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Households' 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 realize shale gas commercial development, following the United States and Canada. So far, there has been a lack of comprehensive discussion on risk perception related to shale gas in China. This paper aims to understand Chinese residents' risk perceptions toward shale gas exploitation. A survey was conducted with 730 interviewed participants in two counties of Sichuan province (Weiyuan County and Gong County). This study shows that, in China, an elderly female tends to perceive lower risks, and a higher education level is commonly associated with lower risk perception. Besides the socio-demographic characteristics, two major findings are also explored in this study. First, household's perceived benefits from shale gas exploitation do not statistically significantly affect their risk concerns. Second, the respondents' environmental consciousness, including their anticipation of environmental impacts and their perceptions about environmental degradation, plays a crucial role in their perception of the risks of shale gas exploitation. This implies that local residents' judgments on the severity of environmental impacts significantly contribute to their risk perceptions. These findings therefore contribute to local authorities' policy making in protecting local residents from the risks of shale gas exploitation and in better communicating about risk with the residents.

Key Words: risk perceptions, shale gas exploitation, environmental consciousness, China

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1. Introduction

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

On one hand, this new energy source provides many countries with a chance to comply with the commitments of the Kyoto Protocol, because natural gas is a less carbon intensive fuel. Replacing other fossil fuels with natural gas will help reduce carbon emissions and other atmospheric contaminants (Burnham et al. 2011; Newell and Raimi 2014). Besides, the development of this nonconventional source contributes to local economies by adding job opportunities, increasing household income, expanding local businesses, improving city development, growing tax revenue, etc. (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 a high-viscosity fracturing fluid into the shale during the exploitation process. If the fracturing fluid penetrates into the underground or overflows during the rainy season, it can easily pollute local shallow and underground water. Shale gas extraction also produces oily sludge and waste water, both of which have become major sources of pollution but haven't received enough attention yet. Waste water produced by shale gas extraction contains more than 100 chemicals,

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including hydrocarbons, heavy metals, salts and radioactive materials. Failure to meet the requirements of infusion technology or improper selection of the infusion layer may cause underground water pollution. In addition, the exploitation of shale gas consumes a large amount of fresh water resources, which will affect the sustainable use of local and regional water resources, water quality, and wastewater disposal (Brown et al. 2013; Osborn et al. 2011; Rabe and Borick 2011; Vengosh et al. 2014; Warner et al. 2013; Willits et al. 2016). Other environmental issues related to the development of shale gas include air pollution, noise pollution, threatened ecosystems, disasters such as earthquakes and landslides, etc. (Israel et al. 2015).

To better understand these issues, this study examines a case in China, which became the world's third country to realize shale gas commercial development in 2014, following the United States and Canada. Specifically, the shale gas recoverable reserves assessment report published in 2011 by the U.S. Department of Energy[1] indicated that China's shale gas recoverable reserves reached 361 thousand cubic meters, ranking first in the world. Nonetheless, shale gas exploitation affects local residents' daily lives and might have serious negative effects on these residents. Hence, it is important to study residents' perceptions of potential risks and environmental protections and their attitudes on shale gas exploitation.

We believe this study makes a threefold contribution to the previous literature. First, it is the first comprehensive risk perception survey on shale gas exploitation conducted in China, and thus provides a Chinese view of shale gas exploitation. Second, previous literature mainly pays attention to how social-demographic influences and geographic characteristics shape risk perception, while this study highlights the influence of environmental consciousness on risk perception toward shale gas. In addition, the interaction between perceived benefits and risks is examined. The last and most important contribution is that we expand the discussion of policy implications, thus providing the Chinese government with policy-oriented information on shale gas development.

In our survey, we find that around 86% of respondents believe that shale gas exploitation induces more than three types of negative impacts, and the most commonly perceived negative impacts include noise, underground water contamination and geological disaster. On the other hand, the three most frequently perceived positive

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

impacts of shale gas exploitation are the local economic boom, service industry development and infrastructure construction. To our knowledge, no previous studies have studied the residents' benefit and risk perceptions toward shale gas in China, and this study is the pioneer in such comprehensive risk and benefit perception analysis.

Moreover, we have learned about interesting China-specific phenomena in our survey. For the respondents who believe that risks outweigh benefits, only 36.6% of them are against shale gas exploitation. The conflict between Chinese households' attitudes towards shale gas exploitation and their perceptions of risks and benefits shows the importance of this research topic in China. Furthermore, more than 85% of the respondents think that both the central and local governments are responsible for managing the potential risks. Approximately 90% of those respondents express their trust in the central government, while only 75% of those respondents have fair or higher trust in the local government. Also, more than half of the respondents believe that shale gas development can increase their sense of pride, and one-third of them have a strong sense of pride. The preliminary survey results illustrate the particular nature of Chinese residents and the necessity of research in China.

One more unique aspect addressed in our study is that a household's environmental consciousness, including anticipated environmental impacts and perceived environmental degradation, is considered in association with risk perception. Previous psychological studies have indicated that households' risk perceptions are developed by interpreting complex social and environmental contexts, which, in turn, affect their behavior (e.g., supporting a policy or taking a protective action) (Lindell and Perry 1992; Lindell et al. 2004, 2012; Riad et al. 1999; Slovic 2000). The majority of the previous studies on the impacts of risk perceptions about shale gas exploitation focused on demographic differences; by contrast, this study explores the environmental context.

The following section outlines previous literature; Sections 3 and 4 presents the study methodology and the data, respectively; Section 5 discusses the influences on households' overall risk perception; and Section 6 concludes with our findings and inferences for policy.

2. Literature Review

Early planning and political theories (e.g., Habermas 1971, 1984) indicated that better understanding of social and environmental contexts would guide the public to pursue better solutions in facing 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, then, has become a popular topic in behavioral implementation studies.

Risk perception has been discussed in an extensive body of research. The earliest research on perceived risk can be traced to the 1960s (Sjöberg 2000), when Starr (1969) provided one of the first methods to measure risks. Since then, subsequent studies have examined households' risk perceptions among different hazards and different demographic groups. Slovic et al. (1980) develop 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 perception on hazards (Fischhoff et al. 1982; Siegrist and Cvetkovich 2000; Sjöberg 1998; Sjöberg 2000), and an extensive body of research recently has intensified interest in lay people's perception of risks. For instance, Slimak and Dietz (2006) conducted a mail survey on ecological risk perception to reveal the lay public's concern about ecosystems. In sum, risk perceptions have been recognized as individuals' interpretations of the social and environmental context in terms of their perceptions of the threats (Lindell et al. 2004, 2012; Huang et al. 2012; in press). However, the mechanism of risk perceptions might vary by different hazards, geographic locations, and ethnic disparities. Hence, studies on each specific threat are required (Lindell et al. 2004, 2007).

Shale gas commercial exploitation offers a growing area 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) categorize 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 include the public's attitude toward environmental issues, political ideology, frequent media exposure, etc. (Clarke et al. 2016; Sjöberg 2000; Whitmarsh et al. 2015).

In terms of the public's perceptions of technological issues and their opinions on shale gas technology or exploitation in the U.S., Boudet et al. (2014) explore the public perceptions of hydraulic fracturing. They find that half of the respondents have heard or read about hydraulic fracturing and only 22% have positive attitudes about it. Boudet et al. (2014) further examine the determinants of the support/opposition attitude and find that a more conservative female is more likely to support hydraulic fracturing technology, and support is also positively associated with the respondent's age and education. Also, the frequency of media use is a factor influencing the respondent's attitude. Willits et al. (2016) in particular study the perceptions of residents in the Marcellus Shale region in the

U.S. toward the safe uses of hydraulic fracturing wastewater. That study shows that females are less likely than males to agree that wastewater treatment and reuse is done safely, and that familiarity with hydraulic fracturing positively affects the respondents' acceptance of reuse by gas/oil industry and municipal uses. Willits et al. (2016) also find that the respondent's trust in selected sources plays a crucial role in affecting their concerns about the wastewater from hydraulic fracturing. Clarke et al. (2016) also investigate the factors that influence the U.S. public's support for shale gas development via hydraulic fracturing. The public is likely to support the exploitation if they perceive benefits outweighing risks and if their political ideology is more conservative.

Whitmarsh et al. (2015) survey the U.K. public about their perceptions of shale gas hydraulic fracturing, finding that around one-third of the respondents feel that the risks outweigh the benefits, while about one-fourth of the respondents think that the benefits outweigh the risks. In terms of favorability toward shale gas, U.K. males are more favorable than females, and a conservative voter who is an urban resident and has a higher level of science education is more likely to be favorable toward shale gas. Also, respondents with a lower environmental identity are more favorable toward shale gas.

Environmental, health, social and economic impacts of shale gas development have been discussed (Colborn et al. 2011; Israel et al. 2015; Jacquet 2014; Jemielita et al. 2015; Kinnaman 2011). Israel et al. (2015) elicit concerns about risks of shale gas development in the U.S., and find that environment, water, air, hazards, social systems and health are the greatest concerns – in particular, environmental degradation, groundwater contamination, and air pollution. Besides, a number of studies in the United States have attempted to estimate the 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) concludes that employment, population and median household income have increased in all shale gas development areas.

The role of social-demographic factors in developing an individual's risk perception regarding shale gas has been outlined. Many studies, for instance, have found that females generally tend to perceive risks as being higher (Boholm 1998; Freudenburg and Davidson 2007; Stern et al. 1993), which is also observed in studies on shale gas exploitation (Boudet et al. 2014; Clarke et al. 2016; Whitmarsh et al. 2015; Willits et al. 2016). Findings in previous studies were inconsistent about the impact of age on risk perceptions. Age has been found to be associated with risk perceptions (Sjöberg 2000), in that older people are likely to perceive fewer risks of shale gas exploitation (Brasier et al. 2013). Also, many studies have noted age as an important but inconsistent 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 tend to support natural gas development; however, Whitmarsh et al. (2015) found that age has no significant impacts on the public's favorability toward shale gas.

Thus, we see that previous research has rarely considered the respondent's environmental consciousness as a factor in risk perceptions toward shale gas exploitation. Whitmarsh et al. (2015) introduce a measure of environmental identity; however, that measure does not identify either perception of environmental degradation or concern about future environmental problems, both of which are important in this paper. Moreover, several strands of literature have discussed the positive impacts from shale gas exploitation, yet few studies address the interaction between perceived risks and perceived benefits. This paper therefore investigates whether respondents who perceive higher benefits are likely to perceive fewer risks of shale gas exploitation.

Besides basic socio-demographic characteristics, political ideology and experience with hazards are also considered. Whether the respondent has joined the Chinese Communist Party is our proxy for political ideology. This paper also includes factors such as familiarity with the technology, trust in the institutions responsible for extraction and for managing its effects, and media usage, all of which have been discussed in previous literature. The comprehensive measures are introduced in the following section.

3. Study Methodology

This section consists of three subsections: "study area" introduces the development of shale gas in China and the study area selection; "survey design" presents the methodology used in data collection; and "measures" illustrates all measurement variables in this study.

3.1. Study Area

In June 2015, the Ministry of Land and Resources of the P.R.C. released the "China Shale Gas Resource Survey Report (2014)," saying that, by the end of 2014, China's total exploration investment in the shale gas industry had reached 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, mainly concentrating in the Sichuan Basin and the surrounding areas. Exploration in the Sichuan Basin has evaluated nearly 500 billion cubic meters of three-level geological reserves and ascertained 106.75 billion cubic meters of geologic reserves. 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 2014, the built capacity was 3.2 billion cubic meters per year and gas production reached 1.3 billion cubic meters in 2014. Furthermore, among the identified shale gas enrichment zones, only the Sichuan Basin and Jianghan Basin are located in areas with relatively abundant water resources. Nevertheless, the geological conditions in Sichuan, Chongqing and Guizhou are complex, and the extensive presence of underground rivers and karst caves makes the prevention and control of underground water pollution more difficult.

This study selects the Changning-Weiyuan area in the Sichuan Basin to conduct the survey. This region is interesting for the present study because it was selected as China’s first national shale gas demonstration area in 2012. Specifically, Weiyuan County in the Weiyuan area and Gong County in the Changning area were selected. Weiyuan County has China’s earliest shale gas well (Wei201-H1), which was drilled in 2009; Gong County has China’s first commercial shale gas well (Ning201-H1), which started to produce shale gas in July 2012. The total household population in Weiyuan County and Gong County is 741,000 and 432,000, respectively; the proportion of male and female is 1.07 in Weiyuan County and 1.06 in Gong County.

3.2. Survey Design

A survey of residents in Weiyuan County and Gong County of Sichuan province provides data for this analysis. During the design of the survey, we first conducted a survey with experts in energy-related fields, in March 2016, to collect their opinions on shale gas exploitation. Several pre-tests of the questionnaire were further conducted in the villages of Weiyuan County in March and April 2016 to finalize the formal version, in particular administering the risk and benefit measurement questions. Face-to-face interviews were then conducted from April to May 2016 to explore local residents’ views about shale gas exploitation in 13 villages of Weiyuan County and 15 villages of Gong County. All the villages in these two counties had experienced a moderate level of damage in the 2008 Great Sichuan Earthquake.

The predictors of risk perceptions studied in this paper consist of socio-demographic characteristics, perceived benefits, environmental consciousness, earthquake and landslide experiences, familiarity with shale gas projects, awareness of shale gas accidents, knowledge about shale gas, information sources, perspectives on shale gas risks, and perspective on the responsible agencies.

3.3. Measures

Perceived Benefits and Risks

There are eight benefit items and ten risk items in regard to shale gas exploitation, and all the interviewees were asked whether they perceived each benefit and risk item. A scale of “not at all (0)” is given if the interviewee said that he/she did not perceive the benefit/risk item. Respondents who claim to perceive the benefit/risk item are then asked to rate the extent on a five-point scale of “very small extent (1),” “small extent (2),” “great extent (3),” “very great extent (4),” and “almost certain (5).” The eight benefit items include local economic boom, 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 decrease. The ten risk items consist 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.

Environmental Consciousness

A general measure of environmental consciousness was developed by asking two types of questions. The first type of question aims to learn how the respondents anticipate future environmental problems; they were asked whether the following six environmental problems, including natural disasters, 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. These questions are then compiled into a measure of anticipated environmental impacts. The second type of question asks the respondents to indicate the extent of perceived environmental problems nearby and in the whole of China, on a scale of 1-5, with 1 indicating “very slightly severe,” 2 = “slightly severe,” 3 = “moderately severe,” 4 = “severe” and 5 = “very severe.” These questions are compiled into a measure of the respondent’s perception of environmental degradation.

Earthquake and Landslide Experiences

Participants were asked about their experience with earthquakes and landslides, using simple "yes" and "no" as response options.

Familiarity with Shale Gas Projects

Participants were asked to indicate how much they know about shale gas projects near their hometown, with the items "do you know the number of shale gas wells under construction or constructed around your hometown?" and "do you know the distance from your house to the nearest shale gas well?" on a three-point scale of 1 = "I don't know," 2 = "yes, but don't know the exact number of wells/distance," and 3 = "yes, and know the exact number of wells/distance." We further take the summation of the scales of 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 "yes, and I know what the accident is," "yes, but I don't recall which one" and "I don't know" as response options.

Information Source

A section asking the participants about their information sources was also included in this survey. Ten information sources were listed in the questionnaire, including the local community (public forum or notice board from the village committee), the government (lectures or education), the petroleum companies (reports from Petro China or Sinopec), internet, newspaper, television, radio, relatives or friends, other residents, and well guards/project staff. The respondents were asked how many sources they use to obtain information about shale gas exploitation; the amount of information they gain from each channel identified, on a scale from little (1) to much (5); and their confidence in each channel identified, from totally distrusted (1) to totally trusted (5). This series of questions thus provides three measurement variables: number of information sources, amount of information received, and trust in information sources.

Knowledge of Shale Gas

Participants were asked to judge true or false on ten questions related to knowledge of shale gas, and their knowledge of shale gas was thus measured from 0 to 10, depending on the number of correct responses to the ten questions.

Households' Perspectives on Shale Gas Impacts and Risks

Four independent questions were asked to reflect the respondents' opinions on shale gas impacts and risks: "do you agree that the negative impacts caused by shale gas exploitation can be avoided by proper management?" and "do you agree that individuals can take measures to reduce the risk posed by shale gas exploitation?" on a five-point scale of "strongly disagree (1)," "disagree (2)," "neutral (3)," "agree (4)," and "strongly agree (5);" "to what extent do you think the negative impacts caused by shale gas exploitation can be observed (if any)?" with five response options from "can't be observed at all (1)" to "can be fully observed (5);" and "to what extent do you think the negative impacts caused by shale gas exploitation can be controlled (if at all)?" on a scale of 1-5 from "can't be controlled at all (1)" to "can be fully controlled (5)." It thus provided four measurement variables: impacts avoided by proper management, impacts avoided by individuals' measures, impacts observed, and impacts controlled.

Households' Perspectives on Responsibility for Shale Gas Risks

The last series of questions asked the participants about their perspectives on responsibility for shale gas risks. The respondents first indicated whether specific entities – including the central and local governments, petroleum companies, environmental protection organizations, scientists and researchers, and the local community and residents – should be responsible 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 of "totally distrusted (1)," "distrusted (2)," "neutral (3)," "trusted (4)" and "totally trusted (5)."

Respondents had the choices of "not sure" and "don't know" in some sections; however, these two response choices are coded as missing values. We also randomly arranged the order of the risk and benefit question sets for the respondents, because the order might affect the respondents' perceptions and result in estimation bias. A dummy variable "benefits questions answered prior to risk questions" is then included to capture this effect.

4. Data Description

Participants who completed this one to two hour survey were paid ￥30 RMB. Among 730 respondents, only 98 (13.4%) of the respondents answered all questions. In addition, 38 out of 52 questions (73.1%) have 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 completely at random. A post hoc test indicates the significance of the remaining item is a result of another relevant item. The MAR test yields an insignificant 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 the measures considered in this study. Table 1 reports the descriptive statistics of all such measures, which are further discussed below.

4.1. Participants

Overall, respondents are 42.6% female. They average 52 years in age, with a range of 15-84, and 7.22 years of education, with around 87% respondents having less than a high school education. Their average annual individual income is ￥11,486 (about USD $1,170) 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 a landslide. In our sample, 50.82% of respondents answered the benefit questions prior to the risk questions.

4.2. Households' Perceived Risks and Benefits

Households' perceived risks and benefits are composed 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 risk/benefit item at all. Those participants who perceived the risk/benefit item then further provided their rating on the extent of the risk/benefit. Figure 1 fully illustrates the participants' responses to each risk and benefit item. The mean rating plus standard deviation of each benefit/risk item on a scale of 0-5 is reported in Figure 2.

The most commonly perceived negative impacts include 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 also can 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). This might be because most of the shale gas wells in our study area are located right in the villages or nearby. Approximately 45% of respondents rate groundwater contamination at a great extent or higher, while 55% of respondents rate geological hazards at a great extent or higher. This result is slightly different from what Israel et al. (2015) found in the United States, but it is still comparable even though there is a different typology of categories and subcategories of risks and benefits. Israel et al. (2015) found that water and air impacts (mentioned by 64.5% and 30.8%, respectively) are the most frequently mentioned concerns in the category of impacts on the environment; approximately 23% of respondents specified groundwater contamination. The results show that water and air are the impacts of particular concern to both U.S. 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 respondents apparently can't perceive long-term degradation because commercial shale gas exploitation has been developed only for a decade.

The five most frequently perceived benefits of shale gas exploitation are local economic boom (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 exploitation vigorously boosts the local economy (great extent or higher), and around half of the respondents also strongly perceive the benefits of infrastructure construction facilitation and service industry development. Israel et al. (2015) have indicated that local business opportunities are expanded by shale gas exploitation because of the demand for direct services (i.e., construction) and indirect services (hotels and restaurants) for the energy industry; this also appears to be the case in China. However, even though 63.84% of the respondents mentioned job opportunities, these respondents do not perceive a high level of benefits due to increased employment (M=2.01, SD=1.81). This might because petroleum companies often assign their own employees from other places instead of hiring workers from the local community. Moreover, more than half of the respondents mentioned that shale gas exploitation can enhance their sense of pride and more than one-third of these respondents have at least moderately positive perceptions.

The ten risk items and eight benefit items are further compiled into a risk perception measure ($\alpha(10) = 0.84$) with $M = 2.04,\ SD = 1.18$ and a benefit perception measure ($\alpha(8) = 0.83$) with $M = 2.06,\ SD = 2.06$ for the following regression analysis. The mean values of both perceived risk and benefit measures are similar; however, the standard deviation of the benefit measure is larger than that of the risk measure. This shows that the benefit perceptions have a larger dispersion among all the participants relative to the risk perceptions. As people tend to do cost-benefit analysis in judging a project, we consider that the composite benefit measure might affect the household's risk perception toward shale gas exploitation. Thus, the composite benefit measure serves as the first major potential predictor, and we propose the first hypothesis: that higher benefit perception reduces a household's risk perception (H1).

4.3. Households' Environmental Consciousness

The first measure of a household's environmental consciousness is the degree of anticipation of six environmental impacts, which are reported in Figure 3. As shown in Figure 3, almost 90% of the 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, the 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 are 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 (by over 60%).

Therefore, we additionally examine these risk perceptions by considering the household's associated anticipation of severity. The risk concerns are classified into two categories: category "Yes" indicates that the participants anticipate that the associated environmental impact will be more severe in the future, while category "No" means no such anticipation. The perceptions toward air pollution and geological hazards are classified by the anticipation of clean air scarcity and natural disasters, respectively, and the perceptions of both groundwater and surface water contamination are classified by the anticipation of clean water scarcity. The results are reported in Figure 4. In general, the participants who anticipate that environmental impacts will be more severe in the future (category "Yes") are more likely to perceive the related risks than those who have no such anticipation (category "No"). For example, almost 70% of the participants who expect that clean air will be more scarce in the future also mention air pollution in response to the risk perception questions, and around 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 15% of them rate the extent of this risk as "great" or higher. Accordingly, we propose the second hypothesis: that a household's expectations of serious future environmental impacts increase the level of risk that they perceive (H2).

The second measure of environmental consciousness is the extent of environmental degradation perceived by the households, which is composed of two questions. Here, we do not report the detailed response proportions of the risk concerns under different levels of perceived environmental degradation, but the results show that around 55% and three-fourths of the participants rate the extent of perceived environmental problems in the whole of China and nearby, respectively, as at least "moderately severe." This measure has a consistent pattern with the measure of anticipated environmental impacts; that is, the participants are likely to mention risk concerns if they perceive higher environmental degradation, either nearby or in the whole of China. Therefore, we propose the third hypothesis: households that perceive greater environmental degradation are more likely to perceive greater risks associated with shale gas exploitation (H3).

In the following analysis, the six environmental impact items and two environmental degradation items are compiled into a measure of environmental impact anticipation ($\alpha(6) = 0.73$) and a measure of environmental degradation perception ($\alpha(2) = 0.65$), respectively. 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 significantly 0.48 and 0.47, respectively, implying the composite measure of environmental impact anticipation is acceptable.

4.4. Descriptive Statistics of Other Predictors

Two measures are associated with shale gas exploitation: familiarity with shale gas projects and awareness of shale gas accidents. The respondents present relatively high familiarity with shale gas projects ($M = 3.35,\ SD = 1.55$); however, only 15.75% of them are aware of shale gas accidents. It might be that the participants can directly observe the construction of shale gas wells, but they are not well informed about any events related to the exploitation. The possibility that the participants might receive insufficient information about shale gas projects can also be observed from the number of information sources. The participants claim that they receive information about shale gas exploitation from an average of only 2.39 out of 10 candidate channels (

$M = 2.39$, $SD = 1.57$). Interestingly, 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 measure of knowledge of shale gas shows that the participants have sufficient knowledge ($M = 6.97$, $SD = 1.41$), which might help them determine the impact of shale gas exploitation. 60% of the participants believe that the impacts of shale gas exploitation can be observed ($M = 3.44$, $SD = 1.35$), and 55% of them also believe that these impacts can be controlled ($M = 3.29$, $SD = 1.39$). Furthermore, 60% of the participants believe that these impacts can be avoided by proper management; however, only 5% of them believe that these impacts can be avoided by individuals.

The last series of potential predictors is associated with the central government, local government, and petroleum companies, based on considerations of responsibility and trust. In general, the majority of the respondents (over 80%) believe that the central government, local government and petroleum companies should take responsibility for shale gas exploitation. The respondents have fairly high trust in these three agencies, particularly in the central government ($M = 4.46$, $SD = 0.78$), implying that the residents' perceptions toward shale gas exploitation might be positively correlated with the shale gas policies announced by the central government. Hence, if households' trust in the central government plays a more crucial role than their trust in the local government or the petroleum companies, shale gas policies should be the responsibility of the central government.

5. Household's Perceptions of Composite Risks

5.1. Predictor Selections

In this section, we investigate the relationships between all the possible influence factors and the composite risk perception scale, to determine the adequacy of the predictors in our empirical analysis, by applying correlation analysis plus a complete regression estimation to rule out the 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.

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

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 years of education, 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 are finally selected for the empirical analysis.

5.2. Empirical Analysis

An ordinary least-squares regression model is applied and incorporates socio-demographic characteristics and all the predictors. 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 household 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. We examine the influences on household's risk perception by employing three specifications of multivariate regressions. Table 3 reports the results.

Our three variables of greatest interest – anticipated environmental impact, perceived environmental degradation 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 shale gas projects, awareness of shale gas accidents, knowledge of shale gas, amount of shale gas information received, and trust in information sources, are further considered in the second 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 households' risk perception toward shale gas exploitation, rejecting our first hypothesis (H1), that household's perceived benefits reduce their risk concerns. This might be the case because these households can separately rate the positive and negative impacts from shale gas exploitation and because we control the order effect on the respondents' judgments on their 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%) consider that benefits outweigh risks, while 22.14% of the respondents consider that risks outweigh benefits, which shows that the respondents nearby shale gas exploitation areas perceive more benefits relative to risks. However, in our pre-survey with experts in shale gas exploitation, only 25.7% of the experts believe that benefits outweigh risks, and almost half of them consider that risks outweigh benefits. This difference in perception between the local residents and shale gas experts gives us an incentive to further analyze how households' risk and benefit perceptions affect their attitudes toward shale gas exploitation; however, we won't extend the analysis in this paper.

On the other hand, there is a statistically significant impact of respondents' environmental consciousness. Both anticipation of environmental impacts and perceptions of environmental degradation have significantly positive impacts on their perception of the risks of shale gas exploitation, which implies that the local residents' opinions on the severity of environmental problems significantly affects their risk perceptions. These results thus support our second and third hypotheses: (H2) respondents' expectations of future environmental impacts positively affect their risk perceptions, and (H3) respondents who more strongly perceive environmental degradation are more likely to perceive a higher risk from shale gas exploitation. Comparing households' 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 exploitation. In addition, people who have experienced landslides might have higher concerns about the risks of shale gas exploitation. It follows from what has been said that environment-related issues, including environmental changes and disaster experience, have significant positive influences on risk perception.

Respondents' familiarity with shale gas projects does not significantly affect their risk perception; however, respondents perceive greater risk if they are aware of previous shale gas accidents. Interestingly, the respondents who received more information or had greater trust in the information source perceive lower risks. This might because most of the sources provide more information on positive impacts than on negative impacts, particularly encouraging the increase in their sense of pride.

The more knowledge respondents have about shale gas, the greater are their risk concerns. In terms of the respondents' opinions on shale gas impacts and risks, respondents are inclined to perceive higher risks if they believe that the negative impacts caused by shale gas exploitation can be observed, while their risk perception will be lower if they believe that the negative impacts caused by shale gas exploitation can be controlled.

Respondents who have greater trust in petroleum companies perceive lower risks, and the result is statistically significant. This might because the petroleum company is the direct operator in shale gas exploitation, so that the more the residents trust the petroleum company, the lower risks they perceive. However, we do not obtain a similar conclusion from the variables related to trust in government. 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 the household's risk perception.

The socio-demographic characteristics in our model include age, gender, education and income, and the results show that an older female perceives a lower level of risk. For example, the average overall risk perceived by females is 0.377 higher than that perceived by males. Our results, however, can't find any significant impacts from households' income and whether they are members of the Chinese Communist Party. Finally, more years of education are associated with lower risk perception.

6. Concluding Comments and Policy Implications

In the past, the model of economic growth adopted by China, which pursued only quantity of production but ignored quality of life, consumed massive amounts of fossil fuel, mainly coal, and brought about severe pollution. In particular, since 2012, atmospheric pollution, especially suspended particulate matter, has become increasingly severe and has caused considerable impacts on daily life and productive activities, seriously restricting the healthy development of the economy and society. As the biggest carbon dioxide emitter, China has to change its economic development pattern and energy structure. Shale gas is the most realistic option for China to achieve low-carbon growth and reduce the dangers of air pollution. The exploitation of shale gas, however, not only consumes a large amount of fresh water resources, which will affect the sustainable use of local and regional water resources, but also produces environmental contamination induced by noise, waste water, waste gas, mining accidents and so on.

A growing body of research, therefore, has been interested in how the public perceives the risks of shale gas exploitation and has investigated the factors that influence perception of the risks of shale gas. Most of the research has focused on developed countries such as the U.S. and U.K., while only a few studies have examined China, although it is the third country that has realized shale gas commercial development. Although existing studies have focused on the public's risk perceptions toward shale gas development for various purposes, the issue of the public's environmental consciousness goes beyond these specific issues, particularly in China. Accordingly, this study was designed to investigate the public's risk perception related to shale gas, by conducting a survey in China.

Our study shows that, in general, though objective environmental impacts exist, Chinese residents' subjective risk perceptions toward the negative impacts are still relatively low. The respondents do perceive the negative impacts, but they generally do not rate these risks as very severe. Those who trust petroleum companies have even lower perceptions of risk. This suggests that neither the various levels of government nor the petroleum companies have provided sufficient information about shale gas exploitation to the public. This fact is also observed from our additional question set asking half of the respondents whether the government or a related entity has provided knowledge and information. Less than 40% of the respondents had been informed or educated by government agencies or petroleum companies about shale gas exploitation. It is thus quite important for the authorities to communicate more with the people to increase their awareness of the negative impacts caused by shale gas exploitation. Besides, all the petroleum companies in China are ministry-level or vice-ministry-level state-owned enterprises and are not regulated by any other entities. While some environmental protection documents exist to regulate the oil and gas industry in China, these do not translate into strict enforcement or binding regulations. Without effective environmental regulations, and without sector-specific regulations on shale gas exploitation, the result is self-regulation by the entities carrying out the exploitation. Therefore, a comprehensive and independent regulatory system is imperative and needs to be strictly enforced to address the potential environmental risks resulting from shale gas development in China.

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

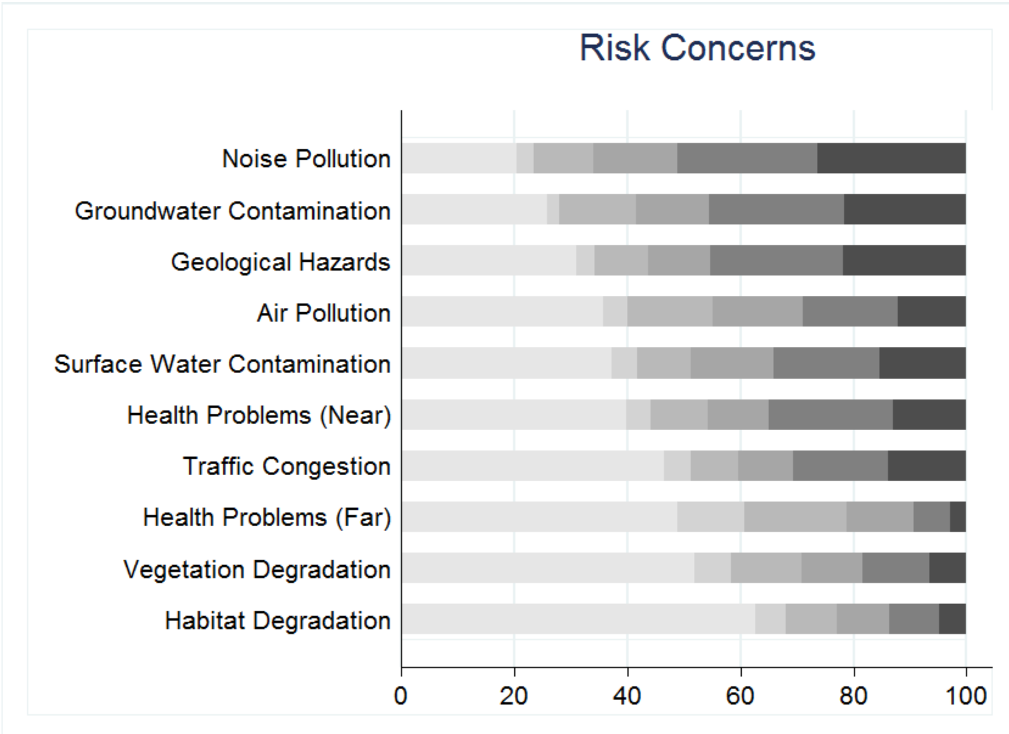
Variables	Descriptive Statistics
Dependent Variable: Perceived Risks	M=2.04 SD=1.18 α=0.84
Perceived Benefits	M=2.06 SD=2.06 α=0.83
Anticipated Environmental Impacts (1=Yes)	M=0.74 SD=0.28 α=0.73
Perceived Environmental Degradation	M=3.08 SD=1.00 α=0.65
Benefit Questions Answered Prior to Risk Questions (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 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
Amount of Information Received	M=2.80 SD=1.05
Trust in Information Source	M=3.78 SD=0.90
Knowledge of Shale Gas	M=6.97 SD=1.41
Impacts Avoided by Proper Management	M=3.47 SD=1.31
Impacts Avoided by Individual's Measures	M=2.01 SD=1.27
Impacts Observed	M=3.44 SD=1.35
Impacts Controlled	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
Trust in the Local Government	M=3.44 SD=1.29
Trust in the Petroleum Company	M=3.33 SD=1.19
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		
	Pearson's R	Spearman's R	Regression
	-0.176***	-0.173***	0.037
	(0.000)	(0.000)	(0.034)
	0.385***	0.391***	0.828***
	(0.000)	(0.000)	(0.154)
	0.373***	0.368***	0.144***
	(0.000)	(0.000)	(0.044)
	0.019	0.020	0.230***
	(0.613)	(0.596)	(0.071)
	-0.035	-0.031	-0.136
	(0.339)	(0.404)	(0.118)
	0.046	0.041	0.200**
	(0.213)	(0.273)	(0.086)
	0.149***	0.127***	0.042*
	(0.000)	(0.000)	(0.025)
	0.270***	0.270***	0.399***
	(0.000)	(0.000)	(0.108)
	-0.039	-0.005	-0.004
	(0.288)	(0.892)	(0.025)
	-0.148***	-0.150***	-0.052*
	(0.000)	(0.000)	(0.035)
	-0.188***	-0.198***	-0.078*
	(0.000)	(0.000)	(0.044)
	0.212***	0.234***	0.129***
	(0.000)	(0.000)	(0.035)
	-0.213***	-0.231***	-0.0559
	(0.000)	(0.000)	(0.030)
	-0.205***	-0.212***	-0.030
	(0.000)	(0.000)	(0.030)
	0.171***	0.168***	0.090***
	(0.000)	(0.000)	(0.026)
	-0.294***	-0.310***	-0.120***
	(0.000)	(0.000)	(0.029)
	0.091**	0.087**	0.128
	(0.014)	(0.019)	(0.097)
	0.021	0.015	0.090
	(0.580)	(0.692)	(0.120)
	0.023	0.022	0.110
	(0.530)	(0.561)	(0.123)
	-0.148***	-0.109***	0.119**
	(0.000)	(0.003)	(0.052)
	-0.303***	-0.299***	-0.008
	(0.000)	(0.000)	(0.038)
	-0.337***	-0.334***	-0.103**
	(0.000)	(0.000)	(0.039)
	-0.180***	-0.180***	-0.006**
	(0.000)	(0.000)	(0.003)
	-0.149***	-0.141***	-0.365***
	(0.000)	(0.000)	(0.082)
	-0.006	-0.003	-0.022
	(0.875)	(0.936)	(0.013)
	0.003	0.000	0.184
	(0.938)	(0.995)	(0.116)
	-0.044	-0.042	-0.071
	(0.240)	(0.262)	(0.119)
	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 *** $p<0.01$.

Figure 1. Households' Responses to Each Risk and Benefit Item (%)



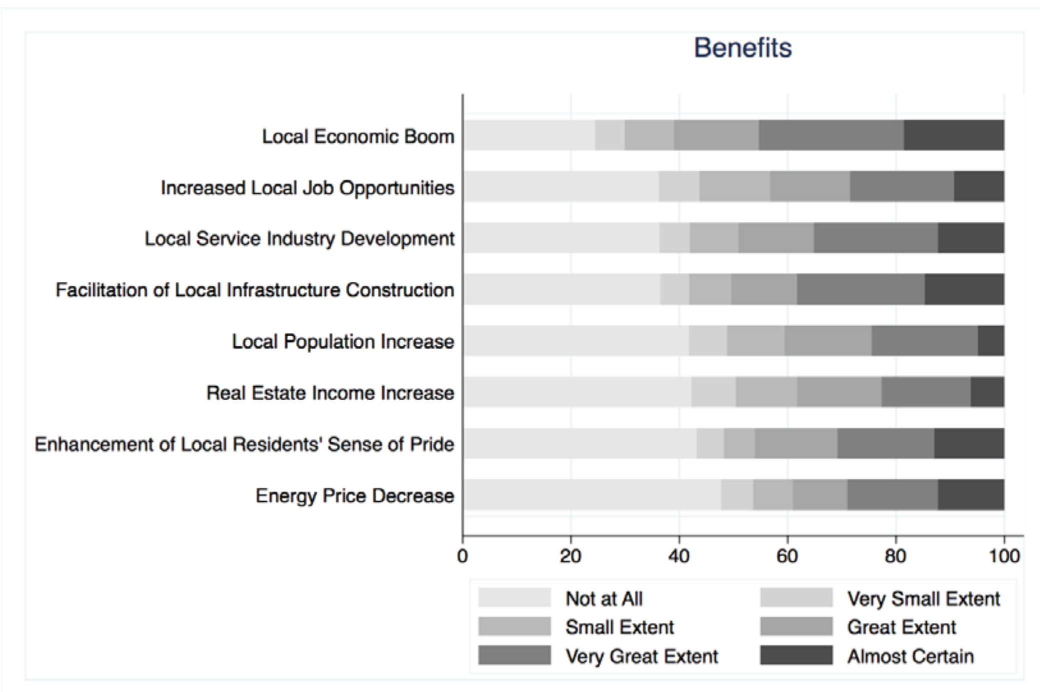


Figure 2. Mean Rating and Standard Deviation of Each Risk and Benefit Item

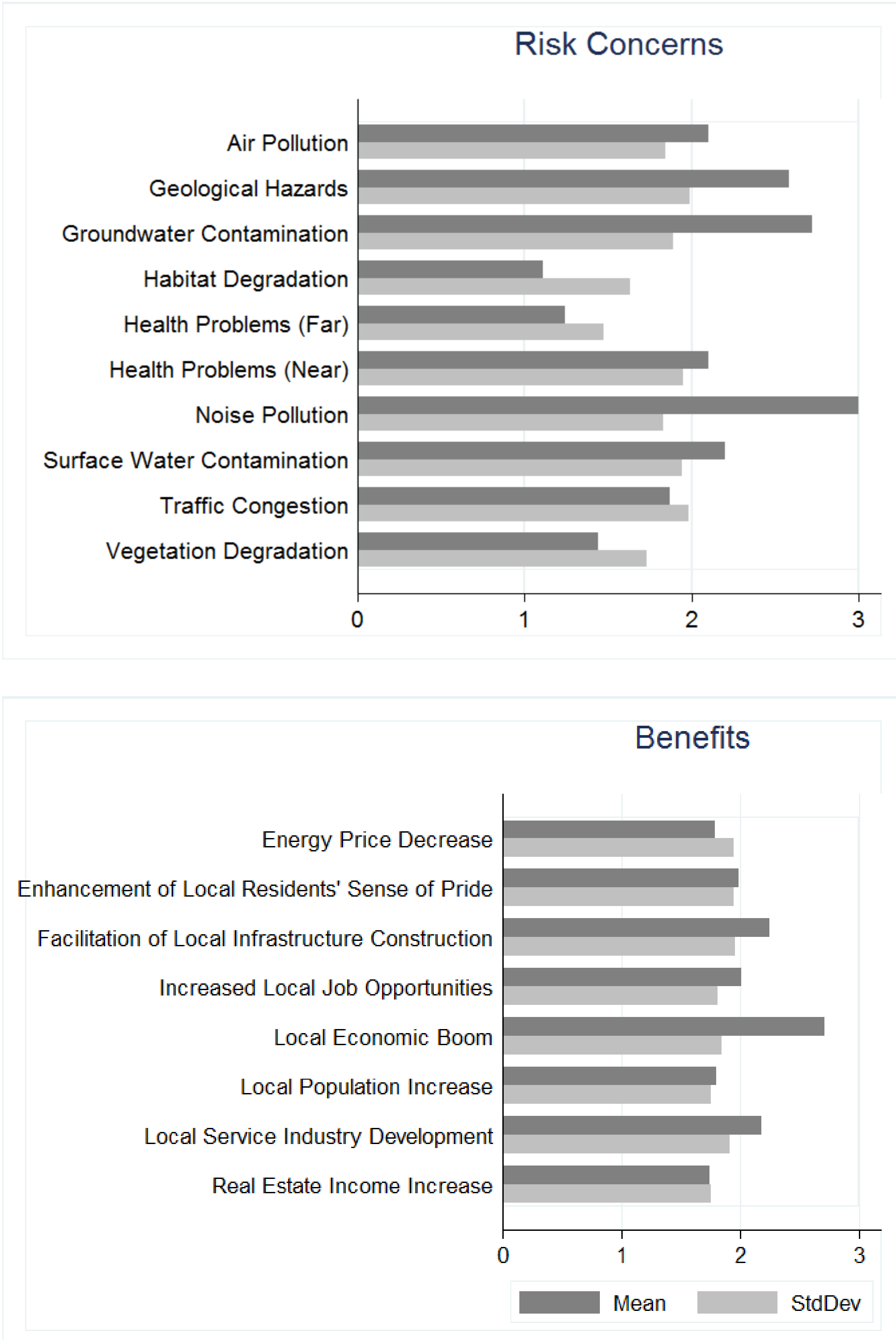


Figure 3. Anticipation of Severity of Each Environmental Impact (%)

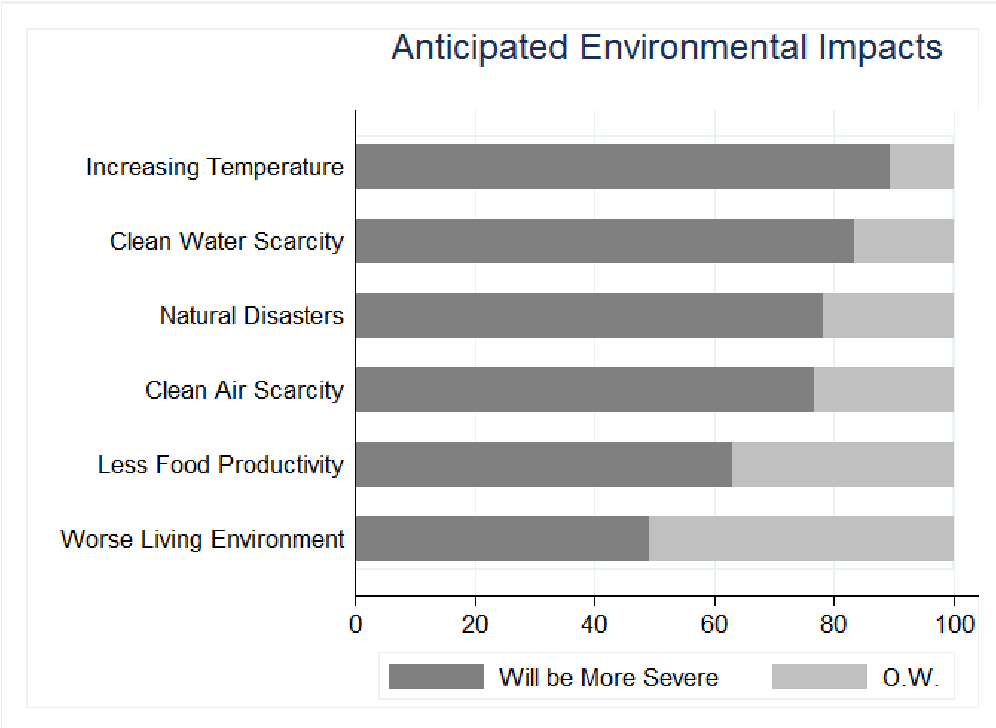
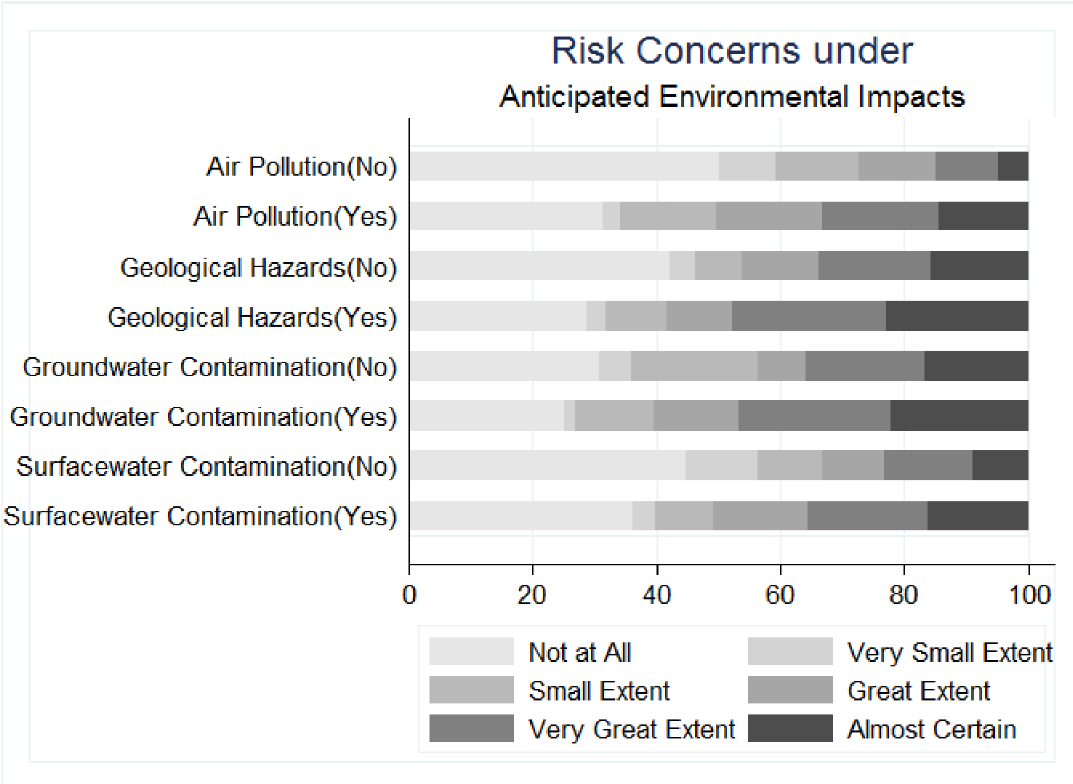


Figure 4. Anticipation of Severity of Each Environmental Impact (%)



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

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 = Anticipated Environmental Impacts, 4 = Perceived Environmental Degradation, 5 = Experience with Earthquake, 6 = Experience with Landslide, 7 = Familiarity with Shale Gas Projects, 8 = Awareness of Shale Gas Accidents, 9 = Number of Information Sources, 10 = Amount of Information Received, 11 = Trust in Information Source, 12 = Knowledge of Shale Gas, 13 = Impacts Avoided by Proper Management, 14 = Impacts Avoided by Individual's Measures, 15 = Impacts Observed, 16 = Impacts Controlled, 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 $r \geqq 0.09$.

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