




Risk Preference, Health Risk Perception, and Environmental Exposure Nexus: Evidence from Rural Women as Pig Breeders, China

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Abstract

Rural women are an integral part of the agricultural economy. Still, their exposure to environmental pollution, especially in the context of risk preference and health risk perception, has not gained much attention in the existing literature. So to explore this notion, a survey and experimental data of 714 rural Chinese women as pig breeders are taken, we innovatively evaluate the degree of environmental exposure from the pre-exposure, in-exposure, post-exposure intervention of women breeders, and two-stage least squares (2SLS) method is employed to address the endogeneity issue between health risk perception and environmental exposure. The results show that rural women breeders suffer from severe environmental exposure, and the degree of environmental exposure is up to 72.102 ($Min = 0$, $Max = 100$). Risk preference also emerges as a crucial determinant behind their environmental exposure, but health risk perception significantly deters the degree of environmental exposure. The health risk perception can offset risk preference effects on women breeders' environmental exposure by 15.15%. Moreover, considering the heterogeneity of the breeding scale, it is found that the impact of risk preference and health risk perception on women breeders' environmental exposure is an inverted U-shaped relationship, i.e., the results are at the turning stage when the breeding scale is 31–40 heads. Based on the empirical findings, the study offers guidelines for policymakers to enhance awareness amongst women breeders regarding health and pollution and encourage them to opt for environment-friendly breeding. Moreover, this research also has substantial guiding significance for related research on environmental exposure of rural women in other developing countries.

Keywords Risk preference · Health risk perception · Environmental exposure · Women breeders · Experimental economics · 2SLS

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1 Introduction

1.1 Health Damage and Governance Dilemma of LPM Pollution

In developing countries, the undisposed harmlessly livestock and poultry manure (LPM) generally contributes to a large amount of greenhouse gas emissions such as CH₄ and N₂O (Adegbeye et al., 2019; Post et al., 2020), sewage embodying urine and flushing water (Herrero et al., 2015; Leip et al., 2015), coupled with bacteria such as *Escherichia coli* and *Salmonella* (Więckol-Ryk et al., 2020), and viruses like African swine fever and pandemic influenza (Jurado et al., 2018) and eventually poses a severe threat to human health especially in rural areas (Sun et al., 2015). It is estimated that China's LPM production was around 4 billion tons in 2020. Still, the probability of harmless disposal or recycling, such as composting and fermentation, is less than 60%, and the total amount of undisposed LPM is as high as 160 million tons (Xu et al., 2020). Moreover, the drastically reduced farmland and farmers' livelihood transformation limits the proper and efficient application of LPM as organic fertilizer, which further limits the LPM's harmless disposal or recycling (Dong et al., 2020; Haase et al., 2017). Over the past 30 years, a rich body of literature is focusing on the carbon emissions reductions arising from LPM to cope with environmental pollution (Ali et al., 2020; Won et al., 2020), such as adopting harmless disposal technologies (Jeswani et al., 2019), and boosting recycling efficiency (Lonappan et al., 2016; Won et al., 2020). But in the context of human health, only a few studies paid attention to the health damage caused by LPM pollution (Andersen et al., 2012; Beek, 2010). In the existing literature, the studies in medicine are mainly based on theoretical and statistical analysis to deduce whether the LPM pollution negatively influences breeders' health or not. But empirical analysis of causal effects between LPM pollution and physical or mental health in context of economics is challenging that requires a long-term randomized controlled trial. The impact of other omitted variables such as age growth on health damage is also noticeable.

1.2 Reducing Environmental Exposure as Feasible Paths to Cut Off the Causal Relationship Between LPM Pollution and Breeders' Health Damage

Some scholars believe that LPM pollution causes damage to breeders' health, mainly human brain impairment (Cai et al., 2018; Zhang et al., 2018). Moreover, breeders have to work for a long time in environments comprised of feed dust, ammonia, and fecal bacteria arisen from manure, so they suffer from many other health problems such as coughing, fever, and shivering (Bontems & Thomas, 2006). Additionally, breeders' mental health is more susceptible to animal epidemics, production losses, as well as experiencing sudden deaths of livestock (Cai et al., 2018; Neethirajan, 2020). However, other scholars argued that mechanization, standardization, and large-scale breeding had brought significant improvements in the environment and manure recycling (Hoffmann et al., 2009). So now, the breeder's health is less likely to be affected by the LPM (Neethirajan, 2020; Yilmaz et al., 2013). Moreover, the present studies mainly explored the effect of LPM pollution on direct individuals' health instead of potential influencers, which are difficult to observe and evaluate. Academia generally considered that the reason for the above dispute may be the ignorance of breeders' heterogeneous degree of environmental exposure, as discussed by Wild (2005) and

Zhang et al. (2018) in their study stated that environmental exposure is a necessary path for the causal relationship between environmental pollution and health damage. When environmental pollution achieves natural purification or within the scope of people's tolerance, that is, the degree of people's environmental exposure is relatively low, health damage is minimal; when people are exposed to severe environmental pollution, it is inferred that health damage is inevitable. Therefore, academia generally believes that there are two notions concerning the cut off between the potential causal effects of environmental pollution and health damage: the first is to eliminate environmental pollution through the sustainable green production model; the second is to reduce environmental exposure when environmental pollution cannot be eliminated entirely (Post et al., 2020; Zhou et al., 2020). Unfortunately, adopting a green sustainable development model requires reconfiguring production factors and industrial transformation and upgrading, which still requires gradual progress for developing countries.

The concept of "exposure" formerly originated from a few occupational diseases and epidemics, which generally act as an intermediary between risk factors and resultant health effects as doctors are more susceptible to viruses exposure (Rappaport, 2011). So the "exposure" is different from the risk and is considered as an interaction effect of individuals' intervention and risk factors (Sogno et al., 2020). There are three broad exposure categories—internal (e.g., hormones, microflora), specific external (e.g., infectious disease, toxicants), and general external (e.g., social, psychological) (Santos et al., 2020). In recent years, much attention has been given to environmental issues. In this pursuit, the new concept of "environmental exposure" has also been developed and already applied in many fields such as medicine, transportation, urban geography, and urban planning (Poom et al., 2021). For instance, obesity, respiratory diseases, and various clinical illnesses have provoked the association of environmental exposure and its effects on residents' health (Sugiyama et al., 2018). Moreover, exposure to stressors such as bad air or water quality, noise, extreme heat, or an overall unnatural surrounding may endure the susceptibility to non-communicable diseases (Sogno et al., 2020). Besides, exposure to environmental factors such as green and blue environments, meteorological factors, noise, and air pollution has also been proven to impact residents' mental health directly (Boers et al., 2018; Dzhambov et al., 2018). Based on the above discussion, it is apparent that the existing studies focused on the assumption that environmental exposure significantly reduces individuals' health welfare. In fact, in addition to unobservable environmental risks, individuals may take positive or feasible actions to reduce health risks of environmental exposure through pre-exposure, in-exposure, and post-exposure interventions (Dai et al., 2020; Oskar & Stingone, 2020). Owing to the significant differences of individuals' risk management, results for environmental exposure may be significantly heterogeneous; that is, environmental exposure in the causal relationship between environmental pollution and health outcomes shows a mediation and threshold effect (Buck Louis et al., 2013; Shaffer et al., 2017). So academia generally argues that "environmental exposure" may provide another innovative path to solve this problem instead of how to implement a sustainable green production model and finally eradicate environmental pollution. In this regard, it is more advantageous to evaluate the degree of environmental exposure, analyze possible influencing factors, and explore the driving mechanism and countermeasures to reduce environmental exposure and effectively cut off the possible causal relationship between environmental pollution and breeders' health. The above discussion is conceptualized as below in Fig. 1.

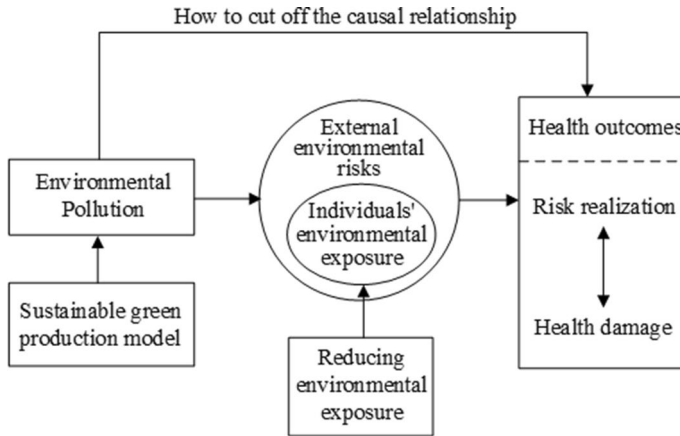


Fig. 1 Paths to remove the causal relationship between LPM pollution and health damage

1.3 Theoretical Analysis of Risk Preference, Health Risk Perceptions, and Women Breeders' Environmental Exposure

The pig breeders dealing with LPM are confronting with a series of environmental risk factors such as sewage, bacteria, viruses, and malodor (Dong et al., 2020). As discussed before, the degree of environmental exposure mainly describes the interactive results of breeders' intervention in response to environmental risk factors, which can also be considered as breeders' decision-making behaviour regarding risk. According to prospect theory, individuals' risk decision-making behavior is jointly determined by risk preference and subjective judgment for the probability of risk realization characterized by risk damage (Kahneman & Tversky, 1979). Risk preference is divided by risk-aversion, risk-neutrality, and risk-taking, and individuals' judgment for the probability of risk realization is represented by risk perception (Bo & Sterken, 2007). Thus, risk preference and risk perception are closely related to breeders' decision-making behavior regarding a series of risks. In particular, risk preference is an individual's attitude or persistent tendency towards risk factors (Elwell, 2009). Roumasset (1976) and Scott (1997) stated that farmers in developing countries are generally risk-aversion. Lence (2009) considers that due to incomplete information, the risk aversion attitude has significantly affected farmers' adoption of agricultural technology, implementation of protection measures, and investment of related funds. Qiu et al. (2014) believed that the higher risk aversion farmers are, the more inclined they are to over-apply chemical fertilizers. Zhu et al. (2016) argued that although new agricultural technologies or measures brought about specific risks, there are still significant differences in the willingness to adopt the technology by different farmers with risk-aversion, risk-neutrality, and risk-taking. However, other scholars considered that the classification criteria of risk preference are unclear and not strict. It is reasonable to employ an experimental economics method to measure the degree of risk preference (Duan et al., 2021; Nie et al., 2021).

Besides, scholars have also focused on the role of risk perception. Risk perception describes individuals' risk judgment on uncertainty and damage consequences (Slovic, 1987). Risk perception directly affects farmers' risk decisions (Kahneman & Tversky, 1984). The stronger the farmers' risk perception, the more likely they take risk

resistance behaviors (Weber & Milliman, 1997). Botzen et al.(2009) believed that the stronger the individual perceives flood risk, the more willing they are to buy sandbags to avoid risks. Bryan and Kandulu (2011) also stated that public health risk awareness has a positive and significant influence on farmers' participation in manure waste management. Si et al. (2020) believed that health risk perception exerts a positive and statistically influence on farmers' recycling behavior of carcass waste. Besides, some scholars also argued that, due to the heterogeneity of risk preference and risk perception, there is a crossed association between risk preference and risk perception, affecting individual risk decision-making behavior such as purchasing insurance and adopting conservation tillage (Lopes, 1986; Turvey et al., 2012). However, other scholars believe that the combined effects of risk-aversion, risk-neutrality, and risk-taking, as well as high-risk perception and low-risk perception, can be verified in theory. Still, actually, it is difficult to be observed and tested(Qiu et al., 2020a, 2020b). Consequently, we mainly measure the degree of risk preference and risk perception and further discuss the parallel effects of risk preference and risk perception.

Furthermore, in China, farmland transfer arouses surplus rural laborers, and the men urban-rural migration work has become the main labor distribution in rural families (Cao et al., 2020; Zhang et al., 2020; Si et al. 2020). Coupled with the demand for caring for the elderly and nurturing children, the women had also taken the responsibility of breeding livestock and poultry to subsidize the family income (Song et al., 2020). Given the small farming scale, the low proportion of green breeding, and insufficient disposal manure, many rural women are exposed to LPM pollution (Kuhn et al., 2020). Although the government requires breeders to implement green livestock and poultry rearing model through the rural revitalization strategy, it still takes a long time due to insufficient capital input. Moreover, although the government has established gender equality in legislation and granted women land rights; still women's rights concerns regarding their health, the voice for their rights are not supported and even taken for granted. Additionally, women in China residing in deprived rural areas have low health risk perceptions, putting their health conditions incredibly at worst for a long time (Li et al., 2020). Although some scholars have discussed rural women's cognitive health (Ginja et al., 2020), nutritional status (Perkins et al., 2019), pregnant women's health rights (Bussink-Voorend et al., 2020), and food insecurity issues (Sinclair et al., 2019), as well as cooking fuels impacting women's health (Imran & Ozcatalbas, 2020) in the existing studies. But as far as rural women breeders' environmental exposure is concerned, to our knowledge, no research is conducted before, which must be addressed on a prior basis.

So keeping in view the above discussion, our research contributes to the existing literature in four ways. Firstly, according to prospect theory, risk preference and health risk perceptions are incorporated into the unified framework for exploring the environmental exposure faced by women pig breeders in rural areas. Secondly, this research initially used exploratory factor analysis to measure the degree of environmental exposure from breeders' pre-exposure, in-exposure, and post-exposure interventions. Thirdly, based on the survey data of 714 rural women as pig breeders, we employed the 2SLS to address the endogeneity issue between health risk perception and environmental exposure and attempted to examine the effects of risk preference and health risk perception on women breeders' environmental exposure. Finally, according to the research conclusions, some targeted suggestions are put forth to reduce rural women's environmental exposure and gradually improve their health status. The research framework is shown in Fig. 2.

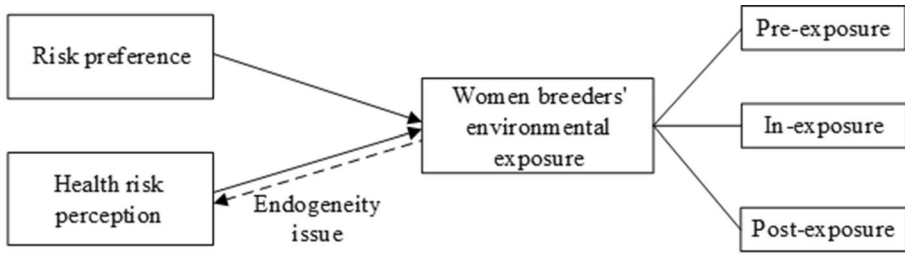


Fig. 2 Research framework of this paper

2 Materials and Methods

2.1 Study Area and Sample Collection

Based on the first survey conducted in 2018, the field survey was again carried out in nine counties of three provinces of China, i.e., Hebei, Henan, and Hubei provinces, from April 15th to May 10th, 2019 (see Fig. 3). The main reasons behind choosing these sample areas are their intensive engagement in pig rearing, which has become a backbone for boosting the agricultural economy of those areas. In 2018, the slaughtering numbers of pigs in Hebei, Henan, and Hubei were 30.04 million, 54.28 million, and 36.14 million, accounting for 4.33, 7.83, and 5.21 percent of the total number of slaughtered pigs in China (National Bureau of Statistics of China, 2019). According to the report of governmental

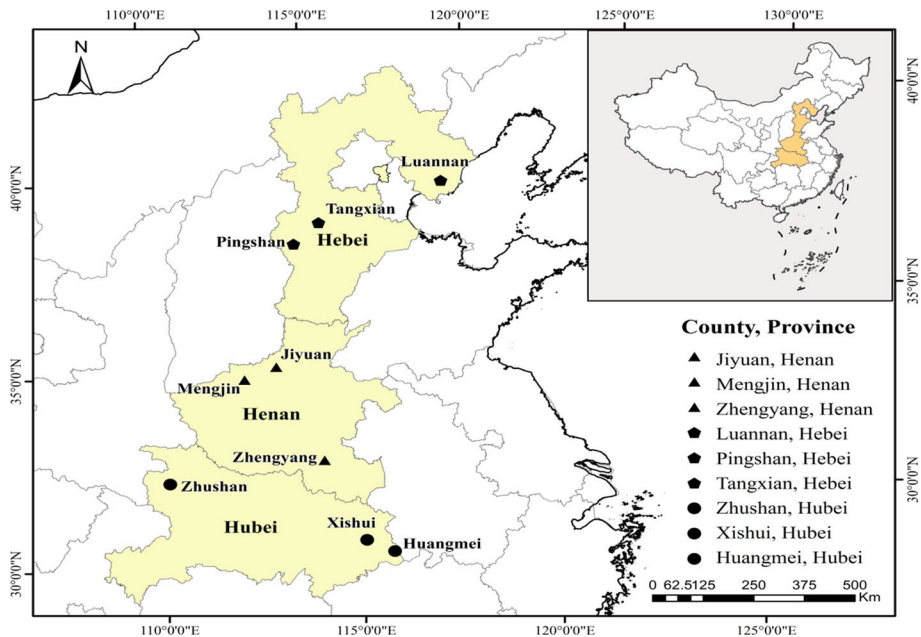


Fig. 3 Sample distribution area (Source: Arc GIS 10)

environmental supervision and inspection in 2018, it is documented that the proportion of pig rearing coupled with agricultural farming in these areas is only 13.50%, and the degree of standardized breeding is 35.15%. Moreover, the harmless disposal or recycling degree of the LPM is less than 50% (Wang et al., 2019). Hence, it is proven that the ecological environment in sample areas is seriously polluted by manure, so this survey area is an excellent representative to meet the desired objective of the study.

By following the sampling methods proposed by Kahneman and Tversky (1979) and Sharifzadeh et al. (2019), the research team also employed stratified and random sampling methods. Randomly 3–5 townships from each sample county were selected; from each township, 4–6 villages were randomly selected, and in the last stage, pig breeders from the villages were also randomly selected. The questionnaires were used to gather the data, and additionally, the research team also interviewed the heads of livestock departments. A total of 40 interview records comprised of a detailed grasp of the pig industry development, environmental manure pollution, environmental regulations, etc., in the sample areas were obtained. The questionnaire content mainly comprised the interviewees' characteristics, family and business characteristics, geographical, environmental conditions, risk perception, protective measures response to manure pollution, and government regulations. Before the formal survey, the research team conducted a pre-survey in Pingshan County, Hebei, and revised the questionnaire's content. A total of 800 questionnaires were distributed in the survey, and 35 invalid blank samples and 51 men as the prominent pig breeders were eliminated. The study sample from Hebei, Henan, and Hubei, was 233, 236, and 245 households. Finally, 714 valid samples of rural women as pig breeders were obtained for the study purpose, accounting for 89.25% of the total sample. Additionally, to verify the questionnaire's representativeness, we performed the questionnaire's reliability and validity test. The results showed that Cronbach's α is 0.805, and Kaiser–Meyer–Olkin (KMO) value is 0.760. The Bartlett sphere test ($p=0.000$) is also significant, which means that the questionnaire has good reliability and validity.

2.2 Variable Selection

2.2.1 Dependent Variable

The dependent variable is rural women as pig breeders' environmental exposure. A few scholars have conducted theoretical and empirical exploration in assessing the level of environmental exposure, such as Rappaport and Smith (2010) have conducted "bottom-up" environmental monitoring and "top-down" bio-monitoring. However, bio-monitoring alone can be challenging to connect to specific exposures, making risk assessment and intervention, including regulatory decisions, more challenging (Wild, 2012). Since environmental exposure is the interaction between environmental risks and individual behavior, it generally depends on particular intervention (Oskar & Stingone, 2020). Thus, we employed the exploratory factor analysis to evaluate the degree of environmental exposure from the perspective of behavioral economics, including women breeders' pre-exposure, in-exposure, and post-exposure intervention. Measurement items of the dependent variable are shown in Table 1.

The result of the rotated factor loading matrix of environmental exposure is presented in Table 2. From the table, it is clear that the KMO value is 0.765, and the Bartlett sphere test (approximate chi-square value) is 4424.898 ($sig.=0.000$), pointing that all variables are suitable for factor analysis. This paper employed the maximum variance method for factor

Table 1 Measurement items of environmental exposure

Variables	Measurement Items	Items	Max	Min	Mean	S. D
Pre-exposure intervention (<i>PRE</i>)	Disinfection times in the pen/week (times)	<i>DT</i>	7	1	2.75	0.36
	Ventilation time in the pen/day (hours)	<i>VT</i>	1.5	0	0.25	0.22
In-exposure intervention (<i>INE</i>)	Whether equipped with manure harmless disposal or recycling equipment or facilities (1 = yes, 0 = no)	<i>WE</i>	1	0	0.37	0.19
	Working times in the barn/day (times)	<i>WT</i>	6	3	3.82	1.15
	Working hours in the barn/days (hours)	<i>WH</i>	4.5	0.5	1.64	0.77
	Degree of individual protection (1 = no protection, 2 = mask or gloves, 3 = wearable work clothes, 4 = professional anti-pollution clothes)	<i>DI</i>	4	1	2.29	0.42
Post-exposure intervention (<i>POE</i>)	The proportion of manure harmless disposal or recycling through biological fermentation or biogas (0–1)	<i>PM</i>	0.72	0	0.28	0.12
	Whether performing personal disinfection/day (1 = yes, 0 = no)	<i>WP</i>	1	0	0.35	0.20
	Whether changing personal clothes/day (1 = yes, 0 = no)	<i>WC</i>	1	0	0.42	0.19

Note: Reference to Yue et al.'s (2019) related research, this survey takes the emission index of fattening pigs as the calculation standard. Stool discharge per pig/day (*M*) is 2.34 kg, urine and sewage discharge per pig/day (*US*) is 2.72 kg, and the pigs' average growth period (*G*) is four months. If the number of fattening pigs bred in the family is *N*, the total amount of manure discharge (*T*) = (*M* + *US*) * *G* * *N*. By querying the sewage tank volume used for manure harmless disposal or recycling (*V*), the proportion of manure harmless disposal or recycling can be calculated as *V/T*

Table 2 Rotated factor loading matrix of environmental exposure

Variables	PRE	INE	POE
DT	0.862	0.352	0.003
VT	0.701	0.019	0.029
WE	0.754	0.054	0.102
WT	0.292	0.072	0.304
WH	0.302	0.086	0.254
DI	0.007	0.081	0.026
PM	0.002	0.029	0.065
WP	0.194	0.025	0.071
WC	0.018	0.201	0.076
Variance contribution rate (%)	25.710	23.052	22.064
Cumulative variance contribution rate (%)	70.826		
Bartlett sphere test (Approximate chi-square value)	4424.898		
KMO value	0.765		
Sig	0.000		

Source Field Survey (2019)

rotation to make the results more reasonable and robust. The principal component method is applied to extract the three common factors having an eigenvalue greater than 1. The cumulative variance contribution rate is 70.826%. Finally, each common factor's variance contribution rate is regarded as the weight. The factor scores (Factor1-Factor3) of the three dimensions of environmental exposure are weighted and summed to calculate the degree of environmental exposure. The specific calculation formula is:

$$\begin{aligned} & \text{Degree of environmental exposure} \\ & = 25.710 \times \text{Factor 1} + 23.052 \times \text{Factor 1} + 22.064 \times \text{Factor 1} \end{aligned} \quad (1)$$

Given some negative factor analysis results, to make the result more intuitive, the sample's factor value is converted into an index of 1–100 by following Bian and Li (2000). The conversion formula is as follow:

$$\begin{aligned} \text{Factor}_{\text{afterconversion}} &= (\text{Factor}_{\text{beforeconversion}} + B)A \\ A &= 99 / (\text{Factor}_{\text{max}} - \text{Factor}_{\text{Minimum}}) \\ B &= [((\text{Factor}_{\text{max}} - \text{Factor}_{\text{Minimum}}) / 99)] - \text{Factor}_{\text{Minimum}} \end{aligned} \quad (2)$$

$\text{Factor}_{\text{afterconversion}}$, $\text{Factor}_{\text{beforeconversion}}$, $\text{Factor}_{\text{max}}$, and $\text{Factor}_{\text{Minimum}}$ represent the factor value of each sample after and before conversion, the maximum and minimum values of factors in all samples before conversion, respectively.

2.2.2 Independent Variables

The independent variables mainly include risk preference and health risk perception. Drawing on the views of Kachelmeier and Shehata (1992) and Charness et al. (2013), we applied experimental economics to measure the degree of women breeders' risk preferences. The research team designed 12 game plans in the questionnaire, and the respondents were asked to choose one by one from each plan. Once the respondent chose each plan, the

investigator presented the next set of game plans. If the respondent chooses option B in each stage of game plans, then the respondent can't choose option A in subsequent games. Option A means winning a lottery ticket (the probability of winning is 50%, and the winning amount is 600 yuan). Option B donates winning a fixed amount (showing an increasing trend from 50 to 599 yuan). Compared with choosing option A, choosing option B indicates that the respondents have a lower risk preference. Table 3 shows the experimental design of women breeders' risk preferences.

According to the data obtained from the experiment and the view of Qiu et al. (2015), the respondents' risk preference level is calculated by using the following formula:

$$RP = 1 - \frac{\text{The number of choosing B}}{12} \quad (3)$$

where *RP* represents the respondents' risk preference degree, if the respondents choose option A for all 12 options, the risk preference value is 1, indicating that they are incredibly risk-taking. If all respondents choose option B for all options, their risk preference value is 0, donating that the respondents are fully risk-aversion. Besides, women breeders' health risk perception is another crucial explanatory variable. The respondent is asked, "Do you think the environment pollution of the LPM harm your body or mind health?" The answer range is "1 = not possible at all, 2 = not possible, 3 = general, 4 = possible, 5 = very possible".

2.2.3 Control Variables

Some control variables such as women breeders' characteristics (age, education level, environmental pollution perception), family characteristics (number of migrant labors, area of farmland), business characteristics (breeding time, the proportion of breeding income), social network (channels of health information acquisition, number of communicating with other

Table 3 Experimental design of rural women as pig breeders' risk preferences

Coding of the game plan	Option A: getting a lottery ticket (50% probability of getting 500 yuan)	Option B: getting a fixed amount(yuan)
01	The probability of getting 600 yuan is 50%	50
02	The probability of getting 600 yuan is 50%	100
03	The probability of getting 600 yuan is 50%	150
04	The probability of getting 600 yuan is 50%	200
05	The probability of getting 600 yuan is 50%	250
06	The probability of getting 600 yuan is 50%	300
07	The probability of getting 600 yuan is 50%	350
08	The probability of getting 600 yuan is 50%	400
09	The probability of getting 600 yuan is 50%	450
10	The probability of getting 600 yuan is 50%	500
11	The probability of getting 600 yuan is 50%	550
12	The probability of getting 600 yuan is 50%	599

Note 1yuan equals 0.1473 USD

Table 4 Statistical analysis of variables

Variables	Definition	Mean	S.D	Sources
Environmental exposure	The result of factor analysis (after conversion)	72.102	9.651	Li (2016)
Risk preference	The result of the experiment analysis	0.712	0.144	Holt and Laury (2002)
Health risk perception	The possibility of manure environment pollution harming health (1 = not possible at all-5 = very possible)	3.052	0.401	Akter et al. (2018)
Age	The actual age of women breeders(years old)	49.282	5.275	Amfo and Ali (2020)
Education level	Education experience(years)	7.152	1.080	Below et al.(2012)
Environmental pollution perception	The possibility of breeding pigs polluting the ecological environment (1 = not possible at all-5 = very possible)	2.451	0.706	Zhou et al.(2020)
Number of migrant labours	Number of migrant laborers over 16 years old(people)	2.015	0.407	Chan (2010)
Area of farmland	The actual area of farmland (Mu)	7.172	1.091	Verburg and Overmars (2009)
Breeding time	Time engaged in breeding pig (year)	14.279	3.064	Molnár and Fraser (2020)
The proportion of breeding income	The proportion of breeding income to family income	0.171	0.059	Xu et al. (2020)
Channels of health information acquisition	Mobile or computer internet = 1, Empirical judgment = 0	0.201	0.036	Xu et al.(2020)
Number of communication with other breeders	Number of communication with other breeders(people)	6.010	1.057	Spielman et al. (2011)
Breeding skills training	The time duration of participating in breeding technology training (Time duration)	2.056	0.401	Connie (2015)
Health education training	The time duration of participating in health education training (Time duration)	0.729	0.101	Mhlongo et al. (2020)

breeders), and government support (breeding skills training, health education training) are also incorporated in the model. The descriptive statistics of variables are shown in Table 4, and it is found that rural women breeders experience severe environmental exposure, and the degree of environmental exposure is 72.102 ($Min=0$, $max=100$). They have a low level of health risk perception ($Mean=3.052$) and a high level of risk preference ($Mean=0.712$). Our interviews further confirmed that women farmers are willing to bear environmental pollution to increase income. The respondents' average age is 49.282, and they mainly have received primary and secondary education. What needs attention is that rural women's environmental pollution awareness is relatively weak ($Mean=2.451$), which indirectly reflects that women as pig breeders in the study area face higher health risks.

2.3 Model Design

The ordinary least square (OLS) is a standard and optimized method to minimize the error square and to give the best fit to the data (Lee et al., 2012). The role of OLS is that (1) the position data can be obtained by the OLS, and the sum of squared errors between position data and the actual data is the smallest; (2) the OLS can also be applied for curve fitting, such as adding interaction or square terms (Lin & Benjamin, 2018). Thus, to empirically examine the effects of risk preference and health risk perception on rural women breeders' environmental exposure, the ordinary least square (OLS) model is constructed as follows:

$$EP_{wpb} = \lambda + \beta_1 RP + \beta_2 HRP + \beta_3 PE + \mu \quad (4)$$

where EP_{wpb} signifies the degree of environmental exposure, RP donates women breeders' risk preference, HRP indicates women breeders' health risk perception and PE are the control variables, λ , β_1 , β_2 , β_3 are some coefficients to be estimated, μ is the error term.

Considering that there may occur simultaneity bias in the formula (4), that is, environmental exposure may also affect women breeders' health risk perception, for instance, breeders aware of possible respiratory disease risks may already take intervention measures, so their perception regarding health risk is already much more potent as compared to others. So to deal with this issue, an instrumental variable method is employed to cope with the endogeneity of health risk perception. By following the previous study of Frankel and Romer (1999), the nearest distance between breeder and hospital is taken as the instrumental variable. It is assumed that if the nearest distance is closer, then the breeders' health protection awareness and the level of health risk perception can be more robust and higher. In contrast, the nearest distance between breeders and hospitals can not directly influence the degree of women breeders' environmental exposure.

Finally, we employed the two-stage least squares (2SLS) regression approach to meet the study objective. The first stage is to make regression for the factors affecting women breeders' health risk perception. The specific form of the model is as follows:

$$HRP = \theta + \alpha_1 RP + \alpha_2 PE' + \alpha_3 IV + \varepsilon \quad (5)$$

where θ donates the intercept term, PE' indicates the control variables, IV signifies the instrumental variable, α_1 , α_2 , α_3 are some coefficients to be estimated, ε is an error term, the meanings of other variables are the same as formula (4).

3 Results

3.1 Correlation Test

A correlation test refers to analyzing two or more variables correlated (Erdfelder et al., 2009; Kong et al., 2020). The relationships between risk preference, health risk perception and women breeders' environmental exposure are also illustrated by the histograms and trend charts between risk preference and environmental exposure (*mean*), as well as health risk perception and environmental exposure (*mean*) respectively (Figs. 4, 5). It can be seen that there is a positive correlation between risk preference and women breeders' environmental exposure. Health risk perception has a negative correlation with women breeders'

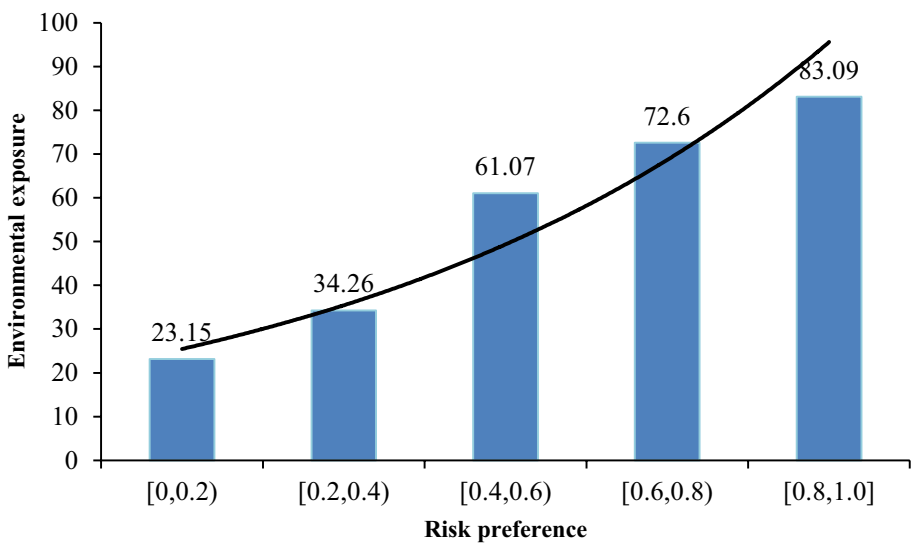


Fig. 4 Relationships between risk preference and environmental exposure

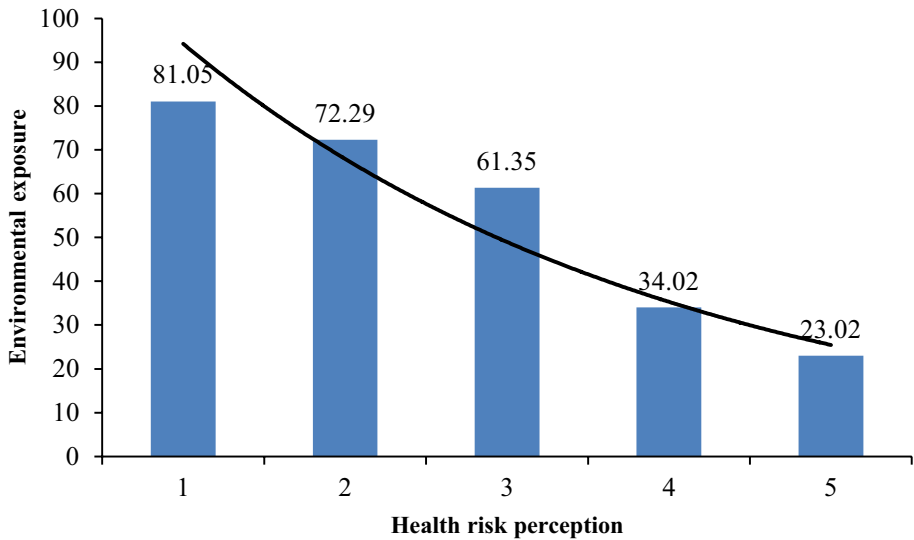


Fig. 5 Relationships between health risk perception and environmental exposure

environmental exposure. It infers that health risk perception weakens the effect of risk preference on women breeders' environmental exposure.

3.2 Multi-Collinearity Test

Multi-collinearity refers to the fact that the explanatory variables' precise or high correlation makes the linear regression model distorted or difficult to estimate (Jaafari et al., 2018). The variance inflation factor (VIF) is a reliable measure index of the variables' multi-collinearity, representing the ratio of the regression coefficient's variance to the

Table 5 Results of the multi-collinearity test

Explained variable	Explanatory variables	Multi-collinearity diagnosis	
		VIF	1/VIF
Age	Education level	1.076	0.929
	Environmental pollution perception	1.286	0.778
	Number of migrant labours	2.012	0.497
	Area of farmland	1.962	0.510
	Breeding time	2.259	0.443
	The proportion of breeding income	1.460	0.685
	Channels of health information acquisition	2.001	0.500
	Number of communicating with other breeders	1.205	0.830
	Breeding skills training	1.208	0.828
	Health education training	1.907	0.524
	VIF mean		1.638

Source Field Survey (2019)

variance when the independent variables are assumed to be non-linearly correlated (Su et al., 2020). In this research, we conducted the linear regression based on breeders' age regarded as explained variable and other variables attributed to explanatory variables. Finally, we obtained the variables' VIF values. Table 5 shows the multi-collinearity test results. It is apparent that the maximum value of VIF is 2.259, the minimum value is 1.076, and the average value is 1.638, denoting that the explanatory variables do not have severe multi-collinearity.

3.3 Validity Test of Instrumental Variable

The validity of instrumental variables is necessary to get consistent estimates (Maydeu-Olivares et al., 2019). Testing methods mainly include weak instrumentals test, which means instrumental variables are not related to endogenous variables and over-identification test, aiming to exclude unknown instrumental variables (Achten & Lessmann, 2020). Firstly, as shown in Table 6, the closest distance between breeder and hospital exerts a positive and significant effect on women breeders' health risk perception. Still, it doesn't impact the degree of environmental exposure. Therefore, the instrumental variable is positively

Table 6 Results of 2SLS model estimation

Variables	The first stage (Health risk perception)		The second stage (Environmental exposure)	
	coefficient	Standard error	coefficient	Standard error
Risk preference	0.0724***	0.0226	0.0825**	0.0359
Health risk perception			-0.1726***	0.0595
Age	0.0429	0.0371	0.0219	0.0180
Education level	0.0701*	0.0389	-0.0409**	0.0184
Environmental pollution perception	0.0017	0.0142	-0.0025**	0.0011
Number of migrant labours	0.0102	0.0072	0.0601	0.0408
Area of farmland	0.0591	0.0405	-0.0072	0.0109
Breeding time	-0.0202***	0.0051	0.0708***	0.0176
Proportion of breeding income	0.0005	0.0117	0.0621	0.0520
Manure harmless or recycling equipment or facilities	-0.0704*	0.0380	-0.0409*	0.0228
Channels of health information acquisition	0.0601***	0.0201	-0.0108	0.0075
Number of communicating with other breeders	0.0027	0.0126	-0.0071	0.0203
Breeding skills training	0.0065*	0.0036	-0.0302	0.0131
Health education training	0.0617***	0.0167	-0.0921**	0.0413
The closest distance between breeders and hospital	-0.0348**	0.0160	-0.0006	0.0125
Constant term	0.2926***	0.0845	0.4062***	0.1456
R ²	0.3031			
DWH test χ^2 (P value)	8.0725***			
	(0.0014)			
F value of the first stage	12.0426***			

Notes *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

correlated with endogenous variables (health risk perception) but not closely related to the dependent variable. It is also concluded that the instrumental variables are identifiable. Secondly, the Durbin-Wu-Hausman (DWH) test value of 8.0725 is significant at 1%, supporting the rejection of the null hypothesis and assuming that health risk perception is an exogenous variable. Equation (4) has serious endogeneity. Thirdly, the weak instruments is judged based on F value in first regression, if the F value is greater than 10, the null hypothesis, i.e. the instrumental variable is weak, and is rejected (Xu et al., 2018). Table 5 shows that the F value is 12.0426 ($P < 0.01$) and the instrumental variable chosen in the current study is relatively appropriate and reasonable.

3.4 Results of 2SLS Model Estimation

Table 6 shows the influencing factors of health risk perception (the first stage) and the effect of risk preference and health risk perception on women breeders' degree of environmental exposure (the second stage). It is found that (1) the risk preference positively and significantly affects women breeders' health risk perception; if the degree of risk preference increases by 1 unit, women breeders' level of health risk perception will increase by 7.24%. (2) Risk preference positively influences breeders' environmental exposure. If the degree of risk preference increases by 1 unit, women breeders' degree of environmental exposure will increase by 8.25%. Nevertheless, health risk perception has a significant and statistically negative effect on women breeders' environmental exposure. Suppose health risk perception increases by 1 unit, women breeders' degree of environmental exposure will decrease by 17.26%. Moreover, the R^2 is 0.3031, indicating that the overall fitting result is good.

Moreover, based on the above analysis, it is concluded that risk preference, directly and indirectly, affects women breeders' degree of environmental exposure. Among them, the indirect effect depends on the breeders' level of health risk perception. To explore the role of the health risk perception, the impact of risk preference on women breeders' degree of environmental exposure is further analyzed by the direct and indirect impact of risk preference on the breeders' environmental exposure through constructing simultaneous equations. Accordingly, we combined Eqs. (4) and (5) to obtain the simplified equation as follows:

$$EP_{wpb} = \lambda + (\beta_1 + \beta_2\alpha_1)RP + \beta_2\alpha_2PE' + \beta_3PE + \beta_2\alpha_3IV + \mu + \theta\beta_2 + \varepsilon\beta_2 \quad (6)$$

where $(\beta_1 + \beta_2\alpha_1)$ signifies that the comprehensive effects of risk preference on breeders' degree of environmental exposure $\beta_2\alpha_1$ indicate the indirect impact and β_1 denote direct impact. From Table 5, it is apparent that the direct effect of risk preference on women breeders' environmental exposure is 0.0825, the indirect effect is -0.0125 (-0.1726×0.0724), and the indirect effect can offset 15.15% (ratio of indirect influence to direct influence) of the direct effect. Hence, health risk perception can reduce risk preference on women breeders' degree of environmental exposure.

Additionally, some control variables influencing women breeders' degree of environmental exposure show that education level, environmental pollution perception, and health education training can significantly reduce women breeders' degree of environmental exposure if the education level increases by one year, women breeders' degree of environmental exposure will decrease by 4.09%. If environmental pollution perception increases by one unit, women breeders' degree of environmental exposure will reduce by 0.25%. Moreover, if health training duration increases by one period, women breeders' degree of

environmental exposure will decrease by 9.21%. Besides, breeding time can also significantly increase women breeders' environmental exposure; if the breeding time increases one year, women breeders' degree of environmental exposure will increase by 7.08%.

3.5 Heterogeneity Analysis: Based on the Breeding Scale

In theory, the larger the breeding scale, the more the manure waste and the higher the degree of environmental exposure (Kovačiková et al., 2020). In fact, in light of the specific research object, small and medium-scale women breeders in rural areas are focused rather than large-scale breeding companies or farms, with a higher manure disposal capability, less human capital investment, and a higher degree of standardized breeding (Wang et al., 2019). The economic structure and social relationships embedded in different breeding scales are heterogeneous (Si et al., 2020). Taking a breeding scale as a classification standard can deeply explain the heterogeneity of women breeders' environmental exposure in this research. Hence, we examined the effects of risk preference and health risk perception on different-scale women breeders' environmental exposure. In the sample, the maximum pig breeding scale is 49 heads, the minimum is two heads, and the average is 32.172 heads ($S.D. = 4.064$). Accordingly, we applied the group regression method and the 2SLS method to estimate the effects of the breeding scale's heterogeneity in Table 7.

The results showed that risk preference and health risk perception have no statistically significant influence on women breeders' environmental exposure with 2–10 heads. However, as the breeding scale gradually increases, the influence coefficient of risk preference gradually increases. The coefficient of health risk perception gradually decreases, indicating that the effect of risk preference and health risk perception on environmental

Table 7 Results of 2SLS model estimation based on the heterogeneity of breeding scale

Variables	The first stage (Health risk perception)		The second stage (Environmental exposure)	
	Coefficient	Standard error	Coefficient	Standard error
Scale: 2–10 heads (131 breeders)				
Risk preference	0.0214	0.0171	0.0125	0.0089
Health risk perception			– 0.0126	0.0132
Scale: 11–20 heads (141 breeders)				
Risk preference	0.0410*	0.0227	0.0175**	0.0079
Health risk perception			– 0.0106*	0.0057
Scale: 21–30 heads (145 breeders)				
Risk preference	0.0515*	0.0271	0.0375***	0.0125
Health risk perception			– 0.0306*	0.0161
Scale: 31–40 heads (152 breeders)				
Risk preference	0.0670**	0.0304	0.0512**	0.0244
Health risk perception			– 0.0426**	0.0177
Scale: 41–49 heads (143 breeders)				
Risk preference	0.0419*	0.0229	0.0266*	0.0140
Health risk perception			– 0.0206*	0.0114

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

exposure of women breeders with 11–40 heads is steadily increased. Surprisingly, the effects of risk preference and health risk perception on breeders' environmental exposure of women breeders' environmental exposure with 41–49 heads are unexpectedly weaker. Further, this trend of effects of risk preference and health risk perception is consistent with the offsetting effect of health risk perception with 2.15%(2–10 heads) < 2.48%(11–20 heads) < 3.24%(41–49 heads) < 4.20%(21–30 heads) < 5.57%(31–40 heads) > 3.24%(41–49 heads). Hence, it is concluded that the effect of risk preference and health risk perception on women breeders' environmental exposure is an inverted U-shaped relationship.

3.6 Robustness Checks

In this research, we employed a method of replacing instrumental variables for the robustness check. The relationship network's range and strength can significantly improve the individual's risk perception level (Fan et al., 2019; Meza et al., 2020). Suppose women breeders have more relatives and friends engaged in health-related work, such as doctors, health insurance sales personnel, health department personnel, etc., in that case, there will be a higher level of health risk perception. Thus, we modified the instrumental variable to "number of relatives and friends engaged in health-related work" and examined the effects of risk preference and health risk perception on women breeders' degree of environmental exposure. From Table 8, it is clear that risk preference exerts positive and significant effects on women breeders' health risk perception and environmental exposure. However, health risk perception significantly inhibits the women breeders' degree of environmental exposure. Accordingly, improving the level of health risk perception weakens the effects of risk preference on women breeders' environmental exposure significantly. The number of relatives and friends engaged in health-related work has a positive and statistically significant impact on health risk perception. Still, it does not affect women breeders' degree of environmental exposure. Therefore, there is no significant difference between the robustness test results in Table 8 and the benchmark regression results in Table 6, indicating that the 2SLS model estimation results are relatively robust.

Table 8 Results of the robustness test

Variables	The first stage (Health risk perception)		The second stage (Environmental exposure)	
	Coefficient	Standard error	Coefficient	Standard error
Risk preference	0.0723***	0.0210	0.0819**	0.0375
Health risk perception			-0.1725***	0.0536
Number of relatives and friends engaged in health-related work	0.0427**	0.0186	0.0179	0.0128
Control variables	Controlled	Controlled	Controlled	Controlled

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4 Discussion

4.1 Theoretical Innovation

Women's health issues, prioritized by the UN Global Strategy, such as food security (Aziz et al., 2020), health check-ups (Scheel et al., 2019), vaccine distribution (Senapati et al., 2017), pregnancy & nutrition (Nath et al., 2019), cognitive health (Akteer et al., 2020), and domestic violence (Koenig et al., 2003) have always been the key concerns especially in deprived rural areas of developing countries. However, with the aggravation of rural environment pollution, many women are fully exposed to environmental pollution, but existing literature paid little or no attention to this issue. Accordingly, we reinterpreted the concept of "environmental exposure." We believed that environmental exposure is the interaction between environmental risk factors and individuals' behavioural intervention, determining the heterogeneity degree of environmental exposure. Besides, we innovatively evaluated the degree of environmental exposure from pre-exposure, in-exposure, and post-exposure behavioural interventions, which made some theoretical contributions and provided a new insight to explore influencing factors to reduce the degree of environmental exposure. Most importantly, consistent with other scholars' studies concerning "environmental exposure" (Kippler et al., 2012; Larsson et al., 2014), we have focused on Chinese rural women farmers exposed to severe environmental pollution emitted from manure. Further, we incorporated risk preference and health risk perception into women breeders' environmental exposure framework from the perspective of behavioral economics. We examined the effects of risk preference and health risk perception on women breeders' environmental exposure. Therefore, our research is a new addition in enriching the research scope of environmental and agricultural economics.

4.2 Discussion of Empirical Results

Our research confirmed that an increase in the level of risk preference could enhance women breeders' health risk perception; that is, risk-taking breeders, in general, have a higher level of health risk perception. However, the findings are inconsistent with some scholars, who argued that under the same risk level, risk-aversion farmers are inclined to overestimate the severity of risks due to weak risk resistance (Dohmen et al., 2011), insufficient risk diversification tools (Tong et al., 2019), and difficulty in making up for risk losses (Meraner & Finger, 2019), resulting in a higher level of risk perception; risk-taking farmers are prone to have a lower level of risk perception owing to a complete risk transfer mechanism (Zhao et al., 2017), better alternative livelihood strategies (Kemeze et al., 2020), and timely compensation for risk losses (Holt & Laury, 2002). Possible explanations for the differences in research conclusions are that: existing studies generally ignored the heterogeneity of risk perceptions based on socio-economic attributes (Flaten et al., 2005). Specifically, environmental, public health, and natural disasters risk perceptions have obvious externalities and altruistic properties, sometimes included in quasi-public goods. Risk-taking farmers exhibit a low level of risk perception (Dohmen et al., 2011). However, other risks such as health, food, and unemployment risk perception are closely related to individuals' interests (Wang et al., 2020). Even if farmers have a high degree of risk preference, they can enhance the risk perceptions through multi-channel information acquisition and broadening acquaintance networks (Meza et al., 2020). Hence, although women

breeders probably allow manure pollution and don't dispose of it harmlessly, they still can enhance the level of health risk perception through communication with other breeders, news media, or government agendas. The high cost of manure cycling, the weak incentive of government support, and the concealment of risk realization make health risk perception vulnerable and drive individuals' towards environmental pollution (Si et al., 2020).

Our research showed that a higher degree of risk preference has become a key determinant of rural women breeders' exposure to severe LPM pollution. This result confirmed the findings of Flaten et al. (2005), Menapace et al. (2016), Meraner and Finger (2019) and Hellerstein et al. (2013), who found that risk-taking farmers are less likely to apply risk management strategies related to labor, land, and capital input. Risk-taking women breeders are usually unwilling to spend additional family income purchasing or buying disinfectant, protective clothing, and manure harmless disposal or recycling facilities. Besides, the degree of rural mechanical breeding is much lower, and women breeders tend to maintain stable production and operation by increasing working hours and frequency. Hence, it can be seen that the higher the degree of risk preference, the fewer measures are taken by women breeders to combat manure pollution and so vulnerable to a higher degree of environmental exposure.

Meanwhile, Wang et al. (2020) and Herberich and List (2012) believed that this intuitive result stems from the fact that risk-taking individuals psychologically allow risks, not linked to individuals' interests, to be infinitely amplified and lose effective management. Breeding pig is relatively intensive, and the negative externality of manure pollution is highly substantial. If any household does not reduce environmental exposure, other breeders will often leave it alone and pay no close attention.

Our results showed that the health risk perception weakens and offsets 15.15% of risk preference's damaging effects. Consequently, risk preference may continue to make women farmers' exposure to a high level. In other words, only when the inhibitory effect of health risk perception is higher than the promotion effect of risk preference, the environmental exposure of women breeders may be at a lower degree. Consistent with the findings of Bryan and Kandulu (2011) and Si et al. (2020), who considered that risk perception could enable farmers to strengthen risk management and implement risk intervention by evaluating the degree of risk damage, calculating the ratio of cost–benefit, and measuring the margin and expected utility. Suppose women breeders' health risk perception is higher. And in that case, they will try their best to reduce the direct damage of fecal odor to the respiratory system by taking appropriate protective measures, reducing the frequency and time of manure contact, and increasing the ventilation frequency disinfection. However, inconsistent with the studies of Kahneman and Tversky (1984) and Qiu et al., (2020a, 2020b), who believed that risk perception plays a positive moderating effect of risk preference on farmers' risk decisions.

Moreover, Zhao et al. (2017), in their study, confirmed that product safety risk perception significantly enhances the risk attitudes of apple farmers' towards safety production decisions. Hence, our research also confirmed the conclusion that the heterogeneity of risk perception dimensions significantly showed differences due to socio-economic attributes. Besides, inconsistent with existing studies such as Kemeze et al. (2020), and Sarwosri and Mußhoff (2020), and He et al. (2020), our results further confirmed that the effect of risk preference and health risk perception on women breeders' environmental exposure is an inverted U-shaped relationship.

5 Research Limitations

Although we have made some novel contributions to rural women breeders' environmental exposure from theoretical and empirical analysis, some flaws still exist, that may provide new research avenues for other scholars and researchers. Firstly, we took only rural women breeders of small and medium-scale as the sample. Future research can also select moderately and large-scale breeders, having a higher ability to prevent and control manure pollution and make a comparative analysis of whether all women breeders expose to environmental pollution respond in the same manner (Kovačiková et al., 2020; Wang et al., 2019). Secondly, we mainly discussed the relationship of risk preference, health risk perception, and women breeders' environmental exposure. According to the "Attitude-Context-Behavior" theory (Guagnano et al., 1995), the moderating effect of external contextual factors such as organizational support can also be used to explore the effect of risk perception on breeders' environmental exposure. Limited to the difficulty in obtaining survey data, we did not discuss the role of organizational support. Thirdly, although we have dealt with the endogeneity between health risk perception and women breeders' environmental exposure, we have not considered the endogeneity of missing variables and measurement errors. Finally, limited to research purposes and data acquisition, the mediating effect of environmental exposure in the impacts of risk preference and health risk perception on environmental exposure, the direct effect of risk preference and health risk perception on the health status, and the direct effect of environmental exposure on the health status of rural breeders are not examined. Consequently, these shortcomings can pave new avenues for researchers and academicians to amend these flaws in their future research work.

6 Conclusion and Policy Implications

In the existing literature, little attention has been given to women groups and their unheard voices in the pollution control of the LPM, making them more vulnerable to frequent and severe environmental exposure. Unlike previous studies, this study opted survey as well as experimental data of 714 Chinese rural women as pig breeders to examine the effects of risk preference and health risk perception on their exposure to the environment. The degree of environmental exposure is evaluated in terms of women breeders' pre-exposure, in-exposure, post-exposure interventions. The results showed that rural women breeders face severe environmental exposure, and the degree of environmental exposure is up to 72.102 ($Min=0$, $max=100$). Moreover, risk preference positively and significantly influences women breeders' health risk perception and environmental exposure. If the degree of risk preference increases by 1 unit, women breeders' level of health risk perception will increase by 7.24%, and the degree of environmental exposure will increase by 8.25%, respectively.

Nevertheless, health risk perception has a significant and statistically negative effect on women breeders' environmental exposure. If the level of health risk perception increases by 1 unit, the degree of environmental exposure will decrease by 17.26%. Therefore, it is believed that health risk perception can offset the effects of risk preference on women breeders' environmental exposure by 15.15%. Furthermore, by considering the heterogeneity of breeding scale, the effect of risk preference and health risk perception on women breeders' environmental exposure with 11–40 heads is more substantial. In comparison, the effects of breeding scale with 2–10 heads and 41–49 head are relatively weak. Hence,

the effect of risk preference and health risk perception on women breeders' environmental exposure presented an inverted U-shaped relationship.

In the last, this study provided some essential guidelines for policymakers to reduce the women breeders' degree of environmental exposure. Firstly, the government should provide information regarding LPM environmental pollution to women breeders through radio, television, or Internet media. They must be aware that the stench, sewage, bacteria, and viruses produced by LPM may worsen their health and encourage them to take the initial steps in implementing the LPM harmless disposal or recycling strategies. Secondly, the government should subsidize women breeders to build or purchase harmless disposal or recycling equipment and facilities such as anti-pollution protective clothing, disinfectant liquids, and other production materials. Thirdly, the health department should enhance women's knowledge towards health concerns and provide them with at least two regular free physical examinations per year. Moreover, the livestock management department should provide financial support to women breeders, to adopt green and standardized breeding technologies and let aware of their susceptibility to physical or mental health by constant exposure to LPM. Finally, the findings of the current China's sample can provide useful experience to other developing countries in reducing the environmental exposure of rural women.

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Availability of Data and Material Extra data is available by emailing to siruishi@126.com on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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