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Ai Yue, Yaojiang Shi, Renfu Luo, Linxiu Zhang, Natalie Johnson, Scott Rozelle, Qiran Zhao,

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Ai Yue and Yaojiang Shi
Center for Experimental Economics in Education, Shaanxi Normal University, Xi'an, China
Renfu Luo
School of Advanced Agricultural Sciences, Peking University, Beijing, China and Center for Experimental Economics in Education, Shaanxi Normal University, Xi'an, China
Linxiu Zhang
Center for Chinese Agricultural Policy, Institute of Geographic Sciences and Natural Resources Research of Chinese Academy of Sciences, Beijing, China and Center for Experimental Economics in Education, Shaanxi Normal University, Xi'an, China
Natalie Johnson
REAP, Freeman Spogli Institute for International Studies, Stanford University, Stanford, California, USA
Scott Rozelle
Freeman Spogli Institute for International Studies, Stanford University, Stanford, California, USA, and
Qiran Zhao
College of Economics and Management, China Agricultural University, Beijing, China

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Abstract

Purpose – Although access to safe drinking water is one of the most important health-related infrastructure programs in the world, drinking water remains a large problem in China today, especially in rural areas. Despite increased government investment in water resource protection and management, there is still an absence of academic studies that are able to document what path the investment has taken and whether it has had any tangible impact. The purpose of this paper is to analyze the impact of drinking water investment on drinking water in China.

Design/methodology/approach – The authors make use of nationally representative data from 2005 and 2012 to measure the impact of drinking water investment among 2,028 rural households in 101 villages across five provinces. Both ordinary least squares regression and probit regression are used to analyze the correlates and the impact of drinking water investment.

Findings – The authors demonstrate that water quality was likely a significant problem in 2004 but that China's investment into drinking water appears to have resulted in initial improvements during the study period. The authors show that the most significant change came about in terms of hardware: villages that received more drinking water investment now have more piped tap water and more access to water treatment infrastructure (disinfecting and filtering facilities). High rates of rural resident satisfaction with drinking water suggest the effects of drinking water investment are being felt at the village level.

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Originality/value – To the authors' knowledge, this is the first empirical study on drinking water investment over time in rural China using nationally representative data.
Keywords Agricultural investment, Drinking water, China, Rural development, Household analysis
Paper type Research paper

Introduction

Helping people access safe drinking water is one of the most important health-related infrastructure initiatives in the world. Polluted water is still responsible for about 1.5 million deaths per year and 60 percent of infant mortality worldwide is due to diarrhea diseases, usually attributable to unsafe water, inadequate sanitation, and insufficient hygiene (Prüss and Havelaar, 2001; Fewtrell *et al.*, 2005; Prüss-Üstün *et al.*, 2008). These high rates of death due to water-borne illnesses are due in part to the fact that more than 700 million people worldwide still rely on unimproved drinking water sources (World Health Organization, 2013).

Drinking water remains a large problem in China today, especially in rural areas. Rising water demand and increasingly limited supplies of water (often due to water pollution associated with rapid economic development) remain serious challenges to efforts at improving safe drinking water in China. A recent World Bank report estimates that about 66,000 people die as a result of poor quality water in rural China every year (World Bank, 2007; Zhang, 2012). Although China's water monitoring system indicates that about 70 percent of river water is unsafe for human use, many rural residents still rely primarily on untreated river water (World Bank, 2006; Ebenstein, 2012). Media reports claim that the contamination of drinking water due to industrial uses has resulted in cancer in some areas of rural China (Kahn and Yardley, 2007; Griffiths, 2007).

In recent years China's government has begun to invest in water resource protection and management. The government first started implementing rural drinking water projects on a large scale in 2005. In 2012, the 12th Five Year Plan's "National Rural Drinking Water Safety Project" made safe drinking water for rural areas one of the top priorities in the national infrastructure investment plan. The target was to solve the drinking water issues of 298 million rural residents. To achieve this goal, the government estimated they would need to invest 160-170 billion yuan.

Despite the massive plans and reports of increasing investment efforts, there is still an absence of academic studies that document the path that investment has taken and evaluate whether it has had any tangible impact. There are some exceptions. For example, according to Xu (2001), investments into drinking water in Guangdong Province reached rural villages in 2000 and had a positive and significant impact on the quality of drinking water (Xu, 2001). Cai and Qiu (2013) find that investment in drinking water in 2012 positively affected the quality of water in one county in Jiangsu Province.

Although previous studies on drinking water investments in China are academically sound, they have serious limitations. First, they do little to inform the debate about the trend in investment at the national level over time because they have typically been focused on rural drinking water investment in circumscribed geographical regions. Second, most existing studies only use cross-sectional data from a single year, limiting the ability of the analysis to assess the impacts of investments. To our knowledge there has been no empirical research on drinking water investment over time in rural China using nationally representative data.

In addition to the scarce research on overall investments into rural drinking water, there has been even less attention paid to the extent to which access to tap water has been improved. WHO guidelines on drinking water quality recognize the importance of expanding access to piped tap water as a way to reduce contamination (World Bank Organization, 2011). International research also suggests that expanding access to piped tap water is a crucial factor in improving drinking water quality. Previous research found a positive relationship

between access to piped water and child health in many countries (Merrick, 1985; Cebu Study Team, 1991; Thomas and Strauss, 1992; Lee *et al.*, 1997; Jalan and Ravallion, 2003; Mangyo, 2008; Galiani *et al.*, 2005). In particular, access to tap water has been shown to improve the anthropomorphic outcomes of children in rural areas of China (Mangyo, 2008).

Assessing access to tap water in rural China is particularly important due to the national government's goal of increasing the share of the rural population with access to the centralized rural water supply (by way of piped tap water) to 80 percent as a part of national rural drinking water plan. Unfortunately, little research has been done on whether the government's investment plan has actually expanded access to tap water or if tap water is associated with improved water quality. Additionally, to our knowledge, no empirical research on this topic has been conducted in rural China using nationally representative data.

The overall goal of this paper is to analyze the impact of drinking water investment on the development of tap water infrastructure and perceived drinking water quality in China. To meet this overall goal, we have four specific objectives. First, we describe the nature of drinking water in China's villages in the early 2000s – a time that predates major increases in government drinking water investments. Second, we track drinking water investment into rural villages over the past decade (between 2005 and 2011). Third, we seek to understand where (or in what types of villages) drinking water investment has taken place. Finally, we analyze the impact of drinking water investment in the case of tap water projects, water treatment infrastructure and subjective assessments of water quality in rural China during the 2000s.

While we believe our paper is addressing an important and timely issue, there are several limitations. First, because of the absence of reliable data on water quality at the village level, we are not able to measure the impact of investments on drinking water quality directly. Water quality is generally measured by assessing whether the concentrations of given substances and chemicals (that are recognized to pose significant health risks) within individual water sources align with guideline values (World Bank Organization, 2011). Accurately measuring water quality is therefore costly, labor intensive, and requires significant expertise. Instead, we investigate the impact of investment on water quality by making use of a series of survey questions about the infrastructure and perceived water quality in our sample villages. In particular, we analyze the impact of drinking water investment on three primary outcomes: whether or not a given village has access to piped tap water, whether or not a given village has access to water treatment infrastructure, and subjective assessments by the village leader of the quality of the water in the village.

The rest of the paper is organized as follows. In the next section we discuss the data. In third section we present our methodological approach. The empirical results are presented in the fourth section. The last section concludes.

Data

The data used in this paper are from a nearly nationally household representative survey conducted in 2005 and 2012. In this survey 101 villages were randomly selected from 50 townships in 25 counties located in five provinces. The total sample includes 2,028 households. In this research, we evaluate the impact of investment on drinking water at both the village and household levels.

The sample villages were selected as follows. First, five provinces were each randomly selected to represent China's five major agro-ecological zones: Jiangsu represents the eastern coastal areas (Jiangsu, Shandong, Shanghai, Zhejiang, Fujian, and Guangdong); Sichuan represents the southwestern provinces (Sichuan, Guizhou, and Yunnan) plus Guangxi; Shaanxi represents the provinces on the Loess Plateau (Shaanxi and Shanxi), Inner Mongolia, and the rest of the provinces in the northwest (Gansu, Ningxia, Qinghai, and Xinjiang); Hebei represents the north and central provinces (Hebei, Henan,

Anhui, Hubei, Jiangxi, and Hunan); and Jilin represents the northeastern provinces (Jilin, Liaoning, and Heilongjiang).

After the provinces were selected, the second step of the sample selection involved choosing the counties, towns, and villages. Five counties were selected from each province, one from each quintile from a list of counties arranged in descending order of per capita gross value of industrial output (GVIO). GVIO was used because it has been shown to be one of the best predictors of standard of living and development potential and is often more reliable than net rural per capita income (Rozelle, 1996). Within each county, the survey team chose two townships, one from each half of a list of townships also arranged in descending order of per capita GVIO. Finally, within each township, two villages were chosen following the same procedure as the township selection. In total, we surveyed 101 villages. The third step was choosing the sample households. In each village 20 households were randomly selected. Because several households in our original sample divided between the time of our baseline and end-line surveys, our final sample contained a total of 2,028 households.

The data set collected for this study includes basic information about villages and households in the study areas for both 2004 (collected in 2005) and 2011 (collected in 2012). Enumerators interviewed village leaders, using a survey form designed to collect basic socio-economic information, such as the minority population (measured as the proportion of the town population that is an ethnic minority), hilly land area (measured as the total land area within the village that has a slope of more than 25 degrees), and the distance from the village office to the closest paved road. Basic socio-economic indicators (such as per capita GDP, net per capita income, and town-level GVIO) were also collected.

Information on the drinking water available in each village was also collected from village leaders. We asked the village leaders a series of questions about the drinking water investment projects in each year (specifically, the number of projects and the total amount of money invested in each project each year). In order to understand the specific nature of each investment project, we also asked the village leader to describe the project, including what types of facilities the project targeted. We also asked the village leaders seven questions about drinking water in their village. Specifically, we asked questions related to the tap water status of each village, the water treatment infrastructure that was available in the village, and the village leader's subjective assessment of water quality in the village. The specific questions asked of villages are detailed in Table I.

Variable name	Survey question	Description
Tap water status		
Tap water village	Do any residents in the village use tap water?	Dummy; 1 = yes; 0 = no
Non-tap water village	Do any residents in the village use non-tap water?	Dummy; 1 = yes; 0 = no
Water treatment infrastructure		
Disinfecting facilities	Does the village have facilities to disinfect their drinking water?	Dummy; 1 = yes; 0 = no
Filtering facilities	Does the village have facilities to filter their drinking water?	Dummy; 1 = yes; 0 = no
Subjective assessment of water quality		
Visible debris	Are there debris visible in the village's drinking water?	Dummy; 1 = yes; 0 = no
Color, bad taste or odor	Does the village's drinking water have off-color, does it have a bad taste, or does it smell?	Dummy; 1 = yes; 0 = no
Originated from polluted source	Does the village's drinking water come from a source that is polluted?	Dummy; 1 = yes; 0 = no

Source: Authors' survey

Table I.
Description of outcome variables

At the same time, the team carried out a survey with the heads of each of sample household during both waves of the survey (2005 and 2012). The main information from the household survey form included in this analysis is the information on the satisfaction of rural residents with different public services including drinking water, health clinics, schools, roads and irrigation, and drainage facilities.

Approach

We use both ordinary least squares regression and probit regression to analyze the correlates and the impact of drinking water investment. In order to analyze the determinants (or correlates) of drinking water investment in China's villages, the econometric model that we use is specified as follows:

$$Investment_{i,t} = a_0 + a_1 \times Water\_quality_{i,t} + a_2 \times Village\_level\_income_{i,t} + a_4 \times Province_{i,t} + a_4 \times Year_{i,t} + e_{i,t} \quad (1)$$

where *Investment* is the value of drinking investment in each village between 2004 and 2011. *Water-quality* represents each of our drinking water quality variables in successive regressions. Villages are defined either as tap water or non-tap water villages based on two binary variables (Table I). "Tap water village" is a binary variable defined by whether or not any residents in the village use tap water (1 = yes). "Non-tap water village" is a second binary variable defined by whether or not any residents in the village use non-tap water (1 = yes). The water treatment infrastructure variables are specified in one of two ways (Table I). First we ask whether the village has facilities to disinfect their drinking water (henceforth, "disinfecting facilities"). Second, we ask whether the village has facilities to filter their drinking water ("filtering facilities"). The village leader's subjective assessment of water quality is specified in one of three ways (Table I): whether there is debris visible in the village's drinking water ("visible debris"); whether the village's drinking water have off-color, a bad taste, or smells ("color, bad taste or odor"); and whether the village's drinking water come from a polluted source ("originated from polluted source").

Village_level_income is a control variable for net income per capita at the village level[1]. The average village per capita income is RMB2608, and the values ranged from RMB300 to RMB6596. *Province* and *Year* are dummy variables used to control the impact of time and the province effect.

Since all of our indicators for tap water status, water treatment infrastructure, and subjective assessment of water quality are binary variables, we use a probit model in the analysis of the impact of investment on water quality. The reason for using probit model is that the linear probability model suffers from two problems: first, the predicted probability is not restricted to between 0 and 1. Second, in a linear probability model, heteroskedasticity may be a problem, which could lead to inefficient estimators. The probit model is constructed as follows:

$$Prob(y = 1) = \Phi(\alpha_0 + \beta D + \delta X) \quad (2)$$

where y is a binary variable, indicating our outcome variables: indicators for tap water status, water treatment infrastructure, or the subjective assessment of water quality. $\Phi(.)$ is the cumulative density function, the main variable of interest is D which indicates investment into drinking water during the survey years (2005-2011). The variable X is a vector of exogenous control variables, including per capita income, the minority population, hilly land area, and the distance from the village office to the closest paved road. X also includes a control variable for the 2004 value of the outcome variable examined in each regression: indicators for tap water status, water treatment infrastructure, or the subjective

assessment of water quality. Furthermore, in order to control for unobservable heterogeneities at the province level, we also include province-level fixed effects. In this way we are able to control for all non-time varying observables and unobservables.

Results

Rural drinking water in the early 2000s

We first examine the extent to which tap water and non-tap water were available in our sample villages in 2004. From Table II we can see that in 2004 access to regular tap water was only available in 20 percent of villages (row 2). Taking into account those villages that had access to both tap and non-tap water, the data also show that about 48 percent of all villages had full or partial access to tap water (row 1). Based on these findings, we can conclude that less than half of villages in rural China had any access to tap water in 2004.

In addition, our data demonstrate that few villages had access to water treatment facilities and subjective assessments of water quality were poor overall (Table III). This was true both in villages with tap water and villages with non-tap water. For example, over half of tap water villages did not have any facilities for disinfecting or filtering the water. Additionally, the data also show that some village leaders in tap-water villages still had unfavorable subjective assessments of water quality. Specifically, 13 percent of village leaders noted visible debris, 17 percent noted color, bad taste, or odor in their water, and 19 percent said their village's water originated from a polluted source.

In spite of these overall quality concerns in tap water villages, the data suggest that non-tap water villages were even worse off in 2004. The proportion of non-tap water villages with disinfecting facilities (16 percent) and filtering facilities (14 percent) were much smaller than that of tap water villages (Table III, row 1-2). Village leaders also gave low subjective assessments of water quality in a greater proportion of the non-tap water villages (Table III, row 3-4). Specifically, 27 percent of non-tap water village water had visible debris and 25 percent had a color, a bad taste, or an odor. However, only 16 percent of non-tap water

	Number of villages
Tap water villages	48
Entire village had access to only tap water	20
Village had access to both tap and non-tap water	28
Non-tap water villages	81
Entire village had access to only non-tap water	53
Village had access to both tap and non-tap water	28
Total sample	101

Source: Authors' survey

Table II.
Drinking water type in 2004: tap vs non-tap water

	Tap water villages (% of villages)	Non-tap water villages (% of villages)
Disinfecting facilities	44	16
Filtering facilities	48	14
Visible debris	13	27
Color, bad taste or odor	17	25
Originating from polluted sources	19	16

Source: Authors' survey

Table III.
Drinking water indicators in 2004

village leaders believed their water originated from a polluted source. Overall, according to the data, the nature of drinking water in non-tap water villages in 2004 was poorer overall than that in tap water villages.

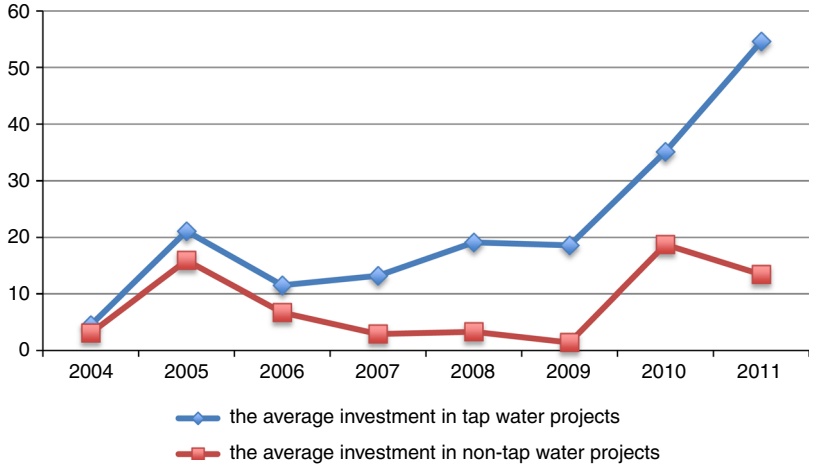
Investment in drinking water from 2004 to 2011

So what was the government's response to low rates of access to tap water, low rates of access to water treatment infrastructure, and poor subjective assessments of water quality during 2005-2011? Figure 1 shows the levels of investment into different types of drinking water projects. The average investment into any type of drinking water project was 26,806 yuan per village in 2004. By 2011 the total investment had increased to 40,806 yuan per village. When examining the water investment projects by their intended goal, it is clear that the government began to focus more attention on tap water projects in this period[2]. Between 2004 and 2011, the average investment in tap water projects was consistently higher than in non-tap water projects.

Trends in the nature of drinking water in the last decade

In this section we describe trends in tap water status, water treatment infrastructure, and subjective assessments of water quality in rural China in the past decade. According to our data, the number of villages where the entire village had access to only tap water increased during this period (Table IV, row 2). We also find that the number of villages with access to both tap water and non-tap water increased (row 3). By 2011, 62 percent (column 2, row 1) of villages had full or partial access to tap water, up from 48 percent in 2004 (column 1, row 1). The number of villages with access to only non-tap water also decreased greatly from 53 percent in 2004 to only 39 percent in 2011 (row 5). Because we know that tap water is generally of higher quality than non-tap water, this increase in access to tap water and decrease in access to non-tap water provide preliminary evidence that water quality likely improved overall during this period. In spite of these improvements, we can also see that non-tap water is still prevalent: 75 percent of villages were still using non-tap water sources in 2011 (column 2, row 4).

The improvement of drinking water conditions is also reflected in increasing access to water treatment infrastructure and improved subjective assessments of water quality,



Source: Authors' survey

Figure 1.
Per village drinking water investment (1k yuan)

especially in tap water villages. From Table V we can see that both access to water treatment infrastructure and subjective assessments of water quality improved in tap water villages from 2004 to 2011 across all five of our indicators (column 3). In contrast, changes in drinking water status in non-tap water villages were more varied, with a marked decline in access to water treatment infrastructure and an increase in the subjective assessments of water quality (column 6).

Our data also show that in 2011 tap water villages continued to have much more access to water treatment infrastructure and higher subjective assessments of water quality than non-tap water villages overall (Table V). In 2011 tap water villages performed better than non-tap water villages in terms of all five indicators (columns 2 and 5). Given that we showed in Table IV that the number of villages with access to tap water increased from 2004 to 2011, this provides further evidence that the nature of rural water likely improved overall across this period.

Although the data indicate that drinking water has improved during the past decade, Table V also shows that the drinking water of rural residents is still far from ideal. For example, up to 20 percent of non-tap water village leaders reported the presence of visible debris in their water in 2011 (row 3, column 5). More work is still needed if the government truly intends to solve the rural drinking water problem.

Village-level drinking water and the path of investment

To better understand the path that drinking water investment took in this period and its probable effectiveness, we next investigate the extent to which the nature of drinking water at the village level (namely, village-level tap water status, access to water treatment infrastructure, and subjective assessment of water quality) in 2004 influenced where water investment took place. According to Table VI, investments appear to have been well-targeted to improve rural China's drinking water. Between 2005 and 2011, for both tap and non-tap water villages, investments were concentrated in villages with less access to

	Number of villages	
	2004	2011
Tap water villages	48	62
Entire village had access to only tap water	20	26
Village had access to both tap and non-tap water	28	36
Non-tap water villages	81	75
Entire village had access to only non-tap water	53	39
Village had access to both tap and non-tap water	28	36
Total sample	101	101

Source: Authors' survey

Table IV.
The trends of drinking water type from 2004 to 2011

	Tap water villages			Non-tap water villages		
	2004 (%)	2011 (%)	Change (%)	2004 (%)	2011 (%)	Change (%)
Disinfecting facilities	44	53	20	17	4	−76
Filtering facilities	48	63	31	14	8	−43
Visible debris	13	11	−15	29	20	−31
Color, bad taste or odor	17	5	−71	26	13	−50
Originated from polluted source	19	7	−63	17	10	−41

Source: Authors' survey

Table V.
The situation of drinking water from 2004 to 2011

	Drinking water investment per village (1k yuan) Yes	No	*t*-test
Drinking water type			
Tap water village	280.4	136.8	143.7 (1.6)
Non-tap water village	226.3	137.0	89.2 (0.9)
Tap water villages			
Disinfecting facilities	192.8	348.7	155.9 (0.9)
Filtering facilities	301.7	260.9	40.7 (0.2)
Visible debris	680.9	223.2	457.6* (1.8)
Color, bad taste or odor	240.3	288.5	48.2 (0.2)
Originated from polluted source	579.0	211.6	367.4* (1.7)
Non-tap water villages			
Disinfecting facilities	184.0	234.8	50.8 (0.3)
Filtering facilities	206.9	229.5	22.6 (0.1)
Visible debris	481.3	124.2	357.1*** (3.1)
Color, bad taste or odor	169.2	246.2	77.0 (0.6)
Originated from polluted source	411.5	188.6	222.8 (1.5)

Notes: The *t*-statistics are reported in parentheses. *,***Significant at the 10 and 1 percent levels, respectively
Source: Authors' survey

Table VI. Village-level drinking water and the path of investment in 2005-2011

water treatment infrastructure and lower subjective assessments of water quality. In particular, for both tap and non-tap water villages, there was greater investment in villages without disinfecting facilities (Table VI, row 3 and 8). Investment was also channeled more toward villages with visible debris (row 5 and 10) as well as toward villages with water believed to be coming from polluted sources (row 7 and 12). In other words, the descriptive results suggest that targeting was fairly good.

To better understand the path of investment, we next conduct a regression controlling for village per capita income and province level variation. Our regression results are largely consistent with the descriptive results (Table VII). Overall investment in both tap and non-tap water villages was concentrated in villages with drinking water with lower subjective assessments of water quality. For example, there was significantly more investment into villages with water originating from a polluted source (tap water villages – row 7) and into villages with visible debris in their water (non-tap water villages – row 10). The one exception was that there was more investment in villages with water with color, bad taste, or odor. In other words, the analysis shows that there was more investment in areas with lower subjective assessments of water quality.

We also see that there was significantly more investment in villages with tap water in 2004 (Table VII, row 1). As mentioned above, this may reflect a conscious government strategy to put more resources into improving tap water infrastructure and quality. Given that we can see from Table III that tap water quality is still far from ideal, this strategy may still be promoting the quality of drinking water in rural areas overall.

Impact of drinking water investments

The results of the multivariate analysis that examines the impact of drinking water investments (Table VIII) show that investment into drinking water between 2005 and 2011 had a significant impact on increasing access to tap water and water treatment infrastructure in 2011, but no clear impact on subjective assessments of water quality. According to our regression results, the more drinking water investment there was between 2005 and 2011, the more likely the village was to have access to tap water in 2011 (Table VIII, column 1). We also

Independent	Dependent: drinking water investment per village (1k yuan) from 2005-2011 (OLS)
Tap water village	211.72* (1.68)
Non-tap water village	68.37 (0.50)
Tap water villages	
Disinfecting facilities	−126.52 (0.64)
Filtering facilities	89.08 (0.46)
Visible debris	205.07 (0.96)
Color, bad taste or odor	−373.06* (1.94)
Originated from polluted source	385.64** (2.05)
Non-tap water villages	
Disinfecting facilities	24.83 (0.11)
Filtering facilities	−70.47 (0.29)
Visible debris	391.44*** (3.08)
Color, bad taste or odor	−325.83** (2.50)
Originated from polluted source	229.50 (0.47)
Per capita income	0.09** (2.28)
Province	Yes
Constant	−536.50** (2.08)
Sample	101

Table VII. Village-level drinking water and the path of investment in 2005-2011 (OLS)

Notes: The value of *t*-statistics are reported in parentheses. *,**,***Significant at the 10, 5 and 1 percent levels, respectively
Source: Authors' survey

find that the more drinking water investment there was between 2005 and 2011, the more likely a given tap water village was to have disinfecting facilities in 2011 (column 2). Finally, the more drinking water investment there was between 2005 and 2011, the more likely a given tap water village was to have filtering facilities in 2011 (column 3).

While there was a positive effect on tap water status and access to water treatment infrastructure, according to our results, there was no significant effect on the village leader's subjective assessment of water quality. In particular, the level of investment had no impact on the number of village leaders reporting that the water in their village had visible debris (column 4 and 9); had color, bad taste or odor (column 5 and 10); or originated from a polluted source (column 6 and 11). And we found that there is no significant difference between the results (see Table AI).

These results on the ineffectiveness of investment in improving quality are perplexing and inconsistent with the cross-sectional results. We can think of two possible reasons – although we cannot empirically assess which one is correct. In part, this result may reflect the subjectivity of the measure of water quality used in this study. The formal guidelines for drinking water released by the WHO recognize that aesthetic quality issues (taste, odor, color, visible debris) are worthy of careful scrutiny, but are not always indicative of quality issues that actually influence health (World Bank Organization, 2011). In other words, the presence of odor in the water (for example) may not actually be an indicator of poor water quality. It is also possible that village leaders' subjective assessments of water quality are simply uninformed or inaccurate. Alternatively, it could also be that the drinking water projects undertaken in rural areas really have not solved the water quality problems. Tap water may bring more convenience; but it remains unclear whether it is actually delivering higher quality water in rural China today.

While village leaders did not perceive an improvement in quality (as seen in the previous section), we find that the improvement in access to tap water and water treatment facilities is underscored by high rates of rural resident satisfaction. When asked to state their degree

Table VIII.
The impact of drinking water investment from 2005-2011 on drinking water in 2011 (probit model)

	Tap water villages						Non-tap water villages				
Independent	Dependent: tap water village in 2011	Dependent: disinfecting facilities in 2011	Dependent: filtering facilities in 2011	Dependent: visible debris in 2011	Dependent: color, bad taste or odor in 2011	Dependent: originated from polluted source in 2011	Dependent: disinfecting facilities in 2011	Dependent: filtering facilities in 2011	Dependent: visible debris in 2011	Dependent: color, bad taste or odor in 2011	Dependent: originated from polluted sources in 2011
Investment from 2005 to 2011 (1k yuan)	0.03** (2.09)	0.01* (1.70)	0.02** (2.14)	−0.005 (0.71)	−0.002 (0.30)	−0.0006 (0.12)	−0.03 (0.36)	−0.005 (0.40)	−0.008 (0.90)	−0.01 (0.85)	−0.0005 (0.10)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101	101	101	101	101	101	101	101	101	101	101

Notes: The value of *t*-statistics is reported in parentheses. *,**,***Significant at the 10, 5 and 1 percent levels, respectively
Source: Authors' survey

of satisfaction with public services (including drinking water and other public goods, such as irrigation and roads), the degree of satisfaction with drinking water was highest as compared to all other types of public investment projects (Table IX). Of all of the major public services in their villages, rural residents are most satisfied with drinking water. We can also see that overall, households in tap water villages are six percentage points more satisfied with their drinking water than households in non-tap water villages. This suggests that the disparity in water quality (or at least the quality of the water service) between tap and non-tap water villages is in fact perceived by rural residents.

Conclusion

In order to address the persistent problem of drinking water safety and quality in rural areas, China's government has allocated large sums of investment funds to rural drinking water projects in recent years. In the past ten years, according to official statistics China's total rural drinking water project investment has been about 178.6 billion yuan and has worked to resolve drinking water safety issues. These drinking water policies explicitly targeted the expansion of the facilities that promote water quality, including water distribution pipes (used to provide tap water) and water treatment infrastructure (such as disinfecting facilities and filtering facilities). The policy also set an explicit goal of bringing centralized water (generally provided through tap water) to 80 percent of rural households. However, there has been little research on what result the investment has had on the nature of tap water, drinking water facilities, and drinking water quality in rural China.

Using a unique survey data set collected across China, we are able to provide a detailed description of access to sources of quality drinking water in rural China in the early 2000s; describe the nature of China's investment into drinking water; and measure the impact of investment on tap water status, water treatment infrastructure, and subjective assessments of water quality. The data show that water quality was likely a significant problem in 2004, but that China's investment in drinking water appears to have resulted in initial improvements during the study period (2004 to 2011). We show that the most significant change came about in terms of hardware: villages with higher levels of investment in drinking water now have more piped tap water and more access to water treatment infrastructure (disinfecting and filtering facilities). Furthermore, our study shows that the success of this investment may be due in part to its well-targeted nature: the government invested more resources in areas with low water quality and in building up and improving tap water sources.

Curiously, the results on the impact of the investments are mixed. We find that there was no significant impact on the subjective assessments of village leaders of water quality and no significant impact of water investment in villages with non-tap water. While we do not know the reason for this, this may be due to a delay in the impact of these investments the insufficiency of the subjective measure of quality used in this study, or that the water quality-improvement projects were not targeting the right things.

	Satisfied (%)	No opinion (%)	Dissatisfied (%)
Drinking water			
Tap water villages	75.9	0.2	22.9
Non-tap water villages	70.2	0.5	29.3
Health clinics	63.2	3.9	32.9
Schools	62.8	8.4	28.8
Roads	60.2	0.4	39.3
Irrigation and drainage facilities	29.4	25	45.7

Source: Authors' survey

Table IX.
Rural residents' satisfaction with different public services in 2011

While our data does not allow us to draw conclusions about absolute water quality in rural China today, our data do demonstrate that villagers are satisfied. Indeed, high rates of rural resident satisfaction with drinking water – especially in tap water villages – suggest that the effects of drinking water investment are being felt at the village level. While the two impact results appear to be a bit contradictory, it could be that village residents are happy with the improved convenience to access – even withstanding the apparent absence of quality improvement.

We believe our research represents a contribution to the literature on access to water in rural China. Our analysis uses a nearly nationally representative data set to examine whether investment has improved water infrastructure and the perceived quality of water sources. Regardless of it contributions, our research still faces several limitations. First, because our analysis is conducted on the village-level, our effective sample size of 101 villages is relatively small. Second, because we can only evaluate the quality of water as perceived by village leaders we are unable to evaluate whether investment has truly improved the quality of water in rural China.

Given these outstanding questions and uncertainties, more research is needed. The ultimate goal of supplying drinking water to villages is to improve health. It is hoped that if drinking water investment is reaching rural villages, there will be positive improvements in health: The WHO guidelines for drinking water quality state that piped tap water is known to reduce the risk of contamination and disinfection and filtration are generally believed to be essential for ensuring the microbial safety of drinking water sources (World Bank Organization, 2011).

Regardless of the nature of the past investments, more investments are needed in drinking water in rural China. The goal of delivering clean drinking water to 80 percent of China's villages has not been achieved. Surely, the uncertainty in the impacts on water quality suggests that further research into the quality of investments is needed. If more drinking water and better drinking water can be delivered to China's villages, villager satisfaction, no doubt, will continue to rise.

Notes

1. Although the village income variable may be endogenous, because it is being used as a control variable and because we are not fully focused on the coefficient of this variable (as the main analysis of the paper), using the variable in the regression will not create any statistical problem.
2. "Investment in tap water projects" is investment for which the money was specifically earmarked for building up or maintaining tap water facilities.

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Corresponding author
Renfu Luo can be contacted at: luorf.ccap@pku.edu.cn

Appendix

Independent	Tap water villages: Dependent: tap water village in 2011	Tap water villages: Dependent: disinfecting facilities in 2011	Tap water villages: Dependent: filtering facilities in 2011	Tap water villages: Dependent: visible debris in 2011	Tap water villages: Dependent: color, bad taste or odor in 2011	Tap water villages: Dependent: originated from polluted source in 2011	Non-tap water villages: Dependent: disinfecting facilities in 2011	Non-tap water villages: Dependent: filtering facilities in 2011	Non-tap water villages: Dependent: visible debris in 2011	Non-tap water villages: Dependent: color, bad taste or odor in 2011	Non-tap water villages: Dependent: originated from polluted sources in 2011
Investment from 2005 to 2011 (1k yuan)	0.02** (2.06)	0.03*** (2.66)	0.03** (2.56)	−0.001 (0.17)	−0.003 (0.07)	0.004 (0.63)	0.03 (0.03)	−0.002 (0.37)	−0.003 (0.29)	−0.003 (0.52)	−0.005 (0.75)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101	101	101	101	101	101	101	101	101	101	101

Notes: The value of *t*-statistics are reported in parentheses. *,**,***Significant at the 10, 5 and 1 percent levels, respectively
Source: Authors' survey

Table AI. The impact of drinking water investment from 2005-2011 on drinking water in 2011 (OLS regression)