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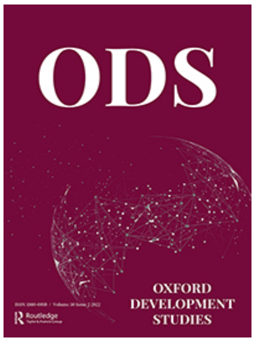

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Household access to water and education for girls: The case of villages in hilly and mountainous areas of Nepal

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ABSTRACT
This study examines the effect of household water accessibility on children's educational attainment in villages situated in the remote hilly and mountainous areas of Nepal. Educational attainment was measured based on school attendance, grade repetition, and completion of primary and lower-secondary schooling. The estimation results show that a one-hour increase in the time spent on a water-fetching trip will decrease the probability of girls completing primary school by about 17 percentage points (in the age group of 14–16 years). Although boys' completion rate is less affected, they are more likely to repeat a grade. Additional analyses indicate that these results are driven by the increased participation of older boys and younger girls in household duties.

KEYWORDS
Water access; household duties; schooling; gender equality; nepal

JEL CLASSIFICATION
I24; I25; O12

1. Introduction[1]

With sustained global efforts, this century has witnessed considerable progress in bridging the gender gap in education: 'gender equality' and 'universal education' have been named in the Millennium Development Goals (MDGs) and subsequent Sustainable Development Goals (SDGs). However, being female is still a primary societal reason for failure to progress in education in several sub-Saharan African and South Asian countries (UNICEF, 2020).

One major likely cause of inequality in education in these countries is the gender-based differences in family roles. In developing countries, household chores such as cooking, cleaning, washing, and child-rearing are typically the responsibility of women. In villages in the hilly and mountainous areas of Nepal, water fetching is also included in this list of activities. In these regions, people live on slopes and the water source is typically located at the bottom, which is not covered by an electric power grid; hence, water supply relies on physical labour. In Nepal, as in several developing countries, water fetching is traditionally done by women and girls. One consequence of this may be reduced opportunities for girls' schooling, as girls spend a lot of time fetching water for their households.

In this study, we examine the link between water accessibility and children's educational attainment using original household data from remote hilly and mountainous villages in Nepal. Ensuring improved water sanitation, gender equality, and universal education have always been urgent issues in the international community. In fact, 2.4 billion people still lack access to improved water sanitation facilities worldwide (WHO/UNICEF, 2015). In Nepal, only 40.7% of the people in

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hilly and mountainous areas have access to an improved water source at a distance that can be covered within a 30-minute round-trip (GoN (Government of Nepal), New ERA, UNICEF, EU, USAID, & CDC, 2018). This indicates that residents must engage in strenuous water-carrying activities daily by descending and ascending precipitous slopes. If children's school enrolment is associated with the time spent on water-collecting activities (Koolwal & van de Walle, 2013; Nankhuni & Findeis, 2004; Nauges & Strand, 2017), the establishment of an efficient water supply system becomes doubly important: it can improve children's educational attainment and increase household welfare by reducing the time spent fetching water. While water resource policies should be the chief priority for marginal settlements without access to basic utilities, we show that exploring the association between water accessibility and education is also important in its own right.

In the literature, many studies have examined the relationship between water accessibility and child welfare. Similar to evaluating the impact of public goods/services, estimating this causality involves empirically difficult issues. Causal inference is pivotal in policy planning because understanding the cause-and-effect linkages can help formulate effective policies. In the current context, there are two typical concerns when evaluating the impact of water access using micro data across communities.

First, provision of public goods/services may be associated with a social or economic hierarchy; the higher a household is on the social/economic ladder in a community, the better is its access to public goods/services. Such between-household heterogeneity within a community potentially biases the estimated effect. Second, wealthier communities may have more access to public goods and services than poorer communities do. Such heterogeneity between communities is usually controlled by community fixed effects; otherwise, its existence results in misidentification of the causal effect.

Thus, the key to isolating the impact of household water access is determining whether the confounding heterogeneity within and between communities can be purged. One way of addressing the issue is by randomisation, that is, to distribute public goods/services (or establish facilities that provide them) in a random manner, both across and within communities. However, according to the literature, there are only a few exceptions that have utilised a randomised experiment.[2] Moreover, in many settings, including remote and isolated villages without basic utilities, it may be physically and financially implausible to conduct such an experiment in a sustainable way. To address this empirical difficulty, almost all studies hinge on identification assumptions without a randomised experiment.

For example, several studies have addressed heterogeneity within a community by using the community-level variable of interest, by implicitly or explicitly assuming there are no confounders driven by between-community heterogeneity after controlling for several community-level variables. The work of Koolwal and van de Walle (2013), which is based on this approach, is closely related to ours.[3] They examined the impact of water accessibility on womens' labour participation and child schooling using household datasets from several developing countries.[4] Furthermore, several studies have addressed both heterogeneities by controlling community- (or entity-) fixed effects by using repeated cross-section (or panel) data, and employing a community-level variable of interest.[5] However, all of these studies focus on health consequences instead of educational outcomes. Therefore, we lack empirical evidence regarding the impact of water accessibility on child education in the context of this strategy.,[6,7]

Our study utilises an alternative approach to examine the effect of water accessibility on child education. The source of variation employed in this study stems from geographical differences within villages, which we assume to be orthogonal to observed and unobserved household characteristics after controlling for village-level unobserved characteristics. Similar to most existing studies without randomisation, we recognise that a strong claim about causality cannot be made. However, we empirically test the identification assumption rigorously to determine its validity. Our approach, which relies on geographical variations with an empirically falsifiable assumption, is one of the most reliable approaches available with observational data, given the limitations of our empirical context of remote and isolated rural areas, where conducting experiments is nearly infeasible.

Furthermore, this study adds to the literature on the link between the provision of basic public goods/services and child education by shedding light on child involvement in household chores. There is a vast body of research on the determinants of educational investment in children and many studies have focused on the nexus between child labour and education (Basu, 1999). However, few studies have addressed the role of unpaid household duties (Assaad et al., 2010; Levison & Moe, 1998; Levison, Moe, & Knaul, 2001). In addition to the main analysis, we explore the impact on child participation in housework. This enables us to conduct a more detailed assessment of the mechanism behind the relationship between household chores and education.

In the next section, we provide a brief overview of the Nepalese education system and explain the dataset and sample features of the study region. Then, in Section 3, we explain our empirical framework. Section 4 presents the estimation results, which show that a one-hour increase in the round-trip to the water source will lower the probability of girls' primary school completion by about 17 percentage points, and when households have poor access to water, boys are more likely to repeat a grade but their completion rate of primary school is less affected. Finally, Section 5 presents the conclusions.

2. Education in Nepal

The Nepalese education structure is divided into five levels: primary (grades 1 to 5), lower-secondary (grades 6 to 8), secondary (grades 9 to 10), higher-secondary (grades 11 to 12), and tertiary. Children start primary education at the age of five, and compulsory education comprises the first two categories, namely, grades 1 to 8. Grade promotion depends on the term-end and year-end examinations, and at grade 8, pupils need to pass the school-leaving examination conducted at the district level.

While the adult population on average has less than primary-level education, steady improvements in education can be expected for the younger population. According to the human development index (UNDP, 2018), the average schooling years for adults (aged 25 or more) is 4.9, but the expected average years of schooling for school-aged children is above the higher-secondary level, or 12.2 years. The latest available nationally representative data show that over 90% of school-aged children attend school. Column 1 of Table 1, which uses *NLSS 2010/2011* data, shows that the ratio of children aged 6–15 currently attending primary, lower-secondary, or secondary school across the country is 92.2%. In addition, there is little difference in the enrolment ratio between genders and regions (rural/urban).

However, regarding the completion ratio, there are still sizable gaps by region and gender, even among young adults. Columns 2 to 4 of Table 1 show that rural–urban differences in the completion

Table 1. Gender disparities in Nepalese education.

		Completion rates (people aged 16–25)		
	Enrolment rates (children aged 6–15)	Primary	Lower- secondary	Secondary
All Nepal	92.20	76.19	58.59	40.70
Urban				
Boys	93.32	92.30	78.39	62.76
Girls	92.98	85.04	72.74	57.68
Rural				
Boys	92.59	78.41	57.93	33.88
Girls	91.17	63.22	43.26	27.10

Source: Calculated by authors from *Nepal Living Standards Survey 2010/2011* (*NLSS-III*).

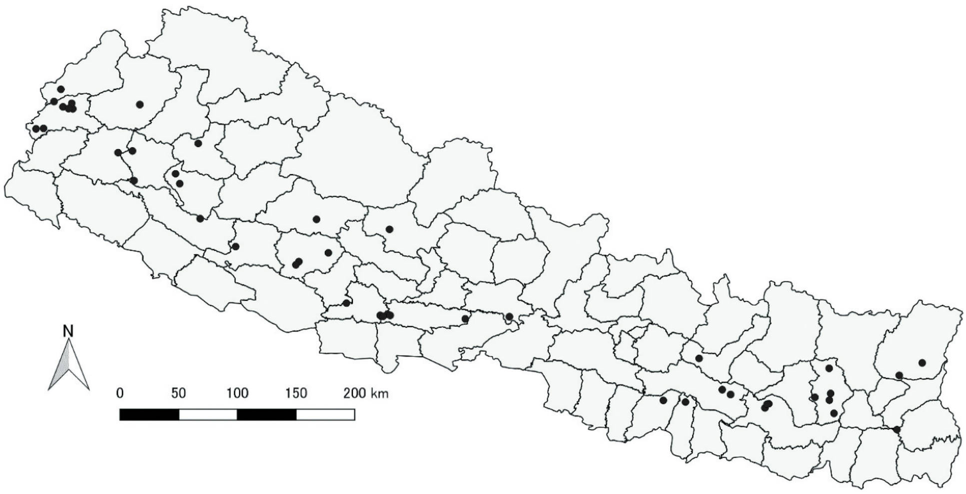

Figure 1. The location of our survey sites.

rates are relatively large and gender disparities are larger in rural areas. Thus, we aim to provide a clearer understanding of the mechanism behind gender disparities in education in rural areas.

3. Research design

To elucidate the link between water accessibility and children's educational attainment in remote settlements with no electricity and water supply systems, we conducted a household survey in villages in the hilly and mountainous areas of Nepal from 2014–2015.[8] In the survey, based on cluster random sampling, we randomly selected 45 wards (villages) out of the 22,545 wards without a water supply system or electricity from our village database. We interviewed 2,642 households in the 45 wards. The survey questionnaire contains items about household chores (including water-collecting activities) and standard questions, including family roster, labour activity, and education. The main respondents were household heads or their spouses. Figure 1 shows the locations of our survey sites.

3.1. Data and sample features

Table 2 summarises the water accessibility of the sample households. Panel A, which reports the mode of fetching water, shows that in the entire sample of 2,642 households, 1,654 households (62.6%) carry water directly from the primary or secondary sources. Since our target villages are those without basic utilities, no households have access to a water supply system such as piped and tap water. Table 2 shows that most of the remaining households that do not collect water directly from the source, use public storage.

Panel B of Table 2 summarises the water-collection activities of the 1,654 households that carry water directly from the water source. On average, one water collection trip takes about 30 minutes, and households make four trips per day, carrying 1.4 bottles – each bottle with a capacity of 15 litres – each trip. In addition, the table shows that water collection is women's work; 75.6% of adult women and 28.4% of non-adult women (aged 10–19) engage in water-collection activities as compared to 19.0% of adult men and 14.0% of non-adult men.

In the analysis, we used a sample of children aged 6–16 years. Since children are more likely to leave their parents' house for employment or marriage as their age increases, we set the target age range for the schooling section of the questionnaire as 6–16 years old. In fact, the gender ratio (defined as the share of females) is 53.0% for children aged 15–16 and 43.3% for those aged 17–18,[9]

Table 2. Household access to water in the study region.

A. Mode of water collection from primary and secondary water sources ($N = 2,642$)	
Household water source	
Directly from a natural water source	1,654
Not directly from a natural water source but from one of the following sources:	988
own well	86
public well	179
own storage	41
public storage	697
B. Summary of water-fetching activities (for households that carry water directly from the natural water source, $N = 1,654$)	
Hours spent in travelling to and from the source (N = 1,645)	
# of water-hauling trips per day (N = 1,645)	4.00
# of 15-litre bottles carried at one time (N = 1,616)	1.36
Non-adult males (19 ≥ age ≥ 10) who engage in water fetching (N = 1,166)	0.14
Non-adult females (19 ≥ age ≥ 10) who engage in water fetching (N = 1,114)	0.28
Adult males (age ≥ 20) who engage in water fetching (N = 2,405)	0.19
Adult females (age ≥ 20) who engage in water fetching (N = 2,236)	0.76

Source: Calculated by authors from our original survey.

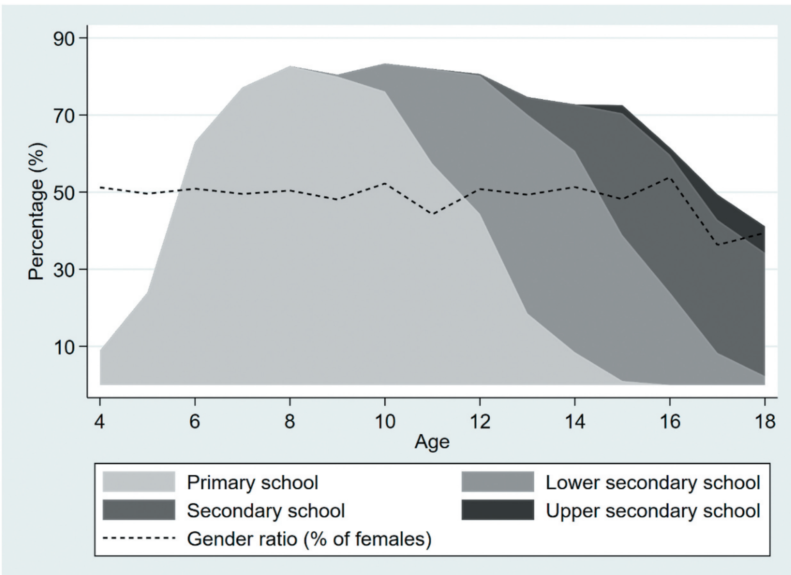

Figure 2. Net attendance ratio of children aged 4–18. Source: Calculated by authors from our original survey.

which implies that females are more likely to get married and leave their parents' house early compared to males.

Figure 2 presents the net attendance ratio for children aged 4–18 years with regards to their level of schooling and the gender ratio. Children's current attendance was based on self-reported answers. According to the graph, at the age of 14–16, about 68.9% of our sample children are still going to school, including 3.2% and 41.2% of children attending primary and secondary schools, respectively.

Table 3. Summary statistics of main variables.

	Obs.	Mean	Std.dev.	Min	Max
A. Analysis for children aged 6–16					
Educational outcome					
Current (last attended) grade	2,325	4.34	2.79	0.00	12.00
No. of repetitions	2,325	0.10	0.33	0.00	3.00
Water accessibility					
Hours spent on water collection	2,325	0.52	0.39	0.00	5.97
Hours spent on water collection by Neighbours	2,253	0.53	0.37	0.02	2.06
B. Analysis for children aged 14–16					
Educational outcome					
Completion of primary educ.	638	0.82	0.39	0.00	1.00
Completion of lower-secondary educ.	638	0.32	0.47	0.00	1.00
Water accessibility					
Hours spent on water collection	638	0.52	0.37	0.00	2.08
Hours spent on water collection by Neighbours	615	0.53	0.36	0.02	2.00

Source: Calculated by authors from our original survey.

3.2. Empirical specification

The key source of variations in our empirical strategy stems from geographical differences, that is, accessibility to natural water sources. We estimate the effect of household water accessibility on children's educational outcomes based on the following equation:

$$educ_{ijs} = \beta_b(w_j \times boy_i) + \beta_g(w_j \times girl_i) + \mathbf{x}_{ij}\gamma + \delta_s + u_{ijs} \quad (1)$$

where $educ_{ijs}$ is the educational outcome of child i in household j in ward (village) s; water accessibility (w_j) is included as interaction terms with gender dummies (boy_i and $girl_i$) to allow for the heterogeneous impact on educational attainment between genders; $\mathbf{x}_{ij}$ is a vector of individual and household characteristics; δ_s represents village fixed effects; u_{ijs} is an unobserved component; and β_b, β_g, and γ are the parameters to be estimated.

For $educ_{ijs}$, we used four different educational outcomes: current (or last attended) grade and the number of grade repetitions for the sample of children aged 6–16 years, and dummies for completing primary (5th grade) and lower-secondary education (8th grade) for children aged 14–16 years. Household access to water (w_j) is measured by the time (in hours) spent to make one round trip to the natural water source. If a household uses multiple natural water sources, we use the closest one in terms of time. As control variables ($\mathbf{x}_{ij}$), we employ individual and household characteristics such as gender and age of the child, household size, dependency ratio, age/gender/education of the household head, education of mother, log of annual household income, commuting time to primary school,[10] and language and social group fixed effects. In addition, we include dummies for the survey month to eliminate the influence of seasonality.

As explained in the previous section, we limit the sample used in the analysis to the 1,654 households that carry water directly from a natural water source and have no public/private well or storage. Furthermore, among them, after excluding households with missing information on some child/household-level variables[11] and no school-age children, our sample consists of 2,325 children from 1,131 households. Table 3 reports the summary statistics of the main variables used in the analysis.

3.3. Identification strategy and its validity

This study utilizes geographical variations in water accessibility to address issues stemming from unobserved heterogeneity within and between communities. Specifically, while we eliminate the influence of *between*-community heterogeneity by controlling for community-fixed effects, as denoted by δ_s in Equation (1), we sever the correlation between *within*-community heterogeneity and treatment status (household access to water) by exploiting distance to natural water sources. The location of natural water sources such as rivers, seepages, ponds, and springs is geographically determined, and therefore, it is plausible to assume that proximity to them is orthogonal to observed and unobserved household characteristics, unlike the provision of public goods/services, after controlling for village-level unobservables.

While we believe our identification assumption is no more assertive than those in prior studies with observational data, there could be several counterarguments against this assumption. For example, if wealthier households live closer to natural water sources for some reason – for example, by their residential selection – the proximity to natural water sources may reflect households' characteristics, which may be partly unobserved, and affect children's educational attainment. Moreover, accessibility to natural water sources may reflect accessibility to other public facilities, including schools. If this is the case, the influence of household access to natural water sources is confounded by the influence of accessibility to other facilities.

To validate our identification strategy, we perform the following two tests. First, we compare several household characteristics between two groups, namely, those who live closer to and farther from the natural water source than the average household in the community (the balancing test). Second, we examine the correlation coefficients between household characteristics and the distance to the natural water source (the correlation test).[12] Table 4 reports the results: the balancing test results (Columns 1 to 5) show that the difference is narrowly estimated to be zero for all characteristics; the correlation test (Columns 6 and 7) also shows that the correlation coefficients are all close to zero. Thus, these results confirm that the observed household characteristics are orthogonal to the distance from the natural water source.[13] In other words, those who live farther

Table 4. Balancing and correlation tests for the identification assumption.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Balancing Test					Correlation Test	
	HHs closer to natural water source than the median		HHs farther from natural water source than the median		(2)-(4)	Correlation with distance to natural water source	
	Obs.	Mean (Std.dev.)	Obs.	Mean (Std.dev.)	Diff. [Std.err.]	Obs.	Coef. {P-value}
HH total income (10,000 NPR)	861	10.089	714	11.076	−0.987	1,575	0.006
		(13.699)		(13.969)	[0.700]		{0.809}
HH size	897	5.317	757	5.412	−0.096	1,654	0.002
		(2.156)		(2.262)	[0.109]		{0.940}
HH head's age	887	44.165	751	45.254	−1.090	1,638	0.034
		(14.035)		(14.391)	[0.704]		{0.168}
HH head's years of education	896	1.465	757	1.448	0.018	1,653	−0.018
		(2.853)		(2.964)	[0.143]		{0.475}
Mother's years of education	630	0.748	542	0.705	0.043	1,172	−0.022
		(2.159)		(2.109)	[0.125]		{0.452}
House built within 10 years	892	0.348	753	0.335	0.013	1,645	0.021
		(0.476)		(0.472)	[0.023]		{0.398}
House built within 20 years	892	0.636	753	0.632	0.004	1,645	−0.012
		(0.482)		(0.483)	[0.024]		{0.635}
House built within 30 years	892	0.762	753	0.776	−0.013	1,645	−0.004
		(0.426)		(0.417)	[0.021]		{0.873}
Commute time (min.) to primary school	441	27.551	386	29.083	−1.532	827	−0.025
		(17.901)		(16.193)	[1.194]		{0.481}
lower-secondary school	285	39.354	221	42.787	−3.433	506	0.060
		(22.249)		(26.031)	[2.149]		{0.180}

Source: Calculated/estimated by authors from our original survey.

from a water source are not relatively poor. In addition, the lack of relationship between water accessibility and the year a house was built indicates that those who are farther from the natural water source in a community are not new households that settled from outside the community or split from their parents' family. Thus, water accessibility does not symbolise the socio-economic status of households in the community. More importantly, distance to the water source seems to be unrelated to the household head's and mother's education and distance to schools.[14] These results suggest that water accessibility is less likely to be correlated with other unobserved household characteristics as well.

Another potential threat to our identification strategy is the use of a subjective measure of water accessibility. Subjective data may raise the issue of measurement errors. Although we cannot determine the direction of bias caused by the correlation between the reported value and unobserved components of the outcome variable, if the classical measurement-error assumptions hold, we have an attenuation bias. In this case, our estimates can be interpreted as the lower bound of the impact of household access to water.

However, another issue attributable to subjective measures of water accessibility may threaten our identification strategy. While our survey data can identify the main water carriers and the average time spent to and from the water sources, it cannot identify the individual (carrier's) specific time spent on a water-fetching trip.[15] Therefore, if boys and girls in households situated farther from their water source are involved in water-carrying activities, it is possible that their reported hours are longer than the hours reported by adult carriers of similar households. It is naturally expected that children will take more time than adults to carry water. Thus, not attending school and spending more time fetching water could be simultaneous outcomes, as decisions on schooling and labouring are made simultaneously. In this case, the impact of water accessibility will be biased upward in magnitude, especially when using the reported hours by households.

To address this issue, we employ an alternative proxy for accessibility to the natural water source and examine the direction of the change in the coefficient. The alternative proxy is the median hours that households' neighbours spend going to and from the natural water source. Here, neighbours are defined as: (i) households within a 100-metre radius; (ii) if there are no households within a 100-metre radius, households within a 200-metre radius are used; and (iii) if there are no households within a 200-metre radius, we expanded the radius in 100-metre increments up to a 500-metre radius. However, neighbours' water accessibility is potentially correlated with their characteristics, and this may cause the estimate to be biased.[16] Therefore, we additionally include the household characteristics of neighbours (in median) such as household size, dependency ratio, age/gender/education of the household head, education of the mother, log of annual household income, and commuting time to primary school.

We also address the issue of sample selection. As already explained, we limit the sample to those who collect water directly from natural water sources. However, whether people collect water directly from the source is dependent on the decision regarding the installation of water facilities, and if done in a non-random manner, our estimate may suffer from selection bias. In other words, if poor households are less likely to introduce water facilities such as storage and wells and our sample consists of poorer households, we may overstate the influence of the lack of access to water. Therefore, we conduct a balancing test to compare several household characteristics between our sample households and those excluded from the sample (see Online Appendix III). The results in Table A3 indicate that our sample households are wealthier and have more educated heads/children's mothers than those excluded from the sample. Nevertheless, there is no statistically significant difference in education among school-age children, probably because our sample households have a disadvantage in terms of water accessibility. These results imply that the Nepal government prioritised the introduction of public water storage in relatively disadvantaged areas. Thus, the households in our sample are not necessarily at the very bottom of the social order and the impact of the lack of water access is less likely to be overstated.

Table 5. Impact on education: current (last attended) grade and repetitions [Children aged 6–16].

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.:	Current (last attended) grade	No. of repetitions	Current (last attended) grade	No. of repetitions	Current (last attended) grade	No. of repetitions
Water accessibility (hours spent on water collection):	Household reported hours		Neighbours' median hours			
× Boy (β_b)	−0.038	0.078**	−0.021	0.065*	0.107	0.071**
	[0.115]	[0.034]	[0.183]	[0.034]	[0.185]	[0.033]
× Girl (β_g)	0.048	0.021	−0.047	0.021	0.046	0.022
	[0.132]	[0.035]	[0.165]	[0.030]	[0.166]	[0.029]
Neighbours' characteristics	No	No	No	No	Yes	Yes
Test for $H_0 : \beta_b = \beta_g$ (F-stat.)	0.338	4.738**	0.032	2.170	0.188	2.940*
Observations	2,325	2,325	2,253	2,253	2,238	2,238
R-squared	0.691	0.054	0.692	0.055	0.701	0.064

Note: This table reports only the coefficients of interest based on Equation (1). All estimations control for fixed effects of age, gender, language, caste, survey month, ward (village), and other individual/household characteristics such as household size, age/gender/education of household head, education of mother, log of annual household income, and commuting time to primary school. Standard errors in brackets are clustered at the village level. ** Significant at the 5% level. * Significant at the 1% level.
Source: Estimated by authors from our original survey.

Furthermore, we examine the validity of our identification assumption by estimating bias-adjusted treatment effects (Oster, 2019). Although a detailed explanation of the estimation and results is provided in Online Appendix V, we report these results briefly in Section 4.2.

4. Estimation results

Table 5 presents the estimation results for Equation (1) regarding the school grades (Columns 1, 3, and 5) and the number of grade repetitions (Columns 2, 4, and 6). Although the table reports only the coefficients of interest, all estimations control for child/household characteristics, as explained in Section 3.1. The sample consists of children aged 6–16 years.

While the results in Column 1 show no statistically significant association between water accessibility and the current grade for both boys and girls,[17] those in Column 2 imply that a one-hour increase in the time spent going to and from the natural water source may increase the number of grade repetitions by 0.078 for boys.[18] Analysing the results in Columns 3 to 6 of Table 5, which use the median hours spent on a water-fetching trip,[19] we found that the coefficient estimates in

Table 6. Impact on education: completion of primary and lower-secondary schools [Children aged 14–16].

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.: Completion of	Primary	Lower-secondary	Primary	Lower-secondary	Primary	Lower-secondary
Water accessibility (hours spent on water collection):	Household reported hours		Neighbours' median hours			
× Boy (β_b)	−0.067	0.149	−0.085	0.013	−0.061	0.028
	[0.087]	[0.128]	[0.067]	[0.125]	[0.065]	[0.132]
× Girl (β_g)	−0.162**	−0.001	−0.190**	−0.049	−0.172**	−0.041
	[0.070]	[0.069]	[0.079]	[0.060]	[0.083]	[0.071]
Neighbours' characteristics	No	No	No	No	Yes	Yes
Test for $H_0 : \beta_b = \beta_g$ (F-stat.)	1.205	1.090	1.417	0.289	1.494	0.352
Observations	638	638	615	615	610	610
R-squared	0.075	0.205	0.081	0.198	0.091	0.213

Note: This table reports only the coefficients of interest based on Equation (1). All the estimations control for the covariates in Table 5. Standard errors in brackets are clustered at the village level. ** Significant at the 5% level.
Source: Estimated by authors from our original survey.

Columns 3 and 4 are slightly different from those in Columns 1 and 2, but the changes are very small and not systematic. This implies that the influence of reverse causality or measurement error bias is very small. In addition, after controlling for neighbours' characteristics, the coefficient estimates are almost unchanged (Columns 5 and 6), implying that bias, if any, due to the correlation between neighbours' water accessibility and characteristics, is very small.

Table 6 presents the estimation results of the association between household access to water and completion of primary education (Columns 1, 3, and 5) and lower-secondary education (Columns 2, 4, and 6). The sample consists of children aged 14–16 years.[20] While we found no significant relationship between water access and school completion for boys, girls' completion of primary education is significantly associated with water access. For example, Column 1 implies that a one-hour increase in the time spent on a water-fetching trip may decrease the probability of girls completing primary education by 16.2 percentage points. For boys, the estimated coefficient is negative but insignificant; they may repeat a grade but will complete primary education.

These results are also supported by the estimations that used the median hours neighbours spent on a water-fetching trip. The point estimates in Column 3 are slightly larger (in magnitude) than those in Column 1 for most cases, indicating the rejection of endogeneity due to the reverse causality between schooling and household labour. Observing the results in Column 5, which controls for neighbours' household characteristics, the estimates shrink slightly in magnitude, but the changes are small, which implies the possibility that girls with an additional hour of water hauling are 17.2 percentage points less likely to complete primary school. This accounts for about one-fifth of the completion rate of primary school for girls aged 14–16 (=17.2/81.7).

4.1. Interpretation and discussion

Several issues must be addressed to interpret the results in Tables 5 and 6. In this section, we discuss three possible issues. First, as shown in Figure 2, some children aged 14–16 are still in primary school; thus, the lowered probability of girls' school completion (Table 6) does not necessarily signify an increased probability of school dropouts. In fact, although the coefficients are small and statistically insignificant, additional analysis of the impact of water access on current school attendance reveals that time spent on water collection is positively associated with current attendance at primary school (see Online Appendix IV). Thus, there is a possibility that children who have not yet completed primary schooling at the age of 14–16 will continue going to primary school and complete it eventually. However, combining all the results so far, this possibility may be low, implying that girls aged 14–16 in a household with poor water accessibility are more likely to withdraw from school for several years without repeating a grade. Thus, it is difficult to expect that they will return to school at the age of 17 or more. It is also worth noting that their current attendance may be overstated since primary education is compulsory and parents tend to answer that children who have not completed primary education are still attending school.

Second, the gender difference in the impact of water access needs to be interpreted with care. Tables 5 and 6 also report, in the third row from the bottom, the test results for the null hypothesis that the coefficients for boys and girls are equal. In fact, the results of the school completion analysis (Table 6) show no significant difference between β_b and β_g. Thus, the results indicate that there is a significant difference in the probability of completing primary school when comparing girls in households with poor water access to children in households with better access, but no significant difference when comparing boys and girls in households with similar water accessibility.

However, we reject the null hypothesis in the grade repetition analysis (Columns 2 and 6 of Table 5). This implies that boys are more likely to repeat a grade than are girls when water accessibility is poor, but we may need to consider the possibility of 'survivorship bias.' Namely, boys tend to continue to study longer than girls (as the results in Table 6 imply), and consequently, they may have more chances to repeat a grade than girls. In this regard, however, there is no evidence that boys in our sample are more likely to attain higher education levels than girls. For example, we see no significant difference in the highest grade attained by boys and girls at the age of 14–16: on average, it is 7.43 for males and 7.31 for females. Furthermore, the impact of water accessibility on current school attendance is not significantly different between boys and girls aged 14–16 (see Table A4 in Online Appendix IV). Thus, the possible influence of survivorship bias seems to be small.

Finally, we estimate the bias-adjusted treatment effects proposed by Oster (2019) to address the case in which our identification strategy is invalid and the estimated coefficients contain bias from unobserved characteristics (see Online Appendix V). Although we provide no detailed explanation here, the estimated bias-adjusted coefficients in Table A5 are close to our estimates and within their 95% confidence intervals in most cases, implying that our main findings from Tables 5 and 6 are robust. Together with the results from the balancing test and correlation test in Section 3.3, the endogeneity issues previously discussed are not so problematic, or are negligible if they exist.

4.2. Potential causal paths of the estimated impacts

To better understand the mechanism behind the results, we further conduct a set of additional causal path analyses. There are two potential scenarios to explain the negative influence of distance to water sources on educational attainment: 1) indirect influence through children's adverse health situation due to lack of clean water, and 2) direct influence through increased household-chore labour allocation to children.

Several studies have documented the positive linkage between childhood health status and later educational attainment (Bleakley & Lange, 2009; Case, Fertig, & Paxson, 2005; Case & Paxson, 2010; Ito & Tanaka, 2018).[21] Hence, if improved access to water causes health improvement, the association between water accessibility and educational attainment is mediated by health improvement. In Online Appendix VI, to test this possibility, we examine the health impact of household water access. The estimation results do not imply a relationship between water accessibility and health.[22]

The second possible path is the increased time devoted to household chores. Table 7 shows the results of the relationship between water accessibility and engagement in miscellaneous household chores (water hauling, child/elder/sick care, cleaning, and laundry) and all household chores. The results indicate that an increase in hours spent on water collection increased the likelihood that children aged 6–9 were engaged in child/elder/sick care, cleaning, and laundry (weakly and significantly, as shown in Columns 4, 6, and 8, respectively). Column 10 shows that when the household is far from natural water sources, boys aged 14–16 and girls aged 6–9 are more likely to engage in domestic duties altogether. These results indicate that when water accessibility is low, households may not necessarily increase children's participation in water-carrying activities but may cope by compensating the adults' increased time burden of water collection with older boys' and younger girls' increased participation in other household duties. This, in turn, is potentially causing the increased grade repetition for boys and low completion of primary school for girls. It is also notable that the coefficients of girl dummy and its interactions with age categories are positive, and many are significant: girls' participation in household chores is inherently high relative to boys' participation. Thus, the results show that participation in household chores by younger girls aged 6–9 increases even more when water accessibility is low.

5. Conclusion

Water fetching is traditionally done by women and girls in Nepal. In hilly and mountainous villages without systematic water or electricity supply, water collection becomes inevitably laborious, and as a result, girls receive fewer educational opportunities than do boys.

This study explored the adverse influence of water-collecting activities on children's educational attainment – measured in terms of school grade, repetition, and completion of primary and lower-secondary schooling – in remote and isolated villages in Nepal. The estimation results indicated that household water accessibility is associated with children's educational attainment. Although we

Table 7. Impact on household chores [Children aged 6–16].

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dep. var.:	Water hauling		Child/elder/sick care		Cleaning		Laundry		All household chores	
A. Sample mean										
Boys ($N = 1,186$)	0.093		0.024		0.048		0.055		0.159	
Girls ($N = 1,187$)	0.127		0.067		0.146		0.163		0.265	
B. Coefficient estimates										
Water accessibility (neighbours' median hours spent on water collection)										
× Boy	0.006		0.024		0.047		0.040		0.098**	
	[0.021]		[0.018]		[0.039]		[0.028]		[0.041]	
× Boy aged 6–9		−0.038		0.047*		0.046		0.059*		0.058
		[0.032]		[0.025]		[0.040]		[0.032]		[0.040]
× Boy aged 10–13		0.018		−0.009		0.027		0.021		0.086*
		[0.033]		[0.019]		[0.042]		[0.033]		[0.050]
× Boy aged 14–16		0.055		0.030		0.068		0.024		0.183**
		[0.068]		[0.028]		[0.054]		[0.045]		[0.088]
× Girl	−0.014		0.018		0.033		−0.029		0.015	
	[0.025]		[0.016]		[0.041]		[0.030]		[0.048]	
× Girl aged 6–9		−0.017		0.032		0.086*		0.081**		0.133**
		[0.038]		[0.021]		[0.044]		[0.033]		[0.065]
× Girl aged 10–13		−0.035		−0.012		−0.020		−0.070*		−0.073
		[0.030]		[0.022]		[0.054]		[0.037]		[0.066]
× Girl aged 14–16		0.019		0.048		0.052		−0.102		0.022
		[0.068]		[0.050]		[0.079]		[0.086]		[0.088]
Girl dummy	0.048**		0.047***		0.111**		0.147***		0.157***	
	[0.020]		[0.016]		[0.047]		[0.033]		[0.045]	
Girl aged 6–9		−0.012		0.036**		0.022		0.010		0.013
		[0.025]		[0.015]		[0.029]		[0.017]		[0.033]
Girl aged 10–13		0.063**		0.051*		0.135**		0.158***		0.210***
		[0.030]		[0.028]		[0.063]		[0.054]		[0.072]
Girl aged 14–16		0.113**		0.049		0.192**		0.310***		0.265***
		[0.047]		[0.031]		[0.072]		[0.065]		[0.066]
Observations	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373
R-squared	0.118	0.123	0.072	0.075	0.142	0.153	0.184	0.210	0.210	0.219

Note: Panel A reports the sample mean of dependent variables and Panel B reports only the coefficients of interest based on Equation (1), with engagement in household chores as the dependent variable. All estimations control for the covariates in Columns 5 and 6 of Table 5. *** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 5% level
Source: Estimated by authors from our original survey.

found no evidence that school grade (and school attendance) is associated with water accessibility for both boys and girls, our results show that with increased time spent on a water-fetching trip, boys repeat grades more but still tend to complete primary and lower-secondary education, while girls have a lower probability of completing primary education. In other words, when households have poor access to water, girls do not repeat grades; rather, they withdraw from school temporarily or permanently. Causal path analyses also indicated that these results are driven by increased participation in household duties by older boys and younger girls. Our findings offer supplemental evidence to the literature on the educational consequences of water accessibility. For instance, Koolwal and van de Walle (2013) found that household access to water is significantly associated with the primary school attendance of children aged 5–14 years when the dataset in 1995–96 was used, but that there is no association when the dataset from 2003–04 was used. This may be partly due to the substantial improvement in primary school enrolment observed during that period in Nepal. The findings of this study demonstrate the possibility that water-collecting activities still have a considerable adverse influence on child education in terms of school completion.

Thus, our findings indicate that providing water supply facilities in remote hilly and mountainous villages can increase household welfare not only by eliminating strenuous water-fetching activities, but also by improving children's educational attainment. This may also promote gender equality in education in these regions. Although the Nepali government has attempted to promote solar photovoltaic and micro-hydro water pumping systems, there are still thousands of remote villages with no electricity and water supply systems. To progress toward the SDGs and achieve the principle of 'Leaving No One Behind,' further actions need to be taken internationally as well as domestically.

Notes

1. An earlier version of this article is available as a discussion paper, see Dhital, Ito, Kaneko, Komatsu, & Yoshida (2018).
2. For example, Kremer, Leino, Miguel, and Zwane (2011) conducted a randomised evaluation of the health impact of a water quality intervention in Kenya. Devoto, Duflo, Dupas, Parienté, and Pons (2012) used a randomised experiment to study the impact of a private connection to the piped water system on several outcomes, including child schooling, in urban Morocco.
3. See also Merrick (1985) and Thomas and Strauss (1992) for child health, and Nauges and Strand (2017) for child education.
4. Using rural household data from the 1995 Nepal Living Standards Survey (NLSS), they found that a one-hour reduction in the time to the water source increases primary school enrolment rates by around 40 percentage points for both girls and boys. However, no significant impact was found using NLSS 2003 data.
5. See Lokshin and Yemtsov (2005), Galiani, Gertler, and Schargrodsky (2005), Mangyo (2008), Gamper-Rabindran, Khan, and Timmins (2010), and Zhang (2012).
6. This type of panel study implicitly assumes that the between-community heterogeneity is constant over time, or that changes in such heterogeneity over years are exogenous after controlling several variables they presume to be the key determinants of the changes. If the improvements are associated with (potential) demands for better child outcomes, as with other public policies in which the treatment status is often determined based on the present (or potential) status of the outcome, reverse causality may prevent the causal inference.
7. Another strand of literature employs the propensity score matching method. See, for instance, Jalan and Ravallion (2003) for piped water access. Additionally, almost all studies using micro (individual/household) data published before 2000 did not address both within-community and between-community heterogeneities.
8. For details of our village database and household survey, see Online Appendix I. The administrative units studied here are those that existed before the recent restructuring of the administrative divisions, which has been conducted according to the new constitution of Nepal in 2015. Note also that we obtained informed consent from all respondents before conducting the interview.
9. While the latter is significantly different from 0.5 at the 10% level, the former is statistically insignificant.
10. For missing values in these household-level variables, we impute any number and control dummies for missing values. Additionally, we do not control commuting time to lower-secondary school because about 50% of the sample have missing values (as implied in Table 4), while it is 20% for commuting time to primary school.

11. Specifically, we have 2,514 school-age children in 1,147 households, and among them, we excluded 189 children due to missing information on individual- (e.g. sex, relationship with household head, and educational attainment) and household-level variables (e.g. hours spent on water-collecting, latitude, longitude, and altitude).
12. Distance to the natural water source (measured in hours) here is demeaned from the community (ward) average.
13. We also conducted a balancing test using the normalised difference proposed by Imbens and Rubin (2015). The results show that the calculated normalized differences are considerably small for each household characteristic and their aggregate measure, indicating no systematic differences between households which live closer to and farther from the natural water source than the average household in the community. See Online Appendix II for more details.
14. Our survey data contain no information on distance to primary and lower-secondary schools, only commuting time. Thus, households that reported children's commuting time comprised only those households with children who have been to school; as a result, there were many missing values.
15. The survey questionnaire contained several questions about the primary and secondary drinking water sources, such as the type of source, means of carrying, time spent to and from the sources, main carriers, the number of trips, and number of water bottles carried at one time.
16. A typical issue is the reflection problem (Manski, 1993).
17. We also examine the impact of water accessibility on the current school attendance, but no significant impact is found for children aged 6–14 and those aged 14–16 (see Online Appendix IV).
18. Considering that grade repetition may occur differently at different levels of education, we conducted the grade repetition analysis separately by education level, namely, primary and lower-secondary level. The results (not reported here) show that the coefficient estimates for primary education are slightly larger than those for lower-secondary education, but the differences are not very large, and all estimates are statistically insignificant, implying that there is no systematic difference in grade repetition between primary and lower-secondary education in the study region.
19. The number of observations in these estimations is smaller than in the estimations in Columns 1 and 2 because neighbour data are unavailable for households with inaccurate/missing GPS information or no neighbours.
20. Again, the number of observations in Columns 3 to 6 is smaller because neighbour data are unavailable for some households due to wrong GPS information or lack of neighbours.
21. Additionally, some studies found a positive relationship between water *quality* and educational attainment. See, for instance, Asadullah and Chaudhury (2011) and Zhang and Xu (2016).
22. Another relevant causal pathway may be mental health (Zimmermann, 2016). However, our dataset does not contain related information, and, therefore, we cannot examine the impact on mental health.

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