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Local Residents' Risk Perceptions in Response to Shale Gas Exploitation: Evidence from China

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Abstract:

In 2014, China became the world's third country to accomplish shale gas commercial development, following the United States and Canada. China still however lacks a comprehensive analysis of its public's concerns about potential environmental risks of shale gas exploration, particularly those of local residents near extraction sites. This paper specifically aims to explore risks perceived as associated with shale gas development in the Changning-Weiyuan area of Sichuan Basin, by conducting a face-to-face household survey with 730 participants interviewed. Some 86% of respondents reported their belief that shale gas exploitation causes more than three types of negative impacts, the most commonly perceived being noise, underground water contamination and geological disruption. Associated variables that were statistically significant predictors of risk perception include demographic characteristics (age, gender, education), environmental awareness level, landslide experience, awareness of past shale gas accidents, information sources, general knowledge about shale gas, and perspectives on whether negative impacts can be observed and controlled, along with trust in the central government and the petroleum company. Our findings implications are discussed, with the goal of informing both central and local authorities' policy development in protecting local residents from risks of shale gas exploitation and better communicating risks to residents.

Keywords: Risk perception, benefit perception, shale gas exploitation, environmental awareness, China

1. Introduction

There has been a long history of shale gas exploitation since its first extraction in New York (U.S.) in 1821. Environmental and economic concerns about shale gas development are much newer. The year 1986, when an air-drilled multi-fracture horizontal well was first applied to shale gas development to overcome a more than century-long technical bottleneck, can be seen as a key threshold date. The modern technology of hydraulic fracturing has dramatically expanded commercial development of shale gas and moved the business into a much higher gear.

On the one hand, this new energy source provides many countries a much improved chance to comply with the commitments of the Kyoto Protocol and Paris Agreement, because natural gas is a less carbon-intensive fuel than most in use, so replacing other fossil fuels with natural gas reduces carbon emissions and other atmospheric contaminants (Burnham et al., 2012; Liu et al., 2015; Newell and Raimi, 2014; Zhang et al., 2015; Zhang et al., 2017; Zhang and Peng, 2017). Development of this new, until recently unconventional source, meanwhile contributes to local economies, adding job opportunities, increasing household income, expanding local businesses, and enhancing urban development while growing tax revenue (Anderson and Theodori, 2009; Boudet et al., 2014; Kay, 2011; Theodori, 2009) .

On the other hand, horizontal well-drilling and hydraulic fracturing technology require injection of a chemical reagent containing high-viscosity fracturing fluid into the shale during the extraction process. If the fracturing fluid penetrates underground or overflows during a rainy season, it can easily pollute local shallow and underground water. Shale gas extraction also produces oily sludge and wastewater as by-products, both of which have become major sources of pollution that haven't yet received adequate attention, prominently in China, with the world's largest extractable shale resources. Wastewater produced by shale gas extraction contains more than 100 chemicals, including hydrocarbons, heavy metals, salts and radioactive materials. Failure to properly meet the requirements of infusion technology or improper selection of the infusion layer may meanwhile also cause underground water pollution. In addition, the extraction of shale gas consumes a huge amount of fresh water, affecting water quality and the sustainability of local and regional water resources as well as wastewater disposal (Brown et al., 2013; Osborn et al., 2011; Rabe and Borick, 2013; Vengosh et al., 2014; Warner et al., 2013; Willits et al., 2016). Other environmental issues related to development of shale gas include air pollution, noise pollution, threatened ecosystems, and potential hazards such as landslides as well as earthquakes (Finkel and Law, 2011; Howarth et al., 2011; Israel et al., 2015; Stedman et al., 2012; Stephen, 2010).

Potential environmental risks posed by shale gas exploration have created requirements for risk analysis, better governance, and a better understanding of the public's perceptions and attitudes toward such activity (Boudet et al., 2014; Brasier et al., 2013; Clarke et al., 2016; Schafft et al., 2013; Stedman et al., 2012; Whitmarsh et al., 2015; Willits et al., 2016). For governments to avoid or at least mitigate future conflicts about shale gas risks, there needs to be clearer communication about them and a better understanding of current public perceptions. Public perception of, and attitudes toward, shale gas in the U.S., Canada, U.K., and other western countries have been studied extensively. However, such analysis is still lacking for China.

China became the world's third country to accomplish shale gas commercial development in 2014, following the United States and Canada. The report 'World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States,' published in 2011 by the US Department of Energy,[1] estimated that China's shale gas recoverable reserves were 36.1 trillion cubic meters, ranking first in the world. To our knowledge, the existing literature on shale gas in China focuses on the development opportunity as well as environmental risks, regulations and policies, predicaments and comparisons with experiences of other countries (Deemer and Song, 2014; Gunningham, 2014; Guo et al., 2015; Hu and Xu, 2013; Krupnick et al., 2014; Lozano-Maya, 2016; Tian et al., 2014; Wan et al., 2014; Yuan et al., 2015; Zhang et al., 2017) but none analyzes the Chinese public's risk perceptions, and this study aims to fill this research gap. The Chinese government is recently paying increasing attention to the public's opinions and attitudes toward local development projects, and increasing its related efforts in public participation and communication. To provide better guidance for relevant policy formulations on shale gas development, there is urgent demand for a comprehensive risk perception study of local populations in China, which our study seeks to accomplish.

We analyze the perceptions of local residents on shale gas development. As negative effects of shale gas extraction burden local residents near development areas, and the public's awareness

[1] The report is the first comprehensive worldwide assessment of shale gas recoverable reserves in 48 shale gas basins in 32 countries.

of risks is enhanced by generally heightening consciousness of both environmental and legal issues, there will be more conflicts of the kind known in the U.S. as ‘Not In My Back Yard’ (NIMBY).

Many studies on shale gas development emphasize risk and opportunity perceptions of local residents (Ashmoore et al., 2016; Brasier et al., 2013; Ladd, 2013; Schafft et al., 2013; Stedman et al., 2012; Wynveen, 2011). Taking the U.S. Marcellus Shale region as an example.Stedman et al. (2012) studied perceptions and attitudes of residents in both New York and Pennsylvania. Brasier et al. (2013) conducted a household survey in core areas of the Marcellus Shale region in those states to study risk perceptions and the effects of possible influencing factors. Schafft et al. (2013) explored how both risk and opportunity were perceived by local stakeholders within the Pennsylvania portion of the region. These researches not only aid in understanding the implications of shale gas exploration but provide reference material for U.S. legislation and regulation. China can learn from U.S and Canadian governance experiences in shale gas development. However, it is still necessary to examine local Chinese residents’ risk assessments and its influences to minimize or transcend ‘NIMBY’-like conflicts. As we explore Chinese local residents’ risk perceptions, we also provide a simple comparison with studies of the U.S. Marcellus Shale region (i.e., Brasier et al., 2013; Stedman et al., 2012).

The following section outlines previous literature in this area; Sections 3 and 4 discuss, respectively, the status of shale gas development in China and study methodology; Section 5 provides the study’s results; and Section 6 concludes with our findings and policy implications.

2. Literature Review

Early planning and political theories (e.g., Habermas, 1984; Habermas and Shapiro, 1971) suggested that better understanding of social and environmental contexts would guide the public to pursue better solutions to problems. Nonetheless, a study by Arlikatti et al. (2007) on earthquake adjustment finds that such efforts are generally mediated by the public’s risk perceptions. Risk perception has since become a popular topic in behavioral implementation studies.

Risk perception has been discussed in an extensive body of research. The earliest work on perceived risk can be traced to the 1960s (Sjöberg, 2000), when Starr (1969) provided one of the first methods to measure risk. Since then, subsequent studies have examined local residents' risk perceptions of different hazards among different demographic groups. Slovic et al. (1980) developed a quantified model to measure the public's risk perception, based on Starr's work (Brasier et al., 2013; Slovic, 2000). Technical experts and laypeople generally have different risk perceptions of hazards (Fischhoff et al., 1982; Siegrist and Cvetkovich, 2000; Sjöberg, 1998, 2000) and an extensive body of research has recently intensified interest in laypeople's perceived risks. For instance, Slimak and Dietz (2006) conducted a mail survey on ecological risk perception to reveal the lay public's concerns about ecosystems. Risk perceptions have been recognized as individuals' interpretations of social and environmental contexts in relation to their perceptions of threats (Huang et al., 2017; Lindell and Perry, 2004, 2012). However, the mechanisms of risk perception vary by specific hazards, (as well as geographic locations and ethnic differences) so studies on each specific threat are indicated (Lindell and Perry, 2004).

Shale gas commercial development has created a new growing domain for studies examining risk perception (Boudet et al., 2014; Brasier et al., 2013; Clarke et al., 2016; Whitmarsh et al., 2015; Willits et al., 2016). Brasier et al. (2013) categorized the influences on risk perception into three sets, including perceived knowledge of effects of technologies, institutional trust, and demographic and geographic characteristics of participants. Other factors included public attitudes toward environmental issues, political ideologies, and frequency of media exposure (Clarke et al., 2016; Sjöberg, 2000; Whitmarsh et al., 2015).

Boudet et al. (2014) explored public perceptions of hydraulic fracturing in the U.S. and found that half of respondents had heard or read about hydraulic fracturing but only 22% had positive attitudes toward it. Boudet et al. (2014) further examined determinants of support and opposition and found that supporters of hydraulic fracturing technology are more likely to be female, older, having a higher educational level, and politically conservative. Frequency of media use was another factor influencing respondents' attitudes. Willits et al. (2016)in particular studied perceptions of residents in the Marcellus Shale region toward safe uses of hydraulic fracturing wastewater. That study showed that females were less likely than males to express confidence in the safety of current wastewater treatment and reuse practices, and that familiarity with hydraulic fracturing increased respondents' acceptance of wastewater reuse by the gas/oil industry but decreased such acceptance in municipal applications. Willits et al. (2016) also found that respondents' trust in selected sources played a crucial rule in alleviating their concerns about wastewater from hydraulic fracturing. Clarke et al. (2016) also investigated factors that influenced the U.S. public's level of support for shale gas development via hydraulic fracturing and found people were likely to support development if they both perceived its benefits as outweighing risks and if their political ideology were conservative.

Whitmarsh et al. (2015) surveyed the U.K. public about their perceptions of hydraulic fracturing, finding that around one-third of respondents said that the risks outweigh the benefits while about one-fourth said that benefits outweigh risks. U.K. males were more favorable to shale gas development than females, and conservative voters, urban resident, and those with a higher level of science education were more likely to be favorable toward hydraulic fracturing. Also, respondents with a lower environmentalist identity were more favorable toward shale gas fracking.

Environmental, health, social, and economic impacts of shale gas development have been widely discussed (Colborn et al., 2011; Israel et al., 2015; Jacquet, 2014; Jemielita et al., 2015; Kinnaman, 2011). Israel et al. (2015) asked about public worries on the risks of shale gas development in the U.S. and found that concerns about potential environmental degradation were the most mentioned – prominently including groundwater contamination and air pollution. A number of studies in the United States have also attempted to estimate economic impacts on communities near shale gas drilling and extraction areas such as Marcellus Shale, Barnet Shale, Hayensville Shale, and Fayetteville Shale (Anderson and Theodori, 2009; CBER, 2008; Considine et al., 2009; Considine et al., 2010; Jacquet, 2011; Perriman Group, 2009; Scott and Huang, 2009; Weinstein and Clower, 2009). Kinnaman (2011) meanwhile concluded that employment, population, and median household income have increased in all U.S. shale gas development areas.

Previous studies had examined risk and benefit perceptions (Alhakami and Slovic, 1994; Frewer et al., 1998; Siegrist et al., 2000; Siegrist and Cvetkovich, 2000) and found an inverse relationship between them. This was also discussed in many shale gas-related studies (Boudet et al., 2014; Brasier et al., 2013; Clarke et al., 2016; Whitmarsh et al., 2015), in which benefit perception was usually regarded as an element of relative benefit/risk perception (i.e. benefits outweighing risks or vice versa) or as a predictor of support or opposition.

Given the lack of discussion on the specific role of benefit perception in predicting risk perception, we offer the following research question:

RQ1. Is benefit perception predictive of risk perception? Specifically, is stronger risk perception associated with less benefit perception?

The role of socio-demographic factors in forming an individual's risk perception about shale gas development has been outlined. Numerous studies, for instance, have found that females tend to generally perceive risks as being higher (Boholm, 1998; Freudenburg and Davidson, 2007; Stern et al., 1993), a finding also observed in studies specifically on shale gas development (Boudet et al., 2014; Clarke et al., 2016; Whitmarsh et al., 2015; Willits et al., 2016). Findings in previous studies have been inconsistent about the impact of age on risk perception; Brasier et al. (2013), for instance, have found that older people are likely to perceive fewer risks from shale gas development. Many other studies have noted age as an important determinant in analyzing the public's attitude towards shale gas (Boudet et al., 2014; Brasier et al., 2013; Clarke et al., 2016; Whitmarsh et al., 2015; Willits et al., 2016). Boudet et al. (2014) and Clarke et al. (2016) showed that older people tended to support natural gas development in the U.S. But Whitmarsh et al. (2015) found that age had no significant impact on favorability toward shale gas among the general U.K. population. A number of studies have also depicted the importance of education on risk perception(Flynn et al., 2010; Sjöberg, 2000; Slimak and Dietz, 2006)Though previous studies had discussed the effect of education on the public's attitudes toward shale gas development (Boudet et al., 2014; Clarke et al., 2016; Jacquet, 2012; Whitmarsh et al., 2015), few of them addressed the relationship between education and risk perception. In the studies of Stedman et al. (2012) and Wynveen (2011), statistics on education level was simply reported but not analyzed. Brasier et al. (2013) explored influences on risk perceptions in the Marcellus Shale area but found no evidence that education level was predictive of risk perception. Political ideology was also considered as a predictor, mostly of support vs. opposition, with the common finding of conservative political ideology associated with a supportive attitude toward development (Boudet et al., 2014; Clarke et al., 2015; Clarke et al., 2016; Whitmarsh et al., 2015).

Based on the literature outlined above, the following hypotheses related to risk perception toward shale gas development are offered:

H1. Men will perceive lower risks from shale gas development than women;

H2. Age will be negatively associated with risk perception; and

H3. Education will be positively associated with risk perception.

Previous psychological studies have indicated that households' overall risk perceptions are developed by interpreting complex social and environmental contexts, which interpretations, in turn, affect behavior (e.g., supporting a policy or taking a protective action) (Lindell and Perry, 1992, 2004, 2012; Riad et al., 1999; Slovic, 2000), and that a psychological factor linking individual environmental concern is also relevant in predicting perceptions and attitudes toward shale gas development (Brasier et al., 2013; Jacquet, 2012; Jacquet, 2014; Whitmarsh, 2008; Whitmarsh et al., 2015). Brasier et al. (2013), for example, found that the perception of higher risks was associated with respondents' pro-environmental attitudes. Jacquet (2012) found that respondents were more likely to oppose natural gas drilling if they ranked higher on an 'environmental attitudes' scale. Whitmarsh et al. (2015) found that people with lower 'environmental identity' (reflecting environmentalist views) and higher climate skepticism are more favorable to shale gas development. Hence we propose the following hypothesis:

H4. Environmental awareness will be positively associated with risk perception of shale gas development.

Other determinants such as trust in specific groups and institutions, availability of information sources, level and type of media use, familiarity with hydraulic fracturing, and previous hazard experiences have also figured into various studies of risk perceptions or attitudes toward shale gas development (Anderson et al., 2012; Ashmoore et al., 2016; Boudet et al., 2014; Boudet and Ortolano, 2010; Stedman et al., 2012; Willits et al., 2016; Wright et al., 2000). Brasier et al. (2013) found that local respondents' risk perception is significantly negatively associated with trust in the natural gas industry but has only non-significant association with trust in state regulatory agencies (e.g., departments of environmental protection and/or conservation). Boudet et al. (2014) studied the U.S. public and found that supportive attitude toward development was negatively associated with increasing familiarity with hydraulic fracturing.

3. Shale Gas in China

In 2012, the Ministry of Land and Resources of the P.R.C. released its first assessment report of China's shale gas reserves, specifically including 41 basins and regions, 87 evaluation units, and 57 shale beds. The assessment reported that China's shale gas reserves totaled nearly 134 trillion cubic meters, and recoverable reserves were 25 trillion cubic meters, excluding the Qinghai-Xizang region. In 2013, the U.S. Energy Information Administration estimated China's technically recoverable shale gas reserves at 36.1 trillion cubic meters, the greatest in the world. In June 2015, the P.R.C.'s Ministry of Land and Resources released the "China Shale Gas Resource Survey Report (2014)," saying that, up through the end of 2014, China's total exploration investment in the shale gas industry would reach 23 billion yuan. The Ministry of Land and Resources designated 54 shale gas exploration rights areas, with a total area of 170,000 square kilometers, and acquired three-level geological reserves with an area of 500 billion cubic meters.

China's shale gas fields are mainly located in four areas: Forty-seven percent of recoverable reserves are in the south, mainly concentrated in the Sichuan Basin and surrounding areas. In Sichuan Basin, the reserves are nearly 40 trillion cubic meters, comprising 30% of the country's total, and recoverable reserves are nearly 6.45 trillion cubic meters, accounting for 26% of the total, both of which rank first of Chinese regions. The production capacity of shale gas in the Sichuan Basin is mainly located in Chongqing Fuling and Sichuan Changning-Weiyuan, where, by the end of 2015, the built capacity was 7 billion cubic meters per year and annual gas production reached 7 billion cubic meters in 2016.

Shale gas exploration geological conditions in China are more complex than in the U.S., with most shale gas distributed areas densely populated and short of water. Extensive consumption of water by hydraulic fracturing could threaten already stressed local water supplies. In addition, the greater depth of shale gas in China – typically double to triple U.S. drilling depth – increases environmental risks of shale gas exploration. Among identified shale gas enrichment zones, only the Sichuan Basin and Jianghan Basin have relatively abundant water resources. Nevertheless, geological conditions in Sichuan, Chongqing and Guizhou are complex, and widespread underground rivers and karst caves make prevention of underground water pollution more difficult.

Changning-Weiyuan, a national shale gas demonstration area in Sichuan province, is an example. The geologic features there are piedmont-structured, with hilly topography and loose surfaces, criss-crossed by ravines and gullies, along with a shortage of water adding to the difficulties of shale gas drilling. One main problem is frequent well leakage and wall caving, demanding repeated well refills and side tracking. Simultaneous leakage, gush, and collapse is another difficulty that can trigger chemical leakage, meaning water and air pollution and stratum contamination. So although China has vast shale gas resources, the conditions of shale gas deposits in China are generally less desirable than those in the U.S., with a large share concentrated in its water-deficient western region, meaning China faces more severe environmental problems from shale gas exploration than does the U.S.

4. Study Methodology

4.1 Study Area

This study selected the Changning-Weiyuan area in Sichuan Basin for its survey. This region is particularly interesting because portions of it were China's first national shale gas demonstration areas in 2012, specifically, Weiyuan County in the Weiyuan area and Gong County in the Changning area. Weiyuan County has China's earliest shale gas well (Wei201-H1), drilled in 2009 and Gong County has China's first commercial shale gas well (Ning201-H1), which started production in July 2012. The total populations of Weiyuan and Gong counties in the end of 2016 are, respectively, 728 thousands and 437 thousands; the proportion of males to females is 1.06 in Weiyuan County and 1.09 in Gong County.

4.2 Survey Design

A survey of residents in Weiyuan and Gong counties in Sichuan province provided data for this analysis. While designing this survey, we first conducted a separate online survey of a relatively expert sample in March 2016, mainly to collect their opinions on the risks and benefits of shale gas development. The expert sample described water contamination, geologic hazards, and vegetation degradation as the top potential risks of shale gas development. Many experts also pointed out other environmental and pollution problems that may be associated with the shale gas extraction process. About 40% of the sample said that shale gas extraction will lead to air pollution, and significant shares noted that extraction brings excess traffic and noise. The expert sample said benefits for local governments were mainly from promotion of local economic development (84.9%), infrastructure construction (64%) and local service industry development (45.5%). The experts cited as key benefits to local residents increased job opportunities (85.3%), increased estate income from enhanced value of, and demand for, their properties (52.4%) and reduced energy consumption expense (39.7%).

Following previous literature and the online expert survey, we then designed the questionnaire for the general population survey, with several face-to-face pre-tests in the villages of Weiyuan County in March and April 2016. Face-to-face interviews were then conducted in April and May 2016 to explore local residents' views about shale gas development in 13 villages of Weiyuan County and 15 villages of Gong County. All villages in these counties, importantly, had experienced a moderate level of damage in the 2008 Great Sichuan Earthquake.

Potential predictors of risk perceptions on the part of the general population sample included socio-demographic characteristics, perceived benefits, awareness of environmental problems, earthquake and landslide experiences, familiarity with shale gas projects, awareness of shale gas accidents, knowledge about shale gas, information sources, perspective on shale gas risks and perspective on government agency responsibilities in this area.

4.3 Measures

Perceived Benefits and Risks

A total of eight potential benefit and ten risk items in regard to shale gas development were adapted from previous studies (Anderson and Theodori, 2009; Boudet et al., 2014; Israel et al., 2015; Kreuze et al., 2016; Stedman et al., 2012) and our own survey results of local 'experts.' The eight benefit items included local economic stimulation, increased local job opportunities, facilitation of local infrastructure construction, local service industry development, real estate income increase, local population increase, enhancement of local residents' sense of pride, and energy price reduction. The ten risk items consisted of groundwater contamination, surface water contamination, air pollution, noise pollution, animals' habitat degradation, vegetation degradation, geologic hazards, health problems of surrounding residents and residents far from wells, and traffic congestion. All interviewees were asked the degree to which they perceived each benefit and risk item as benefit or risk. A scale of 'not at all (0)' is given if the interviewee said that he/she did not perceive the benefit/risk item as such. Respondents who did perceive the benefit/risk item were then asked to rate the extent of that benefit/risk on a five-point scale from ‘very small extent (1)’ to ‘very great extent (5).’

Awareness of Environmental Problems

Adapted from Brasier et al. (2013), a general measure of awareness was developed by asking two types of questions. The first aimed to learn the degree to which respondents anticipated future environmental problems. They were asked whether the following six categories of problems, including natural disruptions, increasing temperature, clean water scarcity, clean air scarcity, less food productivity, and worse living environment, will be more severe in the future with ‘yes’ and ‘no’ as response options. Answers to these questions were then combined into a measure of anticipation of future negative environmental impacts.

The second group of questions asked respondents to indicate the extent they perceived current environmental problems nearby and throughout China, on a scale of 1-5 from ‘very slightly (1)’ to ‘very severe (5).’ These numeric answers were similarly aggregated into a measure of respondent perception of current environmental degradation in China.

Earthquake and Landslide Experiences

Participants were also asked about their experiences with earthquakes and landslides, using ‘yes’ and ‘no’ as response options.

Familiarity with Local Shale Gas Projects

Familiarity with local shale gas projects is considered as a predictive factor in previous studies on shale gas development such as Boudet et al. (2014), Whitmarsh et al. (2015), and Willits et al. (2016). The measurement of familiarity in this study mainly referred to one of the measure items in Willits et al. (2016), which assumed that residents living in high shale well-density areas will have higher familiarity scores.

Participants were asked to indicate how much they know about the shale gas project near their hometown, with the questions:

1) 'Do you know the number of shale gas wells under construction or already constructed around your hometown?' with 'I don't know (1),' 'yes, but I don't know the exact number of wells (2)' and 'yes, I know the exact number of wells (3)' as response options;

2) 'Do you know the distance from your house to the nearest shale gas well?' on a three-point scale, in which 'I don't know (1),' 'yes, but I don't know their distance (2)' and 'yes, and I know their exact distance (3).'

We took the sum of the scaled responses to these two questions minus one, obtaining a five-point scale from 'low familiarity (1)' to 'high familiarity (5)'.

Awareness of Shale Gas Accidents

Participants were asked 'Have there been any accidents involving shale gas well(s) near your hometown?' with potential answers: 'Yes, and I know what the accident was and where,' 'Yes, but I don't recall which one' and 'I don't know' as response options.

Information Sources

Information sources on potential development impacts also play a crucial role in studying shale gas, and factors such as frequency of information provision (Boudet et al., 2014), extent of coverage (Wright et al., 2000), and trust levels (Willits et al., 2016) were considered. A section asking participants about their information sources was included in this survey. Adapted from previous studies (Boudet et al., 2014; Brasier et al., 2013; Whitmarsh et al., 2015; Willits et al., 2016), ten information sources were listed in the questionnaire, including the local community (public forum or village committee notice board), the government (lectures or education), the petroleum companies (reports from Petro China or Sinopec), Internet, newspapers, television, radio, relatives or friends, other residents, and well guards and project staff. Respondents were asked how many sources they used to obtain information about shale gas development; the amount of information they gained from each identified channel, on a scale from little (1) to much (5); and their confidence in each channel, from totally distrusted (1) to totally trusted (5). This series of questions thus provides three measure variables: number of information sources, extent of information received, and trust in information sources.

Knowledge of Shale Gas Technology

Participants were asked to respond True or False to ten statements about shale gas adapted from Stedman et al. (2012) (that it is a type of oil, that it is a type of natural gas, that its principal content is methane, that there are rich deposits of it in Sichuan Province, that there are shallow, easily exploitable, deposits of it in Sichuan Province, that there is an inexhaustible supply, that it does not require water for its exploration, that it does not require chemical reagents in its exploration, that it leaves contaminated water as a by-product, and that its extraction requires hydraulic fracturing). Knowledge of shale gas technology was measured by accuracy of response to the above ten questions on a scale from all incorrect (0) to all correct (10).

Local Residents' Perspectives on Shale Gas Impacts and Risks

Adapted from Brasier et al. (2013) andStedman et al. (2012), four additional questions were asked to evaluate respondents' opinions on shale gas impacts and risks:

1) 'Do you agree that the negative impacts of shale gas development can be avoided by proper management?' and

2) 'Do you agree that individuals can take measures to reduce the risk posed to themselves by shale gas development?' both with responses on a five-point scale from 'strongly disagree (1)' to 'strongly agree (5);'

3) 'To what extent do you say the negative impacts (if any) of shale gas development can be observed?' with five response options from 'can't be observed at all (1)' to 'can be fully observed (5);' and

4) 'To what extent do you say the negative impacts (if any) caused by shale gas development can be controlled?' on a scale of 1-5 from 'can't be controlled at all (1)' to 'can be fully controlled (5).'

These questions thus provided four measure variables: perceived observability and controllability of negative impacts, perceived ability of proper management to avoid impacts, and perceived individual ability to avoid or mitigate impacts.

Local Residents' Perspectives on Responsibility for Shale Gas Risks

The last series of questions asked participants their perspectives on responsibility for shale gas risks, adapted mainly from Brasier et al. (2013) and Willits et al. (2016). Respondents first indicated whether specific entities – including both central and local governments, petroleum companies, environmental protection organizations, scientists and researchers, and the local community and residents – should assume responsibility for shale gas risks, with a simple 'yes' and 'no' as response options. The respondents are further asked 'to what extent do you trust each of them?' on a five-point scale from 'totally distrusted (1)' to 'totally trusted (5).'

Final Considerations re Interview Questions

We randomly arranged the order of risk and benefit question sets, because the order might affect respondents' perceptions and result in estimation bias. A dummy variable 'benefits questions answered prior to risk questions' was included to capture this effect. Respondents had choices of 'not sure' and 'don't know' to some questions; however, these two response choices were coded as missing values. We also asked whether the respondent had joined the Chinese Communist Party, which we used as a proxy for political ideology. Participants who completed the one- to two-hour survey were paid ￥30 RMB.

4.4 Regression Model Specification

An ordinary least-squares regression model was applied, incorporating socio-demographic characteristics and all predictors of risk perceptions. The model is specified as follows:

$$RP_{ij} = \beta_0 + \mathbf{X}_{\mathbf{ij}}^{'}\boldsymbol{\beta}_{\mathbf{i}} + \gamma_i T_i + \delta_j + \varepsilon_{ij} \qquad (1)$$

where RP_{ij} denotes the risk perception of resident i in town j; X_{ij} is a vector of the influence factors; T_i indicates whether benefit or risk questions were asked first, with 1= benefit questions prior to risk questions; δ_j captures the unobserved town fixed effects; and ε_{ij} is the error term.

5. Results

Of 730 respondents, only 98 (13.4%) answered all questions. Thirty-eight out of 52 questions (73.1%) had a missing data rate lower than 5% (37 cases). Although Little's (1998) MCAR (missing completely at random) test yields a significant result ($\chi^2_{15174} = 16956.5$, $p < 0.001$), an additional MAR (missing at random) test for those 14 items having a missing data rate higher than 5% indicates that 13 of them have the missing values at random. A post-hoc test indicates the significance of the remaining item is a result of another relevant item. The MAR test yields a non-significant result ($t = 1.30$, n.s.) as the accompanying effect has been removed. Hence, missing values are replaced using the Expectation-Maximization (EM) algorithm in SPSS 17.0, providing a comprehensive data set of all measures considered in this study. Table 1 reports the descriptive statistics of all such measures, which are further discussed below.

5.1 Participants

Respondents were 42.6% female. They averaged 52 years of age, with a range of 15-84, and 7.22 years of education, with around 87% of respondents having not graduated from high school. Their average annual individual income was ￥11,486 (about USD $1,170, according to official exchange rates) and only 16.16% earn ￥30,000 or more per year. In addition, 13.97% of participants have joined the Chinese Communist Party and 12.47% serve as cadres; 89.72% of respondents had previous earthquake damage experience and a quarter of the interviewees (25.48%) have experienced landslides. In our sample, 50.82% of respondents answered benefit questions prior to risk questions.

5.2 Local Residents' Perceived Risks and Benefits

Local residents' perceived risks and benefits were composed, again, of ten risk items and eight benefit items. For each item, at least one-fifth of the participants did not give a rating, meaning these participants did not perceive the item as being a risk or benefit. Those participants who perceived the item as a risk/benefit then provided their rating of the extent of the risk/benefit. Figure 1 illustrates participants' responses to each risk and benefit item. The mean rating plus standard deviation of each benefit/risk item on a scale of 1-5 is reported in Figure 2.

The most commonly perceived negative impacts included noise pollution (79.73%), groundwater contamination (74.25%), and geological hazards (69.04%), followed by air pollution (64.25%) and surface water contamination (62.88%). This result shows that residents living near shale gas wells not only generally perceive a number of risks but can also distinguish different risk types. Noise pollution is the most common complaint, and more than half of the respondents (66.03%) rated the extent of this risk 'great' or higher (M=3.00, SD=1.83). Approximately 45% and 55% of all respondents, respectively, rate groundwater contamination and geological hazards as a risk to a 'great extent' or more. This result is slightly different from what Israel et al. (2015) found in the United States, but it is still comparable, even though the typology of categories and sub-categories of risks and benefits in the two studies are different.

Israel et al. (2015)found that water and air impacts (64.5% and 30.8% mention rate, respectively) were the most frequently mentioned risk concerns in the category of impacts on the environment; approximately 23% of respondents specified groundwater contamination. In the study of Kreuze et al. (2016), respondents were most concerned with large water withdrawals and contamination. The results show that negative effects on water and air are the most manifest impacts of shale gas extraction to both US and Chinese residents. In addition, our study area, Changning-Weiyuan, is located in an earthquake zone, and most of our respondents have previous earthquake damage experience, which might amplify their perceptions of geological hazards. Vegetation and habitat degradation are the least perceived concerns, which is also the result found in Israel et al. (2015). We propose that, because commercial shale gas development has been developed only for a decade, respondents are unlikely at this point to perceive long-term degradation.

The five most frequently perceived benefits of shale gas development were local economic stimulation (75.62%), increased local job opportunities (63.84%), local service industry development (63.70%), facilitation of local infrastructure construction (63.56%), and local population increase (58.22%). In particular, 61.10% of the respondents strongly believe that shale gas development vigorously boosts the local economy ('great extent' or higher), and about half of respondents strongly perceived benefits of both infrastructure construction facilitation and service industry development. Kreuze et al. (2016) have studied the benefit mention rates in Crawford County (with wells) and Barry County (without wells) in Michigan, finding that almost half the respondents in Crawford County mentioned jobs and increased local revenue, which were mentioned by only 12.5% and 37.5%, respectively, of Barry County respondents. Israel et al. (2015) argued that local business opportunities are expanded by shale gas development because of the demand for direct services (i.e., construction) and indirect services (hotels and restaurants) for the energy industries and this also appears to be the case in China. However, even though 63.84% of respondents mentioned job opportunities, they do not perceive a high level of benefits due to increased employment (M=2.01, SD=1.81). This might be because petroleum companies often bring their own employees from other places instead of hiring workers from nearby communities. More than half of respondents mentioned that shale gas development can enhance their local sense of pride.

The ten risk and eight benefit items were aggregated into a risk perception measure ($\alpha(10) = 0.84$) with $\mathrm{M} = 2.04,\ \mathrm{SD} = 1.18$ and a benefit perception measure ($\alpha(8) = 0.83$) with $\mathrm{M} = 2.06,\ \mathrm{SD} = 2.06$ for the following regression analysis. The mean values of both perceived risk and benefit measures were similar; however, the standard deviation of the benefit measure was larger than that of the risk measure. This shows that the benefit perceptions have a larger dispersion among all participants relative to risk perceptions. As people tend to do cost-benefit analysis in judging a project, we consider that the composite benefit measure might affect local residents' risk perception of shale gas development. Thus, the composite benefit measure serves as the first major potential predictor of risk perceptions.

5.3 Awareness of Environmental Problems

The first measure of a local resident's awareness of environmental problems is their degree of anticipation of six environmental impacts noted in Figure 3. As shown there, almost 90% of participants anticipate that the problem of increasing temperature will be more severe in the future. This might be the case because, in addition to experiencing increasing temperature in person, participants receive information about climate change from the Chinese government, which attaches great importance to this problem. The problems of clean water scarcity, natural disasters and clean air scarcity were also anticipated to be more severe in the future by at least 70% of participants. This proportion is similar to the results of our risk perception questions, in which water, geological hazards, and air pollution are perceived most often as risks (at least over 60%). Therefore, we additionally examine these risk perceptions by considering associated local resident anticipation of severity, with risk concerns classified into two categories: Category 'Yes' indicates participants anticipating environmental impacts will be more severe in the future, while category 'No' refers to an absence of such beliefs. Perceptions towards air pollution and geological hazards are classified by anticipation of clean air scarcity and natural disasters, respectively, and perceptions of both groundwater and surface water contamination are classified by anticipation of clean water scarcity. The results are reported in Figure 4. In general, participants who anticipate that environmental impacts will be more severe in the future (category 'Yes') are more likely to perceive related risks than those who have no such anticipation (category 'No'). For example, almost 70% of participants who expect clean air to be scarcer in the future also mention air pollution in response to risk perception questions, and about half of them rate the extent of air pollution as 'great' or higher. However, only approximately half of the participants who have no anticipation of clean air scarcity perceive the risk of air pollution, and only 15% of them rate the extent of this risk as 'great' or higher.

The second measure of awareness of environmental problems is the extent of environmental degradation perceived by residents, measured in two questions. Here, we do not report detailed response proportions of the risk concerns under different levels of perception of current environmental degradation in China.

The results show that about 55%, and three-fourths of participants, respectively, rate the extent of perceived environmental problems in the whole of China and nearby, as at least 'moderately severe.' This illustrates that residents of areas near shale gas extraction perceive that they face enhanced environmental threats as a result of that proximity, compared with the nation generally. This measure has a pattern consistent with the measure of anticipation of future negative environmental impacts; participants are more likely to mention risk concerns if they perceive higher environmental degradation, either nearby or in the whole of China.

In the following analysis, the responses to the six environmental impact and two environmental degradation items are aggregated, respectively, into measures of environmental impact anticipation ($\alpha(6) = 0.73$) and degradation perception ($\alpha(2) = 0.65$). Though the Cronbach's alpha of the second measure is only 0.65, the Pearson's R and Spearman's R of the two items are significant, 0.48 and 0.47, respectively, implying the composite measure of environmental impact anticipation is acceptable.

5.4 Results of Other Predictors

Two measures associated with shale gas development include familiarity with nearby shale gas projects and awareness of shale gas accidents. The respondents (as could be expected due to their locations) present relatively high familiarity with local shale gas projects ($\text{M} = 3.35,\ \text{SD} = 1.55$)

but only 15.75% of them are aware of past shale gas accidents. The likelihood that study participants might have received little information about local shale gas projects can also be observed from their reported number of information sources. The participants claim that they receive information about shale gas development from an average of only 2.39 out of 10 candidate channels ($M = 2.39$, $SD = 1.57$). Though relatively few channels are mentioned by the participants, and only a small amount of information is received by the participants on average ($M = 2.8$, $SD = 1.05$), the participants express relatively high trust in the information sources ($M = 3.78$, $SD = 0.90$).

Moreover, the average scale of knowledge of shale gas technology is 6.97 ($SD = 1.41$). Sixty percent of participants say they believe the impacts of shale gas development can be observed ($M = 3.44$, $SD = 1.35$), and 55% of them believe these impacts can be controlled ($M = 3.29$, $SD = 1.39$). Furthermore, 60% of the participants say they believe these negative impacts can be avoided by proper management; however, only 5% of them appear to believe that these impacts can be avoided by actions of individual residents.

The last series of potential predictors is associated with the central government, local government, and petroleum companies, and considers responsibility and trust. In general, the large majority of the respondents (over 80%) believe that the central government, local government and petroleum companies should all take responsibility for the effects of shale gas extraction and development.

Among respondents who mentioned the three institutions that should be responsible for the effects of shale gas exploration, 89.62%, 53.58% and 49.45% of the respondents, respectively, expressed trust in central government, local government, and petroleum companies. For the U.S. local respondents in New York (Pennsylvania), by comparison, 48.8% (37.2%) and 28.7% (32.3%) of them had ‘very little or no’ trust in the natural gas industry and the state regulatory agencies, respectively (Stedman et al., 2012). The Chinese local respondents have relatively high trust in the central government ($M = 4.46$, $SD = 0.78$). This implies that residents’ perceptions of shale gas development might be positively correlated with shale gas policies promoted or announced by the central government.

5.5 Analysis of Local Residents' Perceptions of Composite Risks

In this section, we investigate the relationships between influencing factors and the composite risk perception scale to determine the effective predictors for our empirical analysis, by applying correlation analysis plus a complete regression estimation to rule out uncorrelated variables.[2] The bivariate correlations between the composite risk perception measure and all the potential predictors, and the results of the complete regression estimation, are reported in Table 2.

Generally, we will not include a measure as an explanatory variable if its correlation with perceived risks is $R < 0.05$ and the coefficient in the regression is insignificant. Experience with earthquakes, number of information sources, and three responsibility dummies are thus excluded. Notice that the measure of belief that shale gas is the responsibility of the central government is excluded, even though its $R > 0.05$, because this measure and the measure of trust in the central government are structured questions with a Spearman's correlation of $R = 0.17$. However, we still keep the variable of whether benefits questions were asked prior to risk questions, as well as experience with landslides, as they express significant impacts on perceived risks in the complete regression estimation. The variables of education years, Chinese Communist Party membership, and average annual individual income are kept as socio-demographic characteristics, while cadre status is not included because it is highly correlated with Chinese Communist Party membership ($R = 0.43$). To sum up, 17 predictors of interest plus 5 socio-demographic characteristics were selected for the empirical analysis, and we examine the influences on local residents' risk perception by employing three specifications of multi-variate regressions. Table 3 reports the results.

Our three variables of greatest interest – anticipation of future negative environmental impacts, perception of current environmental degradation in China, and perceived benefits – are included in all three specifications as robustness checks. Experience with landslides and measures related to shale gas projects, including familiarity with local shale gas projects, awareness of shale gas accidents, knowledge of shale gas technology, amount of shale gas information received, and trust in information sources, are further considered in the second

[2] The comprehensive correlation matrix can be found in the appendix.

specification, while specification (3) is a full model for estimation. This demonstrates that our estimate results are robust, and we thus continue our discussion based on specification (3).

With respect to risk perception, the correlation result shows that higher benefit perception is associated with lower risk perception (Pearson's coefficients $R = -0.176$, $p < 0.000$). However, the empirical result indicates that perceived benefit doesn't significantly affect residents' risk perception of shale gas extraction; no significant result is supportive of RQ1. This might be the case because these residents can separately rate the positive and negative impacts from shale gas development, and we control the order effect on respondents' judgments of their own perceptions ($\beta = 0.23, \ p = 0.001$). Moreover, during our survey, the respondents were further asked to compare the overall benefits and risks after being asked an array of questions about benefits and risks. A majority of respondents (65.43%) considered that benefits outweighed risks, while 22.14% of the respondents considered that risks outweighed benefits, which shows that a solid majority of respondents physically nearby shale gas extraction areas still perceive benefits outweighing risks.

However, in our pre-survey with experts in shale gas development, only 25.7% of the experts agreed with this position that benefits outweighed risks, and almost half on them in fact considered that risks outweigh benefits. Meanwhile, the study of Stedman et al. (2012) found that only 24.6% of New York and 32.8% of Pennsylvania local respondents within the Marcellus region believed that benefits outweighed costs, and almost half of these respondents in both New York and Pennsylvania showed neutral attitudes for the benefit/cost comparison. The significantly different response results between local residents and experts and between the Chinese and U.S. respondents should be further examined to uncover possible influencing factors. However, we won't extend this analysis in this paper because of the limitations in our survey design.

On the other hand, there is a statistically significant impact of respondents' awareness of environmental problems on their perceptions of risks and benefits. Both anticipation of environmental impacts and degradation have significantly positive impacts on their perception of the risks of shale gas development. Comparing residents' concerns about current environment degradation ($\beta = 0.836$) with their concerns about future degradation ($\beta = 0.146$), their worries about a worse environment in the future aggravate their concerns about the risks of shale gas development more. This result is consistent with what had been found in (Brasier et al., 2013), indicating that both U.S. and Chinese local respondents perceive higher risk concerns when they have greater awareness of environmental problems. It is clear from our findings that experience with, and understanding of, environmental issues, including environmental changes and disaster experiences, have significant positive influences on risk perception.

Respondents' familiarity with local shale gas projects did not significantly affect their risk perception. However, respondents perceive greater risk if they are aware of previous shale gas accidents. Respondents who received more information and/or had greater trust in their information sources perceive lower risks. This might because most of the sources may provide more information on positive than negative impacts. Interestingly, the more knowledge respondents start with about shale gas, however, the greater are their risk concerns. Respondents are also inclined to perceive higher risks if they believe that the negative impacts caused by shale gas development can be observed, while their risk perceptions tend to be lower if they believe that the negative impacts caused by shale gas development can be controlled.

Respondents who have greater trust in petroleum companies perceive lower risks, with a statistically significant result. Trust for the petroleum company, the direct operator in shale gas extraction, clearly is likely to lower the risks respondents perceive. However, we do not obtain a similar conclusion from the variables related to trust in government, which is less directly involved in extraction. The respondents who have more trust in the central government perceive higher risks, at a statistically significant level, while trust in the local government has insignificant influence on local residents' risk perception. Brasier et al. (2013) also found that local residents in the U.S. Marcellus Shale region perceive lower risks when they have greater trust in the natural gas industry, but trust in state regulatory agencies was not found to be significantly associated with risk perception.

The socio-demographic characteristics in our model include age, gender, education, and income. The average overall risk perceived by females is 0.377 higher than that perceived by males and older females perceive a lower level of risk than younger ones. Our results don't find any significant impact from individual income and whether respondents are Chinese Communist Party members.

The finding that years of education had a negative effect on risk perception when other variables were controlled into ordinal regression models is not unique. For example, (Huang et al., 2012) also found a small negative effect of education on households' perception of hurricane impacts ($\text{effect size} = -0.10$) in their Hurricane Ike evacuation study. Similarly, (Lindell et al., 2017)found a negative correlation ($\gamma = -0.27$) between education and households' risk perceptions in 2010 Boston water contamination incident. One explanation is that individuals with higher level of education are more likely to have more knowledge about shale gas and, consequently, tend to believe the outcomes are controllable and/or that they can mitigate its impacts (Huang et al., 2012). This is supported by significant correlations between education and knowledge of shale gas technology ($\gamma = 0.43$) and between education and beliefs that negative impacts are controllable ($\gamma = 0.12$) (See Table A1). The other reason might be because education levels are usually associated with socioeconomic status, in which households with better socioeconomic status find it easier to access more resources and so feel less worry about the outcomes of a disaster (Huang et al., 2017). Our results are different from those of the study of (Brasier et al., 2013), who found that age and education level were non-significant predictors of U.S. local respondents' risk perception, except that female local respondents with higher household incomes tended to perceive higher risks.

To sum up, our findings support these hypotheses.

H1: Males perceived lower risks from shale gas development than females ($\beta = -0.377,\ p < 0.01$);

H2: Age was negatively associated with risk perception ($\beta = -0.006,\ p < 0.05$);

H4: Environmental awareness was positively associated with risk perception ($\beta = 0.836,\ p < 0.01$ for anticipation of future negative environmental impacts and $\beta = 0.146,\ p < 0.01$ for perception of current environmental degradation in China).

And the following hypothesis was not supported:

H3: Education level, which we hypothesized to be positively associated with risk perception, in fact was negatively associated with risk perception ($\beta = -0.023,\ p < 0.1$).

In terms of the research questions, RQ1 explored whether benefit perception is predictive of risk perception, and we did not find significant results that risk perception was associated with benefit perception.

6. Concluding Comments and Policy Implications

This study attempts a comprehensive analysis of the risk perceptions of Chinese respondents located near shale gas exploration sites and the potential influencing factors shaping their perceptions, including perceived development benefits, awareness of environmental problems, hazard experiences, familiarity with the nearby projects, knowledge of shale gas technology more broadly, awareness of shale gas accidents, information sources, and individuals' perspectives on impacts, risks and benefits. Some 86% of respondents reported the belief that shale gas development induces more than three types of negative impacts, with the most commonly perceived being noise, underground water contamination, and potential geological hazard. A more expert sample of respondents agreed with the general sample on water contamination and geologic hazards, but added vegetation degradation as a major potential risk.

Our study shows that, in general, Chinese local residents' subjective risk perceptions of the environmental negative impacts of shale development are still relatively mild. While respondents do perceive them, their ratings on their extent are generally not that severe. Those who trust petroleum companies have even lower perceptions of risk. Less than 40% of respondents reported being informed by government agencies or petroleum companies about the nature of shale gas development.

It is crucial for authorities to communicate extensively with local residents to increase awareness of the negative impacts of shale gas extraction and to enhance their knowledge of shale gas, for them to better understand the exploration process going on around them. As part of this, the authorities and petroleum companies must communicate effectively with local residents in ways that recognize both cultural differences and residents' individual characteristics.

We have also learned significant and interesting China-specific phenomena in this survey. Of respondents who say that risks of shale gas development outweigh benefits, still only a minority, 36.6 % of them, say they are against shale gas development. There is thus an apparent clash between Chinese local respondents' attitudes towards shale gas development and their perceptions of risks and benefits. More than 85% of respondents say that both central and local governments are responsible for managing potential risks. Some 90% of those respondents meanwhile express trust in the central government, while only 75% of those respondents have fair or higher trust in local governments, which they have perhaps been able to observe more closely.

While the central government in China plays a crucial role in realizing large-scale commercial development of shale gas, the huge trust placed in it by the local populace suggests the crucial role it also needs to play in managing the risks of this development and in adequately protecting the people of China who live near extraction sites. The Chinese government should become fully cognizant of the extensive history of U.S. experiences coping with environmental risks, including relevant legislation and regulation.

In the U.S., the use of hydraulic fracturing technology expanded extensively in 2005, when the U.S. Energy Policy Act removed fracturing from regulation under the Safe Drinking Water Act, with the so-called ‘Halliburton loophole,’ making high-polluting chemical reagents more likely to penetrate shallow water and cause drinking water pollution. With increased pollution and opposition from residents near fracking sites and beyond, U.S. legislation about, and regulation of, shale gas development has expanded over the years. For example, the California Department of Oil Gas and Geothermal Resources keeps developing new regulations governing hydraulic fracking operations in California, which started in 2012 with “discussion draft” regulations, followed by formal rule-making in 2013 (Kiparsky and Hein, 2013).

Being a country possessing vast recoverable shale reserves, estimated as the world’s greatest, China still has inadequate environmental legislation and regulation for shale gas development (Lozano-Maya, 2016; Tian et al., 2014). In terms of prevention and control of water pollution, for example, China still lacks standards for wastewater discharge and treatment of fracturing fluids. Volatile organic compounds and hydrogen sulfide, largely emitted during the extraction of shale gas, have not yet become a focus of Chinese air pollution control. All petroleum companies in China are meanwhile ministry-level or vice-ministry-level state-owned enterprises not regulated by any other entities. While there are some formal environmental protection documents with guidelines for regulation of the oil and gas industry in China, these are not binding regulations strictly enforced. Without effective environmental regulations generally and without sector-specific regulation of shale gas extraction, the result is self-regulation by the entities carrying out the development. This means ineffectual regulation. An independent, comprehensive regulatory system with strict enforcement is imperative to address the environmental risks resulting from shale gas development in China and so safeguard the public welfare into the future.

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Table 1 Descriptive Statistics of All Considered Measures (N=730)

Variables	Descriptive Statistics
Dependent Variable: Perceived Risks	M=2.04 SD=1.18 α =0.84
Perceived Benefits	M=2.06 SD=2.06 α =0.83
Anticipation of Future Negative Environmental Impacts (1=Yes)	M=0.74 SD=0.28 α =0.73
Perception of Current Environmental Degradation in China	M=3.08 SD=1.00 α =0.65
Benefit Questions Answered Prior to Risk Questions (1=Yes)	50.82% answered benefit questions first
Experience with Earthquake (1=Yes)	89.73% have experienced
Experience with Landslide (1=Yes)	25.48% have experienced
Familiarity with Local Shale Gas Projects	M=3.35 SD=1.55
Awareness of Shale Gas Accidents (1=Yes)	15.75% know accident(s) happened before
Number of Information Sources	M=2.39 SD=1.57
Extent of Information Received	M=2.80 SD=1.05
Trust in Information Sources	M=3.78 SD=0.90
Knowledge of Shale Gas Technology	M=6.97 SD=1.41
Perceived Ability of Proper Management to Avoid Impacts	M=3.47 SD=1.31
Perceived Individual Ability to Avoid or Mitigate Impacts	M=2.01 SD=1.27
Perceived Observability of Negative Impacts	M=3.44 SD=1.35
Perceived Controllability of Negative Impacts	M=3.29 SD=1.39
Responsibility of the Central Government (1=Yes)	84.93% believe that
Responsibility of the Local Government (1=Yes)	87.40% believe that
Responsibility of the Petroleum Company (1=Yes)	86.58% believe that
Trust in the Central Government	M=4.46 SD=0.78; 89.62% trust that
Trust in the Local Government	M=3.44 SD=1.29; 53.58% trust that
Trust in the Petroleum Company	M=3.33 SD=1.19; 49.45% trust that
Age	M=52.00 SD=13.69
Gender (1=Male)	42.6% Female
Education Years	86.85% - less than high school Averaged 7.22 years
Chinese Communist Party (1=Yes)	13.97% joined
Cadre (1=Yes)	12.47% served
Average Annual Individual Income	16.16% earned ￥30,000 or more Averaged ￥11,486

Table 2 Bivariate Correlation and Full Regression: Predictor Selections (N=730)

Dependent Variable: Perceived Risks	Bivariate Correlation		Regression
	Pearson's R	Spearman's R	
Perceived Benefits	-0.176***	-0.173***	0.037
	(0.000)	(0.000)	(0.034)
Anticipation of Future Negative Environmental Impacts (1=Yes)	0.385***	0.391***	0.828***
	(0.000)	(0.000)	(0.154)
Perception of Current Environmental Degradation in China	0.373***	0.368***	0.144***
	(0.000)	(0.000)	(0.044)
Benefit Questions Answered Prior to Risk Questions (1=Yes)	0.019	0.020	0.230***
	(0.613)	(0.596)	(0.071)
Experience with Earthquake (1=Yes)	-0.035	-0.031	-0.136
	(0.339)	(0.404)	(0.118)
Experience with Landslide (1=Yes)	0.046	0.041	0.200**
	(0.213)	(0.273)	(0.086)
Familiarity with Local Shale Gas Projects	0.149***	0.127***	0.042*
	(0.000)	(0.000)	(0.025)
Awareness of Shale Gas Accidents (1=Yes)	0.270***	0.270***	0.399***
	(0.000)	(0.000)	(0.108)
Number of Information Sources	-0.039	-0.005	-0.004
	(0.288)	(0.892)	(0.025)
Extent of Information Received	-0.148***	-0.150***	-0.052*
	(0.000)	(0.000)	(0.035)
Trust in Information Sources	-0.188***	-0.198***	-0.078*
	(0.000)	(0.000)	(0.044)
Knowledge of Shale Gas Technology	0.212***	0.234***	0.129***
	(0.000)	(0.000)	(0.035)
Perceived Ability of Proper Management to Avoid Impacts	-0.213***	-0.231***	-0.0559
	(0.000)	(0.000)	(0.030)
Perceived Individual Ability to Avoid or Mitigate Impacts	-0.205***	-0.212***	-0.030
	(0.000)	(0.000)	(0.030)
Perceived Observability of Negative Impacts	0.171***	0.168***	0.090***
	(0.000)	(0.000)	(0.026)
Perceived Controllability of Negative Impacts	-0.294***	-0.310***	-0.120***
	(0.000)	(0.000)	(0.029)
Responsibility of the Central Government (1=Yes)	0.091**	0.087**	0.128
	(0.014)	(0.019)	(0.097)
Responsibility of the Local Government (1=Yes)	0.021	0.015	0.090
	(0.580)	(0.692)	(0.120)
Responsibility of the Petroleum Company (1=Yes)	0.023	0.022	0.110
	(0.530)	(0.561)	(0.123)
Trust in the Central Government	-0.148***	-0.109***	0.119**
	(0.000)	(0.003)	(0.052)
Trust in the Local Government	-0.303***	-0.299***	-0.008
	(0.000)	(0.000)	(0.038)
Trust in the Petroleum Company	-0.337***	-0.334***	-0.103**
	(0.000)	(0.000)	(0.039)
Age	-0.180***	-0.180***	-0.006**
	(0.000)	(0.000)	(0.003)
Gender (1=Male)	-0.149***	-0.141***	-0.365***
	(0.000)	(0.000)	(0.082)
Education Years	-0.006	-0.003	-0.022
	(0.875)	(0.936)	(0.013)
Chinese Communist Party (1=Yes)	0.003	0.000	0.184
	(0.938)	(0.995)	(0.116)
Cadre (1=Yes)	-0.044	-0.042	-0.071
	(0.240)	(0.262)	(0.119)
Average Annual Individual Income	0.031	-0.038	0.000
	(0.410)	(0.303)	(0.000)

Note: The values in parentheses in the first two columns are p-values. The values in parentheses in the last column are robust standard errors. * p<0.1, ** p<0.05 and *** p<0.01.

Table 3 Estimation Results of Factors Influencing Local Resident's Overall Risk Perception (N=730)

Variables	Specification (1)	Specification (2)	Specification (3)
Perceived Benefits	-0.053**	-0.023	0.044
	(0.032)	(0.031)	(0.033)
Anticipation of Future Negative Environmental Impacts	1.002***	0.931***	0.836***
	(0.156)	(0.152)	(0.153)
Perception of Current Environmental Degradation in China	0.257***	0.172***	0.146***
	(0.043)	(0.044)	(0.044)
Benefits Questions Answered Prior to Risk Questions (1=Yes)	0.113	0.165**	0.230***
	(0.075)	(0.071)	(0.071)
Experience with Landslide (1=Yes)		0.188**	0.190**
		(0.090)	(0.086)
Familiarity with Local Shale Gas Projects		0.057**	0.040
		(0.026)	(0.025)
Awareness of Shale Gas Accidents (1=Yes)		0.507***	0.388***
		(0.105)	(0.107)
Extent of Information Received		-0.070*	-0.061**
		(0.036)	(0.035)
Trust in Information Sources		-0.072	-0.080*
		(0.046)	(0.044)
Knowledge of Shale Gas Technology		0.157***	0.133***
		(0.034)	(0.033)
Perceived Ability of Proper Management to Avoid Impacts			-0.049
			(0.030)
Perceived Individual Ability to Avoid or Mitigate Impacts			-0.036
			(0.029)
Perceived Observability of Negative Impacts			0.086***
			(0.026)
Perceived Controllability of Negative Impacts			-0.120***
			(0.029)
Trust in the Central Government			0.113**
			(0.053)
Trust in the Local Government			-0.006
			(0.038)
Trust in the Petroleum Company			-0.098**
			(0.039)
Age	-0.011***	-0.008***	-0.006**
	(0.003)	(0.003)	(0.003)
Gender (1=Male)	-0.213**	-0.360***	-0.377***
	(0.085)	(0.083)	(0.081)
Education Years	-0.014	-0.030**	-0.023*
	(0.013)	(0.013)	(0.013)
Chinese Communist Party (1=Yes)	0.139	0.144	0.161
	(0.117)	(0.112)	(0.110)
Average Annual Individual Income	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	1.694***	1.007**	1.213***
	(0.309)	(0.394)	(0.453)
Town Effect	YES	YES	YES
Observations	730	730	730
Adjusted R-squared	0.272	0.347	0.394
F-value	27.93	28.72	24.87

Note: The values in parentheses are robust standard errors. * p<0.1, ** p<0.05 and *** p<0.01.

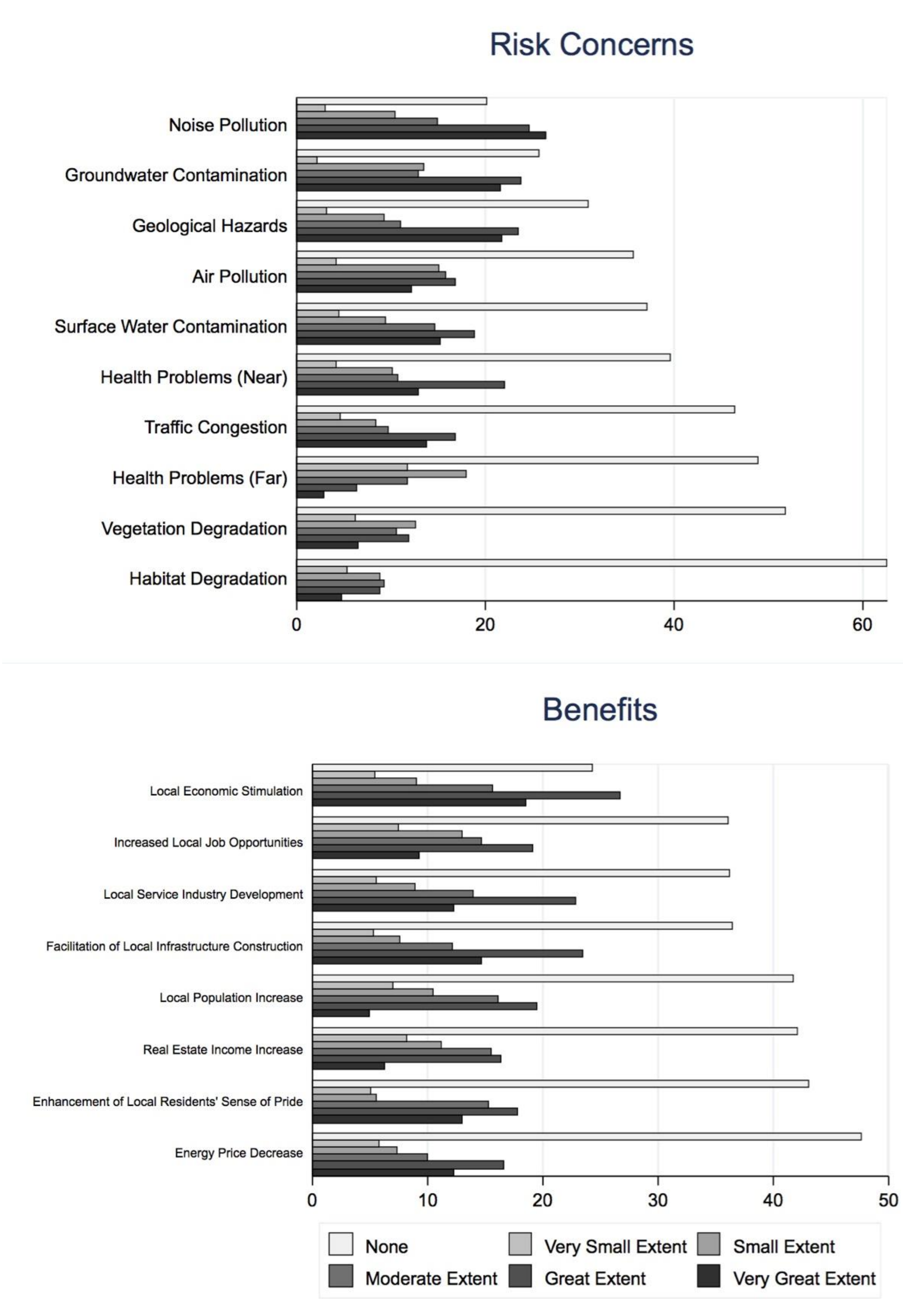


Figure 1 Local Residents' Responses to Each Risk and Benefit Item (%)

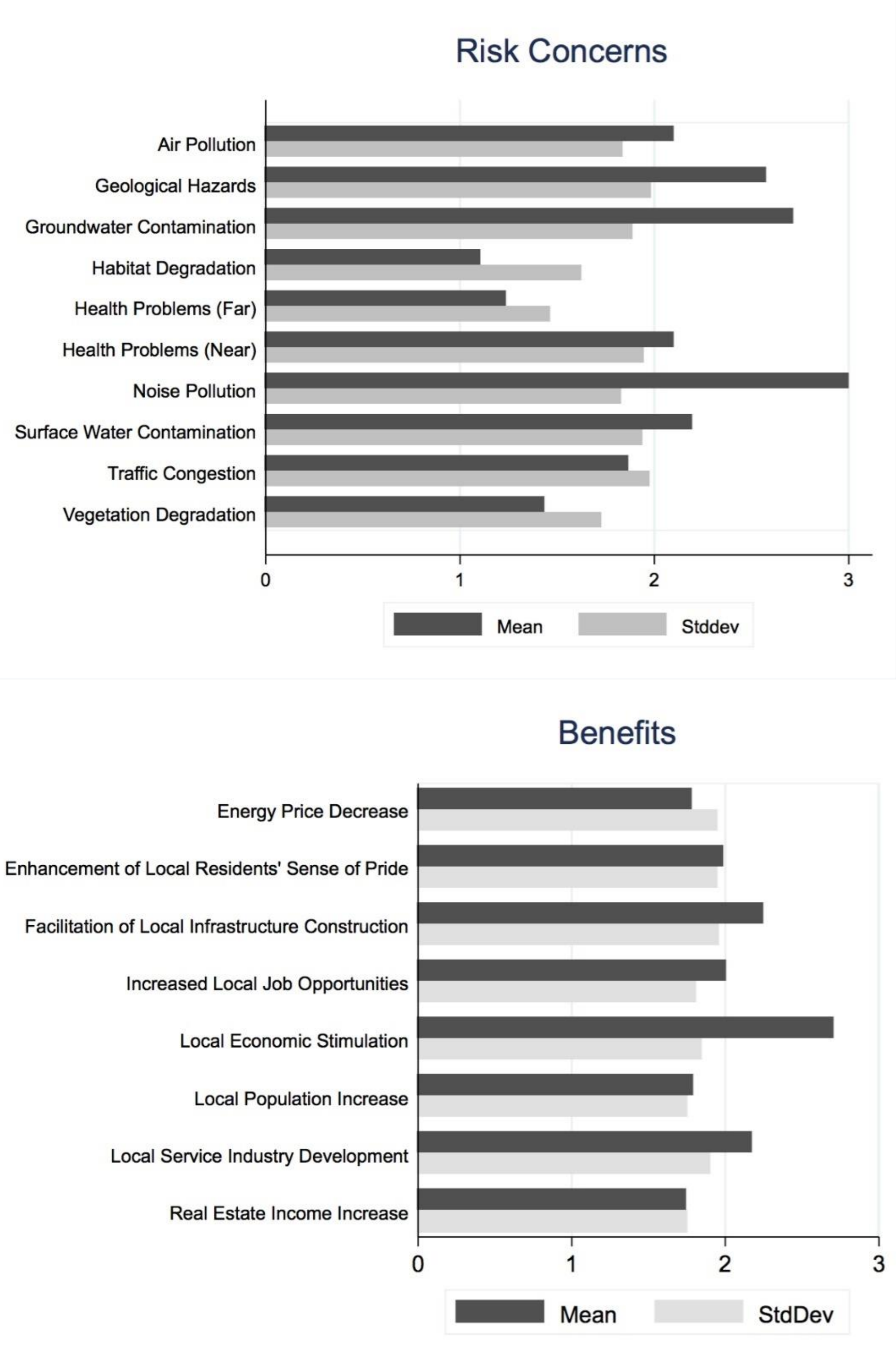


Figure 2 Mean Rating and Standard Deviation of Each Risk and Benefit Item

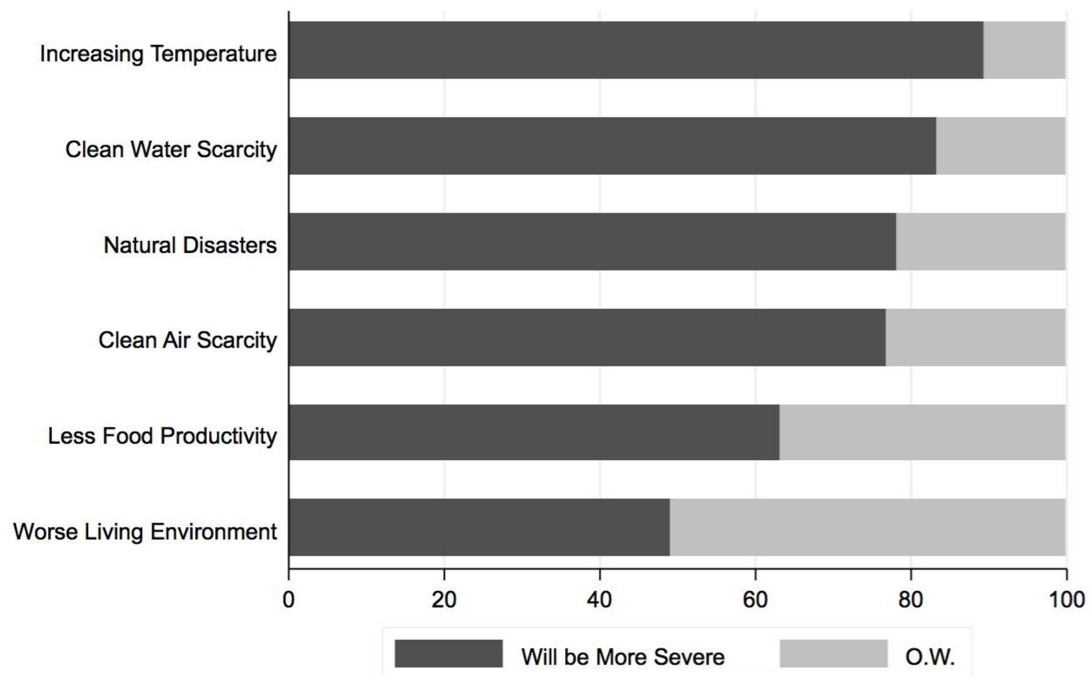
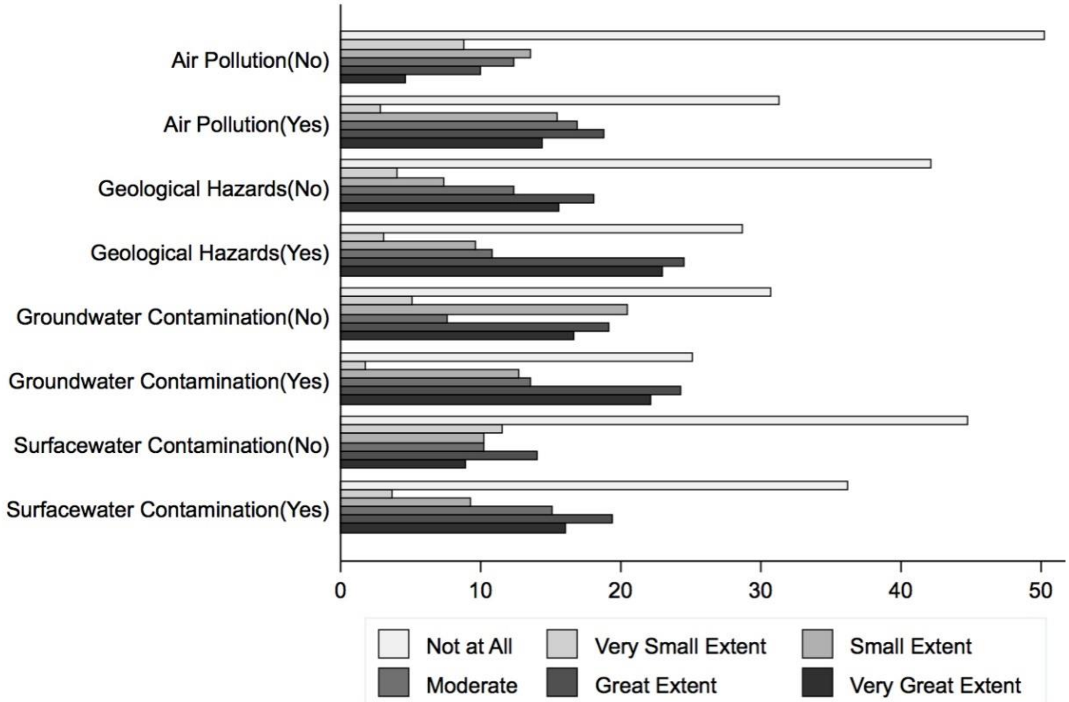


Figure 3 Anticipation of Severity of Each Environmental Impact (%)



Note: "Yes" indicates the proportion of respondents who anticipate that environmental problems will be more severe in the future.

Figure 4 Anticipation of Severity of Each Environmental Impact (%)

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Appendix

Table A1

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
2	-.18																										
3	.38	-.22																									
4	.37	-.22	.47																								
5	-.04	-.01	-.01	.01																							
6	.05	.03	-.07	.03	.06																						
7	.15	-.04	.10	.03	-.03	.02																					
8	.27	-.09	.19	.15	.06	.14	.18																				
9	-.04	.41	-.08	-.10	.04	.02	.14	-.02																			
10	-.15	.23	-.09	-.07	-.01	.01	.01	-.09	.20																		
11	-.19	.14	-.16	-.18	.07	.11	-.11	-.08	.01	.21																	
12	.21	.07	.08	.23	.03	-.12	.20	.11	.30	.04	-.15																
13	-.21	.20	-.13	-.12	-.02	.01	-.08	-.13	.11	.07	.05	.01															
14	-.20	.16	-.16	-.17	.03	-.01	-.07	-.10	.10	.24	.08	-.11	.24														
15	.17	-.09	.08	.11	.04	.01	.01	.04	-.05	-.05	-.04	.13	-.01	-.01													
16	-.29	.27	-.20	-.15	.02	.00	-.13	-.20	.18	.07	.05	.03	.47	.21	.03												
17	.09	.13	.03	.00	-.02	-.02	-.03	.03	.08	-.03	-.04	.13	-.02	-.07	-.03	-.05											
18	.02	.07	-.02	-.03	-.02	-.01	.01	-.13	.10	-.07	-.02	.08	.09	-.03	-.06	.06	.15										
19	.02	.10	.01	.06	-.08	-.01	-.01	-.02	.11	-.13	.01	.08	.13	-.01	-.04	.16	.03	.25									
20	-.15	.19	-.20	-.20	.05	-.02	-.01	-.12	.10	.09	.21	-.06	.13	.09	-.02	.17	.01	-.04	.01								
21	-.30	.33	-.30	-.35	.00	-.06	-.15	-.25	.17	.16	.22	-.14	.18	.17	-.17	.28	.04	.10	-.01	.38							
22	-.34	.42	-.27	-.30	.00	-.01	-.15	-.26	.11	.15	.27	-.23	.17	.22	-.17	.26	.02	-.02	.13	.40	.53						
23	-.18	-.07	-.13	-.11	.06	-.01	-.05	-.08	-.13	.03	.18	-.22	-.02	.10	-.05	.06	-.02	-.07	-.07	.20	.14	.17					
24	-.15	.07	-.09	-.06	.07	.01	.09	.13	.11	.08	.04	.24	.04	.01	.05	.11	.00	-.02	-.05	.15	.03	-.01	.18				
25	-.01	.17	.05	.04	.00	-.02	.07	.06	.26	.17	-.03	.43	.06	.01	.02	.12	.00	.04	.07	.01	.07	-.02	-.35	.22			
26	.00	.13	-.01	.01	.05	-.04	.05	-.01	.15	.20	.08	.16	.06	.04	.02	.11	-.03	.03	.05	.07	.16	.05	.08	.16	.27		
27	-.04	.15	-.02	-.01	.05	.02	.06	-.03	.22	.13	.05	.23	.04	.10	.01	.14	-.08	.08	.06	.11	.14	.05	.06	.17	.25	.43	
28	.03	.15	.05	.02	.06	.04	.10	.15	.22	.10	.00	.19	.06	-.02	-.04	.06	.01	.00	.01	.00	.01	-.02	-.26	.26	.37	.13	.09

1 = Perceived Risks, 2 = Perceived Benefits, 3 = Anticipation of Future Negative Environmental Impacts, 4 = Perception of Current Environmental Degradation in China, 5 = Experience with Earthquake, 6 = Experience with Landslide, 7 = Familiarity with Local Shale Gas Projects, 8 = Awareness of Shale Gas Accidents, 9 = Number of Information Sources, 10 = Extent of Information Received, 11 = Trust in Information Sources, 12 = Knowledge of Shale Gas Technology, 13 = Perceived Ability of Proper Management to Avoid Impacts, 14 = Perceived Individual Ability to Avoid or Mitigate Impacts, 15 = Perceived Observability of Negative Impacts, 16 = Perceived Controllability of Negative Impacts, 17 = Responsibility of the Central Government, 18 = Responsibility of the Local Government, 19 = Responsibility of the Petroleum Company, 20 = Trust in the Central Government, 21 = Trust in the Local Government, 22 = Trust in the Petroleum Company, 23 = Age, 24 = Gender, 25 = Education years, 26 = Chinese Communist Party, 27 = Cadre, 28 = Average Annual Individual Income.

Note: Correlation coefficient is significant at the level of $p < 0.01$ when $r \geqq 0.09$.