Moral Hazard in Compulsory Insurance - Evidence from a Quasi-Experiment on Hog Insurance in China

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Abstract
Agricultural insurance has yet lived up to its full potential despite its apparent benefits to agricultural producers. Moral hazard is suspected to be a major obstacle to the adoption of agricultural insurance, especially livestock insurance. In this study, we examine a government-supported, compulsory sow insurance program in China in which sow farmers were unknowingly enrolled by slacking officials at local governments. The implementation of this program creates a quasi-experiment for us to investigate whether farmers' awareness of insurance coverage have led to hazardous behavior. We estimate the endogenous treatment effects using a unique exogenous variable to control for the endogeneity in the treatment variable. Our robust results suggest that farmers' awareness of insurance enrollment has led to statistically and economically significant differences in their sow mortality rates, thus confirming the presence of hazardous behavior.

Key words: Moral hazard, livestock insurance, quasi-experiment, hog production, endogenous treatment effects

JEL codes: Q14, Q18, G22

1. Introduction

Insurance plays a vital role in agricultural production because of its apparent merits. By sharing risks among agricultural producers, insurance companies, and possibly governments, agricultural insurance can reduce the risks facing farmers and encourage them to pursue and expand risky production activities in exchange for higher economic returns (e.g., Karlan et al., 2014; Cai et al., 2015; Cole, Giné and Vickery, 2017; Hill et al., 2019). Moreover, insurance can serve as a close substitute for collateral such that farmers can access formal credit markets more easily to finance their production and long-term business growth (Hazell, 1992; Shee and Turvey, 2012). Notwithstanding the apparent merits, agricultural insurance worldwide has yet lived up to its full potential. Geographically, agricultural insurance programs have concentrated in developed farming and forestry regions such as North America and Western Europe. The total annual insurance premiums worldwide amounted to about 30 billion U.S. dollars in 2018 (AMR 2019), representing a mere 1.3 percent of the total value of agricultural production globally (FAO, 2019). Existing agricultural insurance programs are also unevenly distributed among commodity categories. For instance, approximately 90 percent of U.S. crop acreage is insured under the federal crop insurance program. In contrast, only 0.13% of total cattle inventory was covered using federally provided livestock insurance between 2003-2019, and the average of other commodities is all likewise very low (RMA 2020).

The stagnant adoption of agricultural insurance can be attributed to several obstacles, such as availability of alternative risk management strategies, lack of government support, and the complex production process of some agricultural commodities (e.g., livestock) compared to major field crops. Economists have suspected the presence of adverse selection and moral hazard due to asymmetric information to be a predominant cause (e.g., Nelson and Loehman, 1987;

Chambers, 1989; Just, Calvin and Quiggin, 1999; Hoag et al. 2006). A long-lasting research interest has been to detect the presence and extent of hazardous behavior (e.g., Quiggin, Karagannis and Stanton, 1993; Horowitz and Lichtenberg, 1993; Smith and Goodwin, 1996; Coble et Al., 1997; Roberts, Key and O'Donoghue, 2006; Liang and Coble, 2009; Yu and Hendricks, 2019). For instance, Horowitz and Lichtenberg (1993) analyzed the Farm Costs and Returns Survey data from the National Agricultural Statistical Service and found crop insurance participation had considerably increased corn farmers' use of risk-increasing inputs (i.e., fertilizer and pesticides), indicating the presence of moral hazard. Recently, Yu and Hendricks (2019) developed a stylized model and showed that farmers align their use of inputs with their moral hazard incentive in spite of the greater amount of information provided by precision agriculture technologies. Meanwhile, Roberts, Key, and O'Donoghue (2006) investigated the incidence of moral hazard for corn, soybeans and wheat in Iowa, Texas, and North Dakota and found little evidence of moral hazard affecting average yield or yield variability. Coble et al. (1997) examined the expected indemnities for a panel of Kansas wheat farms and suggested that hazardous behavior had occurred only in poor production years but not in years when growing conditions were favorable. Overall, the related literature has seen mixed evidence on the presence of moral hazard in agricultural production, leaving it still largely debatable whether insurance participation will necessarily invite hazardous behavior of participants.

To complicate matters, the availability and quality of data from various insurance programs has hampered the current research efforts in two significant ways. Firstly, the majority of studies have relied on data from voluntary insurance programs that will inevitably suffer from adverse selection. The selection bias will compound with moral hazard effects unless researchers can control for unobservable factors associated with insurance participants. Several studies

(Gunnsteinsson 2014; He et al. 2019) have tried to mitigate the compounding effects by implementing an experimental insurance program that allowed farmers to enroll in a random or quasi-random fashion.[1] Secondly, the current literature has largely focused on hazardous behavior in crop insurance programs (e.g., the U.S. federal crop insurance program), which have been the most prevalent among all insurance programs. The implementation of crop insurance does not readily lend its experience to other commodities, such as livestock, the biological features of which may distinctly affect insurance participation and farmers' behavior. Boyd et al. (2013) identified a few key differences between livestock insurance and crop insurance and argued that it is easier for livestock producers to allow their herd to perish and collect indemnity payments from the insurance company, leading to higher chances of hazardous behavior.

Despite the challenges in data availability and quality, several recent studies (e.g., Cai et al., 2015; Zhang, Zhu, and Turvey, 2016; Rao and Zhang, 2019) have attempted to specifically investigate the consequences of insurance participation on livestock production and producers' behavior. Cai et al. (2015) introduced exogenous variations in sow insurance coverage at the village level in 480 villages in China's Guizhou Province by randomly assigning performance incentives to village animal husbandry workers who were responsible for signing up farmers for

[1] Gunnsteinsson (2014) conducted a three-stage random field experiment for the rice grower in the Philippines to separately quantify information asymmetries. This experiment elicited farmers' choices of which plots they would prefer to insure, and then randomly allocated insurance to farmers and plots, generating across- and within- farm variations in which plots were insured. The author found strong evidence for adverse selection and moral hazard in this experiment. However, the sample selection for this study is not completely random, so there is still a problem of selection bias (i.e. farmers who have insurance demand are more willing to participate in the experiment). He et al. (2019) also tried to solve the challenges of selection bias and mixed effects by asking that questions whether the farmer had a cost-of-production crop insurance and whether the farmer would have bought insurance if it was not required by lenders, which can divide farmers into three groups. Using the method of propensity score matching (PSM), they found ambiguous effects of moral hazard. Their study is still faced with the endogeneity from omitted variables and measurement errors.

the insurance. Their findings suggested that insurance participation had increased sow production at the village level. Using a natural experiment of pig insurance in a county in China, Zhang, Zhu, and Turvey (2016) detected no effect of insurance participation on mortality and vaccine use, implying no evidence of hazardous behavior. Their study provided insights into the unique situation where pig producers withdrew from the insurance market instead of purchasing insurance.

In this study, we will contribute to the ongoing debate on hazardous behavior associated with agricultural insurance and further our understanding of the role of insurance in the livestock sector, which generates significant economic value but remain vulnerable to risk and underinsured in both developed and developing countries. We take advantage of a government-supported, compulsory sow insurance program during 2008-2009 in Jiangshan County, China and examine whether farmers' awareness of insurance coverage have led to hazardous behavior. The slacking officials at local governments enrolled sow farmers in the insurance program on their behalf using funds from a concurrent national subsidy program for sow farmers. As a result, not all enrolled farmers were aware of their insurance coverage, hence creating a unique quasi-experiment for us to observe potential hazardous behavior. We estimate the endogenous treatment effects using a unique exogenous variable to control for the endogeneity in the binary treatment variable. Our robust results suggest that farmers' awareness of their insurance enrollment has led to statistically and economically significant differences in the sow mortality rates, thus confirming the presence of hazardous behavior.

The rest of this paper is structured as below. Section 2 provides the context of hog production in China and its various hog insurance programs including the one in Jiangshan County, our study area. In Section 3, we discuss the empirical strategies to derive consistent estimates of moral hazard effects. Section 4 ensues with discussion of the survey, data, and the estimation results, followed by conclusions in Section 5.

2. The Context

China runs the largest hog and pork business in the world by raising about half of the global hog population and contributing more than one third of global pork production in 2020. Despite the significant volume in aggregate, a salient feature of China's hog production is its large number of spatially scattered, small-sized hog farms that rely on intensive use of labor and outdated technologies (Zhang et al. 2019). According to national statistics, as high as 98.7 percent of hog producers are small-sized farmers who raise fewer than 100 hogs, jointly contributing to about 51.6 percent of the national pork output in 2009 (China Animal Husbandry Statistical Yearbook, 2010). Among those individual hog farmers, approximately 38.8 percent of them are still backyard-style producers who raise fewer than five hogs annually and keep the hogs in a barn in their backyard or let hogs run freely in the yard of village (Schneider, 2011).

To reduce the risks facing hog farmers and stabilize pork supplies and prices, China's central government launched in 2007 its national support programs for hog production, starting from directly subsidizing sow farmers. This is because sows are a valuable asset for hog farmers and sow-raising plays a pivotal role in their production decisions. Hog farmers in China can either buy sows from the market (e.g. from professional breeders or other farmers) or breed their own sows using female piglets. In many occasions, however, farmers choose to breed their own sows owing to limited supplies of sows and high prices of sows and piglets. Hog farmers usually decide whether to keep a female piglet for breeding about one month after its birth. Female piglets not for breeding will be spayed for faster growth and better taste. Those to be used for breeding will be raised for an additional eight months before they mature and start to breed. A mature sow can breed multiple litters of piglets, with each pregnancy lasting for about four months. The litter size increases with more pregnancies and peaks at the 4^{th}-6^{th} pregnancy. Piglets from each litter can be either sold to other farmers, raised into fattening pigs and then sold for meat, or raised for breeding more sows. After the litter size peaks, farmers may keep the sow for another 4-6 years before it was culled out.

During this prolonged lifecycle of a sow, farmers have to keep spending on feed, vaccines, and other veterinary medicines for the sow until the sow starts to generate returns for its owner. A farmer may decide to keep more than one sow at various stages of growth depending on management capacities, cash flows, market prices among other factors. Any adverse changes in these factors may make it less profitable, if at all, for the farmer to keep some or all the sows. Whenever farmers believe the risks of unfavorable prices and imminent hog diseases to exceed the expected payoffs, they usually react by immediately slaughtering their sows to prevent further losses in spite of the sunk costs. When a large number of hog farmers are simultaneously reducing their stocks of sows in this manner, it usually presages depressed market situations that may evolve into more market disruptions at greater scales. Therefore, policy makers have been vigilant to these signals and keen to stabilize sow supplied to counterbalance the so-called “hog cycles.”

As a national strategy, China’s central government started promoting sow insurance nationwide since 2007, in collaboration with the People’s Insurance Company of China (PICC) as the main insurance underwriter.[2] The goal is to cover as many hog farms as possible regardless of their size. In principle, hog farmers can opt to insure each of their eligible sows (e.g., aged between eight months and four years) for a premium of 60 yuan (approximately 8.5 dollars), with the

[2] Data from PICC show that PICC underwrote a total number of 115 million sows in 2010, accounting for over 85 percent of the total number of insured sows nationwide.

central and local governments jointly subsidizing 50 to 80 percent of that premium. When sow death occurs due to common diseases, natural disasters or accidents,[3] farmers will receive an indemnity payment of 1,000 yuan (i.e., 142.3 dollars) for each insured sow. In practice, most local governments have retained the voluntary nature of the sow insurance program, while some, such as those with an abundant budget, have required all eligible hog farmers to participate. Since the exact cause of sow death is difficult and costly to identify, the insurance company has almost always accepted farmers' claims and made indemnity payments for the insured sow deaths (Rao and Zhang, 2019). It is possible for hog farmers to receive compensations for sow death due to causes that are originally uncovered by the sow insurance.

The sow insurance program investigated in this study took place in Jiangshan County, Zhejiang Province. Jiangshan lies in a major hog-producing region in China and raised about 1.84 million hogs in 2010, out of which 95.2 thousand were sows. In the same year, the county sold 1.23 million hogs generating a total revenue of 1.1 billion yuan (i.e., 156.5 million dollars). Most of its hogs were sold for pork to nearby metropolitan areas such as Shanghai and Hangzhou. In response to the central government's initiative in 2007, the Jiangshan government started its compulsory sow insurance program from September 2008 till August 2009. Working closely with the County's Bureau of Agriculture and Animal Husbandry, the local branch of the PICC underwrote the sow insurance for all sows that aged between eight months and four years. In accordance with the nationally-uniform premium rate of 60 yuan per sow, the central and local

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[3] Major diseases include septicemia, blue tongue, scrapie, hyopneumoniae, swine erysipelas, porcine reproductive and respiratory syndrome virus, porcine epidemic diarrhea, streptococcus suis, and foot and mouth disease. Natural disasters covered by the insurance are typhoon, tornado, rainstorm, lightning stroke, earthquake, flooding, hailstorm/snowstorm, debris-flow and mountain landslide. Accidents include fire, explosion, building collapse, and falling parts or articles from aircraft and other flying objects.

governments subsidized 80 percent of the premium, with the remaining 20 percent (i.e., 12 yuan or 1.7 dollars) paid by sow farmers.

It is worth noting that in the same year China's central government was implementing a direct subsidy program by paying all hog farmers nationwide 100 yuan (i.e., 14.2 dollars) for each sow they raise. The funds for this direct subsidy program were administered and paid out to hog farmers by the Bureau of Agriculture and Animal Husbandry at county governments, the same office that was administering the concurrent subsidized sow insurance program. In Jiangshan, the Bureau and its field offices at townships had been understaffed for the large number of spatially dispersed hog farmers. Not all Bureau officials were able to conduct the usual home visits to all hog farmers in their township and sign them up for the compulsory insurance program during the open enrollment period. As a shortcut approach, some of the Bureau officials at the townships skipped the home visits. Instead, they deducted 12 yuan from the 100-yuan direct subsidy for farmers and paid the 12 yuan as the premium to the insurance company on farmers' behalf. Eventually each farmer received 88 yuan of direct subsidy from the central government and was enrolled in Jiangshan's sow insurance program without necessarily knowing their insurance enrollment. According to the Bureau's own statistics, the PICC branch in Jiangshan underwrote insurance for 91,843 sows and collected the total premium payments of 5.51 million yuan during the 2008-2009 policy period.[4] Our survey suggests that as many as 21.9 percent of farmers in the survey sample were not aware of their insurance enrollment.

[4] The statistics from the Bureau also shows that PICC made total claim payments of 6.11 million yuan to hog farmers during the same period, making the loss ratio as high as 110.9%, far exceeding the prevailing break-even loss ratio of 77%. Owing to the huge losses in 2008-2009, PICC decided to stop this sow insurance program in Jiangshan since 2009 until 2013.

3. Identification Strategy

The implementation of the sow insurance program in Jiangshan during 2008-2009 provides us a unique opportunity to detect potential hazardous behavior of hog farmers due to insurance participation. The compulsory nature of the program staves off possible adverse selection effects that complicate analysis of voluntary insurance. The fact that some of Jiangshan's hog farmers were unknowingly enrolled in the insurance allows us to compare these farmers with those who were aware of their enrollment. The following linear-form function is deployed to test whether farmer i's awareness of insurance enrollment affects his sow mortality rate:

$$mortality_i = \alpha_0 + \alpha_1 * awareness_i + \boldsymbol{\alpha_2} * \boldsymbol{X_i} + \varepsilon_i$$

In the equation above, the dependent variable $mortality_i$ is calculated as the ratio of the number of dead sows and the number of sows raised by farmer i during the insurance period. This fractional variable has frequently been used in the relevant literature (e.g., Pai et al., 2015; Rao and Zhang, 2019) as a measure of the risk facing farmers, with a higher value representing a higher level of risk. Farmers in Jiangshan filed claims over deaths of sows and received compensations by the count, making $mortality_i$ a pertinent outcome variable for evaluating this insurance program.

For the interest of this study, this outcome variable is possibly affected by farmers' awareness of insurance enrollment. The binary variable $awareness_i$, analogous to the treatment or intervention in a field experiment, takes the value of one when farmer i was aware of his insurance enrollment and the value of zero if otherwise. In addition, $mortality_i$ is likely determined by more factors, captured in the vector $\boldsymbol{X_i}$ with the associated parameter vector $\boldsymbol{\alpha_2}$, such as those related to bio-security practices (e.g., vaccination and cleaning) against hog diseases, farm characteristics, and farmer socio-economics. Given the data available from our survey, we first include in $\boldsymbol{X_i}$ the following variables: farmers' age, education level, experience in hog raising (and its squared term), ratio of income from hog raising and total family income annually, average vaccine expenditure per sow, average vaccine expenditure per hog, and a generated variable $biosecurity_i$ that counts the total number of different bio-security practices (in addition to vaccination) adopted on the farm. Our survey included 27 yes-or-no questions that cover common bio-security practices among hog farmers; such as, whether farmers have used enclosed barns, kept separate barns for sows and other hogs, kept vaccination records for each hog, changed on work uniforms before entering hog barns, installed sterilization equipment, and kept separate tools for different barns. The more such practices farmers have adopted, the lower the sow mortality rate is likely to be.

Moreover, the sow death ratio $mortality_i$ depends closely on farmers' abilities to manage their sows, although it is always challenging to accurately measure abilities using observable variables. We tapped into the literature on rural governance and social network in China and included three binary variables in the vector $\boldsymbol{X_i}$ from our survey as proxy variables for farmers' management abilities: farmers who are party members (i.e., $partymem_i$=1) or cadres in governments ($cadre_i$=1), and farmers whose registered primary residence is non-agricultural (i.e., $hukou_i$=1). According to the literature, Chinese farmers who are party members and more socially adept and connected are more likely to hold positions at the government (e.g., Morduch and Sicular 2000; Li et al. 2007; Jin et al. 2014; Gu and Zheng 2018). Farmers whose residence is registered as non-agricultural (e.g., living at township centers) are often better educated than their agricultural counterparts and have more access to knowledge on hog raising.

If we believe the vector $\boldsymbol{X_i}$ has included all the other explanatory variables for sow mortality so that ε_i captures only random noise, the coefficient α_1 for $awareness_i$ measures the causal effects of farmer's awareness of insurance enrollment on the dependent variable. Then we can conduct a statistical significance test on the ordinary-least-squares (OLS) estimates for α_1 to detect the presence of hazardous behavior. However, this assumption is unlikely to hold because of unobservable factors, such as farmers' attitude toward the risk of livestock diseases, that will affect both sow mortality and the chance they know their insurance enrollment. Measurement errors associated with the proxy variables ($partymem_i$, $cadre_i$, and $hukou_i$) for farmers' management abilities may also violate this assumption. For instance, a conscientious and precautious hog farmer may raise sows to his best ability and actively seek any government policies that can support his business, hence lowering his sow mortality and increasing his chance to know the compulsory sow insurance program. In that case, the OLS estimates of α_1 will be biased and inconsistent. In other words, we need to address the plausible case where the treatment variable, $awareness_i$, is endogenous.

The search for solutions to the endogenous treatment problem entails a further explanation of how this government-backed sow insurance in Jiangshan was promoted among individual hog farmers. For such policy programs in China, county governments often divert funds and personnel to township governments, which then send their officials or technical staff to farmers' households for individual visits and in-person promotion. Such a top-down approach with home visits by government staff has played a preeminent role in Chinese farmers' learning of government policies.

Before the sow insurance started, each township in Jiangshan was already staffed with a few "animal husbandry workers" who oversaw local livestock production such as disease prevention and monitoring, and handing out veterinary vaccines to farmers. County governments funded those staff positions based mostly on its annual budget and, if at all possible, the size of livestock production in each township. When the compulsory sow insurance program was launched, Bureau officials at the county level instructed the animal husbandry workers at the township level to promote this new program to farmers in addition to their routine work, while neither the county government nor the township governments provided any overtime compensations or job performance evaluations.[5] In some townships, the animal husbandry workers were proportionally far outnumbered by hog farmers, some of whom lived far apart and some even in remote mountain villages. In fact, the hog farmer to animal husbandry worker ratio varied notably from 1.7:1 to 20:1 among Jiangshan's 19 townships in 2008-2009. Not all the workers had the capacities or the incentive to visit all the farm households within the short period of insurance enrollment. Instead, some workers took 12 yuan out of the 100 yuan of subsidy payment made to farmers by the central government and used the 12 yuan as the premium to enroll farmers in the insurance. Eventually, all hog farmers were enrolled in the compulsory program although not all of them necessarily were aware of their enrollment.

Given this, we first propose using the animal husbandry workers to hog farmers ratio ($ratio_i$) at each township as an instrumental variable for the likely endogenous variable $awareness_i$. As explained above, proportionally the more workers a township has staffed relative to its number of hog farmers, the more likely the workers in this township would have completed home visits

[5] The compulsory nature of the sow insurance program in Jiangshan generated at least two implications for how governments had operated in this case. First, it would be difficult for the government to supervise and evaluate whether the animal husbandry workers had worked diligently to promote the program since all farmers would anyhow enroll in the program in the end. Second, the Jiangshan government had to spend more on funds to subsidize the insurance premiums for a compulsory program than for a voluntary program and hence had fewer funds to compensate the animal husbandry workers for the extra workload. Therefore, the county officials acquiesced the animal husbandry workers taking the shortcut approach.

and informed farmers of their insurance enrollment. Meanwhile, this ratio is unlikely to correlate with the unobservable variables contained in the error term ε_i in equation (1). In this way, $ratio_i$ can serve as a valid exogenous variable for the model.

This county-level variable $ratio_i$, however, may turn out to be a poor predictor for the individual-level variable $awareness_i$. We include a second explanatory variable for $awareness_i$, $farmdistance_i$, measuring the distance (in meters) from each hog farm to its nearest hog farm. Farmers may learn of the insurance program from their neighboring hog farmers, although the actual dissemination of information among hog farmers may be complex enough to render $farmdistance_i$ inconsequential. Table 1 reports the definitions of the major variables used in this study.

[Insert: *Table 1 Definitions and descriptive statistics of major variables*]

To sum up, we are keen to estimate the causal effect of the binary treatment variable $awareness_i$ on the outcome variable $mortality_i$ while being aware of the possible endogenous nature of $awareness_i$. We identified two explanatory variables, $ratio_i$ and $farmdistance_i$, to explicitly characterize the probability for farmers to become aware of their insurance enrollment (i.e., $awareness_i$=1). Therefore, we use the following endogenous treatment effects model for the ensuing estimation.

First stage: $$awareness_i = prob(\gamma_0 + \gamma_1 * ratio_i + \gamma_2 * farmdistance_i + \boldsymbol{\gamma_3} * \boldsymbol{X_i} + \theta_i)$$

Second stage: $$mortality_i = \beta_0 + \beta_1 * awareness_i + \boldsymbol{\beta_2} * \boldsymbol{X_i} + e_i$$

Given the binary nature of $awareness$, the linear form first-stage equation in usual 2SLS approach will generate inconsistent estimates for the second-stage equation in most circumstances (e.g., Wooldridge 2010). To derive consistent and efficient coefficient estimates, we specify a *probit* equation for $awareness_i$ as the first-stage equation (also known as the treatment model), with the two explanatory variables and $\boldsymbol{X_i}$ as the covariates. Then transformations of the fitted values from the first stage are used along with $\boldsymbol{X_i}$ as covariates for $mortality_i$ in the second stage (also known as the outcome model). Next section will first describe the data used for the empirical analysis and then report the estimation results with more discussions.

4. Data and Results

Survey and Data

To empirically estimate the effects of hog farmers' awareness of insurance enrollment on their sow mortality rates, we conducted a field survey in Jiangshan, Zhejiang Province, in early 2011 using a stratified sampling approach. We obtained access to Jiangshan's hog production census data in 2009 and identified a total number of 10,003 hog farmers located in the 21 townships. Ranking those farmers by their numbers of sows from the largest to the smallest, we assigned all the hog farmers into 1,429 groups with each group having seven farmers indexed from one to seven. A computer-generated random number between one and seven was drawn for each group, and farmer with the corresponding index was selected into our sample to represent that group. In this way, our sample contained hog farms of various sizes.

For each sampled hog farmer, we obtained information from two sources: a non-anonymous household survey and farmer records at the insurance company. The animal husbandry workers working at each township were recruited and trained as enumerators for the household survey for their knowledge of local hog farmers. Survey topics included farmer socioeconomics, hog production (e.g., numbers of sows, mortality rates, use of feed), credit and insurance, livestock disease prevention (e.g., vaccines, veterinary medicines, and other preventive measures), and so on.[6] We used farmers' names to match the survey data with their records at the insurance company, while the survey data were kept anonymous to the insurance company. Insurance records included information such as numbers of insured sows, dates and amounts of claims and payments. In this way, we obtained a total number of 1,397 hog farmers out of the 1,429 initially selected, leading to a response rate of 97.76 percent.

Table 1 reports the definitions and descriptive statistics of variables used in the empirical analysis. It shows that the average number of sows each farmer raised increased from 17.9 in December 2008 to 19.2 in December 2009. Survey data also show that as high as 64.8 percent of hog farmers in 2009 raised fewer than five sows, suggesting that small-sized hog raising was still prevalent in this area. Table 1 also indicates that the average sow mortality rate for Jiangshan is 2.3 percent, slightly higher than the estimated national average.[7] Moreover, only 78.1 percent of sampled farmers were aware of their enrollment in Jiangshan's sow insurance despite its being a compulsory program. The animal husbandry workers to hog farmers ratio averaged 8.26 percent in 2009, meaning that each worker was responsible for about twelve hog farmers, and this ratio varied notably among townships.

We further compare hog farmers who were aware of their insurance enrollment with those who were not and report the comparisons in Table 2. The *t*-statistics suggests that the two groups

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[6] After the enumerators completed the household survey, the management team of this study randomly selected more than five percent of the sampled farmers and conducted telephone interviews to verify the information their provided for the survey.

[7] At the time of survey, there was no census data on national average sow mortality rate. The People's Insurance Company of China (PICC), which is the main insurance underwriter for China's livestock insurance including the one in Jiangshan, estimated the national average mortality rate of insured sows to be around two percent in 2009.

report statistically significant differences in the mean values for education level, hukou, party membership, biosecurity practices, experience in hog raising, income ratio of hog raising, sow mortality rates, ratio of animal husbandry works to number of sow farmers, and distance from nearest hog farm. Meanwhile, age, cadre status, the number of sows in 2009, and average vaccination costs per sow/hog seem to be similar between the two groups.

[Insert: *Table 2 Comparing farmers by awareness status*]

Estimation Results

We use the command *eteffects* in $Stata^{©}$16 to estimate the two stages of equations as a system. Table 3 contains the estimated average treatment effect (ATE) of $awareness_i$ and estimates of the parameters associated with the two stages of equations. We first discuss these parameter estimates and compare them against economic theory and the relevant literature (see Section 3) before giving credence to the estimated ATE and other related treatment effects.

[Insert: *Table 3 Parameter estimates of endogenous treatment effects model*]

Part 3 of Table 3 reports estimates for the first-stage equation (i.e., the treatment model), which uses a *probit* model to characterize the likelihood for farmer i to be aware of his insurance enrollment. As the primary explanatory variable, $ratio_i$ reports a positive coefficient estimate that is significant at the 10% level. This result indicates that the more animal husbandry workers are staffed in a township proportional to its total number of sow farmers, the more likely sow farmers in this township to be aware of their insurance enrollment. In contrast, the coefficient for the distance variable, $farmdistance_i$, turns out to be statistically insignificant. This may be partly because nowadays physical distance is no longer a major obstacle to information dissemination and partly because farmers unlikely learn information from neighbors who they may be competing with. The treatment model also includes a few explanatory variables from the outcome model, such as farmers' age, education, and experience. All of these variables, except $cadre_i$, report coefficient estimates with the expected signs of direction and statistical significance. In particular, being registered with a non-agricultural residence (e.g., living in township centers, so $hukou_i = 1$) and being a party member (i.e., $partymem_i$=1) will increase farmers' chance to know this compulsory hog insurance. Being a cadre in the government is supposed to increase one's chance to know the insurance. The low occurrence of cadre farmers in our sample, 32 out of 800 observations, may account for the statistically insignificant result.

Using the above parameter estimates, the first-stage equation generates fitted values for the treatment variable $awareness_i$ that are to be used alongside other explanatory variables (i.e., the parameter vector $\boldsymbol{X_i}$) for the estimation of the second-stage equation. The generic endogenous treatment model allows the parameter for the same explanatory variable to vary between the control group and the treatment group. Part 4 and Part 5 of Table 5 report parameter estimates of the same set of variables for farmers who were unknowingly and knowingly enrolled in the hog insurance, respectively. Where farmers were unaware of their enrollment, their sow mortality rates would be negatively affected by their average vaccination costs per sow, experience in hog raising (beyond 22.5 years), and party membership. The number of different biosecurity practices that farmers adopted also seems to negatively affect their sow mortality rates, although the estimate is statistically insignificant (*t*-stat=-0.89). The only unanticipated estimate is for farmers who were cadres at local governments; their sow mortality rates are estimated to be higher than those of non-official farmers. It is a completely different story for farmers who were aware of their insurance enrollment (Table 3, Part 5). None of the explanatory variables reports a statistically significant parameter estimate, although they are jointly significant at the 10% level.

Given that the parameter estimates for the two-stage model are satisfactorily consistent with what economic theory suggests, we are confident to answer our core research question using estimates from the current model. Part 1 of Table 3 reports the average treatment effect (ATE) is 0.020 with a *p*-value of 0.000. This result implies that the average sow mortality rate would increase by about two percentage points had farmers become aware of their insurance enrollment. This model also reports in Part 2 a potential-outcome mean value of 0.004 with a *p*-value of 0.002, suggesting that the expected sow mortality rate would have been 0.004 if no farmers had been aware of their insurance enrollment. We also re-estimate the two-stage model using a variant of the command *eteffects* that report identical parameter estimates but with the average treatment effects on the treated (ATET). Part 1' of Table 3 shows the estimated ATET to be 0.03 with a *p*-value of 0.000. All these findings clearly indicate that farmers' awareness of insurance enrollment has led to an increase in their sow mortality rates, corroborating the presence of hazardous behaviors. Considering the average sow mortality rate is 2.64% among all surveyed farmers (N=1,219) and 2.80% among those in the regression sample (N=800), an ATE around 2% is also economically significant.

Lastly, we conduct an endogeneity test against the null hypothesis of zero correlation between the unobservable factors that affect both the treatment (i.e., farmers becoming aware of insurance enrollment) and the outcome (i.e., farmers' sow mortality rates). This test reports a χ^2 of 10.78 and the associated *p*-value of 0.005. Therefore, we reject the null hypothesis of no endogeneity and believe our endogenous treatment model is justified to address the endogeneity problem.

Conclusion and Discussion

Microinsurance is of great value to the development of the agricultural economy in developing countries. However, insurance companies are often reluctant to offer programs on a wide scale due to various reasons including moral hazard due to asymmetric information. Based on an insurance policy change in Jiangshan County, China, we empirically detect moral hazard effects in a compulsory livestock insurance. During the implementation of compulsory insurance in Jiangshan, some farmers did not know that they had participated in the insurance program due to the simplification of government subsidy distribution, thus creating a quasi-experiment for us to compare differences in behaviors between farmers who were unknowingly enrolled in the insurance and those who were aware of their enrollment.

Utilizing an endogenous treatment model to tackle endogeneity, our results suggest this compulsory sow insurance results in moral hazard effects. Compared with farmers with insufficient information about insurance, farmers getting well informed of the insurance program have significantly changed their risky production behaviors, heightening the risk of the death of sow. Therefore, our analysis implies that a sow insurance design can causing hazardous behaviors, which maybe an obstacle to the development of livestock insurance market.

This has strong implications for the government in developing countries, especially for the Chinese government since policy makers and researchers are all exploring the prospects for microinsurance under the facts that the government has already provided substantial premium subsidies for livestock insurance. The evidence of moral hazard at least for one microinsurance program for sow insurance in Zhejiang, China, implies that other risk indicators should be considered in order to enhance and fine tune the design of sow insurance in China.

However, our research still faces some limitations. First, we cannot completely rule out the effects of unobserved variables under the data framework of cross-section, though the explanatory (instrumental) variables have largely solved the endogeneity problem. Also, we did not conduct detailed investigations on the specific input factors that farmers used in 2009, leading to the fact that we can only use a single mortality indicator when analyzing the moral hazard problem. In addition, farmers' hazardous behaviors will largely depend on the market prices of the feed and pork. Thus, it will be better to further explore this potential relation by using panel dataset in the future.

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Table 1 Definitions and descriptive statistics of major variables (Regression sample size is 800)

Variable	Definition	Mean	SD	Min	Max
numsow2008	Number of sows in December 2008	24.585	91.729	0	1,200
numsow2009	Number of sows in December 2009	26.203	96.544	1	1,200
mortality	Fraction of total sows reported to be dead during the insurance period	0.028	0.081	0	0.5
awareness	A dummy variable that equals 1 if the farmer knew that he/she participated in insurance in 2008, and 0 otherwise	0.786	0.410	0	1
ratio	Ratio of the number of local husbandry veterinary workers to the number of sow farmers in each town	8.416	4.692	5.02	58.82
age	Age of pig farm owner	51.400	9.216	26	84
edu	Years of education of pig farm owner	6.629	2.708	0	15
hukou	A dummy variable that equals 1 if the farmer had a non-agricultural household registration, and 0 otherwise	0.106	0.308	0	1
partymem	A dummy variable that equals 1 if the farmer was a party member; and 0 otherwise	0.105	0.307	0	1
cadre	A dummy variable that equals 1 if the farmer was a village cadre; and 0 otherwise	0.040	0.196	0	1
experience	Pig farm owner's experience in pig production, measured in years	13.651	9.149	0	50
incomeratio	Income from sow/total income	40.664	30.352	0	100
biosecurity	Number of different biosecurity practices used on farms	9.538	3.370	1	22
vac_cost_per_sow	Average vaccination costs (in yuan) per sow during the insurance period	1.482	2.677	0	35.24
vac_cost_per_hog	Average vaccination costs (in yuan) per hog during the insurance period	0.159	0.947	0	16.2
farmdistance	Distance (in meters) from the nearest hog farm	329.331	1,024.179	0	20,000

Table 2 Comparing farmers by awareness status

Variable	Not Aware (N=171)		Aware (N=629)		Difference	
	Mean	SE	Mean	SE	Diff	SE
age	52.245	0.713	51.170	0.366	1.076	0.794
edu	6.304	0.185	6.717	0.111	-0.413*	0.233
hukou	0.064	0.019	0.118	0.013	-0.053**	0.027
partymem	0.058	0.0180	0.0118	0.013	0.105**	0.026
cadre	0.035	0.014	0.041	0.008	0.040	0.007
biosecurity	7.678	0.245	10.043	0.129	-2.365***	0.278
experience	10.801	0.532	14.426	0.380	-3.625***	0.779
incomeratio	29.269	2.087	43.762	1.213	-14.492***	2.569
mortality	0.019	0.005	0.306	0.003	-0.012*	0.007
numsow2009	17.556	7.070	26.496	3.649	-8.940	7.910
vac_cost_per_sow	1.547	0.151	1.465	0.113	0.082	0.231
vac_cost_per_hog	0.168	0.099	0.156	0.033	0.012	0.082
ratio	6.859	0.419	8.839	0.174	-1.980***	0.399
farmdistance	203.222	43.631	363.615	44.417	-160.392*	88.201

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels, respectively.

Table 3 Parameter estimates of endogenous treatment effects model

mortality	Coefficient	Standard. Errors	z	P>z	[95% Conf. Interval]	
Part 1: ATE						
awareness (1 vs 0)	0.020	0.003	6.510	0.000	0.014	0.026
Part 2: POmean						
awareness =0	0.004	0.001	3.040	0.002	0.001	0.007
Part 1': ATET						
awareness (1 vs 0)	0.030	0.003	8.910	0.000	0.024	0.037
Part 3: TME1						
ratio	0.057	0.030	1.890	0.058	-0.002	0.116
farmdistance	0.000	0.000	0.930	0.351	0.000	0.000
age	-0.015	0.007	-2.190	0.028	-0.029	-0.002
edu	0.042	0.021	1.970	0.048	0.000	0.084
experience	0.041	0.008	4.950	0.000	0.025	0.058
hukou	0.376	0.186	2.020	0.043	0.011	0.741
partymem	0.367	0.184	2.000	0.046	0.007	0.727
cadre	-0.239	0.276	-0.860	0.387	-0.780	0.303
constant	0.257	0.465	0.550	0.580	-0.654	1.168
Part 4: OME0						
vac_cost_per_sow	-0.151	0.085	-1.780	0.075	-0.317	0.015
vac_cost_per_hog	0.051	0.034	1.500	0.135	-0.016	0.119
incomeratio	-0.003	0.004	-0.700	0.486	-0.012	0.006
age	0.000	0.012	-0.030	0.975	-0.025	0.024
edu	-0.084	0.052	-1.610	0.108	-0.186	0.018
experience	-0.090	0.034	-2.630	0.009	-0.157	-0.023
experience_sq	0.002	0.001	2.100	0.036	0.000	0.004
biosecurity	-0.030	0.034	-0.890	0.375	-0.095	0.036
hukou	-0.497	0.385	-1.290	0.197	-1.252	0.258
partymem	-1.177	0.290	-4.070	0.000	-1.745	-0.610
cadre	0.754	0.394	1.910	0.056	-0.018	1.527
constant	-2.350	1.134	-2.070	0.038	-4.572	-0.128

Table 3 Parameter estimates of endogenous treatment effects model (Continued)

mortality	Coefficient	Standard. Errors	z	P>z	[95% Conf. Interval]	
Part 5: OME1						
vac_cost_per_sow	-0.040	0.033	-1.220	0.223	-0.103	0.024
vac_cost_per_hog	0.002	0.042	0.050	0.963	-0.080	0.084
incomeratio	0.000	0.002	-0.160	0.873	-0.003	0.003
age	-0.008	0.007	-1.090	0.275	-0.022	0.006
edu	0.015	0.024	0.640	0.522	-0.032	0.062
experience	0.038	0.022	1.700	0.090	-0.006	0.082
experience_sq	-0.001	0.000	-1.370	0.170	-0.001	0.000
biosecurity	0.006	0.016	0.370	0.708	-0.026	0.038
hukou	0.104	0.184	0.570	0.571	-0.257	0.466
partymem	0.169	0.166	1.020	0.310	-0.157	0.494
cadre	-0.142	0.294	-0.480	0.629	-0.717	0.433
constant	-2.225	0.530	-4.200	0.000	-3.264	-1.187
Part 6: TEOM0						
constant	-2.612	0.898	-2.910	0.004	-4.372	-0.853
Part 7: TEOM1						
constant	1.301	1.007	1.290	0.196	-0.673	3.274