Who benefits from piped water in the house? Empirical evidence from a gendered analysis in India

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May 3, 2021

Abstract

The disproportionate burden of water collection, maintenance and service on women in developing economies calls for a juxtaposition of water infrastructure and gender differences at the household level. We use spatiotemporal data from the largest gender disaggregated human development survey in India, 2005–2012, and carry out econometric analyses using individual fixed effects, conditionally exogenous village fixed effects and instrumental variable regressions to study the effect of indoor piped drinking water (IPDW) on employment and earnings by gender, self-reported health of women, prevalence of diarrhea and absence from school for children. Among others, results show that IPDW increases the likelihood of women's overall employment by 3.3 percentage points and women's wage salary employment by 3.9 percentage points, comparatively higher than men. Women's earning with IPDW increases by 9.9 percent, their health improves, child's health and education outcomes also improve. Our study recommends evaluating the willingness to pay (demand curve) for piped water supply, and/or the consideration of piped water supply as a right as part of a broader strategy to reduce gender differences.

Keywords: piped water, gender, employment, health, education, India

JEL Codes:

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1 Introduction

The significance of accessibility to water for personal and household use in everyday life is understood when one does not have access, and has to carry water from a distance [Klasen, 2019]. This unproductive burden is disproportionately placed on women and children in patriarchal societies of developing economies [O'Reilly, 2006], where the men (typically the household head) choose, or are socially conditioned for the responsibility of putting food on the table, while the women and children are responsible for home production, which involves fetching water, firewood, cleaning cooking, maintenance, etc. [Fletcher et al., 2017, Jayachandran, 2019]. India is one such nation, with one of the lowest average per capita access to clean drinking water [Jessoe, 2013], where on aggregate, 50% of the households still do not have access to water[1].

Adult women in India, on average, typically spend 1-2 hours every day in collecting and storing water [Ferrant et al., 2014, Ferrant and Thim, 2019].[2] Among others, the relationship between water and gender mirrors gender inequalities in various realms, including ownership and control over assets, employment, wages, household division of labor, exposure to and management of risk, access to services, and decision making, all of which are often intertwined with basic household infrastructures, such as access to indoor piped drinking water (IPDW) [Das, 2017, Fletcher et al., 2017, Ferrant et al., 2014, Koolwal and Van de Walle, 2013, Hulland et al., 2015].[3] These issues in context of gender differences, i.e., women's employment, socio-economic well-being, health and overall achievement of sustainable development goals (SDGs) are central to resource planning, not only in India, but in many low-income nations struggling to provide adequate and safe water supply to households.

The market failure in connecting households to IPDW is astounding in India given the recent progress in other infrastructures, such as electricity and toilets [Sedai et al., 2021, Zérah, 2000]. The time wasted in water collection has been argued to negatively affect women's employment, personal health, child health and education in developing economies [Ilahi and Grimard, 2000, UNICEF et al., 2016, Koolwal and Van de Walle, 2013, Vanaja, 2020]. The main argument for employment with piped drinking water is the labor time saved

[1]There is often no strong public pressure to improve service quality of water delivery in India. Customers in many cities do not expect their tap water to be potable and available for 24 h a day, while the middle class increasingly drinks bottled water instead [Schiffler et al., 2015]. Water supply in India, both in rural areas and in cities is only available for a few hours per day, pressure is irregular and the water is of questionable quality [McKenzie and Ray, 2009].

[2]Also observed in the India Human Development Survey panel, 2005-2012.

[3]Author elaboration from India Human Development Survey, 2005-2012. The raw sample shows that, on average, 51% of households reported having access to water within the house in 2005, and 53% reported the same in 2012. The health-related economic impacts of inadequate drinking water stood at Rs. 191 billion (US$4.2 billion) in 2006 [Bank, 2010].

from not having to fetch water on a daily basis. Among others, the lack of access to water in the household has also been associated with an increase in short term morbidities (fever, cough, diarrhea) and has been argued to dis-allow reallocation of domestic chores that allows children to attend school [Dehury and Mohanty, 2017, Koolwal and Van de Walle, 2013]. For instance, in India, a government report on child health cites that on average, every child under the age of 5 experiences 2–3 episodes of diarrhea yearly [Jessoe, 2013, GOI, 2014]. While, India has committed to increasing access to safe drinking water in accordance with the SDG 6, there has been a relative stagnancy, lack of public private partnerships and little consensus on how to actually achieve this goal [Galiani et al., 2005, Wu et al., 2016].[4] In addition, there is little understanding of how the realization of this goal could influence SDGs 5 and 10, gender equality and reduced inequality. Our study sheds light on how access to IPDW affects women's employment and earnings compared to men, and how it affects their health, child's health and educational outcomes.

The labor, health and education hypothesis related to IPDW are: do women with better access to basic infrastructure (IPDW in this instance) tend to participate more in market-based work, earn more and work more days? Are their children less likely to have short term morbidities (diarrhea) or miss school? There appears to be little rigorous empirical evidence to address these questions at the national level in developing economies, also there are some other questions left unanswered with the above arguments: to what extent is infrastructure per se a key binding constraint to women's labor force participation? Although Koolwal and Van de Walle [2013] examine the issue of women's labor force participation across developing economies with the proximity of the household to the water infrastructure, their study is cross-sectional in nature and does not fully capture the individual placement and household selection into places with water infrastructure.

Our study tests the above hypothesis using a nationally representative gender dis-aggregated panel of the India Human Development Survey (2005-2012). In addition to using the estimation strategy of Koolwal and Van de Walle [2013] to transform the individual level data set to village level data by incorporating exogenous village level characteristics, we use individual and village fixed effects to control for infrastructure placements and the recall bias [Pelz et al., 2021]. Fixed effects controls for all time-invariant unobserved heterogeneity both for the individual level analysis and the village level analysis. We also use the unique instrument of 'non-self community access to IPDW' as an instrument to capture any time variant unobserved heterogeneity, The first transformation allows us to interpret our point estimates as conditionally exogenous, the second and third transformation, we argue, provide

[4]As of 2010, 4,861 of the 5,161 cities/towns in India do not have even a partial sewerage network, and only 21% of the wastewater generated in the country is treated [Ahluwalia et al., 2011].

us the causal point estimates. These point estimates are then compared to the conditionally exogenous point estimates to arrive at a conservative estimates which we believe could be policy relevant.

The econometric analysis using individual fixed effects, village fixed effects and instrumental variable regressions for all outcomes suggest that the individual fixed effects shows the conservative lowest bound estimates. Having IPDW increases the likelihood of employment ($\geq$ 30 days in farm, business, wage, animal husbandry) by 1.7 percentage points (pp) for women and 1.3 pp for men in rural areas, while there are no significant effects in urban areas. For wage and salary employment, having IPDW increases women's employment by 2.9 pp, while there is no significant effect for men. After controlling for work hours, having IPDW increases women's annual earnings by 11.8 percent and men's earnings by 6.9 percentage in rural areas. In urban areas men register a significant increase in earnings of 4.9 percent, but women register no significant effects. Annual work days controlling for work hours increases by 5.7 days for women, while men's work days increases by 1.9 days in rural areas. The village fixed effects analysis and instrumental variable regressions confirm these effects. Overall, the effect of IPDW seems to be a rural phenomenon.

In terms of health, the self reported health of women significantly improves with IPDW, even with variations in ways of estimating the outcome of self-reported health. The likelihood of diarrhea after controlling for other sanitary and hygiene precautions that affect diarrhea shows that IPDW reduces diarrhea by 0.7 pp for poor households and by 0.8 pp in urban areas, no such effect is visible in rural areas. School absence for girls reduces by 0.58 days in rural areas and 0.88 days in urban areas, while for boys there is no significant effect in rural and urban areas.

Section II discuss the literature on water scarcity for households, available studies that highlight the effect of household water supply on women's employment, and studies that look at the effect of household water supply on women and child health and educational outcomes. Section III discusses a simple theoretical model to test our hypothesis. Section Iv discusses the data and the empirical methodology. Section V discusses the results and section VI concludes.

2 Literature Review

2.1 Water scarcity in India

According to the 2001 Census of India, the average share of households in a rural district that had access to tap water (inside and outside the residence) ranged from 3% in the eastern state of Orissa to 83% in the northern state of Himachal Pradesh. The numbers for tap water access within a residence were even worse: from 0% in Orissa to 27% in the western state of Maharashtra. Not only does access to government-provided water services vary widely across the country, no rural district in India had 100% access to tap water [Balasubramaniam et al., 2014]. As of 2015, while 87.9% of the urban households were found to have access to water for use in toilets, only 42.5% rural households had this facility [Banerjee et al., 2005]. India ranks as one of the poorest in household water access in the world. In 2001, the per capita annual surface water availability was 1902 m^3, which went down to 1614 m^3 in 2011 and is expected to reach 1154 m^3 in 2050 [Jain, 2011]. Adding to the scarcity, water inequality is pertinent in both urban and rural India owing to social–caste and religious differences, which are a major challenge to the water distribution system. Inequality and scarcity of water is expected to increase in the future due to the increasing depletion of ground water resources and the increasing demand pressure due to the rising urban population [Malakar et al., 2018].

Majority of India's population in rural area depend heavily on publicly provided water, as such, have to deal with economic hardship due to sustained water shortage. In addition to poverty and inequality, historically persistent social divisions are intricately linked to access to water in rural India [Banerjee et al., 2005].[5] In 2008, no major Indian city had 24 hour supply of water, with 4 to 5 hours of supply per day being the norm [McKenzie and Ray, 2009][6]. In comparison to Asia-Pacific region where the average of 19 hours per day supply, the reliability of water supply in India is dismal. Even the averages conceal a great deal of heterogeneity within and between rural and urban areas . In a survey of Delhi households with in-house connections, Zérah [2000] found that only 40% of households in Delhi had a 24-hour supply of water, while more than 25% had under 4 hours of service each day. The estimates from the IHDS, 2012 survey show that only 25% of the households had 24 h supply of indoor pipe drinking water with the average hours of water supply being 6 h a day.

In most of the urban India, water supply is only available for a few hours per day, pressure is irregular, and the water is of questionable quality [McKenzie and Ray, 2009]. The market failure in water supply imposes both financial (employment, assets, earnings, capital costs) and health costs (short and long term morbidities) on households [Ambrus et al., 2020, Blakeslee et al., 2020, Hill and Ma, 2017, Galiani et al., 2005]. The survey conducted by Zérah [2000] estimated that each household on average spent around 2,000 rupees (Rs) annually in coping with unreliable supply of water, which is 5.5 times as much

[5] To this extent, even pop up infrastructures for water supply, such as the Water ATMs have faced the issue of social division in access and distribution of drinking water [Schmidt, 2020].

[6] The argument is also valid up until 2012, where using the IHDS survey, we find that the average supply hours of indoor pipe drinking water is 3-4 h a day.

as they were paying their municipality for their annual water consumption.

In terms of water quality, a study by Hill and Ma [2017] in Pennsylvania found that a shale gas plant drilled within 1 kilometer of a community water system intake increases shale gas-related contaminants in drinking water. In comparison, it is hard to imagine such planned infrastructure placements in populous Indian cities where monitoring of water distribution and quality in Indian cities is haphazard [McKenzie and Ray, 2009]. McKenzie and Ray [2009] highlight some reports on water quality in India: (i) Ground water in most urban areas exceeded permissible limits in terms of fluoride, ammonia and hardness. Municipal water supply in some cities also contain high numbers of contaminants. A 2003 survey of 1,000 locations in Kolkata found that 87% of water reservoirs serving residential buildings and 63% of taps had high levels of fecal contamination. Even bottled water is not completely safe. A 2003 study (subsequently repeated in 2006) by the Centre for Science and Environment in Delhi found that most popular brands of bottled water had high levels of pesticides [McKenzie and Ray, 2009].

2.2 Water and Employment

Women in developing economies are argued to spending too much time in domestic labor tasks, and too little time in other productive tasks, including market-based labor activities [Ferrant et al., 2014, Fletcher et al., 2017]. Apart from the decreased economic autonomy and access to pooled income, the joint family system in India also lead to increase in domestic labour (cooking, cleaning, collecting water and fuel etc.) as number of household members increase. This is especially so for daughters-in-law or junior married women in India, both in rural and urban areas [Dhanaraj and Mahambare, 2019]. These issues have led to calls for better tailored infrastructure investments for women's needs, so as to reduce the time needed for domestic chores. One such infrastructure is provisioning access to piped water within the confines of the household [Dinkelman, 2011, Ilahi and Grimard, 2000]. Access to water itself has been a major policy headache with very little progress, despite tremendous improvements in other household infrastructures [Sedai et al., 2020].

Household constraints, such as the lack of access to water, electricity, clean cooking fuel and credit have limited women's economic opportunities and restricted their contributions to socio-economic decision making in the household, and elsewhere [Anderson and Baland, 2002, Anderson and Eswaran, 2009, Dinkelman, 2011, Rathi and Vermaak, 2018, Sedai et al., 2020, Aklin et al., 2016]. In developing economies, women appear to be mired in time-consuming domestic chores and child care activities, and possess relatively lower bargaining power in household and community level decisions as compared to men. Decision-making about basic infrastructure provisions—whether by household heads, village leaders, or higher-level authorities—undervalue women's time in domestic labor and thus, may place inadequate weight on the implications for women [Koolwal and Van de Walle, 2013].

It is widely observed that earned income through labor market participation and entrepreneurship by women could lead to desirable empowerment outcomes for women, and also developmental outcomes at the household and national level [Anderson and Eswaran, 2009]. Labor force participation enhances control over economic resources which could then translate into higher financial independence, socio-economic status and bargaining power in the household [Anderson and Eswaran, 2009]. Market work by women has also been associated with child welfare, especially for girls through more equitable investment of women's earnings on children in the household [Schultz, 2001].

2.3 Water, Health and Education

In much of the world, especially in developing economies, diseases from inadequate safe water supply such as diarrhea, fever, cough and respiratory problems are a major public health issue and constraint to development. The most widespread health hazards linked to water are diarrheal diseases, which disproportionately affect young children. Kumar and Vollmer [2013] in their study of India using the District Level Household Survey 3, 2008 find that the incidence of diarrhea for children living in a household with improved sanitation is 2.2 percentage points lower than that for children living in a household without improved sanitation.[7] Even if not fatal, diarrhea may have long-lasting consequences for human health and development hindering the economic and social potential of affected societies [Ziegelhöfer, 2012, Bartram et al., 2005]. The UNICEF [2012] report underscores the need to intensify global commitment and funding for the fight against childhood diarrhoea and argues that scaling up key interventions among the poorest children would save lives. Key preventive interventions include an improved water supply and the promotion of community-wide sanitation.

In the India context, where diarrhea is the most common among developing economies [WHO et al., 2009], it is important to examine the effect of indoor pipe drinking water on the likelihood of diarrheal disease among children under 5. Previous research by Jalan and Ravallion [2003] using propensity score matching technique to combine two cross-section surveys find that expanding piped water reduces the likelihood of diarrhea in India. They find that diarrheal disease prevalence amongst those with piped water would be 21% higher than without it, and illness duration would be 29% lower. However, they also argue that

[7] Nearly one in every five child deaths—around 1·5 million a year—is due to diarrhoea, which kills more children than AIDS, malaria, and measles combined [Wardlaw et al., 2010, Bartram et al., 2005].

indoor pipe water supply is not a sufficient condition to improve child health status; the source of ambiguity lies in the uncertainty about how access to piped water interacts with private health inputs, such as hygienic water storage, boiling water, oral re-hydration therapy, medical treatment, sanitation, nutrition, and also adult women's education and household income [Jalan and Ravallion, 2003]. Also, contamination of drinking water due to the share volume of production in cities could drive the level of diarrheal, typhoid, fever, cough and cholera diseases up. In this regards, when analyzing the effect of IPDW on diarrhea, we control for the hygiene behavior post access to piped water.

Malnutrition among children continues to be a critical limitation to human capabilities right from the early childhood. A report by Ministry of Women and Child Welfare GOI [2014], states that an estimated 39% of children between the ages of 0–5 years were stunted, 29% were underweight, while 62.5% of the adolescent girls aged 10–18 were severely or moderately thin. Li et al. [2018] analyzed the association between Household Water Treatment (HWT) and child's nutritional status using the India Human Development Survey and conducting a bivariate analysis found a negative association between the nutritional status of children and HWT. They use generalized simultaneous equation model and demonstrate that HWT increases the probability of producing normal-weighted primary-aged children by 1.7 %, while it decreases the probability of primary-aged children being thin by 2.5% and being severely thin by 1.7% in India.

3 Model

$$U_{hh} = [U(Y-W)+U(Y+w-D)+\delta(1+\alpha)D]^{\gamma} * [U(Y-W)+U(Y+W-D)+(1-\delta)D]^{1-\gamma} \quad (1)$$

Solution

$$\partial\gamma/\partial W = \theta(Y-W)^{-1+\theta}/1+\alpha\delta-2\delta \quad (2)$$

$$\partial^2\gamma/\partial W^2 = \theta(1+\theta)(Y-W)^{-\theta-2}/1+\alpha\delta-2\delta \quad (3)$$

4 Data

The data used for our analysis is derived from the second and third wave of the Indian Human Development Survey (2005-2012) [Desai and Vanneman, 2018]. IHDS are nation-wide multi topic gender-desegregated stratified random sample surveys jointly carried out by researchers from the University of Maryland and the National Council of Applied Economic Research

(NCAER) in New Delhi [Desai and Vanneman, 2018]. IHDS covers wide-ranging topics at the household, individual, village and school level on demographic, health, education and socio-economic characteristics. The survey covers key gender disaggregated labor and non-labor market characteristics, employment: wage salary, farm, non-farm employment, annual earnings, work days, self-reported health, incidence of illness, such as diarrhea, and water collection minutes, among others at the individual level which are of relevance in our analysis.[8]

The interviewers ask a knowledgeable person, typically the male head of household, questions related to the socioeconomic status of the household (members), including questions related to income, employment, consumption expenditure, physical and social capital. An ever married woman (eligible) between the ages of 15 and 49 in each household are interviewed about health, education, and gender relations, among others, in the household and community. Adolescents between the ages of 15 and 18 are interviewed about their education, employment and behavior, among others.

Our treatment variable 'access to indoor piped drinking water (IPDW)' is derived from the survey item, "Does your household have access to indoor pipe drinking water?" Yes is 1 and No is 0.[9] After dropping the observations for households without IPDW and individuals below the age of 14, we have a time balanced sample of 78,751 men and 71,623 women in each round of the IHDS survey.[10]

The sample for the analysis of the outcome variable are taken at the individual level questionnaire, the treatment variable is derived from the household level questionnaire, and the controls are from individual, household and village level questionnaire. For the robustness of the analysis (discussed in the empirical section), we conduct the analysis at the village level, where we have 1410 villages covered in both rounds of the survey. However, due to missing observations for some variables, we are restricted to 1,386 villages for the rural village level analysis. It is important to note that the comparison of outcomes between men and

[8]Unlike the National Sample Surveys that asks for a woman's principal and secondary status activities, the IHDS has separate modules for different types of work (e.g., own farm and non-farm work, wage and salary labor, animal husbandry) and asks which household members participated in each type of work during the previous year. In this study, following Chatterjee et al. [2018], anyone who worked for at least 240 hours in the previous year across all types of work is considered to be in the labor force.

[9]In addition to IHDS data, we also use the ACCESS survey (2015-2018) to examine the recent trends in IPDW in six states (Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, West Bengal and Orissa). The analysis of descriptive statistics from the ACCESS survey provides inferences of the present state of IPDW in relatively poor and populous states in India [Mani et al., 2018, Sedai et al., 2020]. Note: due to the lack of gender disaggregated data in the ACCESS survey, our regression analysis focuses on the variables in the IHDS survey.

[10]Note: in the analysis, we might not have the the same number of observations in the fixed effects regression. In this regard, the balancedness of the sample is by observations at the beginning of the analysis, by not by each outcome variable.

women is not necessarily for the same household. The inferences drawn and compared are not for couples, or adults in the same household, but for the overall sample.

5 Empirical Model

Why do only some households have IPDW while others do not. It might be the case that households with IPDW are also more forward-looking and possess better socio-economic capital, health, knowledge, habits and behavior [Kumar and Vollmer, 2013, Balasubramaniam et al., 2014]. There are both time variant and invariant unobserved heterogeneity that affect selection into or out of IPDW. Given the likelihood of strong endogeneity of access to IPDW (one of the most basic good for survival), one should clearly not expect to be able to infer the causal impact with confidence [Koolwal and Van de Walle, 2013, Ravallion, 2008].[11] At least, with the panel structure of the IHDS data, the time-invariant unobserved heterogeneity affecting the treatment is controlled for. The baseline individual fixed effects model derived from the IHDS is as follows:

$$Y_{it} = \pi Z_{it} + \phi X_{it} + \delta_i + \sigma_t + \epsilon_{it} \tag{4}$$

Y_{it} is the outcome variable for household i at time t and Z_{it} is an indicator for access to indoor IPDW. The reference households are those that do not have access to indoor pipe drinking water, and the treatment is switching from no access to IPDW to access between 2005-2012. X_{it} are a vector of exogenous individual and household characteristics. δ_j captures the household specific effects. σ_t captures the trend effect. The aim is to estimate the impact of Z_{it} on Y_{it}. However, the problem is that the observed variation in Z_{it} reflects latent factors that also influence Y_{it}.

The fixed effects controls for all time invariant unobserved heterogeneity that could be correlated with the treatment, such as household head's caste, location, religion and cultural characteristics which are time invariant. Even after doing so, there is a strong likelihood that the household-specific differences in treatment, Z_{it} are endogenous to outcomes due to the time varying unobserved heterogeneity. Therefore, despite using the household fixed effects, household selection to IPDW due to time varying unobserved heterogeneity cannot be ignored. Within a given locality, some households will have latent preferences, knowledge, or unobserved resources that lead them to have better access to infrastructure than other

[11] A randomized control trail would not be a feasible option given that our aim is to observe the macro-level effects of the intervention of IPDW. Also, Ravallion [2008] argue that is rarely feasible to randomize the location of infrastructure projects and related programs, which are core activities in almost any poor country's development strategy

(observationally similar) households [Koolwal and Van de Walle, 2013]. The issue of self-selection is concerning when talking about access to basic infrastructure, such as access to safe drinking water. Any natural or policy shock not covered in the IHDS survey could be affecting access to water. The wave dummy σ_t does capture any trend changes, but household specific time variant heterogeneity could bias the casual estimates.

The standard solution to this problem is to find an instrumental variable (IV) that is correlated with Z_{it} but uncorrelated with outcomes given Z_{it}.[12] An IV for presumably high degree of selection is a demanding requirement, as one can reasonably question whether any observed household characteristic that might influence access to household-specific infrastructure would not also be a relevant determinant of overall outcomes, independently of infrastructure [Koolwal and Van de Walle, 2013, Ravallion, 2008, Kumar and Vollmer, 2013].[13] Also, the discussion on exclusion restrictions used with the geographic instrumental variables are questionable, given the feedback and spill-over effects of an intervention.

Koolwal and Van de Walle [2013] argue that geographic averaging with comprehensive regression controls at the community level for infrastructure placements is a defensible approach. Therefore, following Koolwal and Van de Walle [2013] we address the issue of endogeneity by exploiting the geographic differences in infrastructure placements and outcomes, while in addition controlling for any community specific effects overtime. This requires that we have adequately captured the relevant geographic characteristics jointly influencing outcomes and infrastructure through the vector G_{jt} and any geographic means of X_{it} not included in G_{jt}. The addition of community specific effects and time trends presents an additional layer of robustness to the point estimates compared to Koolwal and Van de Walle [2013], as they use cross-sectional data for analysis. This modification to the analysis in equation 4 is given below:

$$Y_{it} = \pi Z_{it} + \phi X_{it} + \lambda G_{jt} + \delta_i + \sigma_t + \theta_{jt} + \epsilon_{ijt} \tag{5}$$

Here, we have added the exogenous community characteristics G_{jt} that affect the IPDW placement, which also includes community means of X_{it}.[14] In equation 5, the error term

[12] We do use a unique instrumental variable from the literature (see Bai et al. [2019], Sedai et al. [2021], Dang and La [2019]), one also used in the same context as ours by Vanaja [2020]. The instrument captures average access to IPDW at the community level (village and PSU level), excluding the community of the household in the district of the state at time t (in short, it is the non-self community access to IPDW).

[13] Ravallion [2008] argues that evaluations for development effectiveness focus too much on internal validity (whether valid inferences are drawn about the impact of that specific project in its specific setting) relative to external validity (whether valid inferences are drawn for other projects, either as scaled up versions of that project in the same setting or as similar projects in different settings).

[14] Note, in the absence of G_{jt} and θ_{jt}, the regression specification in equation 5 is similar to that of equation 4.

has two components, a geographic effect θ_{jt} and an idiosyncratic (household-specific) effect ϵ_{ijt}. The geographic component of the error term sweeps up all level differences in the error term between areas, so that the geographic mean of ϵ_{ijt} vanishes [Koolwal and Van de Walle, 2013].[15] All regressors are exogenous except Z_{it}, which is correlated with ϵ_{ijt}through individual choices, that is, $Cov(Z_{it}; \epsilon_{ijt}/G_{jt}; X_{it}) \neq 0$. Following Koolwal and Van de Walle [2013], we argue that the key identifying assumption is that the endogeneity arises entirely from individual choices within areas, such that on aggregating across individuals within a given area we can treat access to water as conditionally exogenous; that is, we assume that $Cov(\bar{Z}_{jt}; \epsilon_{jt}/\bar{G}_{jt}; \bar{X}_{it}) = 0$ where the bar over a variable denotes its geographic or community-level mean.

We then aggregate equation 5 over geographic areas, giving the standard "between estimator" overtime, as below:

$$\bar{Y}_{jt} = \pi \bar{Z}_{jt} + \phi \bar{X}_{jt} + \lambda \bar{G}_{jt} + \theta_{jt} \tag{6}$$

While household fixed effects applied to equation 4 could still yield a biased and inconsistent estimate given that $Cov(Z_{it}; \epsilon_{ijt}/G_{jt}; X_{it}) \neq 0$, equation 6 shows that π can be identified by geographic aggregation under our weaker assumption that only the geographic placement is conditionally exogenous. In this regard, we assume that we have sufficient geographic controls to make it plausible that the latent geographic effects on outcomes and placement can be treated as uncorrelated. To do so, we use most of the plausibly exogenous geographic controls used by Koolwal and Van de Walle [2013] barring a few as in addition to their model, we also have the leverage of controlling for the time invariant unobserved heterogeneity through the village fixed effects, and the time trend. Note, however, that we still allow for endogenous individual placement within areas between 2005-2012, whereby there are latent idiosyncratic factors that jointly influence outcomes and individual access to IPDW.

The acceptance of the assumption of conditional exogeneity depends on the available data and the setting. The fixed effect model controls for geographic mobility both at the individual level and within the rural areas. Therefore, the residential location choice that could seriously undermine our identifying assumption is controlled for in our analysis. One could collect geographic data relevant to both outcomes and infrastructure placement, but it is justified to be skeptical of any claim that one could collect data on latent preference and knowledge parameters at the individual level. In this regard, the ability of our estimation strategy to deal with endogenous placement across individuals within a given area is desirable. Following

[15] The remaining ϵ_i cancels out with δ_i.

Koolwal and Van de Walle [2013], we control for a wide and rich array of location attributes. However, the possibility of biases due to unobserved geographic factors can never be totally dismissed.

No withstanding the issues with instruments, as a robustness check to our empirical estimations, following [Vanaja, 2020] we do use the instrument of non-self community level access to IPDW as an instrument. The instrument has been widely used in the literature to capture the unobserved heterogeneity in infrastructure placements such as electricity and water supply by Sedai et al. [2020], Sedai et al. [2021], Vanaja [2020], Dang and La [2019]. The first stage estimation is given as:

$$IPDW_{it} = \rho IPDW_{-jt} + \phi X_{it} + \delta_i + \sigma_t + \epsilon_{it} \quad (7)$$

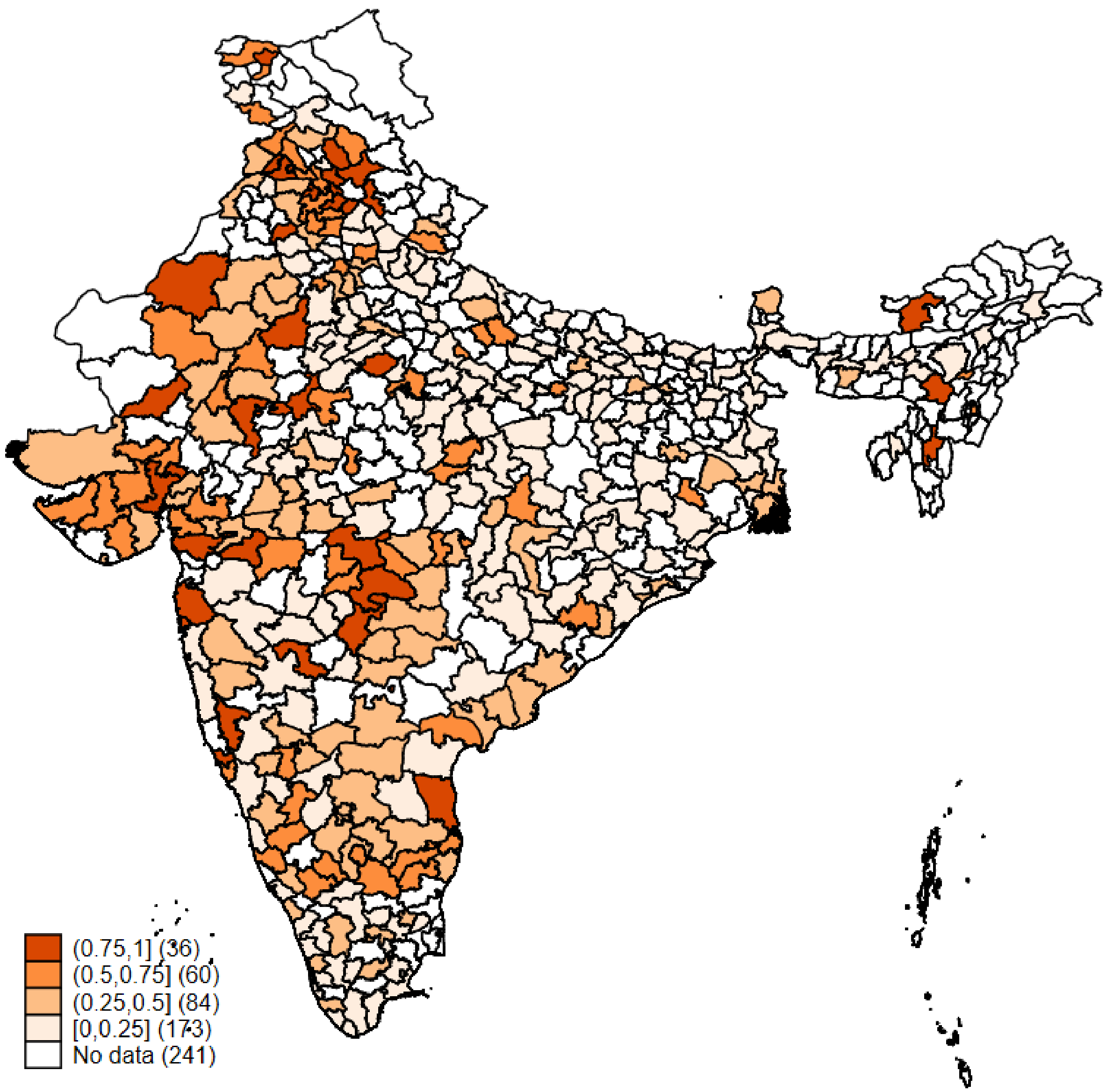
Where, $\rho IPDW_{-jt}$ represents the non-self community level access to IPDW. It gives the average level of village/PSU level access to IPDW in the district of a state, excluding the village/PSU of the treatment household.

The rationale behind the IV is such that if neighboring villages/PSU acquire IPDW and realize the economic and social gains of better safe drinking water, then the status of no IPDW may signal lower socioeconomic standing, therefore IPDW in the neighboring districts is expected to increase one's own IPDW [Sedai et al., 2021, Vanaja, 2020]. We argue that the exogeneity condition for the instrument also holds because IPDW in other communities should not directly affect labor market differences across genders in one's own community. Following the existing literature, we argue that gender differences in the labor market are affected by household's income, relative bargaining power of the individuals, education, age and occupational segregation [Fletcher et al., 2017, Klasen, 2019, Duflo, 2012]. As discussed in the potential threats to identification, we do anticipate that household's own community level IPDW and the availability of other infrastructures will have an impact on individual LFP, hence excluding one's home district from the instrument is key to the exclusion restriction. For the instrument to function, villages/PSUs should be distant from each other, this implies the instrument would be weak in satisfying the exclusion restriction. Therefore, we restrict the panel fixed effects instrumental variable regression to rural areas.

6 Results

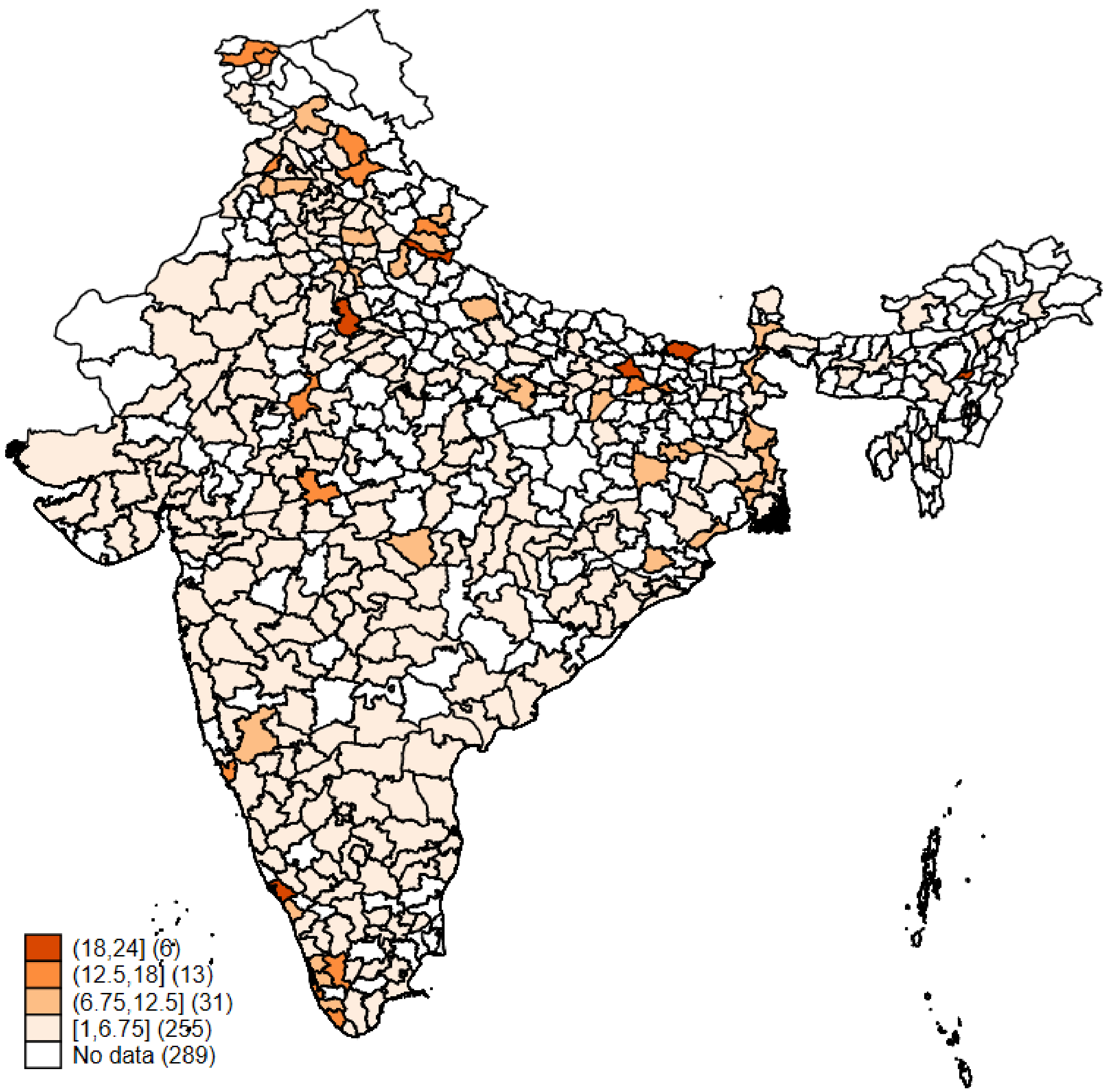
7 Figures and Tables

Figure 1: Access to Indoor Pipe Drinking Water, India, District Level, Label: Fraction of access (0-1), IHDS (2012).



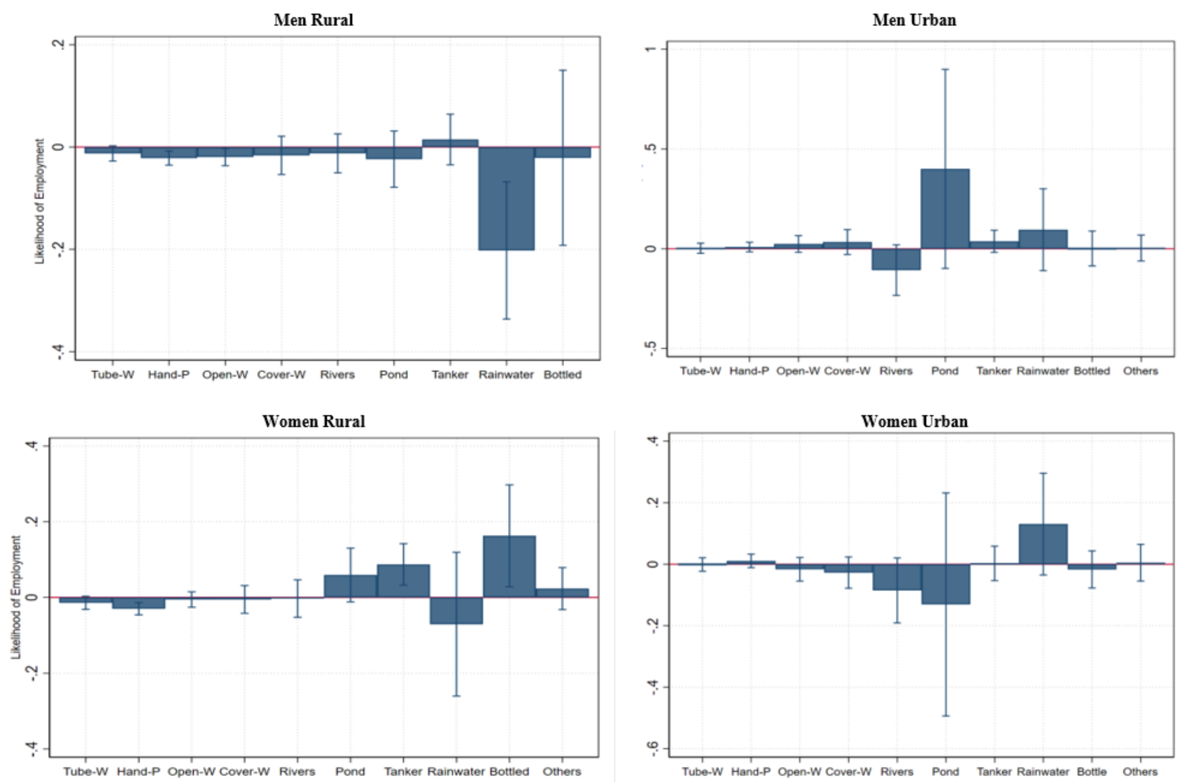
Source: Authors calculations, IHDS, 2012.

Figure 2: Hours of Indoor Pipe Drinking Water on a typical day, India, District Level, Label: Cumulative hours (0-24), IHDS (2012).



Source: Authors calculations, IHDS, 2012.

Figure 3: Panel fixed effects: Source of Water and Employment by Gender and Location.



Source: Authors calculations, IHDS, 2005-2012.

Table 1: Panel Descriptive Statistics from two household surveys India, 2005-2018

	2005			2012			
National level Variables	Obs	Mean	SD	Obs	Mean	SD	T test
Indoor Piped Drinking Water (0/1)	40,018	0.266	0.442	40,018	0.302	0.459	*
		2015			2018		
Six States of ACCESS Indoor Piped Drinking Water (0/1)	8563	0.057	0.232	8563	0.066	0.248	-

Author elaboration, IHDS, 2005-2012, ACCESS survey, 2015-2018. ACCESS survey is for the rural areas in the six relatively poorer states in India namely: Madhya Pradesh, Uttar Pradesh, Odisha, Bihar, Jharkhand, West Bengal. Note, we check for six states average of the ACCESS survey in the IHDS survey for consistency and the averages between 2005-2012 are similar to averages between 2015-2018.

Table 2: Descriptive statistics by treatment and time: Access to Indoor Piped Drinking Water (IDPW), India, 2005-2012

	2005				2012			
	No IDPW		IDPW		No IDPW		IDPW	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Water								
Water in house	0.33	0.47	1.00	0.00	0.32	0.47	1.00	0.00
Water supply hours	4.23	6.14	4.92	6.38	3.88	5.35	4.18	5.78
Walk time water	10.35	10.57	0.00	0.00	10.43	12.30	0.00	0.00
Women Minutes	73.89	70.33	67.69	73.99	50.22	46.83	50.38	49.23
Men Minutes	35.89	53.88	50.14	59.33	29.74	35.90	49.93	43.52
Work								
Employment (>30 days)	0.40	0.49	0.36	0.48	0.47	0.50	0.44	0.50
Non-ag labor (>30 days)	0.08	0.27	0.05	0.21	0.14	0.34	0.09	0.28
Annual work days	201.93	98.66	243.82	95.62	200.47	110.97	242.11	105.83
Any individual business	0.21	0.40	0.30	0.46	0.21	0.41	0.29	0.45
Health & Education								
Self-reported health (0-5)	2.26	0.81	2.18	0.76	2.19	0.87	2.02	0.84
Days ill in last month	0.97	3.36	0.64	2.62	1.18	3.58	0.80	2.81
Diarrhea in last month	0.03	0.17	0.01	0.12	0.02	0.15	0.02	0.13
Days absent, school (30 days)	3.38	5.79	1.81	3.96	3.95	5.26	2.94	5.04
Observations	109700		40676		103969		46340	

Author elaboration, IHDS, 2005-2012

Table 3: Panel Fixed Effects: Indoor Pipe Drinking Water and Women's Daily Water Collection Time in Minutes, IHDS, 2005-2012

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	All	All	Rural	Urban	Non-Poor	Poor
Indoor Pipe Drinking Water	-7.416***	-3.954*	-5.922**	5.918	-1.277	-20.187***
	(2.345)	(2.412)	(2.777)	(5.005)	(2.622)	(6.250)
HH, Ind., Com. Controls	N	Y	Y	Y	Y	Y
Observations	105,278	98,203	79,497	18,706	74,590	23,482
Number of Individuals	71,638	68,346	54,412	14,178	52,877	15,362

Robust standard errors (clustered at the individual level) in parentheses, p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Coefficients are interpreted as percentage point changes Panel(a) shows the effect of access to indoor pipe drinking water on water collection minutes. Additional independent variables in all regressions: availability of electricity in house, any public program for sanitary toilets, individual's age, age squared, marital status, education, household size, Log per capita consumption, wave dummy, social networks with teachers, educators, health practitioners, lawyers, government official, local political leaders.

Table 4: Panel fixed effects: Household's access to indoor pipe drinking water on any employment (wage salary farm business) (≥ 30 days) and only wage and salary employment by gender in rural and urban India, 2005-2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	All	Men	Women	Men Rural	Men Urban	Women Rural	Women Urban
Panel (a): Individual FE							
Any Employment (>30 days)							
Indoor Pipe Water	0.004	0.003	0.005	0.013**	-0.013	0.017**	-0.010
	(0.004)	(0.005)	(0.005)	(0.006)	(0.008)	(0.008)	(0.007)
Wage/Salary Employment							
Indoor Pipe Water	0.008**	0.002	0.015***	0.008	-0.016	0.029***	-0.008
	(0.003)	(0.005)	(0.005)	(0.007)	(0.008)	(0.006)	(0.006)
Ind. and HH. Controls	Y	Y	Y	Y	Y	Y	Y
Observations	209,860	111,061	98,799	74,901	36,160	67,534	31,265
Number of individuals	119,054	62,863	56,193	43,033	20,982	38,626	18,054
Panel (b) Village FE (Rural)							
Any Employment (>30 days)							
Indoor Pipe Water	0.045***	0.047***	0.033*				
	(0.014)	(0.014)	(0.019)				
Wage/Salary Employment							
Indoor Pipe Water	0.025	0.010	0.039**				
	(0.016)	(0.017)	(0.018)				
Village Fixed Effects	Y	Y	Y				
Village controls	Y	Y	Y				
Observations	2,510	2,509	2,507				
Number of PSUs	1,386	1,385	1,383				

Robust standard errors (clustered at the individual level) in parentheses, p-values—$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. β reports the percentage point effect of access to piped drinking water within the house on any paid employment for over 30 days in a year. For panel (a): additional independent variables in all regressions: Household electricity access, any public program for sanitary toilets, household size, any social networks or acquaintance with doctors and health care workers, teachers, school workers, politicians, police, military, government officials. Individual's age, age squared, marital status, adult male and female education. For panel (b) (rural areas), all controls in panel (a) are used (excluding electricity access and marital status). In addition, we control for the presence of local governance body (Panchayat Bhavan) in the village, percentage of household with electricity in the village, agricultural co-operative in the village, government and private school in the village, distance to bank in kilometers and presence of informal credit associations in the village, paved road in the village, distance to bus station in kilometers in the village, sowing and harvesting market wage for Rabi and Kharif seasons for men and women in the village, and presence of market (bazaar) in the village.

Table 5: Panel fixed effects: Household's access to indoor pipe drinking water on log of real annual earnings, by gender in rural and urban India, 2005-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	All	Men	Women	Men Rural	Men Urban	Women Rural	Women Urban
Panel (a) Individual FE							
Indoor Pipe Water	0.075***	0.066***	0.099***	0.069***	0.049***	0.118***	-0.036
	(0.013)	(0.013)	(0.030)	(0.018)	(0.018)	(0.034)	(0.058)
Log Annual Work Hours	0.713***	0.740***	0.660***	0.750***	0.688***	0.659***	0.657***
	(0.008)	(0.009)	(0.013)	(0.010)	(0.024)	(0.014)	(0.049)
Observations	124,836	85,244	39,592	59,827	25,417	33,622	5,970
Number of individuals	80,957	52,744	28,215	37,184	16,312	23,506	4,752
Panel (b) Village FE							
Indoor Pipe Water	0.197***	0.180**	0.234*				
	(0.074)	(0.078)	(0.129)				
Log Annual Work Hours	0.451***	0.529***	0.556***				
	(0.054)	(0.063)	(0.069)				
Observations	2,507	2,505	2,432				
Number of villages	1,386	1,385	1,364				

Robust standard errors (clustered at the individual level) in parentheses, p-values—$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. β reports the percent effect of access to piped drinking water within the house on log of real annual individual earnings. All additional controls are as discussed in table 4

Table 6: Panel fixed effects: Household's access to indoor pipe drinking water on annual work days, by gender in rural and urban India, 2005-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	All	Men	Women	Men Rural	Men Urban	Women Rural	Women Urban
Panel (a) Individual FE							
Indoor Pipe Water	1.958***	0.752	5.475***	1.990**	-1.892	5.773***	-0.129
	(0.682)	(0.774)	(1.339)	(0.986)	(1.196)	(1.400)	(3.899)
Annual Work Hours	0.084***	0.079***	0.103***	0.084***	0.062***	0.106***	0.077***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.002)
Observations	129,410	87,415	41,995	61,795	25,620	35,877	6,118
R-squared	0.660	0.659	0.693	0.687	0.579	0.710	0.589
Number of individuals	82,752	53,427	29,327	37,798	16,397	24,530	4,844
Panel (b) Village FE (Rural)							
Indoor Pipe Water	10.177***	7.830**	9.288**				
	(3.052)	(3.151)	(4.385)				
Annual Work Hours	0.090***	0.084***	0.104***				
	(0.002)	(0.002)	(0.002)				
Observations	2,510	2,508	2,450				
Number of Villages	1,386	1,385	1,367				

Robust standard errors (clustered at the individual level) in parentheses, p-values—$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. All additional controls are as discussed in table 4

Table 7: Panel fixed effects: Household's access to indoor pipe drinking water and women's self-reported health, 2005-2012.

	(1)	(2)	(3)	(4)	(5)
Variables	All	Rural	Urban	Poor	Non-poor
Panel (a) Individual FE					
Good & V. Good=1, OK, Poor & V. Poor==0					
Indoor Pipe Water	0.0294**	0.0316**	0.0352*	0.0686*	0.0241*
	(0.0122)	(0.0154)	(0.0200)	(0.0379)	(0.0128)
Good, V. Good & OK=1, Poor & V. Poor==0					
Indoor Pipe Water	0.00974	0.0163*	0.000689	0.00115	0.0102
	(0.00662)	(0.00840)	(0.0110)	(0.0198)	(0.00704)
Observations	47,225	32,527	14,698	7,819	39,402
Number of Individuals	24,909	17,196	7,713	4,133	20,772
	All	Poor	Non-Poor		
Panel (b) Village FE					
Good & V. Good=1, OK, Poor & V. Poor==0					
Indoor Pipe Water	0.107	0.041	0.105*		
	(0.069)	(0.102)	(0.068)		
Good, V. Good & OK=1, Poor & V. Poor==0					
Indoor Pipe Water	0.041*	0.056	0.044*		
	(0.025)	(0.059)	(0.027)		
Observations	2,500	1,519	2,450		
Number of Village	1,378	889	1,356		

Robust standard errors (clustered at the individual level) in parentheses, p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. β reports the percentage point effect of access to piped drinking water within the house on any paid employment for over 30 days in a year. For panel (a): additional independent variables in all regressions: availability of water source within the house premise, household electricity access, any public program for sanitary toilets, individual's age, marital status, education, household size, any social networks or acquaintance with doctors and health care workers, teachers, school workers, politicians, police, military, government officials. For panel (c) (rural areas), all controls in panel (a) are used and in addition we control for the presence of local governance body (Panchayat Bhavan) in the village, percentage of household with electricity in the village, agricultural co-operative in the village, government and private school in the village, distance to bank in kilometers and presence of informal credit associations in the village, paved road in the village, distance to bus station in kilometers in the village, sowing and harvesting market wage for Rabi and Kharif seasons for men and women in the village, and presence of market (bazaar) in the village.

Table 8: Indoor Pipe Drinking Water and likelihood of Diarrhea, India, 2005-2012

	(1)	(2)	(3)	(4)	(5)
Variables	All	Rural	Urban	Poor	Non-Poor
Indoor pipe drinking water	-0.002**	0.001	-0.008***	-0.007**	-0.002
	(0.001)	(0.001)	(0.002)	(0.003)	(0.001)
Store drinking water with lid	-0.004***	-0.004**	-0.004*	-0.007**	-0.003*
	(0.001)	(0.002)	(0.003)	(0.003)	(0.002)
Wave Dummy	-0.007***	-0.009***	-0.004*	-0.016***	-0.004**
	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
HH & Individual controls	Y	Y	Y	Y	Y
Observations	251,288	171,960	79,328	47,197	204,048
Number of individuals	139,496	96,768	44,732	26,151	113,302

Robust standard errors (clustered at the individual level) in parentheses, p-values—$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Additional independent variables in all regressions: log of per capita consumption, electricity access, any public program for sanitation (latrines/toilets), adult male education, adult female education, household size, age of the respondent, networks with doctors, hospitals and health care workers, teachers, educators, government officials and local politicians.

Table 9: Panel fixed effects: Effect of IPDW on absence from school in the past month, India, 2005-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	All	Boys	Girls	Rural Boys	Urban Boys	Rural Girls	Urban Girls
Indoor Pipe Drinking Water	-0.437**	-0.272	-0.640***	-0.212	-0.453	-0.568*	-0.882**
	(0.174)	(0.243)	(0.246)	(0.323)	(0.379)	(0.312)	(0.417)
Wave Dummy	1.389***	0.827*	2.061***	0.739	0.787	1.369**	2.661**
	(0.355)	(0.470)	(0.547)	(0.575)	(0.888)	(0.632)	(1.036)
Observations	54,446	30,305	24,141	20,738	9,567	16,358	7,783
Number of Individuals	42,421	23,732	18,690	16,471	7,424	12,883	5,956

Robust standard errors (clustered at the individual level) in parentheses, p-values—$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Additional independent variables in all regressions: water stored with lid, log of per capita consumption, electricity access, any public program for sanitation (latrines/toilets), adult male education, adult female education, household size, age of the respondent, networks with doctors, hospitals and health care workers, teachers, educators, government officials and local politicians.

Table 10: Panel instrumental variable regression: Effect of IPDW on employment in rural India, 2005-2012

	(1)	(2)	(3)	(4)	(5)
Variables	All	Poor	Non-Poor	Men	Women
Treatment: IPDW in rural areas					
Any employment (>30 days)	0.079***	0.086***	0.069***	0.062***	0.090***
	(0.020)	(0.048)	(0.023)	(0.025)	(0.033)
Wage and Salary employment	0.068***	0.058**	0.062***	0.048***	0.073***
	(0.020)	(0.049)	(0.022)	(0.028)	(0.029)
F test (instrument)	1,966	473	1,429	1,088	908
Observations	140,197	27,703	112,470	73,705	66,492
Number of individuals	80,373	15,826	64,523	42,336	38,037

Robust standard errors (clustered at the individual level) in parentheses, p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Additional independent variables in all regressions: age, age squared, marital status, individual's education, household size, log of per-capita household consumption, electricity access, public program for sanitation, networks with doctors, hospitals and health care workers, politicians, educators, government officials. The instrument used is the average non-self community level access to IPDW in rural areas. Sanderson-Windmeijer multivariate F test of excluded instruments show that the instrument is strong [Staiger and James, 1997].

Table 11: Access to piped drinking water, water within house and water supply hours by asset quintiles: percentage by relative asset levels, 2005-2012.

	Poor	Lower Middle	Middle	Upper Middle	Richest
	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)
2005					
Indoor Pipe Drinking Water	0.02	0.06	0.19	0.38	0.62
	(0.13)	(0.25)	(0.39)	(0.49)	(0.49)
Water within house	0.19	0.28	0.42	0.65	0.88
	(0.39)	(0.45)	(0.49)	(0.48)	(0.32)
Water Supply Hours	3.26	3.97	4.33	4.62	5.09
	(5.05)	(5.94)	(6.25)	(6.24)	(6.34)
2012					
Indoor Pipe Drinking Water	0.04	0.13	0.26	0.44	0.62
	(0.20)	(0.34)	(0.44)	(0.50)	(0.49)
Water within house	0.21	0.33	0.47	0.67	0.88
	(0.41)	(0.47)	(0.50)	(0.47)	(0.32)
Water Supply Hours	3.48	3.91	3.77	4.00	4.33
	(5.02)	(5.66)	(5.45)	(5.52)	(5.80)
Observations	7723	6801	9639	7888	7780

Source: author elaboration, IHDS, 2005-2012

Table 12: Panel Fixed Effects: Indoor Pipe Drinking Water and Women's Daily Water Collection Time in Minutes by Region, IHDS, 2005-2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Hills	North	North Central	Central Plains	East	West	South
Indoor pipe water	17.571	-9.376	-13.98*	-10.98**	-5.844**	-21.50***	2.021
	(3.789)	(39.01)	(7.178)	(5.227)	(2.473)	(6.486)	(4.008)
Observations	6,665	4,343	17,519	24,836	16,713	12,680	22,931
Number of individuals	4,958	3,697	12,439	17,100	11,991	9,522	17,166

Robust standard errors (clustered at the individual level) in parentheses, p-values—*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. β reports effect of access to piped drinking water in minutes. Additional independent variables in all regressions is the individual's marital status. States according to regions– Hills: Jammu Kashmir, Himachal Pradesh, Uttarakhand, North:Punjab, Haryana, Chandigarh, Delhi, North Central: Uttar Pradesh, Bihar, Jharkhand, Central Plains:Rajasthan, Chattisgarh, Madhya Pradesh, East: Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram,Tripura, Meghalaya, Assam, West Bengal, Odisha, West: Gujarat, Daman and Diu, Dadra and Nagar Haveli,Maharashtra, Goa, South: Andhra Pradesh, Karnataka, Kerela, Tamil Nadu, Pondicherry. Note some of the states mentioned are Union Territories, the classification is following IHDS (2005-2012).

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