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Drinking water facilities and inclusive development: Evidence from Rural China

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ABSTRACT

This paper studies the economic impacts of enhancing the access to drinking water facilities for rural households in China. Using representative survey data, our study finds that obtaining the access to drinking water facilities enhanced households' off-farm employment and increased their labor income. Through exploring varying impacts for households of different sizes, our analysis suggests that water collection may be an important mechanism inducing these benefits. Moreover, the program benefited lower income households more, enhanced off-farm employment locally but did not induce outward migration, and generated equitable benefits for men and women. These findings suggest that enhancing drinking water facilities may be a cost-efficient strategy for promoting inclusive development in addition to its health benefits.

1. Introduction

The past few decades witnessed a wide expansion of water facilities around the world. According to the Millennium Development Goals Report, over 1.9 billion people have obtained access to piped water since 1990 (Way, 2015). Households that newly acquired access to basic or piped water resources during this period accounted for a quarter of the Sub-Saharan African population (World Health Organization, 2019).

A large body of literature reports welfare gains of getting access to drinking water, primarily through its direct impacts on health. However, because domestic work also imposes a constraint on household time allocation (Bittman et al., 2004; Jenkins & O'Leary, 1995; Noonan, 2001), exactly how rural households obtain drinking water matters for development. Our paper focuses on this channel and studies the economic benefits of enhancing drinking water facilities in a broader context. We argue that collecting and carrying water is not only physically demanding, but also a time-consuming job for rural households.[2] This cost can be so high that some household labor must give up off-farm employment simply to ensure daily water collection. Thus, improving access to drinking water facilities may free rural households from water collection and induce more commitments to off-farm jobs.

China provides a unique context for this study. The IndexMundi's 2014 reports ranked China 105th among all countries in per capita renewable freshwater resources, with more severe water scarcity problem in rural areas.[3] Since the 1980s, the Chinese government has carried out a national drinking water program, which has enabled 263 million people (approximately one-third of the rural population) to gain better access to safe water (Meng et al., 2004). During this period, China's drinking water program had rich regional and temporal variations, allowing us to examine the economic impacts of drinking water facilities.

Our empirical study draws on the China Health and Nutrition Survey (CHNS), a widely used representative panel data covering more than 3,000 rural households in nine provinces. We focus on the period 1989–2011, when major construction works of water facilities took place. Using a standard Difference-in-Difference model, our estimations find considerable economic benefits for rural households acquiring drinking water facilities. According to the baseline model, which controls for village and county-year fixed effects, the program was associated with an increase in the off-farm labor participation rate by 18.7 percentage points, and a rise in household income by 57.9%.

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2 For example, Kremer et al. (2011) estimate that the average rural household in Western Kenya spends at least 126 minutes per day on water collection. An earlier report by the World Bank indicates that the per unit time cost of water collection in developing countries can be 20% higher than the hourly wage among the rural population (Whittington et al., 1989). Devoto et al. (2012) report that more than 66% of the Moroccan families considered water collection to be an important concern, and 12% of households had conflicts with their neighbors over water resources.

3 https://www.indexmundi.com/facts/indicators/ER.H2O.INTR.PC/rankings, retrieved October 9, 2020.

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This effect persisted over time and was not susceptible to pre-trends. The drinking water program was associated with a 17 percentage point decrease in the rate of farmwork, suggesting a pattern of employment transition thanks to the water program. The installation of drinking water facilities enabled rural households to take advantage of more profitable off-farm opportunities that would otherwise be infeasible due to the excessive burden of water collection. The economic gain from time saving and the induced off-farm employment is large, considering that the World Bank assessment about the per capita cost of the program was approximately US$30 (Meng et al., 2004). While this cost assessment is rough and may not exhaust all direct and indirect administrative costs associated with the program, the overall results suggest that public investments in the drinking water program can serve as a fairly cost-efficient strategy for enhancing economic development.

We exploit household size to pin down the mechanism of time-saving from water collection after the drinking water program. Our analysis is motivated by the economies of scale in household work. It takes at least one adult to collect water on a regular basis in water scarce areas. This imposes a constraint for small households to pursue off-farm jobs. While the total time allocated to water collection increases with household size, the time needed for water collection per unit of labor decreases with household size, as more efficient allocation of labor can be achieved in larger households. Following this intuition, we examine how the program's effect varied with the number of adults in the household. We find that the program's impact on off-farm working hours was negligible for households without young workers. Interestingly, the gain in off-farm working hours per young adult decreased with the number of young adults. This result is consistent with the economies of scale in household work and lends support to the time-saving channel.

The recent literature calls attention to the distributional effects of infrastructure. Water facilities can have negative socioeconomic impacts on the local population (Duflo & Pande, 2007; Mettetal, 2019; Rosegrant & Binswanger, 1994; Tilt, 2014). Disputes over water utilization rights may also trigger violent conflicts (Gizelis & Wooden, 2010; Gunasekara et al., 2014). Whether and how investments in water facilities deliver benefits inclusively remain under-investigated. We conduct a set of tests to address these issues.

First, we address household income heterogeneity. Our analysis finds that the effects of the drinking water program were stronger for households that were initially located in the bottom 20th percentile income group in the village and for households in the bottom 20th percentile of villages by income. Second, we examine the impacts of water facilities on local employment vis-à-vis outward migration. Our estimates indicate that the drinking water program did not increase the probability of outward migration. Moreover, the income growth mainly stems from young adults who took up local off-farm jobs. Third, we study whether the effects are equitable between women and men. We find that the size of the economic benefit for females is almost the same as for males. Taken together, our analysis suggests that the water program is not only pro-poor and pro-family, but also pro-women.

The remainder of the paper is organized as follows. Section 2 discusses the literature relevant to our study. Section 3 provides the institutional background of the drinking water program. Section 4 introduces the data. Section 5 presents the empirical strategy. Section 6 reports the baseline results. Section 7 explores several underlying mechanisms. Section 8 addresses issues related to inclusive development. Section 9 concludes.

2. Literature review

Our paper echoes a large literature that examines the benefits of water facilities. The previous studies have mostly focused on health and health-induced outcomes (Galiani et al., 2005; Gamper-Rabindran et al., 2010; Jalan & Ravallion, 2003; Kremer et al., 2011; Lamichhane & Mangyo, 2011; Mangyo, 2008). Zhang (2012) finds that obtaining access to tap water improved health outcomes in China. Zhang and Xu (2016) report that the drinking water program had a positive effect on long-term educational attainment. Our paper takes a different path to study how improving water facilities induced off-farm employment. As such, our research expands the definition of access to water facilities in Zhang (2012), Zhang and Xu (2016), who consider only water plants, to a broader definition including several means of drinking water (e.g., pressurized wells in courtyards). Devoto et al. (2012) and Meeks (2017) find evidence that access to water facilities increased the happiness or leisure time of the affected households in the contexts of Morocco and Kyrgyzstan, respectively, but it had no significant effects on their participation in off-farm work. By contrast, we find strong evidence of positive effects of water access on household income and off-farm employment, which enhances our understanding of the impacts of improving water facility access.

Our paper is also related to studies on the productivity and distributional impacts of public infrastructure (Banerjee et al., 2020; Donaldson, 2018; Duflo & Pande, 2007; Qin & Zhang, 2016). Several papers find that electricity promotes development in rural regions (Chakravorty et al., 2014; Dinkelman, 2011; Rud, 2012). Others find that access to highways may trigger adverse social consequences, such as income inequality and crime, as younger generations migrate to cities (Banerjee et al., 2020; London & Smith, 1988; Oyvat, 2016; Soares, 2004). Duflo and Pande (2007) find that the construction of irrigation dams reduced rural poverty in downstream districts in India, but it increased poverty where the dams were built. Asher and Novosad (2020) find that national roads induced labor reallocation to off-farm sectors in India, but they did not promote household income, assets, or predicted consumption. By contrast, our paper presents strong evidence that China's Rural Drinking Water Program not only enhanced rural residents' participation in off-farm work, but also benefited poor households more significantly. We also find that the Program increased participation in off-farm work equally for men and women, and decreased young females' daily time spent on housework. Taken together, these results suggest that China's Rural Drinking Water Program is an effective public infrastructure investment that promotes inclusive development.

Finally, our paper sheds lights on how infrastructure investments may facilitate inclusive development. In the Chinese context, the household registration system (*hukou*) is widely recognized as an institutional obstacle for the rural population to enter urban sectors (Ngai et al., 2019), and it forces millions of "left-behind children" of migrant workers to stay in rural regions (Cameron et al., 2019; Chang et al., 2011). Our estimates show that the drinking water program had a greater effect on poorer households and facilitated the switch to local off-farm jobs without incurring the cost of migration.

3. Institutional backgrounds

3.1. Water shortage and its constraints on Chinese households

China is a country with poor freshwater resources. China's total freshwater resources only account for 6% of the world's total, and its freshwater resources per capita rank 109th in the world (Gu et al., 2017). The distribution of freshwater resources in China is also extremely uneven. Northern provinces have 42% of the population but only 8% of the water resources, and the water environment has continued to deteriorate since the 1990s (Ministry of Water Resources, 2004).

Rural residents have long faced severe water shortage problems. Before the National Rural Drinking Water Program, rural residents were forced to reduce their daily water consumption and collect water from open resources, such as rivers, streams, lakes, and ponds (Meng et al., 2004). They had to go outside to fetch water from a distance. Due to the scarcity of water, they had to use bowls and spoons as units of measurement for the water. With the same bowl of water, a whole family would wash the vegetables first, then wash their faces, then do the laundry, and finally feed the livestock.

Moreover, the problem of water scarcity is aggravated by extreme weather conditions (Moore, 2013). Before the drinking water program, whenever there was a drought, the wells and springs would dry up. The villagers had to look for water everywhere, beg for water, borrow water, and buy water. In extreme cases, villagers had to go to the black market to sell their blood and then use the money to buy high-priced water (Qin, 2013). In some areas, water had to be centrally managed and distributed by the elders of the family. The whole village would criticize villagers if they took a bath or rinsed their mouth. Some people never took a bath in their whole life, and conflicts between clans occurred frequently due to competition for water sources.

Water collection can be prohibitively costly for rural residents in terms of time spent on water collecting. It is estimated that an adult needed to spend at least one hour per day in water hauling to meet the subsistence level of water consumption for a five-member household. In many mountainous or arid areas, residents needed to spend much more time and walk on rugged mountain roads to fetch drinking water. A bucket of water often weighs tens of kilograms and fetching water often required traveling a long distance (sometimes even on rugged mountain roads). Young adults in the family, both men and women, were mainly responsible for obtaining drinking water.

In turn, the routine water collection task prohibited at least one adult member from seeking a regular job that would require a full-time commitment. After the completion of the drinking water program, rural families can conveniently obtain drinking water at home, and the labor burden of going out to fetch water every day was relieved. Some policy reports estimate that obtaining convenient access to water facilities helps save roughly 50 full-time workdays for a five-member household every year.[4]

3.2. The water program in China

The Chinese government has been investing in a nationwide water program since the 1980s. The implementation of the program had three features. First, local governments took an active part in constructing water facilities. The coverage of water facilities became an important basis of the performance evaluation of local officials. The investments in water facilities were jointly financed by the central government, local governments, and loans from the World Bank. As a result, the location choices of the water facility investments were spatially dispersed.

Second, the central government mandated local governments to determine the type of water facilities according to their local natural conditions (e.g., water source and terrain) and control construction budget. For mountainous and hilly areas, it was recommended to make full use of differences in terrain elevation, to build artesian water supply projects. For rural areas close to the existing water supply pipe networks of county seats or towns, extending the water supply networks to rural areas was recommended. In areas with scarce water sources and relatively few users, local governments would build decentralized water supply facilities, such as wells and impounding reservoirs for collecting rainwater.[5] The construction of all these kinds of water facilities enabled 263 million rural people (approximately one-third of the rural population) to obtain sufficient, clean and affordable water in a timely and convenient way (Meng et al., 2004).

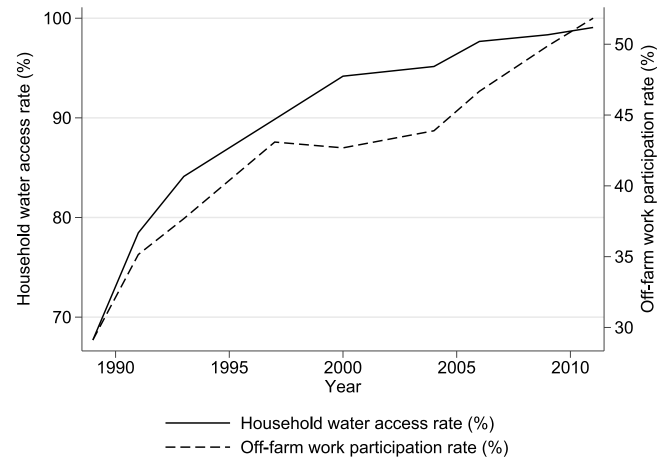

Fig. 1. Household access to water facilities and participation in off-farm work. Notes: This figure presents the household-average rate of water access, calculated based on the CHNS data. The definition of the access to water facilities on the household level follows the coding criteria in Section 4.2. The off-farm work participation rate is from the National Bureau of Statistics of China.

Third, the water program was implemented incrementally. Water facilities took different forms, including water plants, water diversion projects, reservoirs, and groundwater collection. Fig. 1 presents the trend of household-average rate of access to drinking water, reconstructed from CHNS data. In the CHNS data, one-third of the rural households did not have access to water in 1989. The share of rural households with access to water was close to 100% in 2011. This development involved rich temporal variations across regions in the coverage of water facilities over 1989–2011.[6] The figure also shows that the trend in the water access ratio is synchronized with the off-farm labor participation rate, which was 29.1% in 1989 and rose to 51.8% in 2011. The figure shows a strong positive correlation between the expansion of the water program and the off-farm labor participation rate.

4. Data

CHNS provides 10 waves of demographic surveys of more than 30,000 individuals in 7,200 households located in 15 provinces and municipal cities over 1989–2015. The survey adopts a multi-stage, random cluster sampling strategy, with four counties drawn randomly from each province. In addition, the provincial capital and a lower income city are selected when feasible in each province. The length of time between two adjacent survey waves is two to four years. The CHNS data provide a rich set of socioeconomic variables at the individual, household, and village levels, as well as economic and family planning decisions.

For the purpose of examining the water program, we focus on the 1989–2011 period, when the program incrementally provided coverage to villages that were having difficulty in obtaining water.[7] Since the water scarce units in this period were mostly located in rural regions, we do not use the urban sample. This streamlines the sample size to

[4] See *The 11th Five-Year Plan of the National Rural Drinking Water Program*, retrieved on March 1, 2020. https://wenku.baidu.com/view/adc6cedb6bec0975f465e2d6.html?rec_flag=default&sxts=1584098962209&pn=50

[5] We refer to *The 12th Five-Year Plan of the National Rural Drinking Water Program*, retrieved on July 8, 2022. https://wenku.baidu.com/view/0c465f257a563c1ec5da50e2524de518974bd37c.html

[6] Section 6.4 explores the correlation between the location of facility investment and local conditions.

[7] The coverage rate of water facilities is close to 100% in the 2011 survey. The data source is CHNS (China Health and Nutrition Survey), and the implementation process of China's Rural Drinking Water Program is shown in Fig. 1. We conduct a robustness check including the 2015 sample for the baseline estimations. The results are similar and presented in Table A5 in Appendix.

Table 1
Summary Statistics.

Variable	Mean	S.D.	Min	Max	Obs
Village Level					
Off-farm work participation rate	0.301	0.184	0	0.764	975
Population	3,628	6,622	5	86,733	842
1[Rugged]	0.548	0.498	0	1	854
1[Near a navigable river]	0.187	0.390	0	1	838
Distance to county seat	16.134	14.374	0	60	675
Population in 1989	2,950	5,411	108	44,611	811
Per capita income in 1989	2,586	1,085	438	6,573	863
1[Paved road]	0.636	0.482	0	1	933
1[Electricity]	0.988	0.111	0	1	961
1[Railway station]	0.142	0.349	0	1	959
1[Telephone]	0.795	0.404	0	1	961
Household Level					
1[Off-farm work]	0.651	0.477	0	1	19,540
# Off-farm workers	1.264	1.232	0	12	19,540
# Off-farm working hours	8.106	8.899	0	70	19,316
1[Farm work]	0.479	0.500	0	1	19,540
# Farmers	1.040	1.318	0	9	19,540
# Farming hours	5.384	8.209	0	70	19,494
Labor income	16,814	26,592	0	913,762	19,105
1[Head is male]	0.858	0.349	0	1	19,454
Age of head	50.510	13.844	16	102	19,454
# Schooling years of head	6.592	3.899	0	18	17,878
# Family members	4.259	1.734	1	16	19,540
# young adults	2.086	1.233	0	10	19,540
1[Sick]	0.175	0.380	0	1	16,003
Average weight-for-height	36.453	4.618	21.176	87.336	16,821
1[Water plant]	0.408	0.492	0	1	19,264
# Average schooling years of labor force	6.992	3.090	0	18	17,263
Individual Level					
1[Off-farm work]	0.276	0.447	0	1	83,227
# Off-farm working hours	1.816	3.363	24	0	80,405
1[household head]	0.234	0.423	0	1	83,227
1[Male]	0.494	0.500	0	1	83,227
Age	34.702	19.982	0	106	83,215
# Schooling years	6.167	3.924	0	18	57,112
# Family members	4.965	1.890	1	16	83,227
1[Migrating work]	0.123	0.329	0	1	48,067

Notes: The data source is CHNS. The unit for distance to the county seat is kilometers. Per capita income in 1989 is the village's average household net income per capita measured in yuan in 1989. Labor income is the yearly household total labor income measured in yuan and has been adjusted according to the price level in 2011. 1[Sick] equals 1 if any household member ages 16–64 got sick or injured within four weeks before the survey, and 0 otherwise. The average weight-for-height is the mean weight/height of family members ages 16–64, and it is measured in kilograms per meter. 1[Water plant] equals 1 if the household's water source is (at least mainly) a water plant, and 0 if otherwise.

3,488 households and 123 villages in nine provinces, spanning nine survey waves over 1989–2011.[8]

Two features make the CHNS data appealing for investigating the impacts of the water program. First, the CHNS sampling strategy ensures the representativeness of the surveyed households. The data present meaningful snapshots of economic and social transformation in China. Second, the CHNS data provide a rich set of occupational information at the individual level. For this reason the CHNS data are widely used in empirical studies on industrialization and urbanization in China (Cao & Birchenall, 2013; Chen, 2006; Giles & Yoo, 2007; Lee & Malin, 2013; Liu, 2013; Wang, 2011).

4.1. Dependent variables

The main dependent variable throughout the analysis is a dummy variable, 1[Off-farm work], indicating whether a household participates in off-farm work. CHNS asks questions about the employment and occupational choices of all family members aged 16 or older. We consider an individual to have a regular off-farm job if they receive regular wages as opposed to being self-employed, mostly in agriculture. If at least one member of the household receives regular wages, 1[Off-farm work] equals 1, and 0 otherwise. By a similar token, we define 1[Farm work] as a dummy variable indicating that a household works in agriculture, fishery, orchard, or animal farming.

4.2. Independent variables

The main independent variable in this research is defined at the village level. CHNS classifies households' means of obtaining water into four types: (1) piped or tap water in the house, (2) piped or tap water in the courtyard, (3) pressurized wells in the courtyard, and (4)other places. We first define that a household has access to water if its means of obtaining water falls in the first three categories

[8] In the 2015 wave of the CHNS, more than 99% of the households were covered by the water program. The 2011 survey added three centrally administered municipalities, Beijing, Shanghai, and Chongqing, and the 2015 survey added three provinces, Shaanxi, Yunnan, and Zhejiang. These six province-level administrative regions are not included in our 1989–2011 sample. Our 1989–2011 sample covers longitudinal surveys in nine province-level administrative regions: Liaoning, Heilongjiang, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, and Guizhou. For the sake of simplicity, we use "province" to refer to provincial administrative regions in this paper.

(that is, 1[Household water access]=1).[9] We then adopt a three-step coding procedure to construct a village-level dummy variable, 1[Water access].[10]

In the first step, we code 1[Water access] as 1 for a village in which more than 80% of all households have access to water in the first survey year, and 0 otherwise. Second, we code 1[Water access] as 1 if there is more than a 20 percentage point increase in the water access rate each year since the last survey wave, and 0 otherwise. For example, if a village's water access rate rose from 5% to 75% from 1997 to 2000 (23.3% each year on average), then the main independent variable, 1[Water access], is set to 1 in 2000. Third, once 1[Water access] = 1 in a given year, in all subsequent years it is coded as 1, because water facilities generally remain available after that and the ratio of households with access to water almost never falls. Table A1 in the Appendix presents the summary statistics of 1[Water access] in each survey wave.

In addition to the key dependent and independent variables, we control for a set of demographic and socioeconomic variables at the village, household, or individual level that may confound employment choices or economic outcomes. Table 1 provides the summary statistics for the key variables used in the empirical analysis.

5. Identification strategy

The empirical analysis investigates the participation in off-farm work and labor income of treated households. The basic regression model is as follows:

$$Y_{i(jk)t=\gamma \cdot 1[\text{Water access}]_{jt}+\beta \cdot X_{i(jk)t}+\mu_j+\lambda_{kt}+\epsilon_{i(jk)t}} \tag{1}$$

In Eq. (1), the dependent variables are economic outcomes, such as participation in off-farm work and labor income. The subscripts $i(jk)t$ indicate that the outcomes vary at the household or individual level (i), and the right-hand side variables vary at the county (k), village (j), and year (t) levels. The main independent variable is $1[\text{Water access}]_{jt}$, which varies at the village-year level. The identification is based on the assumption that water facilities can only be provided by governments, and thus are unaffected by the occupational choice of individual households. Controlling for village and year fixed effects, this specification is largely a staggered Difference-in-Difference design, in which the treatment occurs in different units during different time periods.[11]

In Eq. (1), μ_j is a set of village fixed effects, and λ_{kt} represents county-specific year fixed effects. As we described in Section 3, the allocation of drinking water facilities was also determined by the urgency of the need for water, which may have been correlated with geographic and initial economic conditions. These conditions may have affected household employment choice and income as well. Controlling for village fixed effects eliminates endogeneity arising from the villages' geographic and initial economic conditions. Meanwhile, controlling for county-year fixed effects in the estimations absorbs all the unobservable effects, such as the counties' fiscal spending, which may comove with the trends in water facilities and household income.[12]

$X_{i(jk)t}$ is a vector of household-level demographic variables. The dummy 1[Head is male] indicates that the head of household is male. The norm of the residence registration system (*hukou*) in China considers the husband (father) as the default head of household. Thus, 1[Head is male] = 0 may suggest the absence of adult males in the household, affecting income and the probability of pursuing off-farm work. We also control for the age and education (measured by years of schooling) of the head of household. Both variables may be correlated with the capability of seeking external job opportunities. In addition, we control for the number of family members, to address the economies of scale for large households. $\epsilon_{i(jk)t}$ specifies the random disturbance varying at the household-year level.

6. Baseline results

6.1. Effects on off-farm employment and income growth

Table 2 presents the baseline results estimated at the household level. Column (1) reports the univariate estimate using 1[Water access] only. The coefficient is 0.363 and statistically significant. In column (2), we control for the demographic variables, year fixed effects, and village fixed effects. The size of the coefficient drops to 0.149 and remains significant at the 0.01 level. Column (3) additionally controls for the county-year fixed effects. The estimated coefficient is 0.187 and statistically significant at the 0.01 level, representing nearly 30% of the mean value of the dependent variable. The result translates into an increase of 30% in the probability of off-farm work. This is a considerably large impact on employment choice.

Column (4) in Table 2 presents the impact of the drinking water program on the number of off-farm workers. The program led to an increase of 0.455 off-farm worker, or 36.0% of the mean number of off-farm workers per household. In column (5), we substitute the dependent variable with the number of off-farm working hours. The estimate is 3.320, which amounts to 41.0% of the mean number of off-farm working hours.[13]

Column (6) in Table 2 presents the results for the labor income effect. A discrete increase in 1[Water access] is associated with an increase of 57.9% in annual household labor income. A back-of-the-envelope calculation implies that the presence of water facilities translates into an increase in per household labor income of US$458 each

[9] According to China's 11th Five-Year Plan of the National Rural Drinking Water Program, there were various types of drinking water facilities and they were determined by local natural conditions (e.g., water source and terrain) and construction costs of the villages. In villages located in hilly areas or where farmers lived in scattered homes, the government mainly constructed decentralized drinking water facilities such as wells and rainwater storage facilities. In the 1990s, most wells were built by China's National Rural Drinking Water Program. Therefore, the drinking water facilities should include pressurized wells in the courtyard. Excluding pressurized wells in the courtyard from our definition of water access does not affect our key results.

[10] Our method follows Zhang (2012) and Zhang and Xu (2016) to capture the implementation of the water program through observing a large, discrete increase in the ratio of households with access to water, which was more likely to be counted as an exogenous government program rather than a spontaneous change in each household's demand. However, replacing the village-level water access rate with the household-level water access rate does not affect our key results.

[11] There may be a concern about potential bias in estimating staggered two-way fixed effect (TWFE) models, as demonstrated by the recent literature (Callaway & Sant'Anna, 2021; de Chaisemartin & D'Haultfoeuille, 2020; Goodman-Bacon, 2021). We address this methodological issue in a separate section in the Appendix (see Table A12 and the explanation).

[12] Note that we cannot control for village-year fixed effects since our main independent variable 1[Water access] varies at the village-year level. In China, counties play a vital role in local spending and infrastructure investments. In our sample, there are 36 counties; each county has 3.42 villages on average. This renders relatively small cross-village variation in terms of time-varying factors such as local fiscal spending. Hence, controlling for village and county-year fixed effects in the regression model helps alleviate the unobservable effects.

[13] By contrast, Devoto et al. (2012) and Meeks (2017) find that access to water facilities had no significant effects on residents' participation in off-farm work in Morocco and Kyrgyzstan, respectively. One possible reason is that China enjoyed a much higher level of industrialization than Morocco and Kyrgyzstan, and even in China's rural areas there were plenty of off-farm job opportunities. China's secondary industry contributed to 46.7% of GDP,much higher than Morocco's 28.6% and Kyrgyzstans 28.2% in 2010 (United Nations Statistics Division Database). This may explain why China was able to provide more non-agricultural jobs for rural labor forces when they were liberated by the rural water program.

Table 2
Access to Water and Off-Farm Work (1989–2011).

Dependent variable	1[Off-farm work]			# Off-farm workers	# Off-farm working hours	Log(labor income+1)
	(1)	(2)	(3)	(4)	(5)	(6)
1[Water access]	0.363***	0.149***	0.187***	0.455***	3.320***	0.579**
	(0.052)	(0.045)	(0.052)	(0.120)	(0.900)	(0.241)
1[Head is male]		0.004	0.001	0.064	0.106	0.323***
		(0.016)	(0.015)	(0.040)	(0.267)	(0.105)
Age of head		−0.004***	−0.004***	−0.007***	−0.099***	−0.070***
		(0.000)	(0.000)	(0.001)	(0.009)	(0.005)
# Schooling years of head		0.013***	0.013***	0.026***	0.156***	0.041***
		(0.001)	(0.001)	(0.003)	(0.024)	(0.009)
# Family members		0.043***	0.044***	0.205***	1.298***	0.420***
		(0.003)	(0.003)	(0.011)	(0.085)	(0.027)
Observations	19,540	17,878	17,878	17,878	17,656	17,557
R-squared	0.028	0.298	0.362	0.386	0.314	0.314
Year FE	NO	YES	NO	NO	NO	NO
Village FE	NO	YES	YES	YES	YES	YES
County*Year FE	NO	NO	YES	YES	YES	YES

Notes: This table reports the regression results for the impact of access to water facilities on off-farm work at the household level. Standard errors in parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

year, or an increase of US$108 in per capita income for an average household size of 4.259 (price level adjusted to that of 2004). This is a large effect considering the lump-sum cost of the program at roughly US$30 per person (Meng et al., 2004).[14]

We provide a set of robustness checks with alternative measures of the key variables and econometric specifications. First, there may be a concern that our use of a 20 percentage point increase in the household water access rate as a threshold for 1[Water access] drives the results. As a robustness check, we use different ratios as cutoffs to define the implementation of the water program at the village level, and we obtain similar results (Table A2 in the Appendix). Second, while we define 1[Water access] as the village improvement of water facilities, it may be possible that households' own access to water facilities plays a more important role. To address this concern, we use 1[Household water access], defined at the household level, as the key explanatory variable, and obtain similar results (Table A3 in the Appendix). Table A4 in the Appendix provides a further robustness check, in which we exclude pressurized wells in the courtyard as a regular water resource in defining 1[Household water access]. Our results remain robust for alternative definitions of the independent variables. In Table A5 in the Appendix, we conduct a robustness check including the 2015 sample for the baseline estimations and get similar results. This is not surprising provided that the majority of the surveyed villages completed the drinking water program by 2011. Finally, we also estimate the overall impact of water facilities on participation rates in off-farm work at the village level. As Table A6 in the Appendix shows, the results are consistent with those obtained at the household level.

6.2. Transition from farmwork

Water facilities may enhance income growth through different channels. We test if the drinking water program works mainly through facilitating an employment transition from agriculture to off-farm work. The results in columns (1) to (3) in Table 3 show that access to water facilities was negatively associated with farmwork. According to the most rigorous specification controlling the village and county-year fixed effects, rural households were 17 percentage points less likely to have any household member working in the agriculture sector after the drinking water program, 35.5% of the dependent variable's

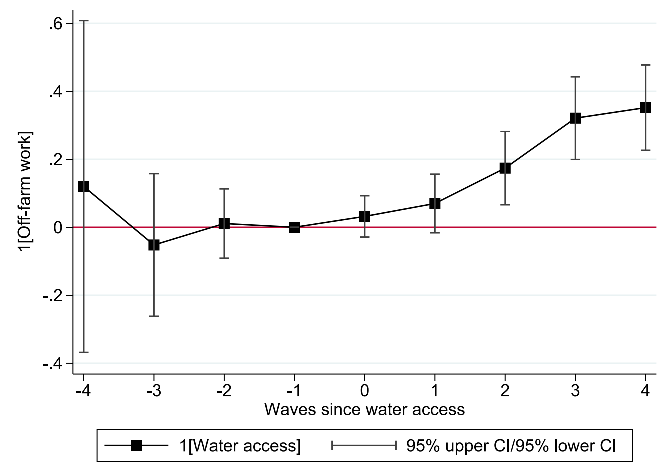

Fig. 2. Dynamic effects.
Notes: This figure presents the point estimates and 95% confidence intervals for the dynamic effects of access to water facilities from $t-3$ to $t+3$. $t=-1$ is the normalized time one year before the program was implemented. $t = 0$ refers to the year of implementation. $t=-3$ indicates three or more waves before the water program. $t=3$ is three or more waves after the water program.

mean. Columns (4) and (5), respectively, report the effects on the number of farmworkers and total farming hours. Both are significantly negative. Interestingly, decreasing farming hours (−3.635) has a larger magnitude than that of increasing off-farm working hours (3.320). Put together, the results suggest that the labor reallocation was driven by income substitution between the farm and nonfarm sectors.

6.3. Examination of parallel trends

The baseline specification relies on the assumption that 1[Water access] is not correlated with unobservable factors that comoved with development outcomes. This assumption would be violated when the villages that had improved water facilities had already spent public funds to expand off-farm jobs. To test whether there is a significant pre-treatment difference between the control and treatment groups, we estimate the dynamic impacts of the water program by interacting 1[Water access] with a set of dummy variables indicating years before or after the treatment.

Fig. 2 shows the 95% confidence intervals for the dynamic effects of 1[Water access]. There is no pre-trend in the treatment effect on

[14] The average annual labor income of rural households in the 1989 CHNS sample was about US$791 (adjusted to the 2004 price level). Thus, access to water facilities is associated with an increase of $791 * 57.9\% \approx US\$458$ according to column (6) in Table 2.

Table 3
Transition from Farmwork (1989–2011).

Dependent variable	1[Farm work]			# Farmers	# Farming hours
	(1)	(2)	(3)	(4)	(5)
1[Water access]	−0.445***	−0.158***	−0.170***	−0.562***	−3.635***
	(0.036)	(0.034)	(0.054)	(0.144)	(1.077)
1[Head is male]		0.062***	0.059***	0.242***	1.230***
		(0.012)	(0.012)	(0.037)	(0.221)
Age of head		−0.004***	−0.004***	−0.005***	−0.034***
		(0.001)	(0.001)	(0.001)	(0.008)
# Schooling years of head		−0.004***	−0.004***	−0.017***	−0.106***
		(0.001)	(0.001)	(0.004)	(0.022)
# Family members		0.018***	0.020***	0.137***	0.706***
		(0.003)	(0.003)	(0.014)	(0.084)
Observations	19,540	17,878	17,878	17,878	17,834
R-squared	0.038	0.550	0.599	0.508	0.470
Year FE	NO	YES	NO	NO	NO
Village FE	NO	YES	YES	YES	YES
County*Year FE	NO	NO	YES	YES	YES

Notes: This table reports the regression results for the impact of the drinking water program on farmwork at the household level. Standard errors in parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 4
Local conditions and the timing of water facility construction.

Dependent variable	Year of obtaining the access to water			
	(1)	(2)	(3)	(4)
1[Rugged]	5.168***	5.452**	5.439**	5.728**
	(1.899)	(2.086)	(2.100)	(2.119)
1[Near a navigable river]		−2.002	0.001	0.809
		(2.612)	(2.731)	(2.794)
Log(1+ distance to county seat)			0.540	0.393
			(0.998)	(1.002)
Log(population in 1989)				−2.474*
				(1.315)
Log(per capita income in 1989)				−0.536
				(2.032)
Observations	100	97	74	71

Notes: This table reports the effects of local conditions on the timing of water facility construction, estimated by a Tobit model. Per capita income in 1989 is the average yearly household net income per capita measured in yuan of the village in 1989 and has been adjusted according to the price level in 2011. Robust standard errors are reported in parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

participation in off-farm work. Evidently, the coefficients for $t-2$ and $t-3$ are close to zero and not statistically significant. The point estimates for 1[Water access] remain positive after $t = 0$, the year when the treatment is registered. The point estimates for 1[Water access] remain positive after $t = 1$ and increase slightly over time. Put together, the results alleviate the concern that the water program was driven by other factors correlated with development and labor market outcomes.

6.4. Examination of the program's location choices

There is a legitimate concern that the allocation of the water program may be correlated with unobservable factors that affect development. For example, local governments may prioritize the construction of water facilities in regions with higher potential for development. According to the *The 11th Five-Year Plan of the National Rural Drinking Water Program*, local governments should economize construction costs and consider geographic and socioeconomic conditions in assigning new investments. This implies that water facilities might have arrived later in peripheral, poor, and mountainous regions, because the investment was costlier there. The estimation of the program's impacts might be biased if there was a systemic difference between peripheral and central regions in the availability of water facilities.

Table 4 shows the correlation between the preexisting conditions of villages and the timing of the drinking water program. We include two dummy variables, 1[Rugged] and 1[Near a navigable river], respectively, to indicate whether the village is located in a hilly area and whether the village is close to a navigable river, which means having an abundant water source. In addition, we control for the logarithm of the distance to the county seat, village population in 1989, and per capita income of the village in 1989. The estimations suggest that water facilities arrived later in rugged villages and earlier in villages with a larger population. Apart from this, the timing of water access was not correlated with other characteristics, such as water source (measured by 1[Near a navigable river]), geographic remoteness (measured by log(1+ distance to county seat)), or initial level of economic development (measured by per capita income of the village in 1989). Since we have controlled for village fixed effects in all the baseline regressions, the differences in the ruggedness of village locations and initial population size should not bias our estimation.

To check whether 1[Rugged] may be correlated with the year of water program implementation, we conduct an additional robustness check. We address the heterogeneous impacts of the drinking water program by adding two interaction terms, 1[Rugged] and village population in 1989 (logarithm), interacted respectively with year dummies, to our baseline estimation as in Table 2. As reported in Table A7 in the Appendix, our results remain robust after controlling for the two interaction terms.

7. Mechanism and possible confounding factors

7.1. Accounting for the time-saving mechanism

We explore household size to demonstrate the time-saving mechanism after the drinking water program was implemented. Suppose a household has only one young adult and there is no easy access to water. This young adult must devote a significant amount of time to collecting water from afar on a regular basis. For households with several young adults, although the demand for water increases with household size, the time spent on water collection per young adult would be much less, thanks to economies of scale in water collection (e.g., through labor specialization and coordination). Therefore, we would expect that the average amount of time spent on water collection per unit of labor decreases with the number of workers in the household. Given this observation, if we believe that the water facility program facilitated the transition to off-farm employment through saving time spent on water collection, the increase in off-farm working hours per unit of labor due to the program should follow a similar relationship with household size (number of workers).

We conduct the tests as follows. We first create a set of dummy variables indicating the number of young adults in the household. Column (1) in Table 5 presents the estimates with demographic controls only. In columns (2) through (4), we include more household control variables

Table 5
Mechanism: Time saving from water collection.

Dependent variable	# Off-farm working hours			
	(1)	(2)	(3)	(4)
1[Water access]	1.879***	1.172**	−2.799***	−0.972
	(0.538)	(0.538)	(1.019)	(1.157)
1[Water access] *1[1 young adult]	2.612***	1.972**	2.212**	2.434**
	(0.834)	(0.839)	(0.874)	(0.932)
1[Water access] *1[2 young adults]	3.385***	3.431***	4.411***	4.527***
	(0.681)	(0.666)	(0.809)	(0.819)
1[Water access] *1[3 young adults]	5.123***	4.914***	5.409***	5.658***
	(1.051)	(0.983)	(1.224)	(1.258)
1[Water access] *1[4 young adults]	2.113	2.196	2.854	3.930**
	(2.101)	(2.171)	(1.814)	(1.887)
1[Water access] *1[5 or more young adults]	5.098**	4.529**	3.500*	4.706**
	(1.989)	(1.857)	(2.030)	(1.938)
Observations	19,316	17,656	17,656	17,656
R-squared	0.076	0.109	0.245	0.326
Demographic Controls	YES	YES	YES	YES
Household Controls	NO	YES	YES	YES
Year FE	NO	NO	YES	NO
Village FE	NO	NO	YES	YES
County*Year FE	NO	NO	NO	YES

Notes: This table examines how the estimated coefficient of 1[Water access] varies with household size. The demographic control variables include 1[1 young adult], 1[2 young adults], 1[3 young adults], 1[4 young adults], and 1[5 or more young adults]. Household-level control variables include 1[head is male], age of head, number of schooling years of head, and number of family members. Standard errors in parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

and village and county-year fixed effects. As is evident from the results in Table 5, the coefficient of 1[Water access], which is interpreted as the impact on households without young adults, is insignificant under the most rigorous and preferred specification (column (4)). This result makes sense since there would be no labor available for off-farm work.

Following the estimated results in column (4) in Table 5, if a household had one young adult, the time spent in off-farm work would increase by 2.434 h per day due to improved access to water facilities. The effect on off-farm working hours was larger for households with two or three young adults, with increases of 4.527 and 5.658 h for each household, respectively. But the increases in off-farm working hours per young adult, which we interpret as the household average time saved in water collection, were 2.264 and 1.886 h, smaller than the case of households with one young adult (2.434 h). For households with four or five young adults, the increase in off-farm working hours per young adult was less than one hour and decreased with the number of young adults. From these estimates, we can see that the increase in off-farm working hours per unit of labor was smaller when the number of workers in the household was greater. This pattern is consistent with our argument about the economies of scale in water collection prior to the program implementation. This finding lends support to the notion that the time saved in water collection might be an important channel through which access to water facilities helped promote off-farm employment.

7.2. Accounting for confounding factors

We also address the concern that the impacts of enhancing water facilities may be correlated with other confounding factors. A noteworthy confounding channel is improvement in health. As previous literature demonstrates, clean water lowers the probability of infectious disease (Zhang, 2012) and promotes educational attainment (Zhang & Xu, 2016). Hence, the program may also affect employment and income through enhancing human capital.

Table 6 reports the effects of the program on participation in off-farm labor estimated at the household level. Column (1) controls for dummy variables indicating whether any family members had been sick and the average weight-to-height ratio, two proxies for health condition. Column (2) controls for whether the household has access to water from a water plant.[15] Column (3) controls for the average years of schooling of adult family members. Column (4) controls for all the previously used confounding variables. The results attest to the importance of health and education in occupational choice. The variable 1[Water access] remains a strong and robust predictor of 1[Off-farm work] throughout all the estimations.

There may be a concern about the possibility that the installation of water facilities was accompanied by other types of construction of public infrastructure, which might have contributed to the reallocation of labor toward off-farm work. We add a set of dummy variables indicating whether the village had an access to public infrastructures, such as paved roads, electricity, railway stations, and the telephone network, to the baseline estimation in Table 2. As reported in Table A8 in the Appendix, our key results on the access to water are robust to controlling for access to other types of public infrastructure.

8. Inclusive development

We address the issue of inclusive development in three ways. First, we account for different income groups benefitting differently from the program. Second, we disentangle labor reallocation at the individual level into outward migration and local employment. Third, we investigate whether there was a gender difference in the effects of the program.

8.1. Was the program pro-poor?

We first examine the link between the water program and income disparity. A priori, it is unclear whether the relatively rich or poor benefited more from the program. On the one hand, poorer households had a lower opportunity cost of labor reallocation, so they might have been more responsive to new economic opportunities facilitated by the program. On the other hand, poorer households were likely to face other obstacles to moving around and were hence less mobile than richer ones. To examine the impacts of the program on households with different economic conditions, we allow the estimates of the impacts of the program to vary according to the initial income level. More specifically, we define the initial income level of households (villages) as the average household (average village) income in 1989, the first survey year of CHNS.

Fig. 3 presents the differences between households with different initial levels of income within the same village between 1989 and 2011 in the ratio of water access and the rate of participation in off-farm work. It shows that the changes in water access rate between rich and poor households were almost the same. However, the increase in the rate of participation in off-farm work among poor households was much larger than that of rich households, indicating that relatively poorer households had greater gains from the water program.[16] In Figure A2 in the Appendix, we plot the coverage of water facilities and the ratio participation in off-farm work by village income percentile. The figure indicates that poor villages benefitted more from the water program.[17] We also estimate the results addressing income heterogeneity at the household and village levels, respectively. The results are reported in Tables A9 and A10 in the Appendix and are consistent with the intuition illustrated in Fig. 3.

[15] Water plants ensure drinking-water quality, and were previously adopted as a proxy for potential health quality (Zhang, 2012).

[16] We depict the number of off-farm workers, number of off-farm working hours, and household labor income figures in this way and obtain similar results.

[17] We plot the number of off-farm working hours per capita and household labor income per capita figures in this way and obtain similar results.

Table 6
Controlling for confounding factors.

Dependent variable	1[Off-farm work]			
	(1)	(2)	(3)	(4)
1[water access]	0.206***	0.207***	0.193***	0.229***
	(0.064)	(0.053)	(0.051)	(0.065)
1[sick]	−0.000			0.010
	(0.010)			(0.010)
average weight-for-height	0.002**			0.002**
	(0.001)			(0.001)
1[water plant]		−0.014		−0.015
		(0.015)		(0.016)
# average schooling years of labor force			0.028***	0.027***
			(0.002)	(0.002)
Observations	14,212	17,665	16,220	14,059
R-squared	0.381	0.362	0.391	0.392
Household Controls	YES	YES	YES	YES
Village FE	YES	YES	YES	YES
County*Year FE	YES	YES	YES	YES

This table controls for additional village-level variables that might confound labor reallocation and income growth. 1[Sick] equals 1 if any household member age 16-64 was sick or injured within four weeks before the survey, and 0 if otherwise. The average weight-for-height is the mean of weight/height of household members ages 16-64, and it is measured in kilometers per meter. 1[Water plant] equals 1 if the household water source is (at least mainly) a water plant, and 0 if otherwise. Household controls include 1[head is male], age of head, number of schooling years of head, and number of family members. Standard errors in parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

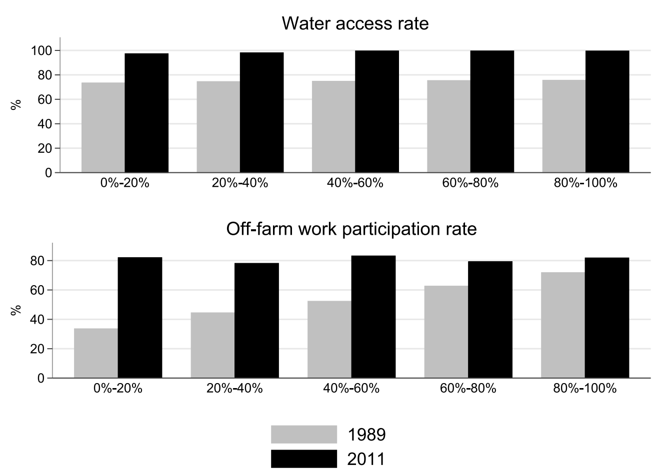

Fig. 3. Access to water and off-farm employment, by income cohorts.
Notes: The grey bars present the household averages in 1989, and the black bars present the household averages in 2011. The bars from left to right in each subfigure present the household averages within a village: 0–20th, 20th–40th, 40th–60th, 60th–80th, and 80th–100th income per capita percentiles, in which the 80th–100th income per capita percentile has the highest income per capita in the village. The percentile groups are classified according to the household income per capita in a village in 1989, the first wave of CHNS.

8.2. Migration versus local development

Recent research suggests that there are mixed effects of infrastructure on local development due to factor mobility (Banerjee et al., 2020; Faber, 2014). Although migration is an inherent part of industrialization, it imposes additional costs on migrants. In China, the social cost of migration is aggravated by the household registration (*hukou*) system, which, through restricting migrant workers' legal rights, forced millions of rural children to stay in the countryside with their grandparents and become "left-behind children". The separation of migrant workers from their children gave rise to severe social problems (Cameron et al., 2019; Knight & Gunatilaka, 2010).

Table 7 disentangles migration and local employment. Columns (1) and (2) report the effects of the program on the probability of becoming a migrant worker.[18] It is evident that the probability of being a migrant worker was not correlated with the availability of water facilities. Columns (3) and (4) show that the existence of water facilities lowered the probability that an individual permanently moved out of the village.[19] These results alleviate the concern that the water program might have hampered local development.[20]

8.3. Was there a gender difference?

We examine whether the program's benefits vary by gender and age. The results in columns (1) to (4) in Table 8 show that water facilities had a significant effect of inducing off-farm work for young adults, but not for children and elders. This result is consistent with the conjecture that the water program saved the time cost of water collection, which was normally carried out by young adults. Moreover, the water program produced similar effects for female and male young adults, as columns (2) to (4) show. The literature documents that women in developing countries often take a larger part in household work (i.e., child raising and cooking), which generates no monetary payoff, while men earn income outside the household (Danziger et al., 1982; Graham et al., 2016). The traditional division of labor gives rise to socioeconomic inequality in gender in an agriculture-dominant society. Our results show that the economic benefits are comparable for younger men and women under age 45.

The water program also changed intra-household time allocation. The results in columns (1) to (4) in Table 9 illustrate that the program decreased the time spent on cooking, washing, caring for children, and total housework by young men and women. Meanwhile, the time spent on housework by children and elders increased. In rural China, it is common that most household work fall squarely on the shoulders of housewives. Our results show that enhancing the access to drinking water facilities may help bridge this gap through inducing younger females

[18] The information on becoming a migrant worker is based on self-reporting in the household survey. The question about migrant work was included only after the 1997 wave. So this estimation is obtained based on a smaller sample over 1997–2011. A young adult is defined as any individual age 18–45.

[19] We define an individual as "permanently moving out" from time t if he or she never appears in the sample in t or later.

[20] To address the concern about attrition bias, we also replicate the baseline estimates using only the households who had stayed within their own villages throughout the whole period,1989–2011. The estimates are reported in Table A11 in the Appendix and are similar to those in Table 2.

Table 7
Outward migration versus local employment (1989–2011).

Dependent variable	1[Migrating work]		1[Missing permanently next surveys]	
	(1)	(2)	(3)	(4)
1[water access]	−0.066	−0.053***	0.034***	−0.039***
	(0.046)	(0.020)	(0.003)	(0.015)
1[household head]	−0.016***	−0.017***	−0.005	0.005**
	(0.003)	(0.003)	(0.003)	(0.002)
1[male]	0.014***	0.009***	−0.008***	−0.005***
	(0.003)	(0.003)	(0.002)	(0.002)
age	−0.001***	−0.000***	0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
# schooling years	0.002***	0.004***	0.004***	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
# family members	0.002**	0.002***	−0.010***	−0.009***
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	36,492	36,492	57,096	57,096
R-squared	0.021	0.103	0.020	0.173
Village FE	NO	YES	NO	YES
County*Year FE	NO	YES	NO	YES

Notes: This table reports individual-level regression results for the effects of the water program on different patterns of labor reallocation. The outcome variables correspond to different occupational choices. 1[Migrating work] is a dummy variable indicating that the individual leaves the town and becomes a migration workers. 1[Missing permanently in the next surveys] equals to 1 when the individual is registered alive at T but not in the sample of all the next surveys from T to the survey of 2015, and 0 otherwise. Standard errors in the parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 8
Gender Differences (1989–2011).

Dependent variable	1[Off-farm work]		# Off-farm working hours	
	(1)	(2)	(3)	(4)
1[water access]	0.035	0.035	0.053	0.052
	(0.030)	(0.030)	(0.212)	(0.212)
1[water access]*1[young adult]	0.167***		1.461***	
	(0.026)		(0.191)	
1[water access]*1[young male adult]		0.168***		1.558***
		(0.037)		(0.280)
1[water access]*1[young female adult]		0.166***		1.354***
		(0.018)		(0.150)
1[household head]	0.067***	0.067***	0.658***	0.655***
	(0.008)	(0.008)	(0.070)	(0.070)
1[male]	0.059***	0.059***	0.464***	0.427***
	(0.007)	(0.008)	(0.050)	(0.055)
age	0.004***	0.004***	0.022***	0.022***
	(0.000)	(0.000)	(0.001)	(0.001)
# schooling years	0.026***	0.026***	0.201***	0.201***
	(0.001)	(0.001)	(0.009)	(0.009)
# family members	0.008***	0.008***	0.054***	0.054***
	(0.001)	(0.001)	(0.013)	(0.013)
Observations	57,109	57,109	54,348	54,348
R-squared	0.389	0.389	0.346	0.346
Demographic Controls	YES	YES	YES	YES
Village FE	YES	YES	YES	YES
County*Year FE	YES	YES	YES	YES

Notes: This table reports the individual-level regression results for the effects of the water program by males and females, respectively. Demographic controls include 1[Young adult] in columns 1 and 3, and 1[Young male adult] and 1[Young female adult] in columns 2 and 4, respectively. An adult is defined as young if his or her age is 45 or under. Standard errors in parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

to participate in off-farm sectors. After the completion of the drinking water facilities, fetching water becomes easier and less time-consuming. Children and the elders are now more capable of collecting water by themselves and reallocating time on other household works. The changed time allocation allows younger women to explore outside job opportunities. In this sense, the water program displayed inclusiveness in its pro-poor, pro-family, and pro-women nature.

9. Conclusion

Governments around the world invest on infrastructure and development programs. The effects of the investments lie at the heart of scholarly debates. This paper examines the economic impacts of drinking water facilities in rural China. Using representative survey data, we find that improving access to water facilities led to significant labor reallocation and income growth of rural households. Further analysis suggests that the transition to off-farm employment mainly stemmed from time saved in water collection, which imposed a particularly binding constraint on the labor market participation of small households. Our findings on labor market outcomes and income growth are consistent with the argument that development programs can play a positive role in development.

Our research also finds that the water program delivered more benefits toward the relatively disadvantaged groups. Households and villages with lower initial income registered greater growth in income. The induced off-farm employment was most concentrated in local firms,

Table 9
Effects on household work.

Dependent variable	log(# cooking minutes + 0.01)	log(# washing minutes + 0.01)	log(# caring for children minutes + 0.01)	log(# housework minutes + 0.01)
	(1)	(2)	(3)	(4)
1[Water access]	0.411***	0.426***	0.824***	0.618***
	(0.128)	(0.126)	(0.197)	(0.166)
1[Water access] *1[Young male adult]	0.080	−0.193	−0.579**	−0.073
	(0.186)	(0.148)	(0.225)	(0.256)
1[Water access] *1[Young female adult]	−1.127***	−0.733***	−1.472***	−1.312***
	(0.238)	(0.183)	(0.310)	(0.198)
1[Young male adult]	0.613***	0.865***	1.001***	1.217***
	(0.172)	(0.132)	(0.212)	(0.239)
1[Young female adult]	2.992***	2.872***	3.052***	3.724***
	(0.235)	(0.183)	(0.298)	(0.198)
Observations	49,868	49,273	30,514	50,855
R-squared	0.439	0.491	0.228	0.438
Individual controls	YES	YES	YES	YES
Village FE	YES	YES	YES	YES
County*Year FE	YES	YES	YES	YES

This table reports the individual-level regression results for the effects of the water program on males and females, respectively. Demographic controls include 1[Young adult] in columns (1) and (3), and 1[Young male adult] and 1[Young female adult] in columns (2) and (4), respectively. An adult is defined as young if his or her age is 45 or under. Standard errors in parentheses are clustered at the village level. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

and it did not increase outward migration. Moreover, the positive effects on off-farm employment were almost identical for men and women. These findings suggest that the water program is largely inclusive to the extent that its economic effects are pro-poor, pro-family, and pro-women.

Our findings contrast with those of recent studies on the distributive consequences of development programs. Two conditions may be prerequisites for the program to be effective and inclusive. First, the water program did not need to affect factor mobility as transportation facilities do. Rather, the water program helped lower entry barriers for rural households to work in local enterprises. Second, the liberation of rural workforces may have been complementary to the growth of township and village enterprises in rural regions, thanks to a relatively decentralized and self-contained economic system (Che & Qian, 1998; Montinola et al., 1995).

This paper also sheds light on how public policies may shape socioeconomic transformation, such as the reallocation of rural labor forces into urban sectors. A conventional wisdom in the literature holds that China's household registration system (*hukou*) deters such transformation (Imbert et al., 2022; Ngai et al., 2019). By focusing on the impacts of water facilities, our findings suggest that enhancing drinking water facilities may be a cost-efficient strategy for promoting inclusive development in addition to its health benefits.

Declaration of competing interest

None.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.worlddev.2023.106428.

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