Access to Piped Water and Off-Farm Work Participation: Evidence from Rural China

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Abstract: The lack of access to water services for a considerable share of the world population has been challenging the international community for decades. Billions of hours are spent each year on water collection in developing countries. Access to piped water can liberate individuals from the task of collecting water. Based on data from the China Labor-force Dynamic Survey (CLDS), this paper examines the impact of access to piped water on off-farm work participation. We find that access to piped water significantly improves off-farm work participation in rural China. This result remains robust when we use the PSM approach, Lewbel IV method, placebo test, and Dose-Response Model. Anyway, we find that the positive effect of access to piped water on off-farm work participation is greater in rugged areas and women, reflecting the role of access to piped water in promoting inclusive growth. Further research shows that access to piped water increases household income, and off-farm work participation mediates, in part, the link between access to piped water and household income.

Keywords: access to piped water; drinking water; off-farm work; inclusive development

1. Introduction

The lack of drinking water facilities has long been a severe public health issue in many developing countries. As of 2020, 2 billion people lacked safely managed services, including 1.2 billion people with basic services, 282 million with limited services, 367 million using unimproved sources, and 122 million drinking surface water [1].

A large number of studies have investigated the impact of access to piped water on health and education outcomes from the perspective of water quality [2–5]. In contrast to these studies focusing on the quality of piped water, this paper attempts to find an alternative channel through which access to piped water shapes development outcomes. This channel is related to another characteristic of piped water: time savings.

Water is essential for life, and it is widely used for drinking and other purposes. At the same time, water (unlike fuel) has few substitutes. When lacking water facilities close to homes, households must collect water from other sources (including springs, wells, streams, etc.). Water collection is a time-consuming and physically demanding job, thereby diverting time from potentially income-generating activities. Especially in many countries, due to population growth, weather fluctuations, and social unrest, the daily chore of collecting water has become a serious problem [6].

Generally, the time required for water collection depends on three factors. First, the distance from the household to a water source. Second, the terrain around the water source. Third, crowding and queuing when collecting water. Based on data from 44 developing countries, Sorenson et al. reported that women and children spend considerable time supplying water to their households [6]. Kremer et al. reported that in Western Kenya, a rural household makes around seven water-fetching trips per day, with each trip requiring a 20-min walk on average [7]. Devote et al. reported that more than 66 percent of Moroccan households without a water connection considered fetching water to be an...
important concern, and 12% of households had conflicts with their neighbors over water resources [8].

Piped water facilities can reduce the time it takes to fetch water, which can help to liberate household members from household chores. According to the time allocation theory proposed by Becker [9], as the productivity of household chores increases, it is optimal to reallocate some of the time saved from home chores to market-based income-generating activities.

Both agricultural production and off-farm work participation are income-generating activities. The impact of access to piped water on agricultural production has been discussed [10,11]. However, attention to off-farm work participation is still quite lacking. The mobility of labor from the agricultural to non-agricultural sectors is critical to economic development [12]. Higher per capita value added in the non-agricultural sectors contributes to poverty reduction in rural areas [13]. Anyway, participation in off-farm work has become a critical mechanism for rural households to cope with risks and shocks in the context of imperfect credit and labor markets [14]. Thereby, many developing countries are committed to facilitating the transfer of labor from the agricultural to non-agricultural sectors [15–17].

There are many differences between agricultural production and off-farm work, and the impact of access to piped water on agricultural production does not imply that there is an impact of access to piped water on off-farm work participation. On the one hand, rural households in developing countries have a relatively small area of arable land. According to the law of diminishing marginal returns, additional labor time input can only lead to a limited increase in agricultural output when land area is limited. In contrast, under a competitive market wage rate, the relationship between labor time input and off-farm income is linear. On the other hand, agricultural production usually has a relatively higher flexibility of time allocation. Individuals can carry out normal agricultural production while undertaking water collection tasks. In contrast, off-farm work has limited time flexibility, and the allocation of individual labor time is constrained by the employer’s arrangement. Individuals are unable to balance their water collection responsibilities with their off-farm work. Thus, this paper argues that off-farm work participation may be more sensitive to piped water accessibility.

China provides an ideal setting for investigating the impact of access to piped water on off-farm work participation. On the one hand, China has about 2005 cubic meters of renewable internal freshwater resources per capita as of 2018, which ranks 105th in the world. On the other hand, water facilities in rural China have developed rapidly, but there are great differences between regions. In addition, insufficient arable land is an important constraint on China’s agricultural productivity. Arable land (hectares per capita) in China was reported at 0.08 in 2020. This is six times as the United States. Per capita income in agriculture has been low due to the limited marginal labor productivity. The conflicts between land shortage and labor surplus are more serious. Even though peasants have a strong incentive to leave the land for lucrative job opportunities, some choose less productive agricultural production due to domestic work responsibilities. Water-related domestic works include fetching water, preparing food, cleaning the home, bathing, and home gardening, etc. When there is a lack of piped water, individuals have to spend a lot of time fetching water. Meng et al. [18] estimate that households in rural China spend 30 min per trip to collect water, and in order to meet the subsistence level of water consumption of a family of five, an adult must spend one hour a day fetching water. In addition, the limited amount of water makes other water-related chores more tedious and time-consuming. For example, cleaning the room will become more time-intensive. In recent decades, although many surplus rural laborers have been released from the agricultural sector and there has been a massive transition of rural residents from agricultural to non-agricultural sectors, a large number of rural people remain in the less productive agricultural sector.

The empirical analysis draws on the CLDS dataset. One feature of this dataset is that it provides the exact year when piped water was first connected at the village level. We use the relative time of exposure to piped water of the individual to measure piped
water accessibility. This measure can avoid individual self-selection and greatly alleviate endogeneity. More importantly, this measure is able to measure the intensity of exposure to piped water rather than a simple dichotomy. To further address the endogeneity problem, we use the PSM approach, village fixed effects specification, placebo test, and Lewbel IV method for identification. This paper finds that access to piped water significantly increases off-farm work participation in rural China. The results remain robust when we remeasure the dependent variable, take other infrastructure into account, and use a dose-response model. Anyway, we find that the positive effect of access to piped water on off-farm work is greater in rugged areas and for women. Further research shows that access to piped water increases household income, and off-farm work participation mediates, in part, the link between access to piped water and household income.

2. Literature Review

With industrialization, microorganisms and chemical impurities such as untreated industrial waste and pesticides are major contaminants in drinking water in many developing countries. Microbially contaminated water can lead to the transmission of infectious diseases [19]. Water contaminated with chemical impurities can also lead to chronic diseases [20].

Contamination is widespread during the collection, transportation, storage, and withdrawal of water [21]. Access to piped water indicates that households do not need to treat and store water. Zhang et al. investigated water quality in rural Chinese households and found that piped water is of better quality than untreated water [22].

Although estimates vary widely, most studies have found positive health impacts from improved water facilities. Esrey et al. conduct a review of 144 studies and found that better water quality can reduce the incidence of dracunculiasis, but its role in diarrheal disease control is less important than that of sanitation and hygiene [23]. Overbo et al. provide evidence that households with on-plot water supplies have fewer diarrhea and helminth infections and greater child height [24]. In particular, the impact of on-plot water access on water-washed (hygiene-associated) diseases is greater than that on waterborne diseases. A recent review estimates that the continuous piped water supply can reduce the risk of diarrheal disease by up to 75% [25].

In addition, many studies have suggested time savings as a channel through which improved piped water access can affect productivity performance in rural areas. This channel recently became of particular interest as several studies show that improved water facilities do not yield the desired effects on the health of the target population [26,27].

Many studies find that access to improved water facilities can reduce the time it takes to water collection. However, disagreements have emerged regarding the reallocation of time since any benefits regarding water interventions may be dependent on the location, technology, and other circumstances of implementation.

Based on 1991 data from Pakistan, Ilahi and Grimard analyze the allocation of women’s time between water collection, empowerment activities, and leisure [28]. They find that public water supply infrastructure is negatively associated with the time women spend collecting water. Anyway, the access to on-site water sources at the village level increases female labor force participation. However, investing in private water technology (compared to poorer public infrastructure outside the home) reduces the total work burden of female household members, and women are more likely to spend time on leisure than on market-based work. Based on data from 27 African countries over the period of 1990–2010, Kiendrebeogo finds that an increased access rate to drinking water is beneficial to agricultural productivity due to increased intrinsic productivity of individuals and additional gain in time for agricultural production [10]. Meeks finds that despite the lack of health benefits, improvements in water technologies can make adults reallocate time to leisure and labor on the household farm in Kyrgyzstan [11]. Bisung and Elliott find that access to piped water is associated with water security and significant time savings [29]. Interestingly, they also find since most households no longer use well water, well queues may be significantly reduced for
households that continue to use unimproved sources, which partially explains the significant
time savings for all households regardless of their type and level of the water source.

On the contrary, Lokshin and Yemtsov find that the public water supply project
in rural Georgia between 1998 and 2001 has no significant effect on income-generating
activities for women [30]. A randomized study also finds that shifting households from
free neighborhood-level shared public taps to individual household connections in the
Moroccan city of Tangiers results in significant time savings but no impacts on productive
activities [8]. A cross-country study of developing countries finds that although proximity
to water may reduce women’s participation in agricultural production and other unpaid
work in some countries, have no effect on off-farm paid work [31].

Based on the above review, there is no consensus on whether improvements in water
facilities can help shift time allocation from basic household tasks related to water collection
to market-based income-generating activities. More importantly, few studies have examined the impact of improved water facilities on non-farm work participation.

3. Background on Piped Water in Rural China

Before the 1980s, China’s rural residents relied primarily on untreated water (wells,
rivers, lakes, etc.). To improve access to water in rural areas of China, the Chinese government
began to initiate a drinking water improvement program in rural areas in the
1980s. The program aims to build water plants to provide safe drinking water and construct
a pipeline system to transport the water. Between 2001 and 2020, the Chinese government
invested 513.7 billion RMB (about 79 billion U.S. dollars) in improving water facilities.

To implement water improvement programs, the central government sets the guide-
lines while local governments implement the specific logistics. Since no distinct roll-out
rules have been prescribed, there are significant variations in project practices from region
to region. For example, in terms of program financing, between 1980 and 2002, 25.7%
of funds came from the central and local governments, 26.9% from villages, 42.5% from
beneficiaries, and 4.9% as loans and donations from international organizations and other
countries [18]. In poor areas, funding comes mainly from the government and international
organizations, while in rich areas, funding depends mainly on beneficiaries and villages. In
1980, only 4.8% of villages were connected to piped water. By 2016, this number had risen
to 78.6%. Figure 1 shows this trend in detail.

![Figure 1](image.png)

**Figure 1.** Percentage of villages with piped water. Data source: China Labor-force Dynamic Survey (2016).

4. Data and Variables

4.1. Data

The data used in this study comes from the 2016 wave of the China Labor Force Dynamics Survey (CLDS). The CLDS is a nationally representative survey data. The survey uses a multi-stage, clustered, stratified probability-proportional to size (PPS) sampling technique to select respondents. The dataset includes information at the village, household,
and individual levels. Compared to other household survey datasets, the advantage of CLDS is that it provides the year in which the village was first connected to the piped water, which contributes to accurately measuring the intensity of piped water exposure, not just the dichotomy. Since this paper focuses on work decisions, respondents aged over 64 years are excluded.

4.2. Model Setting and Variable Definition

To investigate the impact of access to piped water on off-farm work participation, we exploit the following model as shown in Equation (1).

\[
Off_{\text{farm}}_{ic} = \beta_0 + \beta_1 Water_{ic} + \beta_2 X_{ic} + \{FE\} + \epsilon_{ic}
\]  

(1)

\(Off_{\text{farm}}_{ic}\) is the dependent variable of off-farm work participation for an individual \(i\) from village \(c\), defined as a dummy variable that equals 1 if the rural resident participated in off-farm work in 2015 and 0 otherwise.

\(Water_{ic}\) is the independent variable of access to piped water, measured by years of exposure to piped water divided by age. Years of exposure to piped water equals 2016 minus the year when the village was first connected to piped water. \(Water_{ic}\) takes continuous values from zero to one. Note that if the year of birth of the individual \(i\) is equal to or later than the year when the village \(c\) was connected to piped water, \(Water_{ic}\) takes the value of 1. If the village was not connected to piped water in 2016, \(Water_{ic}\) takes the value of 0.

\(X_{ic}\) is a set of factors that may affect the participation of rural residents in off-farm activities. Individual characteristics are important factors influencing labor market decisions. Therefore, by referring to Schultz [32], Blau and Kahn [33], Wang and Zhang [34], and Liu et al. [35], we control for gender, age, years of education, marital status, health, and height. In addition, off-farm work participation is associated with internet usage [34], arable land area [36], and irrigation facilities [37], so these characteristics need to be controlled for. Sunner [38] also finds that distance from the farm to the nearest town is negatively associated with off-farm work participation. Wang and Shen [39] indicate that working hours are associated with toilet type. Topography affects job search, and non-agricultural industries affect the number of off-farm jobs. Therefore, these factors also need to be controlled for.

\(\{FE\}\) is province fixed effects. \(\epsilon_{ic}\) is the random error term. Table 1 reports the definition of the variables. In this paper, the linear probability model is used for estimation.

Table 1. Definition of the variables.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off_farm</td>
<td>1 = yes; 0 = no</td>
</tr>
<tr>
<td>Water</td>
<td>Relative time of exposure to piped water</td>
</tr>
<tr>
<td>Women</td>
<td>1 = women; 0 = men</td>
</tr>
<tr>
<td>Age</td>
<td>Respondent’s actual age (years)</td>
</tr>
<tr>
<td>Agesq</td>
<td>Age squared/100</td>
</tr>
<tr>
<td>Eduy</td>
<td>Years of education</td>
</tr>
<tr>
<td>Married</td>
<td>1 = presently on first marriage; 0 = otherwise</td>
</tr>
<tr>
<td>Health</td>
<td>1 = very unhealthy; 2 = unhealthy; 3 = general; 4 = healthy; 5 = very healthy</td>
</tr>
<tr>
<td>Height</td>
<td>Respondent’s actual height (cm)</td>
</tr>
<tr>
<td>Internet</td>
<td>1 = yes; 0 = no</td>
</tr>
<tr>
<td>Toilet</td>
<td>1 = indoor toilet; 0 = otherwise</td>
</tr>
<tr>
<td>Lnpland</td>
<td>Natural logarithm of household land area per capita</td>
</tr>
<tr>
<td>Industry</td>
<td>1 = the village has non-agricultural industries; 0 otherwise</td>
</tr>
<tr>
<td>Lndistance</td>
<td>Natural logarithm of the distance to the county government</td>
</tr>
<tr>
<td>Topography</td>
<td>0 = plain; 1 = otherwise</td>
</tr>
<tr>
<td>Irrigation</td>
<td>1 = yes; 0 = no</td>
</tr>
</tbody>
</table>
5. Empirical Results

5.1. Baseline Regression Results

Table 2 presents the baseline regression results. Column (1) only controls for Water; column (2) adds individual characteristics; column (3) adds household characteristics; column (4) adds village characteristics; column (5) adds province-fixed effects; column. As control variables are gradually added, the coefficient of Water is always significantly positive, which indicates that access to piped water increases the probability of participating in off-farm work. Columns (6) and (7) report the regression results based on the Logit model and Probit model, respectively, which suggest that the results are still robust.

Table 2. Baseline regression results.

<table>
<thead>
<tr>
<th>Variables</th>
<th>LPM</th>
<th>Logit</th>
<th>Probit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Water</td>
<td>0.406 *** (0.016)</td>
<td>0.336 *** (0.017)</td>
<td>0.223 *** (0.017)</td>
</tr>
<tr>
<td>Women</td>
<td>−0.125 *** (0.011)</td>
<td>−0.128 *** (0.011)</td>
<td>−0.139 *** (0.011)</td>
</tr>
<tr>
<td>Age</td>
<td>0.038 *** (0.002)</td>
<td>0.036 *** (0.002)</td>
<td>0.034 *** (0.002)</td>
</tr>
<tr>
<td>Agesq</td>
<td>−0.048 *** (0.002)</td>
<td>−0.045 *** (0.002)</td>
<td>−0.045 *** (0.002)</td>
</tr>
<tr>
<td>Eduy</td>
<td>0.019 *** (0.001)</td>
<td>0.015 *** (0.001)</td>
<td>0.013 *** (0.001)</td>
</tr>
<tr>
<td>Married</td>
<td>0.082 *** (0.014)</td>
<td>0.073 *** (0.013)</td>
<td>0.075 *** (0.013)</td>
</tr>
<tr>
<td>Health</td>
<td>0.042 *** (0.004)</td>
<td>0.037 *** (0.004)</td>
<td>0.032 *** (0.004)</td>
</tr>
<tr>
<td>Height</td>
<td>−0.000 (0.001)</td>
<td>0.001 (0.001)</td>
<td>−0.000 (0.001)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.081 *** (0.011)</td>
<td>0.058 *** (0.011)</td>
<td>0.047 *** (0.011)</td>
</tr>
<tr>
<td>Toilet</td>
<td>0.097 *** (0.009)</td>
<td>0.099 *** (0.009)</td>
<td>0.099 *** (0.009)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>−0.113 *** (0.006)</td>
<td>−0.089 *** (0.006)</td>
<td>−0.050 *** (0.006)</td>
</tr>
<tr>
<td>Industry</td>
<td>0.070 *** (0.011)</td>
<td>0.015 (0.012)</td>
<td>0.113 (0.012)</td>
</tr>
<tr>
<td>Lndistance</td>
<td>−0.048 *** (0.005)</td>
<td>−0.048 *** (0.005)</td>
<td>−0.048 *** (0.005)</td>
</tr>
<tr>
<td>Topography</td>
<td>−0.029 *** (0.009)</td>
<td>−0.010 (0.010)</td>
<td>−0.098 (0.010)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.013 (0.009)</td>
<td>0.029 *** (0.009)</td>
<td>0.177 *** (0.009)</td>
</tr>
</tbody>
</table>

Province Fixed Effects | NO | NO | NO | NO | YES | YES | YES |
| Constant        | 0.175 *** (0.006) | −0.695 *** (0.126) | −0.720 *** (0.127) | −0.379 *** (0.129) | −0.510 *** (0.129) | −6.268 *** (1.009) | −3.534 *** (0.586) |
| Observation     | 9049 | 9049 | 9049 | 9049 | 9049 | 9049 | 9049 |
| Adj,R²          | 0.073 | 0.185 | 0.243 | 0.256 | 0.301 | 0.289 | 0.287 |

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1%.
Other factors can also affect off-farm work participation. Due to the influence of traditional culture, men take on the responsibility of earning money. Thus, men are more likely to participate in off-farm work. The positive age effect and negative age-squared effect imply that the probability of participating in non-farm work will increase with age, but once a certain age is reached, this probability will decrease. Married people will be more involved in off-farm employment. People with higher education have higher skills and are, therefore, more likely to be involved in non-farm work. Healthier individuals are more likely to participate in off-farm work. The use of the Internet has a positive impact on off-farm work participation. Improved toilet facilities are positively correlated with off-farm work participation, but when controlling for city-fixed effects or county-fixed effects, this relationship does not exist. Households with more land have a smaller intention to engage in non-farm work than other households. The presence of non-agricultural industries in villages is not correlated with off-farm work participation when region-fixed effects are added. Individuals are less likely to engage in off-farm work when the village is further away from the county government. In general, individuals living in villages with flat terrain and irrigation facilities tend to participate in off-farm work.

5.2. Endogeneity

5.2.1. PSM

To address the problem of non-random selection, we employ the PSM method to ensure that treatment and control groups are comparable. A dummy indicator variable, $D_{\text{Water}_{ic}}$, is constructed ($D_{\text{Water}_{ic}} = 1$ if $\text{Water}_{ic}$ is greater than the median, and 0 otherwise). We conduct logit regression to estimate the probability of being in the treatment group ($PS$):

$$PS(X_{ic}) = Pr[D_{\text{Water}_{ic}} = 1 | X_{ic}] = \frac{\exp(\beta X_{ic})}{1 + \exp(\beta X_{ic})} \quad (2)$$

The treatment and control groups are matched according to the $PS$ value using nearest-neighbor matching and kernel matching. Table 3 reports the balancing test results. Figure 2 displays the kernel density functions of the $PS$ values of the treated group and the control group based on the after-matching and post-matching of the two groups, respectively. According to Table 3 and Figure 2, the PSM method significantly reduces the difference between the treatment group and the control group.

Table 4 reports the estimation results of Average Treatment Effects on Treated (ATT) based on Matching methods using different algorithms, which indicate that access to piped water improves off-farm work participation.

Table 3. Balancing test.

<table>
<thead>
<tr>
<th>Means</th>
<th>Raw</th>
<th>Matched (ATT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treated</td>
<td>Untreated</td>
</tr>
<tr>
<td>Women</td>
<td>0.528</td>
<td>0.533</td>
</tr>
<tr>
<td>Age</td>
<td>41.159</td>
<td>47.536</td>
</tr>
<tr>
<td>Agesq</td>
<td>18.904</td>
<td>24.089</td>
</tr>
<tr>
<td>Eduy</td>
<td>8.371</td>
<td>6.877</td>
</tr>
<tr>
<td>Married</td>
<td>0.772</td>
<td>0.856</td>
</tr>
<tr>
<td>Health</td>
<td>3.702</td>
<td>3.438</td>
</tr>
<tr>
<td>Height</td>
<td>163.180</td>
<td>162.730</td>
</tr>
<tr>
<td>Internet</td>
<td>0.445</td>
<td>0.227</td>
</tr>
<tr>
<td>Toilet</td>
<td>0.653</td>
<td>0.474</td>
</tr>
<tr>
<td>Lnpland</td>
<td>0.662</td>
<td>0.847</td>
</tr>
<tr>
<td>Industry</td>
<td>0.401</td>
<td>0.151</td>
</tr>
<tr>
<td>Lndistance</td>
<td>2.778</td>
<td>3.030</td>
</tr>
<tr>
<td>Topography</td>
<td>0.500</td>
<td>0.558</td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.563</td>
<td>0.433</td>
</tr>
</tbody>
</table>

Note: Kernel matching (bandwidth = 0.06).
The treatment and control groups are matched according to the ... 1 2 3
0 10.5 0 10.5
Raw Matched (ATT)
Untreated Treated
Density
Propensity score

Figure 2. Kernel densities before and after matching. Note: Kernel matching (bandwidth = 0.06).

Table 4. PSM estimation.

<table>
<thead>
<tr>
<th>Matching Mode</th>
<th>ATT</th>
<th>Std Dev</th>
<th>Critical Level of Gamma (Γ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearest neighbor matching (n = 1)</td>
<td>0.108 ***</td>
<td>0.018</td>
<td>Greater than 1.8</td>
</tr>
<tr>
<td>Nearest neighbor matching (n = 3)</td>
<td>0.114 ***</td>
<td>0.016</td>
<td>Greater than 2.1</td>
</tr>
<tr>
<td>Nearest neighbor matching (n = 5)</td>
<td>0.113 ***</td>
<td>0.016</td>
<td>Greater than 2.25</td>
</tr>
<tr>
<td>Kernel matching (bandwidth 0.01)</td>
<td>0.114 ***</td>
<td>0.014</td>
<td>Greater than 2.5</td>
</tr>
<tr>
<td>Kernel matching (bandwidth 0.03)</td>
<td>0.111 ***</td>
<td>0.014</td>
<td>Greater than 2.5</td>
</tr>
<tr>
<td>Kernel matching (bandwidth 0.06)</td>
<td>0.107 ***</td>
<td>0.014</td>
<td>Greater than 2.5</td>
</tr>
</tbody>
</table>

Note: Rosenbaum bounds for ATT in the presence of unobserved factors (Critical level of gamma, Γ, p < 0.1) are calculated using the Stata module rbounds. *** denotes significance at 1%.

If there are certain factors in addition to the variables specified in the model (2) that can have a significant effect on the probability of treatment, it would lead to inefficient matching and estimation bias. According to Rosenbaum’s bounding approach [40], the magnitude of the bias can be ascertained by looking at the gamma values and their significance levels. The gamma variable measures the ratio of the log odds of the probabilities of getting selected for any two observations. The higher the value of the gamma variable at the specified significance level, the more robust the estimation results. For example, the critical value of gamma is 2.5, which implies that if individuals with the same covariates differ in their access to piped water by a factor of 150% (due to unobserved heterogeneity), the effect of access to piped water on off-farm work participation becomes statistically insignificant. When significance is specified as 10%, the estimates of gamma variables in this paper range from 1.8 to 2.5, which is greater than the critical value used in existing studies [41,42].

5.2.2. Village Fixed Effects

For all individuals in the same village, the year when the village was first connected to piped water was the same. Therefore, in the baseline specification, this paper chooses to control county FE rather than village FE to take advantage of the full variation in data. However, the county FE specification entails the risk of omitted variable bias. If some unobservable factors that vary within counties affect both the year when the village was connected to piped water and individual off-farm work participation, baseline specification would still obtain inconsistent estimates.
Several studies examining the outcomes of access to piped water in rural China use village fixed effects specification for causal identification [5,43]. In order to address the endogeneity arising from the non-random assignment of the year when the village was first connected to piped water, this paper uses village FE specification.

Regression results are reported in Table 5. The coefficient of Water remains significantly positive at the 1% level, suggesting that access to piped water still significantly increases the probability of individuals participating in off-farm work.

Table 5. Village fixed effects.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Off_farm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Water</td>
<td>0.409 ***</td>
</tr>
<tr>
<td></td>
<td>(0.040)</td>
</tr>
<tr>
<td>Women</td>
<td>−0.123 ***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Age</td>
<td>0.037 ***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Agesq</td>
<td>−0.049 ***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Eduy</td>
<td>0.012 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Married</td>
<td>0.062 ***</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
</tr>
<tr>
<td>Health</td>
<td>0.030 ***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>Height</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.025 **</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Toilet</td>
<td>−0.007</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>−0.023 ***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
</tr>
<tr>
<td>Village fixed effects</td>
<td>YES</td>
</tr>
<tr>
<td>Constant</td>
<td>0.175 ***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
</tr>
<tr>
<td>Observation</td>
<td>9049</td>
</tr>
<tr>
<td>Adj.R²</td>
<td>0.253</td>
</tr>
</tbody>
</table>

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1% and ** at 5%.

Some studies examining the consequences of infrastructure use random assignment of treated cities to perform placebo tests [44,45]. Following these studies, a placebo test was conducted by randomly assigning the year when the village was first connected to piped water to test whether unobservable factors drive these results. If the off-farm work participation is due to the access to piped water in the village fixed effects specification, then the coefficient should be insignificant for false assigning. We conducted 1000 times random assignments, and Figures 3 and 4 report the regression results. The distributions of estimates using random assigning are mostly gathered around zero and are mostly insignificant, which indicates that the outcomes of the placebo test confirm the robustness and accuracy of the original village fixed effects specification.
5.2.3. Lewbel IV

This further paper employs the Lewbel two-stage least squares (2SLS) [46] technique to solve endogeneity. This technique has been widely used in literature to resolve the endogeneity when valid external instruments are unavailable [47,48].

To implement the Lewbel IV approach, we first estimate the Equation (3) and obtain the estimated residuals $\hat{r}_{ic}$. Then, $(Z_{ic} - E[Z_{ic}])\hat{r}_{ic}$ is used as the set of internal instruments, where $Z \subseteq X$. There are no clear criteria about which variables in $X$ should be selected as $Z$ [49,50]. As such, one could include different variables in the vector to obtain a ‘desired result’ [50–52]. Some studies use all the variables in $X$ as $Z$, although these studies usually did not conduct the Hansen-J test. However, there are also a number of studies that select specific variables based on data characteristics, such as $Z$ [50–52]. When a large number of variables are included in $Z$, overidentification tests may fail to support them, and downward bias will occur if there is a large number of weak instruments [52]. In this paper, $Z$ includes Age and Height, satisfying the requirement that $Z \subseteq X$. More
importantly, the internal instrumental variables constructed based on these two variables have good statistical properties. In the second step, these internal instruments are used in the standard two-stage instrumental variable estimation.

$$Water_{ic} = \lambda_0 + \lambda_1 X_{ic} + \{FE\} + \nu_{ic}$$

(3)

The regression results are shown in Table 6. Lewbel IV models are well specified in this paper. The Breush Pagan test confirms the assumption of heteroscedasticity. In the first stage, the Kleibergen-Paap rk Wald F statistic (1018.029) is greater than the critical value (10), which indicates that the internally generated instruments do not weakly identify. The Hansen-J statistics support that the null hypothesis of over-identification cannot be rejected. The second-stage results of Lewbel 2SLS suggest that the pattern of the effect of access to piped water on off-farm work participation is similar to that in the baseline estimation results.

Table 6. Lewbel 2SLS results.

<table>
<thead>
<tr>
<th>Second Stage</th>
<th>First Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off_farm</td>
<td>Water</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Water</td>
<td>0.105 **</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
</tr>
<tr>
<td>Error*Age</td>
<td>−0.126 ***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Error*Height</td>
<td>0.034 ***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Women</td>
<td>−0.045 ***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Age</td>
<td>0.013 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Married</td>
<td>0.066 ***</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
</tr>
<tr>
<td>Health</td>
<td>0.031 ***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>Height</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.048 ***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Toilet</td>
<td>0.019 *</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>−0.049 ***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
</tr>
<tr>
<td>Industry</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
</tr>
<tr>
<td>Lndistance</td>
<td>−0.049 ***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>Topography</td>
<td>−0.010</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.029 ***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
</tr>
<tr>
<td>Province Fixed Effects</td>
<td>YES</td>
</tr>
<tr>
<td>Constant</td>
<td>−0.302 **</td>
</tr>
<tr>
<td></td>
<td>(0.145)</td>
</tr>
<tr>
<td>Observation</td>
<td>9049</td>
</tr>
</tbody>
</table>
Table 6. Cont.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Second Stage</th>
<th>First Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Off_farm</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>Kleibergen-Paap rk Wald F statistic</strong></td>
<td>1018.029</td>
<td></td>
</tr>
<tr>
<td><strong>Hansen J statistic (p-Value)</strong></td>
<td>0.107 (0.7431)</td>
<td></td>
</tr>
<tr>
<td>Centered R²</td>
<td>0.301</td>
<td></td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.591</td>
<td></td>
</tr>
</tbody>
</table>

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5% and * at 10%.

5.3. Heterogeneity

5.3.1. Topography

Before connecting to the piped water, a resident living in rugged villages spent more time fetching water than those living in plain villages and, therefore may enjoy greater benefits of labor liberation after having access to the piped water. We perform subsample regression according to village topography. The regression results are reported in columns (1) and (2) of Table 7, which indicate that the positive effect of access to water on off-farm work participation is greater for those living in rugged areas.

Table 7. Heterogeneity.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Off_farm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plain</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Water</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td>(0.081)</td>
</tr>
<tr>
<td>Women</td>
<td>-0.116 ***</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
</tr>
<tr>
<td>Age</td>
<td>0.036 ***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
</tr>
<tr>
<td>Agesq</td>
<td>-0.048 ***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>Eduy</td>
<td>0.012 ***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Married</td>
<td>0.088 ***</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
</tr>
<tr>
<td>Health</td>
<td>0.034 ***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>Height</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
</tr>
<tr>
<td>Toilet</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>-0.012</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
</tr>
<tr>
<td>Village fixed effects</td>
<td>YES</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.639 ***</td>
</tr>
<tr>
<td></td>
<td>(0.205)</td>
</tr>
<tr>
<td>Observation</td>
<td>4219</td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.369</td>
</tr>
</tbody>
</table>

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5% and * at 10%.
5.3.2. Gender

Women are particularly affected by inadequate water supplies because they are primarily responsible for household water management [53,54]. At the same time, women are less likely than men to be involved in non-farm work. Thus, we perform subsample regressions according to gender. Column (3) and (4) of Table 7 reports the regression results, which show that women benefit more from piped water than men.

5.4. Robustness Checks

5.4.1. Substitution of Dependent Variable

In the baseline regression, we focus on non-farm work in 2015. In this section, the paper concerns the work history. Off_farm_hist equals 1 if the individual has always been engaged in off-farm work in the work history, and 0 otherwise. The regression results based on this dependent variable are reported in Table 8, which suggests that the positive impact of access to piped water on off-farm work participation is well robust.

Table 8. Substitution of the dependent variable.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Off_farm_hist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Water</td>
<td>0.314 ***</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
</tr>
<tr>
<td>Women</td>
<td>−0.036 ***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
</tr>
<tr>
<td>Age</td>
<td>0.005 **</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Agesq</td>
<td>−0.013 ***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Eduy</td>
<td>0.009 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Married</td>
<td>0.046 ***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
</tr>
<tr>
<td>Health</td>
<td>0.011 ***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
</tr>
<tr>
<td>Height</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.019 **</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
</tr>
<tr>
<td>Toilet</td>
<td>0.045 ***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>−0.036 ***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>Industry</td>
<td>0.067 ***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
</tr>
<tr>
<td>Lndistance</td>
<td>−0.026 ***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>Topography</td>
<td>−0.016 **</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>−0.014 *</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
</tr>
</tbody>
</table>

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5% and * at 10%.
5.4.2. Other Infrastructure

One potential concern is that other types of infrastructure may have been built along with the water facilities, which may contribute to reallocating labor to off-farm work. In order to alleviate this concern, this paper adds a set of proxies for access to infrastructure, such as electricity, road, and telephone. The measurements of the access to these infrastructures are similar to that of piped water. The regression results are reported in Table 9, which shows that the coefficient of Water remains significantly positive.

Table 9. Other infrastructure.

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.193 ***</td>
<td>0.169 ***</td>
<td>0.215 ***</td>
<td>0.300 ***</td>
</tr>
<tr>
<td></td>
<td>(0.059)</td>
<td>(0.063)</td>
<td>(0.061)</td>
<td>(0.068)</td>
</tr>
<tr>
<td>Electric</td>
<td>0.226 ***</td>
<td></td>
<td></td>
<td>0.304 ***</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
<td></td>
<td></td>
<td>(0.082)</td>
</tr>
<tr>
<td>Road</td>
<td>0.136 **</td>
<td>0.127 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.073)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telephone</td>
<td></td>
<td>0.167 ***</td>
<td></td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.060)</td>
<td></td>
<td>(0.065)</td>
</tr>
<tr>
<td>Women</td>
<td>−0.116 ***</td>
<td>−0.122 ***</td>
<td>−0.120 ***</td>
<td>−0.124 ***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Age</td>
<td>0.036 ***</td>
<td>0.037 ***</td>
<td>0.039 ***</td>
<td>0.042 ***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Agesq</td>
<td>−0.044 ***</td>
<td>−0.047 ***</td>
<td>−0.049 ***</td>
<td>−0.047 ***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Eduy</td>
<td>0.011 ***</td>
<td>0.011 ***</td>
<td>0.011 ***</td>
<td>0.010 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Married</td>
<td>0.057 ***</td>
<td>0.052 ***</td>
<td>0.065 ***</td>
<td>0.051 ***</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Health</td>
<td>0.028 ***</td>
<td>0.030 ***</td>
<td>0.026 ***</td>
<td>0.027 ***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Height</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.041 ***</td>
<td>0.031 **</td>
<td>0.030 **</td>
<td>0.030 **</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Toilet</td>
<td>−0.000</td>
<td>−0.002</td>
<td>−0.003</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>−0.018 **</td>
<td>−0.016 *</td>
<td>−0.015</td>
<td>−0.015</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Village fixed effects</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Constant</td>
<td>−0.961 ***</td>
<td>−0.779 ***</td>
<td>−0.943 ***</td>
<td>−1.337 ***</td>
</tr>
<tr>
<td></td>
<td>(0.169)</td>
<td>(0.165)</td>
<td>(0.168)</td>
<td>(0.215)</td>
</tr>
<tr>
<td>Observation</td>
<td>7166</td>
<td>6625</td>
<td>6515</td>
<td>5346</td>
</tr>
<tr>
<td>Adj.R²</td>
<td>0.337</td>
<td>0.338</td>
<td>0.346</td>
<td>0.338</td>
</tr>
</tbody>
</table>

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5% and * at 10%.

5.4.3. Dose Response Model

Farmers may exhibit heterogeneous behavior in making off-farm work participation decisions. The Dose Response Model (DRM) is an econometric model for estimating continuous treatments under heterogeneous responses to observable confounders [55]. The Dose Response Function (DRF) is equal to the average treatment effect (ATE) given the level of treatment t (that is, ATE(t)).

Let the indicator \( w_i = \{0, 1\} \) shows whether a rural resident has access to piped water (\( w_i = 1, \) if \( \text{Water}_{ic} > 0 \)) or not (\( w_i = 1, \) if \( \text{Water}_{ic} = 0 \)). Rural residents have different intensities of piped water accessibility (t). t take values strictly within the continuous range of \([0, 100]\) (\( t = 100 \) if \( \text{Water}_{ic} = 1, t = 0 \) if \( \text{Water}_{ic} = 0 \)).
Following Cerulli [38], the population off-farm work outcomes can be written as:

\[ w = 1 : \quad y_1 = a_1 + f_1(x) + g(t) + e_1 \]  
\[ w = 0 : \quad y_0 = a_0 + f_0(x) + e_0 \]

where \( y_1 \) and \( y_0 \) are the off-farm work participation outcomes, \( f_1(x) \) and \( f_0(x) \) are individuals’ responses to the vector of confounding variables \( x \), \( g(t) \) measures the responses of off-farm work participation outcomes to the intensity of piped water accessibility \( t \).

Assuming \( f_1(x) \) and \( f_0(x) \) have linear parametric forms as \( f_1(x) = x\delta_1 \) and \( f_0(x) = x\delta_0 \). The causal parameters conditional on \( x \) and \( t \) can be written as:

\[ \text{ATE}(x, t > 0) = E(y_1 - y_0|x, t > 0) \]  
\[ \text{ATENT}(x, t = 0) = E(y_1 - y_0|x, t = 0) \]  
\[ \text{ATE}(x, t) = E(y_1 - y_0|x, t) = \begin{cases} (a_1 - a_0) + x(\delta_1 - \delta_0) + g(t) & \text{if } t > 0 \\ (a_1 - a_0) + x(\delta_1 - \delta_0) & \text{if } t = 0 \end{cases} \]  
\[ = \begin{cases} a + x\delta + g(t) & \text{if } t > 0 \\ a + x\delta & \text{if } t = 0 \end{cases} \]

where \( a = (a_1 - a_0), \delta = (\delta_1 - \delta_0) \), ATET and ATENT refer to Average Treatment Effect on the Treated \((w_i = 1)\) and Average Treatment Effect on Non-Treated \((w_i = 1)\) respectively. ATE refers to Average Treatment Effect.

Rewriting Equation (8) conditional on \( x, t, w \) gives:

\[ \text{ATE}(x, t, w) = \begin{cases} \text{ATE}(x, t > 0) & \text{if } w = 1 \\ \text{ATE}(x, t = 0) & \text{if } w = 0 \end{cases} = w[a + x\delta + g(t)] + (1 - w)[a + x\delta] \]

According to the law of iteration, the unconditional ATE is obtained as:

\[ \text{ATE} = E_{(x,t,w)}[\text{ATE}(x, t, w)] = p(w = 1)(\text{ATE}) + p(w = 0)(\text{ATENT}) \]
\[ \text{ATEN} = a + \overline{x}_{t>0}\delta + \overline{g} \]  
\[ \text{ATENT} = a + \overline{x}_{t=0}\delta \]

where \( \overline{g} \) is the average response function taken over \( t > 0 \). \( p(w = 1) \) is the probability of having access to piped water, \( p(w = 0) \) is the probability of not having access to piped water.

The Dose Response Function (DRF) is derived algebraically by averaging ATE \((x, t, w)\) over \( x \) and \( w \) so that:

\[ \text{ATE}(t) = \begin{cases} \text{ATE} + (g(t) - \overline{g}) & \text{if } t > 0 \\ \text{ATENT} & \text{if } t = 0 \end{cases} \]

Figure 5 shows the different responses of individuals at different piped water accessibility intensities. The shape of the relationship depicts that, on average, piped water accessibility increases the probability of participating in off-farm work. Anyway, the linkage between piped water accessibility and off-farm work participation exhibits a cubic function shape, although, at lower and higher levels of intensity of piped water accessibility, the panel exhibits wider confidence bands than in the middle.
5.5. Further Research

In this section, we further examine the effect of access to piped water on household income and analyze the mediating role of off-farm work participation in this relationship. The dependent variable is the natural logarithm of household income per capita (Lnhhpincome). The independent variable is the mean value of access to piped water at the household level (M_water). The control variables include individual characteristics of the householder and household characteristics. The mediating variable is the mean value of off-farm work at the household level (M_off_farm).

Following Baron and Kenny [56], this paper conducts a mediation analysis. Column 1 of Table 10 shows that the coefficient of M_water is significantly positive, which indicates that access to piped water improves household income. Column 2 shows that access to piped water at the household level remains positively correlated with off-farm work participation. Column 3 reports the impact of off-farm work participation at the household level on household income, which shows that off-farm work participation is positively and significantly related to household income. Column 4 shows that when we control for off-farm work participation at the household level, the coefficient of M_water becomes smaller compared to column 1. Sobel’s test reaches significance (p < 0.001), indicating a significant mediating effect of off-farm work participation on the association between access to piped water and household income.

Table 10. Results of mediation analysis for off-farm work participation.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Lnhhpincome</th>
<th>M_off_farm</th>
<th>Lnhhpincome</th>
<th>Lnhhpincome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>M_water</td>
<td>1.248 ***</td>
<td>0.236 ***</td>
<td>1.036 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.417)</td>
<td>(0.083)</td>
<td>(0.411)</td>
<td></td>
</tr>
<tr>
<td>M_off_farm</td>
<td></td>
<td></td>
<td>0.911 ***</td>
<td>0.899 ***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.089)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>Women</td>
<td>0.055</td>
<td>-0.032</td>
<td>0.075</td>
<td>0.083</td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.021)</td>
<td>(0.102)</td>
<td>(0.102)</td>
</tr>
<tr>
<td>Age</td>
<td>0.071 ***</td>
<td>0.009 *</td>
<td>0.056 **</td>
<td>0.063 ***</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.005)</td>
<td>(0.024)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>Agesq</td>
<td>-0.089 ***</td>
<td>-0.016 ***</td>
<td>-0.071 ***</td>
<td>-0.074 ***</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.005)</td>
<td>(0.025)</td>
<td>(0.025)</td>
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</table>
Table 10. Cont.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Lnhhpincome (1)</th>
<th>M_off_farm (2)</th>
<th>Lnhhpincome (3)</th>
<th>Lnhhpincome (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eduy</td>
<td>0.029 ***</td>
<td>0.008 ***</td>
<td>0.021 **</td>
<td>0.022 **</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.002)</td>
<td>(0.009)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Married</td>
<td>0.147 *</td>
<td>−0.030 *</td>
<td>0.174 **</td>
<td>0.174 **</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.017)</td>
<td>(0.085)</td>
<td>(0.085)</td>
</tr>
<tr>
<td>Health</td>
<td>0.201 ***</td>
<td>0.025 ***</td>
<td>0.177 ***</td>
<td>0.178 ***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.006)</td>
<td>(0.028)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Height</td>
<td>0.007</td>
<td>0.001</td>
<td>0.006</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.001)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Internet</td>
<td>0.308 ***</td>
<td>0.038 ***</td>
<td>0.297 ***</td>
<td>0.273 ***</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
<td>(0.014)</td>
<td>(0.068)</td>
<td>(0.068)</td>
</tr>
<tr>
<td>Toilet</td>
<td>0.088</td>
<td>0.009</td>
<td>0.082</td>
<td>0.080</td>
</tr>
<tr>
<td></td>
<td>(0.074)</td>
<td>(0.015)</td>
<td>(0.073)</td>
<td>(0.073)</td>
</tr>
<tr>
<td>Lnpland</td>
<td>0.246 ***</td>
<td>−0.025 **</td>
<td>0.266 ***</td>
<td>0.269 ***</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.010)</td>
<td>(0.048)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Village fixed effects</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Constant</td>
<td>4.400 ***</td>
<td>−0.035</td>
<td>5.140 ***</td>
<td>4.431 ***</td>
</tr>
<tr>
<td></td>
<td>(1.041)</td>
<td>(0.208)</td>
<td>(0.986)</td>
<td>(1.024)</td>
</tr>
<tr>
<td>Observation</td>
<td>3295</td>
<td>3295</td>
<td>3295</td>
<td>3295</td>
</tr>
<tr>
<td>Adj.R²</td>
<td>0.193</td>
<td>0.431</td>
<td>0.218</td>
<td>0.219</td>
</tr>
</tbody>
</table>

Note: White’s standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5% and * at 10%.

6. Conclusions and Policy Recommendations

Water collection is a time-consuming and physically demanding task. This tangible time requirement imposes a constraint on rural households’ ability to pursue off-farm work. The process of economic development is usually accompanied by changes in household time allocation patterns. This paper suggests that piped water, as a time-saving household technology, reduces the time intensity of household production and liberates household members from the task of collecting water. Using data from a nationally representative survey, this paper finds that access to piped water significantly improves off-farm work participation in rural China. The results remain robust when we use the PSM approach, Lewbel IV method, placebo test, and Dose-Response Model. Anyway, we find that the positive effect of access to piped water on off-farm work participation is greater in rugged areas and women, reflecting the role of access to piped water in promoting inclusive growth. Further research shows that access to piped water increases household income, and non-farm work participation mediates, in part, the link between access to piped water and household income.

Departing from the conventional literature focusing on health and education. This paper explores a new channel, off-farm work participation, by which access to piped water shapes development outcomes. Considering the importance of the mobility of labor from agriculture to the non-agricultural sector for economic development and poverty reduction, the government is supposed to invest more in the construction of piped water facilities. In particular, in many developing countries, droughts are increasing in frequency, severity, and duration [57]. According to climate change projections from the United Nations, future water stress in Africa will increase, and fresh water supplies in many parts of Asia will decrease [58]. In this context, some rural households will have to spend more time on water collection. Policymakers should be aware of the time intensity of domestic work in the absence of piped water infrastructure and how households deal with this time allocation trade-off.
7. Questions and Limitations

This study has some questions and limitations that need to be addressed in the future. First, because we lack detailed information on individual time use, we cannot simultaneously test the impact of access to piped water on leisure, agricultural production, off-farm production, and domestic work. Future research could address this issue using a more detailed dataset. Second, from a policy perspective, a cost-benefit analysis is important, and future research could analyze this by collecting more information on the investment costs of piped water facilities and developing a structural estimation model.

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