservable

variables correlated with the agricultural insurance. Otherwise, no such omitted variable in this study.

Table 3 reports results of this falsification test. Columns (1) and (2) are regression results for the secondary industry. In column (1), the coefficient on agricultural risk is -0.510 with a standard error of 0.486. It is not statistically significant, indicating that agricultural risk does not affect secondary industry production. The coefficient on the agricultural insurance is 0.002 with a standard error of 0.004, and the coefficient on the interaction is also statistically insignificant. In column (2), after adding controls into the regression, the coefficients on agricultural risk, agricultural insurance, and their interaction remain statistically insignificant. It indicates that agricultural risk and agricultural insurance do not have a significant effect on secondary industry production. Columns (3) and (4) are regression results for the tertiary industry. The coefficients on the agricultural risk, agricultural insurance, and their interaction are also statistically insignificant. This means that agricultural risk and agricultural insurance do not have a significant effect on tertiary industry production.

In sum, the agricultural insurance and agricultural risk do not significantly affect the secondary and tertiary industries. This means that the baseline regression does not omit any variable that can simultaneously affect the primary, secondary and tertiary industries. Hence, the results of this paper are not likely driven by unobservable variations.

4.4. Results for Sub-industries of Primary Industry

China's primary industry consists of agriculture, forestry, husbandry, and fishery. Agricultural insurance in China mainly covers agriculture, forestry, and husbandry, while no fishery-related agricultural insurance products. This makes the development of agricultural insurance related to the four sub-industries diverse. So, the impacts of agricultural insurance on these four sub-industries may be different. To test it, this paper estimates equation (14) for these four sub-industries productions. The results are reported in Table 4.

Column (1) of Table 4 reports the results for agriculture. The coefficient on agricultural risk is -0.66 which is significant at 5%. All other things equal, an 1% increase in agricultural risk will reduce the production of the agriculture sub-industry by 0.66%. The coefficient on agricultural insurance is -0.011 which is statistically insignificant. The coefficient on the interaction between agricultural insurance and agricultural risk is 0.059 with a standard error of 0.026. Considering the scenario that the mean agricultural risk as before. A 1% increase in agricultural insurance would increase the primary industry production by the equivalent of 0.0057%. Specifically, an increase of 1 RMB in agricultural insurance premium income can increase the primary industry production by 25.1 RMB.

Columns (2) and (3) of Table 4 are the results of regressions for forestry and husbandry. The results show that agricultural risk can significantly reduce the production of forestry and husbandry. The results also show that agricultural insurance mitigates losses caused by agricultural

risks. At the mean agricultural risk, an 1% increase in agricultural insurance could increase 0.0057% of forestry production and 0.0012% of husbandry production. Besides, the result In column (4) of Table 4 indicates that the impact of agricultural risk and agricultural insurance on the fishery is statistically insignificant.

In short, this paper finds that agricultural risks and agricultural insurance have significant effects on the production of agriculture, forestry, and husbandry but not on the production of a fishery. This may be because using the loss area of farmland land to measure agricultural risks fails to fully portray the impact on the fishery. Also, due to the limitation of data, this paper cannot distinguish the amounts of agricultural insurance premium income for each sub-industry. This measurement error of agricultural risks and agricultural insurance may drive the results. Nevertheless, the results here provide some evidence consistent with the current situation in China's agricultural insurance market that the policy-based agricultural insurance primarily covers agriculture, forestry, and husbandry but not fishery.

5. Discussion on Moral Hazard

The results above demonstrate that agricultural risk reduces primary industry production and that agricultural insurance can mitigate the negative effects of agricultural risk. According to the theoretical model, the precondition of this conclusion is that the moral hazard problem in the agricultural insurance market is not severe. So, this paper is to verify whether agricultural insurance significantly increases the level of moral hazard. If the results show no significant increase in moral hazard with the development of the agricultural insurance market, then it supports the precondition of the main conclusion. Otherwise, I need to reconsider the validity of these conclusions.

Referring to Horowitz and Lichtenberg [10] and Smith and Goodwin [9], I analyze moral hazards in agricultural insurance markets by examining changes in usage of fertilizer and pesticides. One evidence of moral hazard is that agricultural producers change their production behavior after purchasing agricultural insurance. Hence, the (upwards) change in expendable inputs such as fertilizers and pesticides would be the evidence of an increase in moral hazard. This paper tests it by estimating equation (16),

$$\Delta Usage_{i,t} = \beta Ins_{i,t-1} + \gamma X_{i,t} + \theta_i + \lambda_t + \epsilon_{i,t} \quad (16)$$

where $\Delta Usage_{i,t}$ is the change in expendable inputs of province i in year t. $Ins_{i,t-1}$ is the agricultural insurance premium income of province i in year $t-1$. $X_{i,t}$ denotes a set of controls, including the labor force, farmland acreage, agricultural machinery power, primary industry production. $X_{i,t}$ is a set of control variables; θ_i is province fixed effects, and λ_t is year fixed effects; $\epsilon_{i,t}$ is the error term.

Table 5 reports the results from estimating equation (16). Columns (1) and (2) are regression results for fertilizers. In column (1), the coefficient on agricultural insurance is -0.029 with a standard error of 0.286. It is statistically insignificant.

This suggests that agricultural insurance would not significantly affect fertilizer usages. In column (2), after adding the controls to the regression, the coefficient on agricultural insurance is 0.064 with a standard error of 0.270. It is also statistically insignificant. This means that adding controls does not alter the results.

Regression results for pesticide are reported in columns (3) and (4) of Table 5. In column (3), the coefficient on agricultural insurance is -0.070 with a standard error of 0.125. It is statistically insignificant. In column (2), the coefficient on agricultural insurance is -0.049 with a standard error of 0.133 after adding the controls to the regression. It is also statistically insignificant. These results suggest that agricultural insurance would not significantly affect usage of pesticide.

The results show no significant change in the usage of fertilizers and pesticides with the development of agricultural insurance market. It indicates that the moral hazard problem in agricultural insurance market is not that severe at least in the province level. This corroborates the precondition of the main conclusions in this paper. Combining the results here and the main conclusions obtained in the previous section, this paper completes the verification of the hypotheses.

In sum. this study makes two contributions to existing literatures. First, this paper adds moral hazard to the traditional model. Existing papers ignore this effect when analyzing the impact of agricultural insurance, like Xu and Liao [12]. The inclusion of moral hazard in the theoretical model allows a more reasonable estimate of the impact of agricultural insurance on the agricultural economy. Second, this paper gives new empirical evidence of how agricultural risks and agricultural insurance affect the agricultural economy to related literature [17]. Especially, it verifies that the moral hazard is not severe to support the main conclusion of promoting effects of agricultural insurance.

6. Conclusion

This paper develops a risk and insurance model incorporating the moral hazard. The model predicts that agricultural insurance can promote agricultural production only when the moral hazard problem is not that severe. Then the fixed effects regressions are used to test the prediction. Empirical results show that agricultural risks do harm to the primary industry production and that the agricultural insurance can mitigate these risks and thus promote the primary industry production. Also, results of robustness check, subsample estimations and analysis of endogeneity problem all support the validity of the conclusion. Besides, this paper shows that the moral hazard problem in agricultural insurance market in China is not severe. It verifies the precondition of the main conclusion of this paper.

The results in this paper have essential implications for agricultural producers and the government. The results confirm that the agricultural insurance is an important risk management tool for agricultural producers. Without agricultural insurance, the loss caused by adverse natural

event would significantly reduce the income of agricultural producers, and hence decreases inputs for reproduction. If these losses were covered by agricultural insurance, it would not affect the reproduction that much. Hence, it is imperative for agricultural producers to manage agricultural risks with agricultural insurance.

More importantly, the results indicate that the government should use the agricultural insurance as one critical tool of poverty reduction. Agricultural insurance increases the income level of agricultural producers by stabilizing and promoting the agricultural production. As opposed to other ways, like savings, agricultural insurance can greatly reduce the burden on agricultural producers in the face of agricultural disaster losses, thus effectively avoiding poverty due to disasters.

Appendix

Table 1. Summary Statistics.

Variables	Meanings of Variables	Mean	S.D.	Median	Max	Min
Pri	Production of Primary Industry	16.420	1.147	16.645	13.234	18.375
Agr	Production of Agriculture	15.755	1.180	15.979	12.440	17.713
For	Production of Forestry	13.114	1.301	13.432	9.393	15.154
Hus	Production of Husbandry	15.232	1.104	15.390	12.453	17.078
Fis	Production of Fishery	13.066	2.492	13.397	0.000	16.603
Pre	Premium Income	8.920	3.251	9.969	0.000	12.897
Pay	Payment of Agriculture Insurance	8.438	3.057	9.407	0.000	12.977
Los	Loss area	0.139	0.102	0.120	0.000	0.750
Acr	Acreage of Farmland	17.141	1.073	17.541	14.456	18.882
Fer	Usage of Fertilizers	13.875	1.204	14.156	10.309	15.784
Pes	Usage of Pesticides	19.469	1.383	20.011	15.601	21.274
Fex	Fiscal Expenditure	16.608	1.034	16.700	13.735	18.829
Pow	Machinery Power	16.659	1.090	16.860	13.767	18.710
La1	Labor force of primary industry	16.522	0.991	16.746	14.403	18.008

Notes: This table reports the mean, standard deviation, median, maximum and minimum of the variables. The sample contains data for 31 provinces in mainland China from 2002 to 2017. The variables are expressed in logarithmic except for the "Loss area". "Loss area" is the ratio of area occurring loss and the total farmland area.

Table 2. Results of Fixed Effects Regressions for Primary Industry Production.

	(1)	(2)	(3)	(4)
Risk ×Insurance	0.059^{***} (0.021)	0.053^{**} (0.023)	0.099^{*} (0.052)	0.041^{**} (0.018)
Risk	-0.630^{***} (0.203)	-0.570^{**} (0.218)	-1.160^{**} (0.534)	-0.436^{**} (0.173)
Insurance	-0.013^{*} (0.006)	-0.008 (0.007)	0.010 (0.023)	-0.009 (0.006)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	465	465	341	405
Adjusted R^2	0.995	0.995	0.997	0.997

Notes: This table reports fixed effects regression results for primary industry production. In column (1), agricultural risk is measured by loss area, and the development of agricultural insurance is measured by premium income. In column (2), the development of agricultural insurance is measured by insurance payment. Column (3) only uses data for 2007 and after. Column (4) presents results without four municipalities. Standard errors in parentheses are clustered in province level. *, **, *** denotes statistical significance at 10%, 5%, 1%.

Table 3. Results for Secondary and Tertiary Industries.

	Secondary Industry		Tertiary Industry	
	(1)	(2)	(3)	(4)
Risk ×Insurance	0.038 (0.048)	0.005 (0.013)	0.017 (0.024)	0.015 (0.015)
Risk	-0.510 (0.486)	-0.042 (0.113)	-0.137 (0.238)	-0.163 (0.137)
Insurance	0.003 (0.013)	0.002 (0.004)	0.003 (0.007)	0.001 (0.005)
Controls	No	Yes	No	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	465	465	465	465
Adjusted R^2	0.984	0.997	0.994	0.997

Notes: This table reports the regression results of the fixed effects regressions for the secondary and tertiary industries. Columns (1) and (2) are results for the secondary industry, and columns (3) and (4) are results for the tertiary industry. Standard errors in parentheses are clustered in province level. *, **, *** denotes statistical significance at 10%, 5%, 1%.

Table 4. *Results for Sub-industries.*

	(1)	(2)	(3)	(4)
	Agriculture	*Forestry*	*Husbandry*	*Fishery*
Risk ×Insurance	0.059** (0.026)	0.042* (0.021)	0.055** (0.026)	0.029 (0.019)
Risk	-0.660** (0.247)	-0.496** (0.188)	-0.639** (0.240)	-0.382** (0.174)
Insurance	-0.011 (0.007)	-0.006 (0.005)	-0.010 (0.007)	-0.003 (0.005)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	496	496	496	496
Adjusted R^2	0.992	0.992	0.992	0.991

Notes: This table reports the results from estimation equation (14) for the agriculture, the forestry, the husbandry and the fishery. Standard errors in parentheses are clustered in province level. *, **, *** denotes statistical significance at 10%, 5%, 1%.

Table 5. *Results for Sub-industries.*

	Fertilizers		Pesticides	
	(1)	(2)	(3)	(4)
Insurance	-0.029 (0.286)	0.064 (0.270)	-0.070 (0.125)	-0.049 (0.133)
Controls	No	Yes	No	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	465	465	465	465
Adjusted R^2	0.389	0.483	0.215	0.240

Notes: This table reports the results from estimation equation (14) for the agriculture, the forestry, the husbandry and the fishery. Standard errors in parentheses are clustered in province level. *, **, *** denotes statistical significance at 10%, 5%, 1%.

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