



Influence of contract commitment system in reducing information asymmetry, and prevention and control of livestock epidemics: Evidence from pig farmers in China

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ABSTRACT

The prevention and control of infectious diseases in livestock is of great significance for maintaining the food and health of people. The main bottleneck in preventing and controlling the epidemic is asymmetrical information between farmers and the livestock department regarding dead livestock. In this pursuit, China has levied the contract commitment system to ensure farmers to cooperate with livestock departments, cooperative organizations, and other farmers by proper contract in order to combat the livestock epidemic by reporting the status of dead livestock on time. Based on the data of 514 pig farmers in Hebei, Henan, and Hubei, this research employed the Heckprobit model to explore the contract commitment system's effect on pig farmers' behavior in reporting the status of dead livestock. The outcome showed that the contract commitment system encouraged the farmers to report dead pig information promptly. Moreover, modern information channels such as mobile phones or the Internet further enhanced the contract commitment system's effectiveness. Besides, the impacts of the contract commitment system on different scale farmers are found substantially heterogeneous. Based on the empirical findings, it is confirmed that the contract commitment system should not exclude government regulatory measures and economic incentive policies. It is a useful remedy to encourage farmers to report dead livestock information on time and supports in preventing and controlling livestock epidemics. Additionally, the government should enhance and strengthen the contract commitment system, establish the channels and platforms required to deliver necessary information about epidemics, and implement differentiated policy programs for different scale farmers. More importantly, these countermeasures can also provide important guidelines for other developing countries, facing livestock epidemics.

1. Introduction

In response to an increasing population, urbanization, rising income, and an emerging middle class, the demand for livestock products has increased, leading to an increase of livestock epidemics such as African swine fever [1,2]. According to the World Health Organization report, it is documented that the livestock industry's output caused by epidemics decreased up to more than 20% each year, and posed severe challenges to meat-food safety, and further lead to the outbreak of zoonotic infectious disease [3]. Therefore, it is proven that livestock epidemics poses serious threats to the livestock industry, animal-derived food safety, and public health safety [4,5]. Based on the above discussion, there is a high need to prevent and control the livestock epidemic, which is one of the

prime mandatory issues that need to be addressed in an international public health field [6].

The literature has debated that the government is the main administrative body that can design strategies necessitated to prevent and control epidemics and, in turn, lead to maintain good public health [7]. Likewise, in the context of grassroots social governance, farmers may also prevent and control epidemics by improving the operating efficiency and increasing investment in biosafety measures [8]. The core strategy behind the prevention and control of livestock epidemics is the augmentation of cooperation between the government and farmers [9]. The mutual interaction between both parties requires disclosure of symmetrical information, especially reporting dead livestock. The asymmetric information creates the gap for implementing strategies

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needed to prevent and control epidemics, and is also not conducive to sustain livestock raising and maintaining farmers' good health [10]. Thus, the efficient measures required for the prevention and control of epidemics are the timely diagnosis of disease, scientific determination of epidemic levels, harmless disposal of dead livestock, and unsafe product embargoed. However, the effective implementation of these measures depends on farmers' timely reporting of dead livestock to the livestock department [11].

In the literature, many researchers have affirmed that information symmetry between government and farmer mainly requires government regulations such as supervision and penalty and economic incentive policies such as subsidies [12,13]. But the government had faced many challenges, such as incomplete supervision systems and less stringent punishments [14]. The subsidy incentive policies also have shortcomings, making it difficult to compensate for preventing and controlling epidemics costs. Besides, some scholars have explored incentive policies for farmers to report dead livestock information based on the game and principal-agent theories [15]. However, the design of incentive-compatible compensation mechanisms always remained a difficult problem for the academic community [16]. The reason is that if the subsidy standard is very high, farmers will prefer to allow infectious diseases to break out rather than increase their investment in biosecurity measures. Finally, the implementation of policies is also inefficient and unsuccessful [17,18]. Additionally, other scholars have also explored the impact of education, training and technology promotion provided by livestock departments on farmers' reporting of dead livestock. The results showed that differences in individual education and security risk perception make these measures unsustainable [19,20]. Therefore, against this backdrop, most countries worldwide continued to explore new innovative systems for preventing and controlling epidemics.

Our study focused on China as it plays a significant role in rearing livestock, with more than 50% of the world's pig production. But the standardization of raising livestock is relatively low [21]. The farmers don't have enough capacity and financial resources to prevent and control livestock epidemics. Consequently, various livestock diseases resultantly lead to huge rates of livestock mortality [22,23]. To strengthen the government governance on livestock epidemics, the Chinese government has successively implemented supervision policies and direct subsidy policies that has triggered farmers to take biosafety measures in advance and actively participate in reporting the status of dead livestock [24]. However, several challenges occur, such as concealment, misrepresentation, late reporting, and underreporting cases. Even dead livestock are either discarded or sold, which remarkably inhibited the measures' effectiveness to control livestock diseases [25]. Since 2015, the government has implemented the contract commitment system (see supplementary materials). Farmers commit by signing contracts with livestock departments, cooperative organizations, and other farmers, stipulating their rights and obligations. But how much does the contract commitment system inspire farmers to report dead livestock information and combat livestock epidemic remain unexplored. To fill the gap in the literature, the current study explores the contract commitment system's effect on farmers' behaviors to report dead livestock information by collecting data of 514 pig farmers in China. Besides, the study employed the Heckprobit model to achieve the main objective of the study. It is anticipated that the current research will set avenues for policymakers to identify farmers' behaviors in reporting information about dead pigs via the contract commitment system. The outcome of relative evaluation and feedback by both government and farmers can positively incentivize good practice and aid in controlling livestock epidemics.

The paper's remaining structure is organized below. The subsequent "Materials and Methods" section shows the study sites, sampling, participants, and analytical strategies. The results based on estimations are presented in the "Results" section and discussed in the "Discussion" section. Finally, the conclusion is revealed in the "Conclusion" section.

2. Materials and methods

2.1. Study sites, sampling, and participants

The data was gathered from the field survey conducted from July to September 2018 in Hebei, Henan, and Hubei, China. The distribution of the sample counties (districts) is shown in Fig. 1. A combination of stratified and random sampling was adopted in the survey. The specific sampling steps include randomly 2 to 4 towns are selected among the sample counties (districts); 3 to 5 villages with different breeding scales farmers in the towns are selected; then sample farmers are selected by random sampling. A total of 550 questionnaires were distributed during the survey, invalid samples such as missing data were eliminated, and finally, 514 valid samples were employed in the data analysis, which accounts for 93.46% of the total sample. The sample includes 194 farmers from Hebei, 156 farmers from Henan, and 164 farmers from Hubei. Besides, considering some differences in farmers' behaviors to report dead pig message due to different farm output, the research team implemented random sampling to categorize farmers based on their production in the survey. According to the study of Wu et al. [26] about the standard division of breeding scale, if the annual output of the farmers is less than 50 heads, the farmers are classified as free-range farmers. If the yearly production is between 50 and 499 heads, the farmers are regarded as professional farmers; if more than 499 heads, the farmers are called large-scale farmers. Among the 514 samples, 169 free-range farmers, 195 professional farmers, and 150 large-scale farmers, align with China's moderate-scale breeding trends and the olive-type breeding structure layout.

2.1.1. Explained variables

The explained variables consist of reporting decisions and reporting timeliness. Farmers not only have to fulfill their reporting obligations but also need to register on time. The former is called the reporting decision and belongs to a discrete binary variable. If the farmer chooses to report dead pig information, the assigned value is 1; if not, the assigned value is 0. Reporting timeliness is the time when the dead pig information is reported to the livestock department. Reporting timeliness is usually the critical point at which infectious diseases can be effectively controlled. China has not imposed a standard time constraint on "reporting timeliness," which generally refers to the first time of behavioral response. The livestock department usually sets a threshold of 2 h; if the farmer reports dead pig information within 2 h, it is deemed to be a timely report, and the value is assigned as 1. But if the farmer reports more than 2 h, it is considered as untimely reporting, and the value is set as 0.

2.1.2. Explanatory variables

The explanatory variable is the contract commitment system, which comprises farmers signing contract commitments with the livestock department, cooperative organization, and other farmers. If some contract commitment is signed, the value is 1; if not signed, the value is 0.

2.1.3. Control variables

The research also includes control variables as it is an empirical study, and government regulations and economic incentives are taken as main control variables. The supervision frequency characterizes government regulation measures, and the report subsidy represents financial incentive policies. Additionally, referring to related researches of Ramirez [27], farmers' characteristics, families characteristics, operating characteristics, and social aspects were used as other control variables as portrayed in Table 1.

2.2. Research method

Farmer's reporting of dead pig message is divided into two stages: reporting decision and reporting timeliness. The two stages are discrete

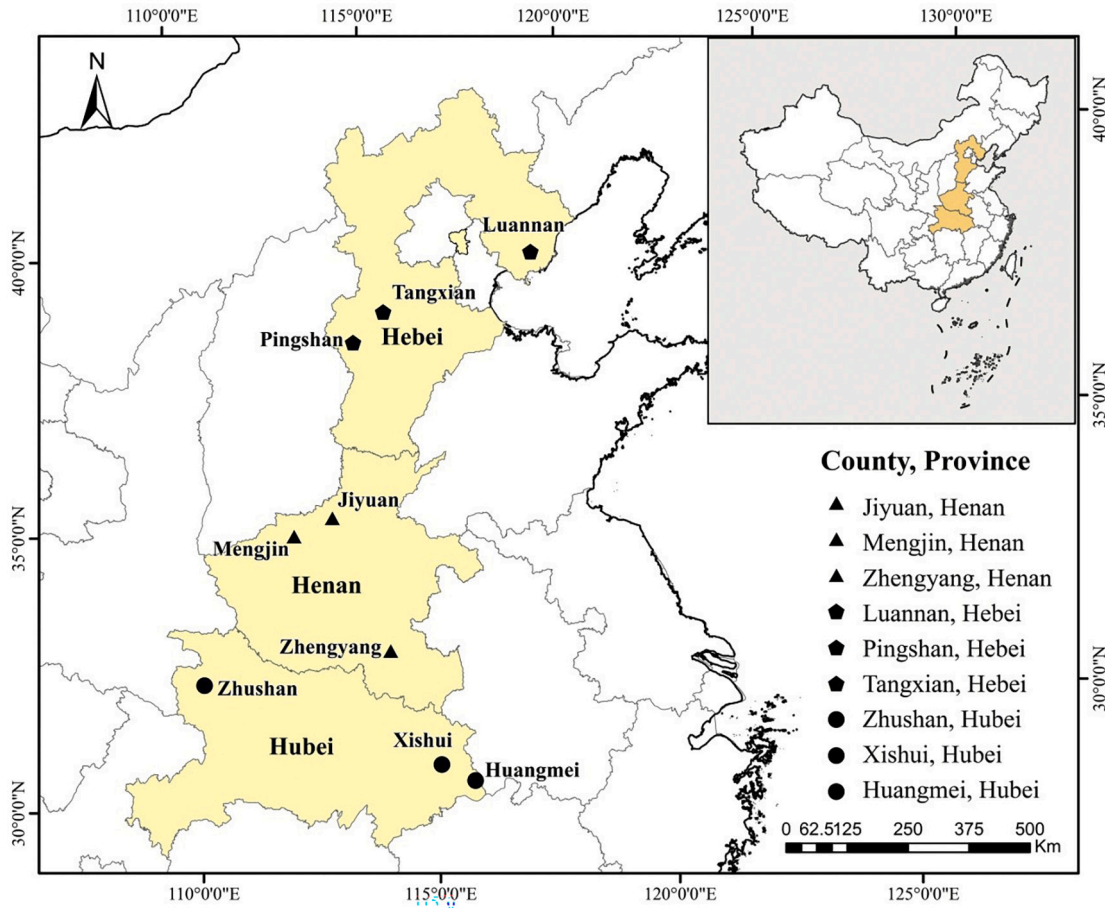


Fig. 1. Distribution of the sample counties (districts).

binary variables, so the Probit model is the best approach to analyze. However, only when a farmer makes the reporting decision can be further observed by reporting timeliness. So there is a problem of sample selection bias in farmers' reporting of a dead pig. The Heckprobit model proposed by Wyckhuys et al. [28] is used to control and test the two-stage Probit model's sample selection problem. The model is built as follows:

$$Y_{aj}^* = X_j\beta + u_{aj}, \text{ when } Y_{aj}^* > 0, Y_j^{probit} = 1, \text{ otherwise } Y_j^{probit} = 0 \quad (1)$$

$$Y_{bj}^* = Z_j\gamma + u_{bj}, \text{ when } Y_{bj}^* > 0, Y_j^{select} = 1, \text{ otherwise } Y_j^{select} = 0 \quad (2)$$

$$u_a \sim N(0, 1)$$

$$u_b \sim N(0, 1)$$

$$corr(u_a, u_b) = \delta$$

According to formulas (1) and (2), if $Y_j^{select} = 1$, the farmer makes the reporting decision, Y_j^{probit} will be observed; that is, the reporting timeliness will be obtained.

Among them, Y_{aj}^* and Y_{bj}^* represent unobservable latent variables, Y_j^{probit} and Y_j^{select} represent observable dummy variables (explained variables), X_j and Z_j represent explanatory variables, including control variables and regional dummy variables, respectively. β and γ are coefficients to be estimated, u_{aj} and u_{bj} are random error terms, which meet the standard normal distribution, the expected value is 0, and the variance is 1. The correlation coefficient is ρ , j represents the observation sample. When $\delta \neq 0$, the value probability can be obtained and a log-likelihood function can be generated.

$$\begin{aligned} prob[Y_j^{select} = 0|X, Z] &= 1 - \Phi(Z'\gamma) \\ prob[Y_j^{probit} = 0, Y_j^{select} = 1|X, Z] &= \Phi_2(-X'\beta, Z'\gamma, -\delta) \\ prob[Y_j^{probit} = 1, Y_j^{select} = 1|X, Z] &= \Phi_2(X'\beta, Z'\gamma, \delta) \end{aligned} \quad (3)$$

$$lnL = \sum_{m_1} ln\{\Phi(-Z'\gamma)\} + \sum_{m_2} ln\{\Phi_2(-X'\beta, Z'\gamma, -\delta)\} + \sum_{m_3} ln\{\Phi_2(X'\beta, Z'\gamma, \delta)\}$$

According to formula (3), m_1 represents the sample when $Y_j^{select} = 0$, m_2 represents the sample when $Y_j^{select} = 1$ and $Y_j^{probit} = 0$, m_3 represents the sample $Y_j^{select} = 1$ and $Y_j^{probit} = 1$, and $\Phi(\cdot)$ is the cumulative normal distribution function.

Also, if the Heckprobit model is employed, in that case, the identification of at least one variable is required, which will affect the selection equation (reporting decision) but not result in the equation (reporting timeliness). Therefore, moral and obligation perception is introduced as the identification variable in formula (3). The main reason is that moral and obligation perception is an essential driving factor for farmers' decision behaviors [29]. The stronger the sense of moral and obligation, the farmer tends to make reporting decisions, but there is no direct causal relationship with reporting timeliness. In the survey, the question is, "Is it unethical to discard or sell dead pigs?" If the answer is "Yes," it is assigned a value of 1; otherwise, it is assigned a value of 0. Therefore, the model can be extended as follows:

Table 1
Assignment and descriptive statistical analysis of variables.

Variables	Assignment of variables	Max	Min	Mean	SE
Explained variables					
Reporting decision	Reporting = 1, not reporting = 0	0	1	0.7782	0.4159
Reporting timeliness	Reporting timely = 1, not reporting timely = 0	0	1	0.6150	0.4872
Explanatory variables					
Farmer signing contract commitment with livestock department	Yes = 1, no = 0	0	1	0.6001	0.3815
Farmer signing contract commitment with cooperative organization	Yes = 1, no = 0	0	1	0.7325	0.4012
Farmer signing contract commitment with other farmers	Yes = 1, no = 0	0	1	0.6822	0.3906
Control variables					
Government regulatory measures	Supervision frequency	0	6	3.3562	1.0562
Economic incentive policies	Report subsidy (Yuan)	0	650	285.2015	32.4045
Gender	Male = 1, female = 0	0	1	0.9669	0.1790
Age	Actual age (year)	30	70	47.7082	8.6028
Education level	Actual year of schooling (year)	1	16	8.8502	2.5230
Net income	Amount of family net income (Thousand yuan)	-90	191	17.8652	32.8867
Number of laborers	Number of laborers over 16 years old (people)	1	8	2.5817	1.8285
Number of mobile phone or computer	Number of mobile phone or computer (part/set)	0	9	4.1556	2.2389
Breeding year	Engaged in breeding pig year (year)	1	37	8.6342	5.1703
Breeding scale	Number of breeding pig (head)	5	1965	471.0467	514.0692
Reciprocated farmer	Number of communicating with other farmers (people)	5	70	10.8813	9.2885
Acquired buyer	Number of communicating with pig buyers (people)	1	17	5.8152	3.8473

$$\begin{aligned}
 \text{prob}[Y_j^{\text{select}} = 0|X, Z] &= 1 - \Phi\left(\gamma_0 + \sum_{k=1} \gamma_{kj} Z_{kj}\right) \\
 \text{prob}[Y_j^{\text{probit}} = 0, Y_j^{\text{select}} = 1|X, Z] &= \Phi_2\left(-\beta_0 - \sum_i X_{ji} \beta_{ji}, \gamma_0 + \sum_{k=1} \gamma_{kj} Z_{kj}, -\delta\right) \\
 \text{prob}[Y_j^{\text{probit}} = 1, Y_j^{\text{select}} = 1|X, Z] &= \Phi_2\left(-\beta_0 + \sum_i X_{ji} \beta_{ji}, \gamma_0 + \sum_{k=1} \gamma_{kj} Z_{kj}, \delta\right)
 \end{aligned}
 \tag{4}$$

Where γ_0 and β_0 are the intercept terms in the equation. Finally, the maximum likelihood estimation method is adopted for estimation, and the corresponding statistics are used for testing parameters.

3. Results

3.1. Statistical analyses

To explore the relationship between the contract commitment system and farmer's reporting of dead pig (reporting decision and timeliness), the statistical inference of the relationship is first performed. The reporting decision and timeliness are grouped, and an independent sample *t*-test is performed on the mean differences of different groups' contract commitments as shown in Table 2. From the reporting decision, the results showed that the mean value of the contract commitment signed by a farmer with a livestock department, cooperative organization, and other farmers are significantly different. The differences are 0.1156, 0.1068, and 0.1160, respectively, indicating that the contract commitment system is positively correlated with the farmer's reporting decision. There is a significant difference between the mean value of the contract commitment signed by farmers with a cooperative organization and other farmers in reporting timeliness. The differences are 0.0576 and 0.0693, indicating that if the farmers make a contract commitment with the cooperative organization and other farmers, the dead pigs will be reported on time. However, there is no significant difference in the mean value of contract commitment between farmers and the livestock management department.

3.2. The impacts of contract commitment system

Table 3 shows the effect of the contract commitment system on farmer's reporting of a dead pig. It can be seen that the value of the Wald chi-square validates the significance test at the statistical level of 1%, indicating that the model fits better. A likelihood ratio test of the correlation coefficients between the two stages shows that the ρ value results are significant at 5%, indicating that the model rejects the native hypothesis " $\rho = 0$." The two phases of reporting decision and timeliness are interdependent, and the Heckprobit model employed is rational. Also, the moral and obligation perception has a positive and significant impact on farmer's reporting decisions. Still, it has no more tremendous influence on reporting timeliness, indicating that moral and obligation perception is suitable for identification variables.

According to Model 1, a farmer signing a contract commitment with the livestock department has a positive and significant impact on farmers' reporting decisions at a 5% significance level. Still, it does not influence farmers' reporting timeliness. Firstly, the livestock department promises to give farmers reporting subsidies and cull compensation, which can significantly alleviate operating losses caused by epidemic shocks [30]. Secondly, livestock breeding is an industry with a higher demand for land, credit, and insurance [31]. The livestock department implements the policy of linking dead pig reported with credit rating evaluation. The more times farmers report dead pig information, the more likely it is to obtain priority policies for more land, credit, and insurance [32]. Thirdly, the livestock department is usually the representative of administrative actions, and in practice, the contract performance is not balanced and negotiated [33]. So the trust and reliance

Table 2
T-test of the differences in the mean value of core variables.^a

Variables	Variables grouped				Differences	
	Reporting (A)	Not reporting (B)	Reporting timely (C)	Not reporting timely (D)	A-B	C-D
Farmer signing contract commitment with livestock department	0.8015	0.6859	0.6422	0.5935	0.1156***	0.0487
Farmers signing contract commitment with cooperative organization	0.7980	0.6912	0.6301	0.5725	0.1068***	0.0576**
Farmers signing contract commitment with other farmers	0.8064	0.6904	0.6520	0.5827	0.1160***	0.0693**

^a *, **, and *** represent significance at the 10%, 5%, and 1% probability levels, respectively.

Table 3
Estimated results of contract commitment impacts.^{a,b}

Explanatory variables	Model 1	
	First stage	Second stage
Farmer signing contract commitment with livestock department	0.3974** (0.1794)	0.2583 (0.2545)
Farmers signing contract commitment with cooperative organization	0.3714*** (0.1160)	0.1701*** (0.0607)
Farmers signing contract commitment with other farmers	0.1929*** (0.0643)	0.1397** (0.0607)
Government regulatory measures	0.2417*** (0.0691)	0.1055 (0.1248)
Economic incentive policies	0.2108** (0.0985)	0.0515 (0.1223)
Gender	0.9746** (0.4679)	0.2995 (0.4557)
Age	-0.0496*** (0.0135)	0.0175 (0.0145)
Education level	0.0901* (0.0496)	0.0132 (0.0385)
Net income	0.0053 (0.0058)	0.0052** (0.0027)
Number of laborers	-0.0115 (0.07889)	-0.0538 (0.0589)
Number of mobile phone or computer	0.1638*** (0.0545)	0.0013 (0.0461)
Breeding year	-0.0131 (0.0197)	-0.0121 (0.0189)
Breeding scale	0.0013*** (0.0004)	0.0001 (0.0002)
Reciprocated farmer	-0.0099 (0.0101)	0.0046 (0.0115)
Acquired buyer	0.0005 (0.0356)	-0.0641** (0.0280)
Moral and obligation perception	0.5430** (0.2378)	-
_cons	-0.3343 (0.2704)	-0.0968 (0.8358)
ρ value	0.0135**	
χ^2	24.62**	
Log-likelihood	-378.5151	
LR-test(p value)	0.3125	
N	514	

^a *, **, and *** represent significance at the 10%, 5%, and 1% probability levels, respectively.

^b Values outside the parentheses represent the regression coefficient values. Values in parentheses represent the standard error of robustness.

of farmers on subsidy and compensation policies are low, which creates hindrances in reporting dead pigs information by farmers on time [7].

Farmer signing contract commitment with the cooperative organization also exerts a positive and significant influence on farmers' reporting of the dead pig at a 1% statistical level. Predominantly, the relationship between farmer and cooperative organization is subjected to the organization's rules and regulations [34,35]. Meanwhile, cooperatives promote and support farmers' breeding of pigs through sharing information, supporting industry, and training technology, which can better drive farmers to report dead pig information [36].

Secondly, the market price of slaughter pigs fluctuates wildly, and the farmer's ability to withstand market risk is weak [37]. Joining cooperatives has become a "haven" for farmers to cope with market price risk because cooperatives can offer high-quality information and transportation services to alleviate the risk of the lower market prices [38]. Lastly, the geographical distribution between farmers and other cooperatives members is relatively concentrated. If farmers cannot report dead pigs promptly, then the spread of pathogens carried by dead pigs will lead to more risk vectors. Farmers, therefore, need to compensate for the direct losses suffered by other farmers [23].

Farmer signing contract commitments with other farmers are positively correlated with farmers' reporting decision and timeliness at significance levels of 1% and 5%, respectively. The possible explanations are the contract commitment signed by farmers whose farms are adjacent and have neighborly mutual assistance and social supervision attributes. It is also an essential part of the relationship network and social capital [39]. If the farmer conceals, misreports, and delays reporting dead pig information and then implement mishandling attributes such as discard actual selling, the neighboring farmers are more prone to bear the highest risk of pathogen exposure. Secondly, if farmers do not report the dead pig information in time and are learned by other farmers, the farmers' dangerous behaviors will threaten other farmers' production and operation. Then other farmers may choose to stop sharing their information and mutual assistance. Thirdly, farmers' reporting dead pig information is an essential part of social credibility. If a farmer loses social credibility, he will experience strict social supervision and face difficulty in obtaining social support such as information, technology, and loans provided by adjacent farmers [32,40]. Besides, other control variables, such as gender, educational level, net income, mobile phones or computers, breeding scale, and acquired buyers, are instrumental for farmers' reporting of dead pigs.

3.3. Moderating effects based on information reported channels

With the continuous improvement of rural infrastructure construction, modern communication equipment based on the 4G or 5G mobile phone and the Internet has become an essential part of family production [41]. But current communication channels affecting farmer's production behaviors are highly controversial. Wyckhuys et al. [28] stated that a mobile phone could help farmers obtain pest control information by raising awareness of pesticide application and even driving other small farmers to standardize pesticide application. The same notion was presented by Odhiambo [42], who believed that farmers could adopt new plant varieties by having modern agricultural information. However, other scholars didn't find the same results, such as Futch and McIntosh [43] in Rwanda proved that phones did not directly affect farmers' production decisions. The reasons for the differences in the above studies may be because the rural communication equipment is mainly in the form of government socialized service provision and the heterogeneity of farmers' information acquisition preferences and information literacy are ignored, which results in the mismatched of demand as well as insufficient information services.

Information-reported channels can also affect farmers' reporting of

the dead pig through sharing knowledge and allocation of resource mechanisms [44,45]. The information-reported media are divided into traditional informational channels such as farmers' face-to-face reporting and modern information reported channels such as the telephone or the Internet. Modern information-reported channels can improve reporting timeliness while depending on mobile communication stations or computer software and hardware rationing. Though traditional information reported channels are less time-sensitive, farmers prefer the livestock department to draw attention to the epidemic through the channel. Among the report samples, 167 farmers employed traditional information reported channels, and 233 introduced modern information reported channels (the data excluded farmers who adopted both). Since the contract commitment system and the moderator "information reported channels" are both categorical variables. Therefore, the grouping regression model is used to test the moderating effect of the information reported channel in the contract commitment system and the farmers' behaviors of reporting dead pigs.

The sample was divided into traditional information reported channels and not reporting (281 households) and the group of modern information reported channels and not reporting groups (347 households). Table 4 shows that unlike Model 1, the traditional information-reported channels (Model 2) have no significant correlation on the contract commitment system; that is, traditional information reported channels have no regulatory role in affecting farmers' behavior in reporting dead pig through the contract commitment system. From the modern information reported channels group (Model 3), compared with model 1, the contract commitment system significantly influences both farmer's reporting decisions and timeliness and entails that modern communication media in rural areas can prompt farmers to make reporting decisions, regarding reporting of the status of dead pigs to the livestock department within 2 h.

3.4. Heterogeneity analysis based on different sizes of farmers

Since the economic structure and social relationships embedded in farmers' different sizes are heterogeneous, existing studies on farmer's production behaviors have rarely considered the influencing factors of different sizes of farmers' behavior choices [46]. However, other scholars argued that considering the breeding scale as a classification index does not fully explain the farmers' production behaviors [47]. Therefore, this article further enriches the present literature by exploring the impact of the contract commitment system on farmers' reporting behaviors by taking breeding sizes as a classification standard

Table 4
The moderating effects based on information reported channel.^a

Explanatory variables	Traditional information Reported Channel Group (Model 2)		Modern Information Reported Channel Group (Model 3)	
	First stage	Second stage	First stage	Second stage
Farmer signing contract commitment with livestock department	0.1025*** (0.0441)	0.2732 (0.4275)	0.0935*** (0.0311)	0.0721*** (0.0225)
Farmers signing contract commitment with cooperative organization	0.0085** (0.0037)	0.0721** (0.0350)	0.1203*** (0.0462)	0.0926*** (0.0331)
Farmers signing contract commitment with other farmers	0.2212* (0.1228)	0.0915** (0.0421)	0.1215*** (0.0337)	0.0814*** (0.0232)
Control variables	Controlled		Controlled	
Regional dummy variables	Controlled		Controlled	
X ²	22.17***		24.25***	
N	281		347	

^a *, **, and *** represent significance at the 10%, 5%, and 1% probability levels, respectively.

and simultaneously considering the farmers' individual, family, operating, and environmental characteristics. It is apparent from Table 5 that Models 4 to 6 showed the estimated results of the impact of the contract commitment system on reporting dead pig of free-range, professional, and large-scale farmers.

Model estimation results show that signing contract commitment with cooperative organization and signing contract commitment between farmers has a vital role in free-range farmers' behaviors in reporting dead pig message. Nevertheless, the impact of contract commitment with the livestock department on free-range farmers' reporting behaviors is insignificant. Overall, the contract commitment system plays an important role in professional farmers' behaviors in reporting dead pig message. Additionally, signing a contract commitment with the livestock department is instrumental in large-scale farmers' reporting dead pig message. Still, the effects of signing contracts with the cooperative organization and signing contracts with other farmers are not noticeable.

4. Discussion

4.1. System innovation for livestock epidemic prevention and control

It is debated that prevention and control of livestock epidemics are related to the production safety of the breeding industry, animal-derived food safety, and public health safety. Information asymmetry is the main obstacle in the prevention and control of livestock epidemics [48,49]. Most countries worldwide have experienced many difficulties in exploring the potential measurement to combat livestock epidemics. Although biosafety measures strengthened the production process's inputs, there is also a dire need to actively encourage farmers to report dead livestock information on time [50]. Existing research such as Lian [14] also urged farmers to report dead livestock information on time. Still, it is only possible due to the simultaneous implementation of government regulations and economic incentives.

Compared to the existing research, this research is the pioneer one that conducted an empirical test to explore the effects of the contract commitment system. The outcome found the effectiveness of the contract commitment system in the prevention and control of livestock epidemics aligned with the previous studies, stated that government regulatory measures such as regulatory penalties and economic incentive policies are insufficient in prevention and control systems of livestock epidemics [51,52]. However, the conclusions cannot exclude the effectiveness of government regulations and economic incentives. Specifically, government regulation measures are challenging to form an endogenous driving mechanism for farmers to report dead livestock. Still, they can provide suitable system implementation environments or conditions for other prevention and control policies and measures [53,54]. Economic incentive policies are the primary measure recommended by various countries to strengthen the prevention and control of livestock epidemics disease and provide capital support for implementing the contract commitment system [55]. However, the subsidy standards in the incentive measures have been difficult to design. Thus, achieving the optimal policy efficiency and the incentive compatibility of the farmer regarding the reporting of dead livestock is still a problem that plagues the academic community. Therefore, the present research is useful in supplementing government regulatory measures and economic incentive policies and providing new ideas for improving epidemics prevention and control from multiple perspectives [56,57]. Therefore, this study does not advocate the abandonment of government regulatory measures and economic incentive policies but emphasizes the joint promotion of various efforts to maximize different measures' effectiveness.

4.2. Response to the controversial issues

This article responds to two controversial issues on the farmer's

Table 5
Estimation results of impacts based on different sizes farmers.^a

Explanatory variables	Free-range farmers (Model 4)		Professional farmers (Model 5)		Large-scale farmers (Model 6)	
	First stage	Second stage	First stage	Second stage	First stage	Second stage
Farmer signing contract commitment with livestock department	0.0522 (0.0448)	0.0621 (0.0532)	0.1025*** (0.0282)	0.1532 (0.2264)	0.1424*** (0.0445)	0.0833*** (0.0304)
Farmers signing contract commitment with cooperative organization	0.0884*** (0.0294)	0.0721*** (0.0248)	0.0285*** (0.0089)	0.0828*** (0.0290)	0.0165 (0.0192)	0.0428 (0.0399)
Farmers signing contract commitment with other farmers	0.0816*** (0.0313)	0.0312*** (0.0115)	0.1730** (0.0864)	0.0617** (0.0273)	0.1011 (0.0907)	0.0625 (0.0572)
Control variables	Controlled		Controlled		Controlled	
Regional dummy variables	Controlled		Controlled		Controlled	
X ²	17.65***		19.27***		16.10***	
N	169		195		150	

^a *, **, and *** represent significance at the 10%, 5%, and 1% probability levels, respectively.

production behavior compared with some existing research. Firstly, can modern communication channels represented by mobile phones or the Internet affect farmer's production behavior? The research results show that modern information-reported channels significantly enhance the impacts of the contract commitment system. Modern information transmission channels have an essential effect on farmers' production behavior [42]. They can improve agricultural productivity by providing sufficient technical information and influence farmers' production behaviors by optimizing resource allocation and reducing operating risks [58]. Just as Dione et al. [59] stated that, in the context of African swine fever, the popularization of modern communication technology could improve pig farmers' capacity of prevention and control epidemic and production efficiency. Therefore, strengthening hardware infrastructures such as mobile phone base stations or Internet equipment terminals can improve the reporting timeliness and continuously enhance epidemics prevention and control [60].

Secondly, considering breeding scale as a classification criterion, can it explain the difference in farmer's production behavior? The research conclusions found that the contract commitment system has a strong heterogeneity effect on reporting dead pig message of different scale farmers. So, an in-depth analysis of pig farmers' social and economic characteristics is also required [60]. Due to the differences in the internal mechanism of the contract commitment system's impact on different sizes farmers' reporting behaviors, empirical results show that it is not comprehensive to regard the rearing scale as the criterion for determining the strength of the system's impact [61]. Correspondingly, this provides the government's experience to optimize policy measures and steers farmers to report dead pigs actively.

4.3. Feasible countermeasures designed

The research conclusion draws some policy implications. The government should implement detailed rules of contract commitment system to strengthen the institutional and implementation process of contract commitment and promote the system normalization and standardization running [62]. Meanwhile, when the government formulates the contract commitment system's detailed rules, the role of the contract commitment system for different sizes of farmers should be considered. For various sizes of farmers, policies should be design in accord with the contract commitment system [63]. The government should strengthen the construction of epidemics reported channels and information platforms, fully introduce modern communications media in the report, continuously improve the information reported timeliness, and enhance the contractual commitment system's effect [64]. The government should not slow down the implementation of government regulatory measures and economic incentives, Still, it should continuously improve the regulatory mechanism and subsidy policies, achieve various steps to complement each other and mutual promotion, and maximize the system advantage of livestock epidemics prevention and control [10,63].

4.4. Limitations of the study

The successful practice of the contract commitment system in China provides a good experience in preventing and controlling livestock epidemics in other countries, especially for developing countries. Of course, there are still some deficiencies. The judgment of livestock epidemics depends much on farmers' professional skills, which affects the reporting timeliness. Because dead pigs may be caused by productive damage more rather than epidemics disease, it is difficult for free-range farmers to judge whether it is an epidemic or not. If asking farmers to report all dead pigs will also put more significant pressure on the livestock department for detecting [65]. Therefore, strengthening the ability and level of free-range farmers' epidemics judgment is essential for future research. Besides, considering that pig farms are densely distributed in China, the contract commitment signed between farmers has become a crucial part of the system. However, large-scale livestock farming in the Netherlands, Canada, and Mexico follow decentralized operations [66]. The risk of pathogen transmission in adjacent farms is relatively small, so there may be no objective conditions for a contract agreement. It is also a limitation of the application scope of this research conclusion.

5. Conclusion

In short, the contract commitment system has become an innovative exploration for the prevention and control of livestock epidemics. It plays an essential role in the prevention and control of livestock epidemics in China. Specifically, signing contract commitment with cooperative organization and signing contract commitment between farmers significantly correlate with farmers' reporting dead pig message. Signing contract commitment with the livestock department has a positive incentive effect on farmers' reporting decisions, but reporting timeliness is not apparent. Modern information reported channels have an influential impact on the contract commitment system affecting farmer's reporting behaviors; that is, the popularity of mobile phones or the Internet in rural areas can improve the reporting timeliness. Also, empirical results confirm that the contract commitment system has a firm heterogeneity in the effect of different sizes of farmers regarding reporting dead pig messages. The findings also emphasize that government should pay attention to government regulatory measures, and economic incentive policies and contract commitment systems, to promote and strengthen the epidemics prevention and control policies. Which may effectively maintain public health, secure the meat-derived food, and safeguard the livestock sector. Our research can draw further conclusions that China's contractual commitment system can provide useful experience to other developing countries and aid in preventing and controlling global livestock infectious diseases.

Availability of data and materials

The datasets generated and analyzed during the modern study are not publicly available but are available from the corresponding author on reasonable request.

Authors' contribution

Conceptualization, Methodology, and Software = Xueqian Zhang; Investigation, Data curation, and Formal analysis = Yumeng Yao; Writing original draft, Funding acquisition, and Project administration = Ruishi Si; Resources, Supervision, and Validation = Li Liu; Visualization, Writing - review & editing = Lu Qian.

Consent for publication

Not applicable.

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Declaration of Competing Interest

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.onehlt.2021.100302>.

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