Public WASH Programs, Child Development, and Intergenerational Mobility in Rural China

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Abstract

Using individual-level longitudinal data from 1989 to 2015, we examine the long-run effects of nationwide water plant construction and household-level toilet subsidy programs in rural China on children's education and health. We exploit the differential timing of these programs across rural villages and use a dynamic Difference-in-Differences strategy to estimate their long-run effects. We find that each program independently increased years of schooling up to 20 years after its implementation. Effects on education are larger for toilet subsidy programs than for water improvement programs. On average, toilet (water) improvement increases 0.469 (0.341) years of schooling and the effects are larger for girls than for boys. We find evidence of positive complementarities between the two programs: their simultaneous introduction increased years of schooling by 0.739 years. Investigating underlying mechanisms, we find that toilet programs allowed adults to reallocate their time from farms and to increase working hours. This affected children's time use by crowding out child work. Water programs had limited labour reallocation effects, but improved child health. We then investigate how both programs affected intergenerational education persistence. The toilet program significantly reduced maternal-child education persistence, while improving the upward education mobility of exposed children. Our findings suggest that improving household sanitation has larger educational benefits than expanding access to safe drinking water and that public WASH programs can be effective at reducing intergenerational inequality in socioeconomic outcomes.

Keywords— Sanitation; Water and Toilet Improvements; Health and Human Capital; Child Development; Education; Intergenerational Mobility; Inequality; Rural China

JEL codes— I18; I24; J24; J13

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1 Introduction

In 2020, just over half of the global population, and only 18% of those in low-income countries, had access to safely managed sanitation (United NationsUnited Nations 2023). This was despite recent Water, Sanitation, and Hygiene (WASH) campaigns by national governments, including the Swachh Bharat Mission in India, Community-Based Total Sanitation plans in Indonesia, and the Toilet Revolution in China. Prior research has demonstrated that some of these campaigns contributed to a decline in child mortality rates, as well as improvements in childhood health outcomes (e.g., Augsburg and Rodríguez-Lesmes 2018; Alsan and Goldin 2019; Chen et al. 2022).

A few policy-relevant gaps in the understanding of effects of improved WASH access may hinder further progress. First, limited by the scale and duration of their implementation, most studies were only able to investigate the short- and medium-run effects of these programs on child health and educational attainment. There are good reasons to believe that their long-run impacts on child outcomes may differ completely, given concerns about rigidities in sanitation behaviors (e.g: Augsburg et al. 2022). Failing to account for long-term effects may lead policy makers to underestimate net gains from WASH investments, hence undermining incentives and political willingness (Leong and Howlett 2017). More importantly, there is little empirical evidence on whether such WASH programs can not only improve children's health and educational outcomes on average, but can also break the link between parental socioeconomic status (SES) and child development. This is theoretically ambiguous: on the one hand, public provision of better WASH services may disproportionately benefit those with lower SES status, given a socioeconomic gradient in private willingness to pay for sanitation; on the other hand, positive externalities from such provisions could benefit all within a given community.[1] Yet, a better understanding of how WASH programs affect intergenerational SES persistence is crucial to inform policymakers of their relative merits to reduce intergenerational inequality in lifetime socioeconomic outcomes. Finally, while public programs often improve several dimensions of WASH services in combination, whether different program components (e.g., sanitary toilets, safe drinking water, sewage connections) are complementary in improving child development remains an open question, with limited findings on their effects on child health, and no evidence at all on effects on children's later life outcomes.[2] This question is crucial to inform policymakers of whether combining multiple interventions, and which interventions, deliver greater "bang for the buck".

This paper provides new empirical evidence that addresses all three questions. We provide one of the first quasi-experimental estimates of long-run education and health effects of the nationwide safe drinking water and sanitary latrine subsidy programs, focusing on rural China, from 1989 to 2015.[3] This setting is especially valuable for a few reasons. First, there was a remarkable increase in the coverage of both safe drinking water and sanitary toilets in the last three decades. The coverage of clean water supply in rural China increased from 30%-40% in 1990 to 83% in 2020 (National Patriotic Health Campaign 1990; Ministry of Water Resources 2021) while the coverage of sanitary latrines increased from 7.5% in 1993 to 76% in 2022 (National Bureau of Statistics 2018; National People's Congress of China 2022). In 2000, 13.7% of the Chinese population had access to safely managed sanitation, below the average of 20.7% in Eastern and South-Eastern Asia, by 2015, the fraction in China reached 52.5%, above the average of 48.7% in the region. Second, there was substantial regional variation in the timing of the introduction of both programs. Program implementation years varied from early 1980s to late 2010s. A variety of reasons

[1] An exception was Abramovsky et al. (2023), who show that a WASH intervention in Nigeria had greater effects on open defecation in lower-wealth communities. We also find larger positive effects on education among children from households in the bottom quintile of the household income distribution

[2] Alsan and Goldin 2019 find clean water and sewerage improvements were complements in reducing child death in Massachusetts; Bhalotra et al. 2017 find water chlorination in Maxico had larger impacts on child mortality in municipalities with younger water supply systems.

[3] There are a growing number of studies that evaluate the short-run effects of improved sanitation or water access, e.g: Spears and Lamba (2016) for the Total Sanitation Campaign in India; Adukia (2017) for school sanitation program in India.

likely led to this, including differences in engineering costs, funds available for subsidy, and distances from villages to nearest running water sources (World Bank Group 2010). These two unique features allow us to exploit the staggered introduction of both programs across villages and years to implement a stacked Difference-in-Differences(Stacked DiD) strategy. Our event-study estimates show that both toilet and water programs increased children's years of schooling and the effects persisted for up to 20 years after they were first introduced. On average, for those aged 6-18 in survey years, toilet programs increase children's years of schooling by 0.469 years; water programs increase their years of schooling by 0.341 years, and both the effects are larger for girls than for boys. We then investigate whether these two program have complementary effects. Comparing the effect size in villages that simultaneously introduced both programs, relative to those that introduced both across different years, we find that simultaneous implementation increases children's years of schooling by 0.739 years, while in non-simultaneous villages, the toilet program increased years of schooling by 0.476 years and water program increased it by 0.285 years. This provides supportive evidence that the two programs had positive complementary effects on children's education.

Next, we investigate how these programs shaped the intergenerational transmission of education and health. To do so, we construct measures of education rank persistence and upward rank mobility. Our stacked DiD estimates show that the toilet program significantly reduced the correlation between the mother's education rank and the children's education rank. We then show, using a "transition matrix" approach, that the reduction in average intergenerational education persistence was driven by the increased probability that children whose mothers were in the bottom two quintiles of their education distribution made it to the top quintile of their cohorts' education distribution. On average, after villages introduced toilet construction programs, the fraction of daughters born to mothers in the lowest education quintile who made it to the top quintile increased from 4.4% to 21.6%, while the fraction of sons who made it to the top quintile increased from 7.6% to 25.5%. We find a similar reduction in intergenerational health persistence, where the mother-child correlations in height have been significantly reduced after toilet programs.

We explore three potential mechanisms underlying positive effects on education. First, motivated by qualitative evidence from the World Bank during its inspections, we test for effects of both programs on adult labour supply and wage income.[4] We find both toilet and water programs helped shift workers, especially women, out of agriculture, into manual and service jobs. We also find that the toilet program significantly increased workers' labour supply, by 6 hours per week (15% of control mean). This translated into increased monthly wages. Occupational shifts induced by the toilet program also led to increased hourly wage earnings. In addition, we observe positive complementarities in the effects on adult labour supply and earnings. This points to the existence of complementarities in labour reallocation effects in driving higher household incomes and investments into children's education.

As a second potential mechanism, we find that children significantly reduced the amount of time spent doing housework after the toilet program. Finally, we find evidence of a significant increase in children's height for age after the water program, although there is no evidence of a significant reduction in child sickness after either program.

This study first contributes to the growing literature that exploits within-country variation in WASH interventions to study their effects on child health and educational outcomes (Gamper-Rabindran et al. 2010; Koolwal and Van de Walle 2013; Duflo et al. 2015; Spears and Lamba 2016; Adukia 2017; Augsburg and Rodríguez-Lesmes 2018; Alsan and Goldin 2019; Orgill-Meyer and Pattanayak 2020; Abramovsky et al. 2023).We contribute in several ways. First, the long horizon of the programs, combined with children's full education trajectories, allows us to estimate the causal effects of both programs up to 20 years after their implementation. The longitudinal data further allow us to include child fixed effects to remove any

[4]The World Bank inspections observed that after the water program, "small businesses, mostly food related, proliferated in all areas, many operated by women who have been relieved of water carrying. Larger scale commercial and industrial development has also accelerated with the availability of water and new construction was visible everywhere." (World Bank Group 2010).

individual-level unobserved heterogeneity that could bias estimated program effects. The stacked DiD estimates are also robust to treatment effect heterogeneity given the staggered timing of the programs (Baker et al. 2022). Further, we move beyond establishing the effects of water and toilet programs *on average* by showing that they can be effective at breaking the link between maternal education, health, and children's developmental outcomes. To the best of our knowledge, little prior evidence exists on the effectiveness of sanitation interventions in reducing intergenerational persistence in socioeconomic outcomes.

We also contribute to the literature evaluating the overall costs and benefits of water and sanitation programs introduced in rural China (Zhang and Xu 2016; Chen et al. 2022; Wang and Shen 2022). Previous studies found that early-life exposure to safe drinking water had improved child health, educational attainment, and cognitive test scores. However, they considered safe drinking water programs in isolation, may have attributed the effects of toilet improvements to better water quality, and their OLS-TWFE estimates can be biased due to both treatment effect heterogeneity and the staggered implementation of both toilet and water programs across villages (de Chaisemartin and d'Haultfoeuille 2022). We explicitly account for the fact that the two programs not only had *independent* effects but could also *interact with each other*. Our findings suggest that toilet constructions have played a quantitatively more important role in improving rural children's educational attainment and health than access to safe drinking water. We also find positive compelementaritie between toilet and water programs, as villages that introduced both programs simultaneously saw larger effects than if they were introduced at different timing and villages that toilet programs were introduced 10 years below the implementation of water program experienced also experienced more pronounced effects than those villages that toilet programs were introduced 10 years above the implementation of water program.

The remainder of this paper is organized as follows. In Section 2, we describe the background of water and toilet programs in rural China. In Section 3, we introduce our main data sources and empirical strategy to identify causal effects of interest. In Section 4, we discuss our main findings. In Section 5, we investigate three potential mechanisms: adult income and labour supply effects, changes in children's time use, and improvements in child health. We perform robustness checks in Section 6 and conclude in Section 7.

2 Water and Toilet Programs in Rural China

2.1 Water Program

In early rural China, access to safely managed drinking water was limited, and households had to rely on contaminated water sources such as wells, rivers, and snow. The presence of chemical and heavy metal pollutants in water presented substantial health hazards in China arouse the government concern on water improvement. [5] In response to this, from the 1980s, the Chinese government launched a multi-stage drinking water improvement program to improve water quality across the country. The first stage of the program (1985 to 2002) primarily focused on reducing the fluoride content in water and constructing irrigation and water systems and roads connected to water projects. This was financially supported by central and local government subsidies and USD228.9 million in loans from the World Bank.[6] From 2000, the Chinese Ministry of Water Resources proposed to "implement projects focused on solving rural drinking

[5] Due to the Chinese traditional custom of consuming boiled water and cooked food, the adverse health consequences associated with common drinking water contaminants, such as microorganisms, were relatively less severe compared to many other developing countries (Zhang et al. 2009).

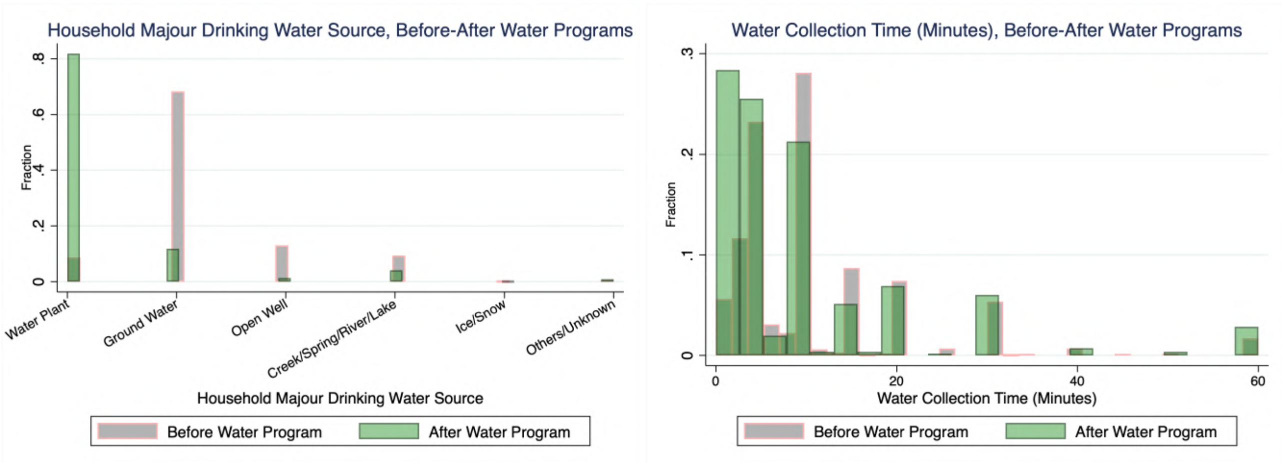
[6] The first-phase (1985â1990) loan of USD80 million had an estimated number of beneficiaries of 600 million people in 25 counties in Beijing, Liaoning, Shanxi, Zhejiang, and Sichuan provinces; the second-phase (1992â1997) loan of USD78.9 million affected 900 million people in 75 counties in Xinjiang, Guangxi, Yunnan, Gansu, Inner Mongolia, and Hunan provinces; the third-phase (1997â2002) loan of USD70 million benefited 460 million people in 40 counties in Hebei, Inner Mongolia, Jiangxi, Hubei, and Yunnan provinces.

water difficulties" in the Tenth Five-Year Plan, as part of the second stage of the water program (2000 to 2004). This stage was funded by a national debt of USD144 million, together with local government subsidies and villagers' self-raised funds of USD120 million. However, at the end of 2004, 34% of the rural population still faced either an insufficient or unsafe supply of water, prompting the third stage of the water program, which was aimed at upgrading the water supply and further improving water quality. From 2005 to 2015, 230,000 centralized water systems were built to ensure that water plants could be shared among villages. Furthermore, to expand remote villages' access to clean water, 680,000 decentralized water supply systems were newly constructed. It was estimated that the third-stage program would improve the issue of the lack of safe water access for 298 million rural residents and 41.33 million rural teachers and students nationwide.

Panels A and B in Figure 1 highlight the positive influence of the water programs, presenting the changes in the household's drinking water source and the time for getting water before and after the implementation of water programs. Notably, there was a substantial shift, accounting for 73% of households, towards using plant water as the primary drinking water source, accompanied by a significant reduction in the time burden associated with water collection after the introduction of water programs. Furthermore, the coverage of water plants is statistically different between villages that did not implement water programs and villages that implemented water programs. On average, the coverage increased from 6% in 1989 to 21% in non-water programs villages whereas it increased from 42% to 76% in villages with water programs (Figure 2).

Figure (1) Changes in Household Majour Drinking Water Source & Water Collection Time

(a) Panel A (b) Panel B



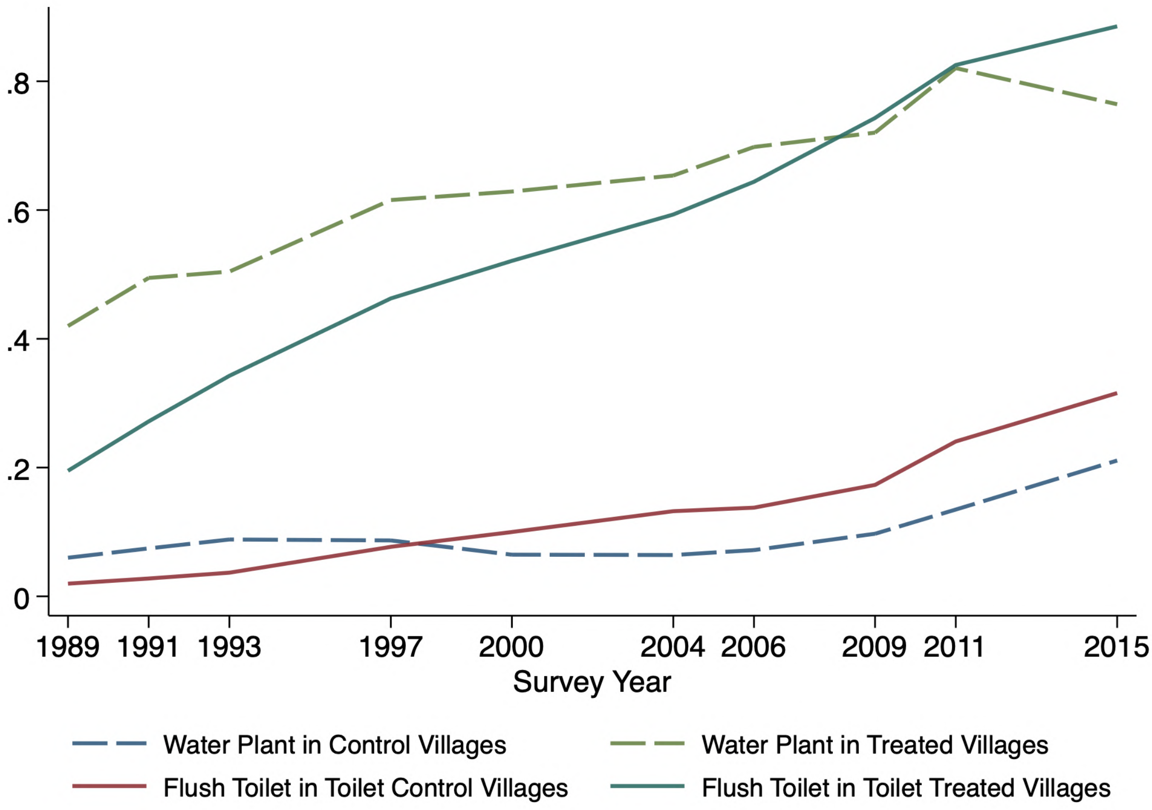
Note: Panel A shows the changes in the household majour drinking water source in villages before and after water programs; Panel B shows the changes in water collection time before and after water program. *Data source:* China Health and Nutrition Survey

2.2 Toilet Program

In the early 1990s, the smelly and dirty sanitary environment and its related children's health problems became a serious social concern in rural China.[7] To address this, the Chinese government launched an unprecedented "Toilet Revolution" to subsidize rural households to build clean toilets. In 1992, the State Council first clearly listed rural toilet retrofitting in the government's document named "Program for

[7] A prominent example was the widespread media coverage of Beijingâs prevalent open defecation during the 1990 Asian Olympics.

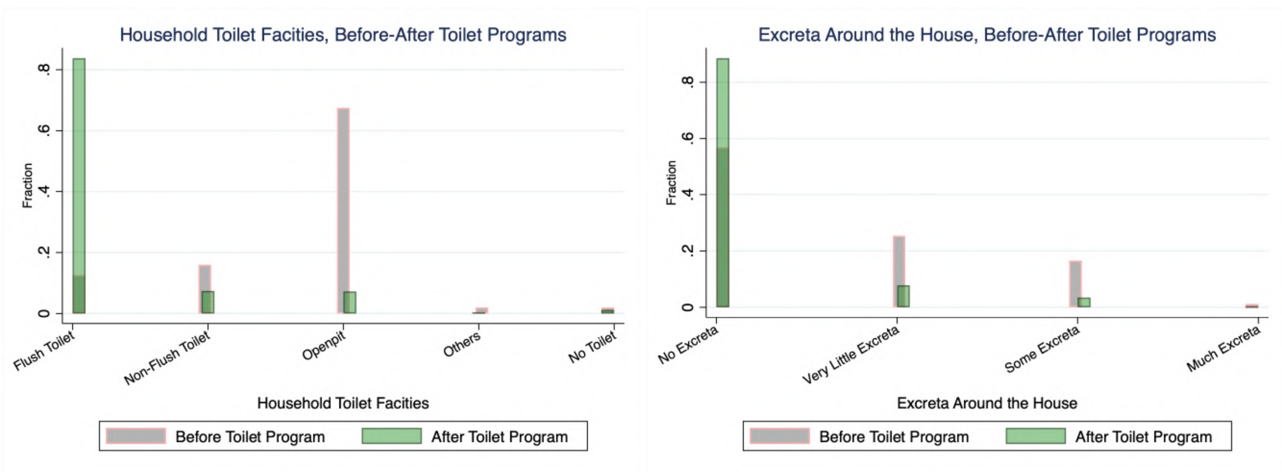
Figure (2) Coverage of flush toilets and water plants by year in control and treated villages in rural China



Note: This figure shows the fraction of CHNS sample villages that had water plants, and flush toilets, in a given survey year for both control and treated villages. There are 181 villages in the raw CHNS sample. *Data Source:* China Health and Nutrition Survey

Figure (3) Changes in Household Toilet Type & Excreta Around House

(a) Panel A (b) Panel B



Note: Panel A shows the changes in the household toilet type in villages before and after toilet programs; Panel B shows the changes in excreta around house before and after toilet program. *Data source:* China Health and Nutrition Survey

Chinese Children Development in the 1990s" and set out policy guidelines. In 2004, to motivate households to improve their toilets, the state spent about USD10.6 billion on subsidizing households to install sanitary toilets, while the cost of the second round of the subsidy program was an estimated USD1.2 billion in 2009. In addition to governments, private capital and non profit organizations contributed to sanitation improvement. We are therefore unable to precisely estimate overall financial expenditures for toilet improvements. However, from 2005 to 2015, it is estimated that a total of USD5.53 billion was invested, including USD2.16 billion to improve toilets in nine provinces in the China Health and Nutrition Survey, and the average cost of toilet improvement was around USD81 per household (Wang and Shen 2022).

Through concerted government efforts, the coverage of flush toilets witnessed a remarkable increase, rising from 12.55% before the implementation of toilet programs to 83.78% thereafter (Panel A in Figure 3). This substantial improvement in toilet coverage corresponded to a more sanitary household environment, characterized by a significant reduction in the presence of excreta around households (Panel B in Figure 3).[8] Furthermore, the coverage of flush toilet is statistically different between villages that did not implement toilet programs and villages that implemented toilet programs. On average, in toilet treated villages, the average coverage increased from less than 2% in 1989 to 32% in 2015. In contrast, villages with toilet programs experienced a substantial increase in coverage, with the average coverage rising from 19% to 89% (Figure 2). Table 1 provides an overview of these two programs.

Table (1) Overview of Water Improvements and Toilet Construction Programs

	Water Program	Toilet Program
Target Counties	Counties with a high incidence of disease and poor water quality	Counties with low sanitary toilet coverage rate
Payments	Subsidies (administered to villages) to improve water quality & supply capacity	Household-level subsidy, after examining toilets (Wang and Shen (2022))
Average Cost	30 USD per-capita	81 USD per household
Implementation Level	Village-level water plants	Village local authorities/committees

3 Data and empirical strategy

3.1 Data

We primarily use an individual- and household-level panel data set from the China Health and Nutrition Survey (CHNS), which started in 1989 and had nine follow-up waves in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015, covering 12 out of 32 provinces in the China. CHNS questionnaires measured individuals' socioeconomic status, health conditions, and information on household characteristics, such as physical infrastructure, which we use to construct our treatment variables. Because toilet and water programs were implemented in rural China and our main interest is children's educational attainments, we restrict the sample to rural areas and to school-age children aged between 6, the age of starting primary school, and 18, the age of graduating from senior high school. Our estimation sample consists of 180 villages, which have an average sample population of over 800 individuals.

[8] Note that the excreta data provided by the interviewers' observation does not distinguish between open defecation or feces from livestock. However, even considering the potential mixture with livestock feces, the reduction can still be attributed to the positive impact of the toilet programs, as they were also associated with a decrease in livestock raising (Wang and Shen 2022)

To avoid household self-reported measurement errors and potential endogenous effects of the toilet and/or water improvement on children's outcomes, we define our treatment variables of exposure to these programs at the village level. This is further motivated by the logistical nature of program rollout, where county governments implement them at the village level. Specifically, we construct a binary measure of toilet/water improvement, which equals one if one of the two following conditions are met. The first condition is that the village has more than 75% coverage of flush toilets or that over 75% of the village households' water source is from plant water. 75% is the target of Chinese government on sanitary toilet/plant water coverage in the rural area. The second condition is that the village had more than a 10 percentage point increase in the coverage rate for each year between two survey waves.[9] In Section 6, we show that our results are unaffected by changing these threshold definitions, suggesting that our findings are not driven by a specific treatment definition.

Table 2 shows the summary statistics for our main analysis sample.[10] We restrict the sample to years before the programs were introduced to avoid a confounding imbalance with treatment effects and then we collapse our sample of children aged 6 to 18 years at the village-year level. Our primary outcomes of interest are children's total years of schooling, school attendance, and the probability of completing grade for age, defined as whether a child completed primary education by 12 years old, lower-secondary by 15 years old and upper-secondary by 18 years old.

Compared to control villages, those that experienced toilet programs had lower levels of schooling and worse anthropometric outcomes (height and weight). We then run balancing tests using the village-level panel by regressing these outcomes on toilet and water treatment dummies, controlling for county and year fixed effects. We report coefficients, standard errors, and p-values from these regressions in Panel B of 2. Most of the coefficients are statistically insignificant, indicating that the treatment is not systematically correlated with the prior observed characteristics. To the extent that there were level differences between treated and control villages prior to the introduction of each program, our difference-in-differences strategy flexibly controls for these through the inclusion of individual (child) fixed effects.

Other Data—We use the 2011 community dataset of the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey of the elderly across 450 villages/towns, to check potential correlations between the introduction of water, toilet programs, and other programs that could have independent effects on health or education. The 2011 community survey records the year (based on surveying village heads/township officials) that the community (either a rural village or a near rural town) introduced water and/or sanitation, and other social programs. One limitation is that water and toilet programs are recorded as the same class in the survey, and thus we can only examine the correlations of these two programs together in this analysis. We construct an annual district-level panel data set, recording whether the community had experienced any of the social programs that may have an effect on children's education. We focus on four other programs that were rolled out around the same period as the water and sanitation programs, and that could have an impact on children's education: introduction of sewage systems, electrification, elderly pensions, and township mergers or splits.[11]

3.2 Empirical strategy

3.2.1 Baseline: Stacked Difference-in-Differences

We use a generalized Difference-in-Difference strategy to estimate the effects of sanitation and water programs. Given the staggered introduction of these two programs across villages and years, conventional OLS-TWFE estimates could be biased by treatment effect heterogeneity across villages and/or years (e.g: de Chaisemartin

[9]For more details about the definition of treatment variables, see Table A1 in Wang and Shen 2022.

[10]A1 reports the summary statistics separately for toilet and water programs in Panels A and B.

[11]We plot the number of surveyed communities in CHARLS that have been exposed to these programs over time in Figure 9. Descriptively, most of these programs started to be rolled out before the water and toilet programs.

Table (2) Village-level Summary Statistics, Children Aged 6-18

Panel A:Summary Statistics						
	Toilet/Water Treated			Control		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Total years of schooling	5.18	1.43	250	5.38	1.74	263
School attendance	0.76	0.17	251	0.80	0.21	264
Prob(Completing grade-for-age)	0.36	0.17	251	0.33	0.22	272
Mother total years of schooling	5.10	2.35	208	6.74	2.27	241
Prob(Sickness)	0.07	0.16	239	0.07	0.17	261
Prob(Contagious diseases)	0.35	0.43	140	0.20	0.35	188
Height	136.30	12.72	236	141.33	12.99	259
Weight	33.18	8.53	239	37.19	10.75	258
BMI	17.21	1.86	236	17.77	2.39	258
Household income	8969.64	11702.30	251	15357.42	21461.53	272
Panel B:Regressions						
	Toilet			Water		
	Coef	Std. Err.	P-val	Coef	Std. Err.	P-val
Total years of schooling	0.43	0.15	0.00	-0.12	0.17	0.49
School attendance	0.01	0.02	0.55	0.00	0.02	0.90
Prob(Completing grade-for-age)	0.06	0.02	0.00	-0.00	0.02	0.96
Mother total years of schooling	0.29	0.36	0.42	-0.77	0.40	0.05
Prob(Sickness)	0.01	0.02	0.74	0.00	0.02	0.83
Prob(Contagious diseases)	0.06	0.04	0.15	-0.07	0.04	0.11
Height	1.22	0.90	0.18	-0.55	1.10	0.62
Weight	1.69	0.67	0.01	0.42	0.84	0.61
BMI	0.32	0.18	0.08	0.28	0.25	0.27
Household income	3821.28	1279.37	0.00	-477.07	1418.83	0.74

Panel A shows summary statistics at the village-year level, using a sample of 6- to 18-year-olds for each survey year. The summary statistics are based on the sample of observations prior to the introduction of water/toilet programs. Household Income is measured in units of Chinese Renminbi (RMB). We compare the villages that have experienced either toilet or water programs to those that have experienced neither. Panel B reports the coefficients of toilet and water treatment from the same regression, controlling for county and year fixed effects. Heteroskedasticity-robust standard errors are clustered at the village level.

and d'Haultfoeuille 2022, Sun and Abraham 2021). Causal identification is further complicated by the presence of two programs of interest that have been introduced across villages, with correlated timing, and we are also interested in the effects of their interactions. For instance, de Chaisemartin and d'Haultfoeuille (2022) show that in the presence of multiple treatment variables with a staggered introduction, OLS-TWFE estimates suffer from bias both from treatment effect heterogeneity and from contamination among treatments.

To address these empirical challenges, we use a stacked Difference-in-Differences model, in a similar spirit to Biasi et al. (2023), Deshpande and Li (2017), Cengiz et al. (2019), and Baker et al. (2022). We construct our event-specific stacked data set as follows.

1. We group villages based on the year they introduced water plants and toilet subsidies. For instance, villages that introduced water program in 1989 and toilet program in 1991 are in the same group. There are a total of 61 groups based on this definition.

2. We stack observations for individuals in each group of treated villages and in all villages that experienced neither water plant nor toilet subsidy program. This forms an "event-specific" dataset. We then stack up all "event-specific" datasets to arrive at the estimation sample.

In this way, we allow for heterogeneous treatment effects across villages, based on the specific combination of toilet and water program years. The stacked OLS-TWFE estimator is then a weighted average of these group-specific treatment effects, where the weights are based on data-specific treatment variance and sample size, and are strictly positive (Gardner 2022). We then append all the event-specific/treatment vector-specific data sets to form our estimation sample. For individual i who is resident in village v observed in year t, we estimate the following OLS event-study specification on this stacked sample:

$$Y_{ivt} = \alpha_{gi} + \phi_{gt} + \sum_{k1=-B}^{T} \beta^{k1} Toilet_{vt} \times D_{ivt}^{k1} + \sum_{k2=-B}^{T} \beta^{k2} Water_{vt} \times D_{ivt}^{k2} + \epsilon_{ivt} \quad (1)$$

In this equation, we fully saturate individual and year fixed effects (α_{gi}, ϕ_{gt}) by event-source fixed effects, which are dummy variables for which treatment vector source the observation belongs to. D_{ivt}^{k} are dummies indicating whether individual i was observed in event time k before or after either program was introduced in the village. We include event time dummies for toilet subsidies/water plant construction. The parameter of interest are β^{k1} and β^{k2}, which, under the conditional parallel trends assumption, consistently estimates the Average Treatment Effect on the Treated k years before/after the introduction of the program. We group event times in four-year bins to increase statistical power, and we omit the dummy variables for four to one years before each program's introduction as our reference time period. α_{gi} are individual-group fixed effects, which control for common individual-level shocks for each group; ϕ_{gt} are year-group fixed effects, which control for individuals' time-invariant characteristics for each group. Standard errors are clustered at the village level to allow for serial correlations over time.

We include event-time indicators for both programs in the same equation to estimate their respective effects, controlling for potential changes in outcomes induced by the other program. This helps answer the first policy question about which program had a larger impact on children's education. To study potential program complementarities, we compare the overall average effects of two programs with their effects in villages that had already introduced the other program earlier. For instance, we compare the effects of the toilet program in villages that introduced these two programs and the effects in villages that had already introduced water programs by the time the toilet programs were introduced. If there are positive complementarities, we will find larger effects in villages that had already introduced the other programs than in villages that only introduced one program.

3.2.2 Test for Program Complementarities

A key contribution of this paper is to empirically test complementarities between two types of WASH programs (toilet and water improvements). We hypothesise that there are a few reasons for potential complementarities between water and sanitation improvements in improving children's educational attainment.

First, there is a physical complementarity between the availability of clean/piped water and effectiveness of sanitation improvements, as water is used to flush the sewage. Further, without effective sewerage infrastructure in place, clean water can quickly be recontaminated and undermine any potential health benefits (Motohashi 2022). The joint introduction of water and sanitation improvements could also be more effective than any single component, owing to aging of water pipe networks. Indeed, a large engineering literature in Mexico has demonstrated that water purification led to larger mortality declines in municipalities with younger (and potentially less defective) water pipe networks (Bhalotra et al. 2017). However, there are also reasons why there may be no strong complementarity between the two programs. In particular, improved water access could weaken private incentives for protective health behaviours, thus reducing the amount of health gains from sanitation improvements (Bennett 2012,)

We adopt a few strategies to test potential complementarities between the water and sanitation programs. First, we estimate effects of each program in villages that did not introduce them at the same time, and compare these to effects of the program in villages that introduced both at the same time. In our sample, there are 32 villages which introduced both programs in the same year. If there are positive complementarities, we should find that the effects of simultaneous introduction are bigger than adding up toilet and water effects.

Second, motivated by the engineering literature that stresses the importance of water pipe conditions in determining their health effects, we examine heterogeneous effects of the toilet program, depending on the age of the water plant. We proxy water plant age by the number of years between the water and toilet improvement programs. We split the sample by whether water plans were below/above 10 years old when the village experienced the toilet improvement program. If water plant age is indeed important in mediating the effects of toilet improvements (for instance, since flushing the toilet with dirty water results in limited reduction in disease transmission), we will find the effects of toilet programs to be larger in magnitude in villages that had introduced water programs relatively recently, when they experienced the toilet program.

3.2.3 Effects on Intergenerational Education and Health Persistence

We next assess whether, and how, the two programs affected the intergenerational transmission of health and education, by looking at changes in mother-child health and education relationships. We focus on mother-child relationships given the finding from prior literature (which spans across countries and time) that maternal education has a larger impact on child health, survival, nutrition, and academic performance(Le and Nguyen 2020, Chou et al. 2010, Alderman and Headey 2017, Harding et al. 2015). To measure intergenerational educational persistence/mobility, we use two approaches: rank persistence, which measures correlations between mothers' rank and children's rank; and upward rank mobility, which measures how children's specific family backgrounds affect their probability of completing more education. To examine rank persistence, we use the same stacked sample of 6- to 18-year-olds. Using this sample, we construct percentile education ranks for children and their mothers, which vary by their birth cohorts. Importantly, mothers' education rank doesn't vary over time, but we allow the children's education ranks to vary over time, reflecting changes in their relative position in the education distribution. We then regress the child's rank on the mother's rank in the education distribution of their own birth cohorts:

$$ChildRank_{ivt} = \alpha + \beta MotherRank_{iv} + \epsilon_{ivt} \tag{2}$$

where $ChildRank_{ivt}$ and $MotherRank_{iv}$ are the child's and mother's ranks in their birth cohort education distributions. Assuming the rank-rank regression is linear, the estimated parameter β measures the relationship between the ranks of children and their mothers in the education distribution of their respective birth cohorts. α measures the expected rank of children whose mothers are at the bottom of the education distribution. Given these measures of persistence, we use a specification similar to Bütikofer et al. (2018), by looking at differential change in rank-rank correlations after each program. We differ from their specification as changes in child rank allow us to control for other confounding shocks through year fixed effects.

$$\begin{aligned} ChildRank_{ivt} = \beta_0 + \beta_1 MotherRank_{iv} \times PostToilet_{vt} + \beta_2 MotherRank_{iv} \times PostWater_{vt} \\ + \beta_3 MotherRank_{iv} + \rho_{gc} + \lambda_{gv} + \phi_{gt} + \epsilon_{ivt} \end{aligned} \tag{3}$$

$PostToilet_{vt}$ and $PostWater_{vt}$ are the indicators for children being observed after being exposed to toilet/water programs, ϕ_{gt} are group-year fixed effects. λ_{gv} are group-village fixed effects. ρ_{gc} are group-birth cohorts fixed effects. Standard errors are clustered at the village level to allow for serial correlations over time. Our key coefficients of interest, β_1 and β_2, estimate the changes in intergenerational persistence in villages that experienced toilet subsidy/water plant construction. To more clearly see what drove the observed changes in children's education ranks over time, we also estimate stacked OLS-TWFE event studies, splitting the sample of children by quintiles of their mother's education rank. By assessing the relative size of the change in children's schooling based on mothers' education, we can investigate whether changes in education persistence were driven by upward or downward mobility.

Finally, we use a "transition matrix" to measure upward rank mobility. The matrix maps out the empirical probability that a child, whose mother is in a given quintile of their own cohort's education distribution, made it to each quintile of the child cohort's education distribution. We specifically examine changes in the fraction of children whose mothers were in the bottom quintiles and who made it to the top quintiles (those who "moved up the education distribution") after the introduction of each sanitation program. This shows the change in the fraction of children whose relative standing in the education distribution improved as a consequence of the programs.

3.2.4 Changes in Intergenerational Mobility Across Cohorts

Our empirical strategy above allows children's education rank to vary over time. This addresses the question of whether children with less educated mothers experienced a differential increase in their relative position in the education distribution after program exposure. As an alternative strategy, we investigate how the correlation between the mother's and child's stock of human capital (measured by completed years of schooling) has changed for cohorts exposed to toilet and water programs at different ages. This empirically tests the hypothesis that early-life exposure to better sanitation has larger potential effects on child health, not only because of their vulnerability to adverse health shocks, but also because of the higher marginal returns to early-life investments. To do so, we construct a cross-sectional data set by keeping date on the last time each person was observed, in a similar spirit to Zhang and Xu (2016).We then use the sample of individuals with their highest observed education to construct time-invariant percentile education ranks, which vary by children's and mothers' birth cohorts. As our interest is now the correlation in the stock of human capital, we restrict our sample to those aged between 12 and 50 years (post-primary school completion age), 16 and 50 (post-lower-secondary completion age), and 18 and 50 (post-upper-secondary completion age). We construct a stacked sample of individuals based on the years they were exposed to water and/or toilet programs in the same way. Using the time-invariant education rank, we estimate the following specification:

$$\begin{aligned} ChildRank_{icvt} = \alpha_0 + \alpha_1 Age_i + \alpha_2 Age_i^2 + \beta_0 MotherRank_{icvt} + \beta_{1j} MotherRank_{icvt} \times 1[AgeToilet \leq j] \\ + \beta_{2j} MotherRank_{icvt} \times 1[AgeWater \leq j] + \rho_{cg} + \lambda_{gv} + \epsilon_{icvt} \end{aligned} \tag{4}$$

In this specification, $ChildRank_{icvt}$ is the percentile education rank for a child i in cohort c, village v, last observed in year t. g denotes the event-source, which varies based on program exposure years. We control for a second-order polynomial in individuals' age, cohort fixed effects (ρ_{gc}), village fixed effects (λ_{gv}). $MotherRank_{icvt}$ is the corresponding mother percentile rank. The parameters of interest are β_{1j} and β_{2j}, which estimate the effect of being exposed to water & toilet program in a given age interval j, relative to those being exposed at an older age. If early-life program exposure reduced intergenerational education persistence, we should expect $\beta_j < 0$. We include under-6 or under-18 exposure indicators separately. The identifying assumption required for β_j to be an unbiased estimate of the differential effect of programs on intergenerational education persistence is the common trend assumption, which requires that for cohorts sufficiently young to have their education affected (those exposed at/under 18 years old), individuals in never-treated villages experienced similar trends in education across cohorts to those in treated villages. We provide supportive evidence by showing in 6 that there was no change in education after programs for those exposed after the age of 18.

4 Results

4.1 Stacked DiD: Effects on Water and Sanitation Access

We first estimate a series of "first-stage" event studies to verify that our definition of each program did indeed reflect a sharp and economically meaningful increase in access to plant water and flush toilets. Figure 4 shows event-study estimates of dynamic changes in fractions of households who had access to flush toilets and plant-sourced water, before and after our defined years of water improvement/toilet subsidy programs.

For both programs, we observe no pre-program trends in either flush toilet or water access, supporting our assumption that the programs were not correlated with other shocks that could have affected sanitation/water access. We observe a statistically and economically significant jump in the fraction of households with access to a flush toilet plant water) after the defined toilet (water) program year. From zero to three years after the toilet programs, there was a 45 percentage points increase in the fraction of households with access to flush toilets, which is around 400% of the mean flush toilet access rate (10 percentage points), prior to the program. This positive effect persisted for over 20 years after the program's implementation, alleviating concerns about reversals in toilet access over time. After the water program, there was a 60 percentage points increase in the fraction of households with plant water, which is ten times the pre-water program village mean. Importantly, we observe no significant change in the fractions of households with access to tap water after the toilet program (from Panel (a) of Figure 4). We also observe no significant change in the fraction of households with access to flush toilets up to seven years after the water program, although we observe a gradual increase in the toilet coverage rate from years after.

A second potential concern with our treatment definition is some unobserved contemporaneous household-level shock. For instance, given a positive income shock among many households, it could lead to a sharp increase in village-level sanitation/water access rate and we would erroneously attribute this change to the toilet/water program.

We directly test for this via heterogeneous effects of the village-level water/toilet program treatment on household-level access, depending on their income level in the first survey observed. If our village-level treatment definition captures some unobserved shocks, we should see the increase in toilet/water access to be concentrated among households at certain pre-existing income levels. Panels c and d of Figure 4 show the effect of toilet (water) program on toilet (water) access rate, by households' income quintile in the first year observed. We find similar increase in access among bottom 2 and top 2 quintile households, pushing against the concern of differential shocks confounding our treatment definition. In Panels e and f, we show that the income-gradient in household sanitation/water access was not changed before and after either program: there was a large increase in access across households at different income levels.[12]

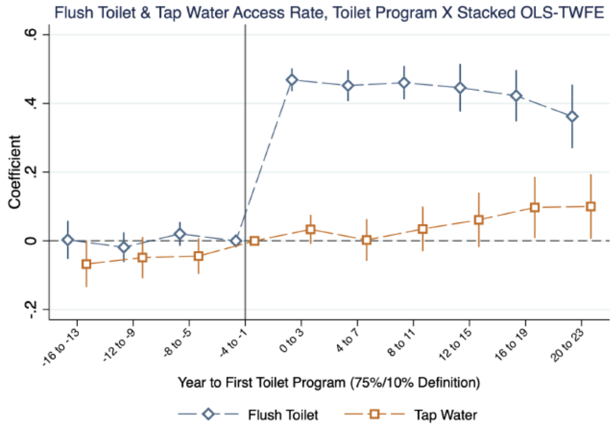
Taken together, these results provide strong evidence that justifies our defined toilet and program variable capturing sharp and economically meaningful change in households' access to a flush toilet and plant water. Further, the absence of contemporaneous change in access to both toilets and water after each program provides evidence that we have enough variation to identify independent effects of each program and that our estimates are highly unlikely to capture the effects of introducing the other types of WASH services.

Project Area Selection.—The primary design challenge of both programs was to channel funds towards areas that were economically disadvantaged yet possessed adequate resources to upgrade their water supply and sanitation once the long-term financing became available. According to World Bank Group (2010), the selection of water improvement villages was based on several criteria: (i) priority was given to counties with lower income levels to ensure that the benefits of improved sanitation facilities reach the most

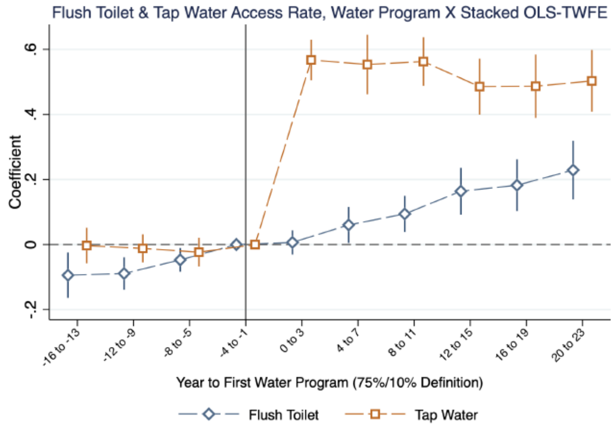
[12] In Appendix Figure A2, we show that households at different quintiles of the income distribution saw a similar increase in flush toilet and tap water access after each program.

Figure (4) Event-study, Effects on Water and Toilet access

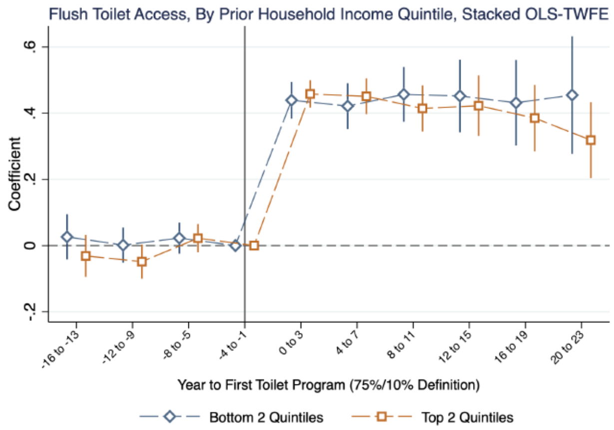
(a) Toilet Program



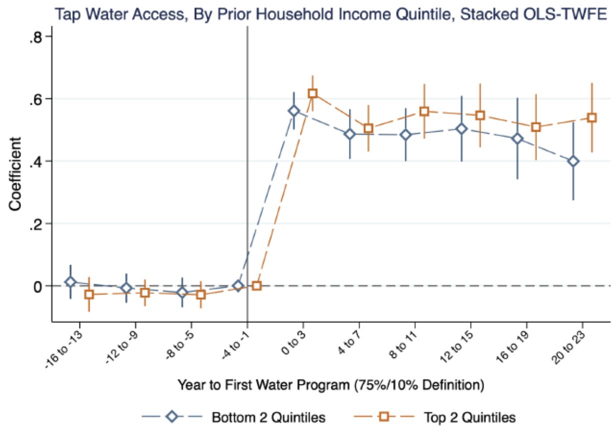
(b) Water Program



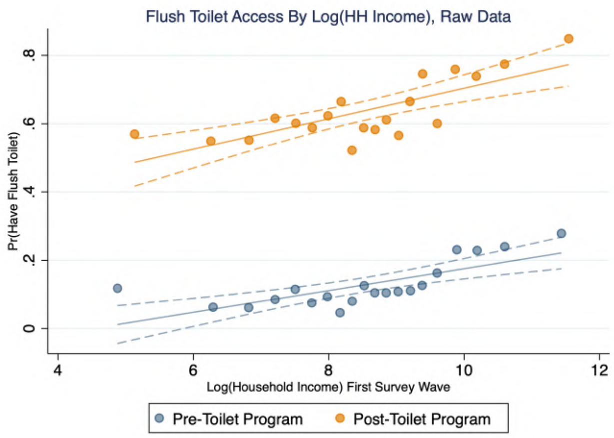
(c) Toilet Access, by Household Income



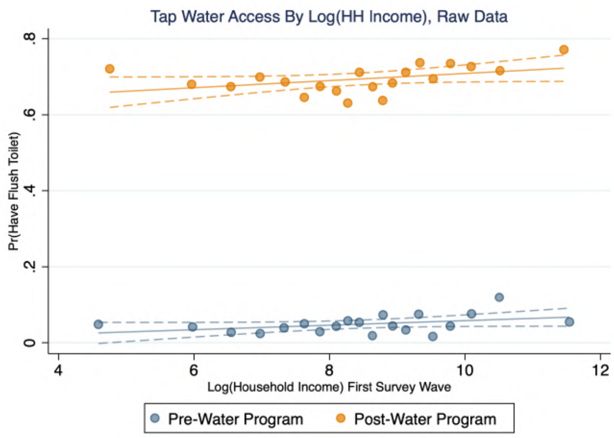
(d) Water Access, by Household Income



(e) Income Gradient in Toilet Ownership



(f) Income Gradient in Water Access



Note: Panels a and b show the average effect of toilet & water programs on household access to flush toilet and tap water. Panels c and d allow the effect to vary by households being in the bottom 2/top 2 quintiles. Panels e and f show binned scatterplots of toilet & water access by household income, separately, for households observed before and after each program.

vulnerable populations; (ii) areas with a greater proportion of rural population lacking access to improved water supply/sanitary toilet or exposed to unsafe water/toilet were given consideration; (iii) emphasis was placed on areas demonstrating the capacity to effectively manage and utilize the required funds, including having skilled and adequate staffs.

This implies that treated villages could have been on divergent trends in their relevant outcomes even prior to being treated. For instance, if treated villages had lower income levels, children's educational attainment could have been increasing at a slower rate prior to the program. To directly probe the plausibility of selection into toilet/water programs across villages, we examine pre-treatment differences in outcome trends between treated and never treated villages. We do this via stacked event studies, restricting our sample to periods before villages received either water or toilet program. If there are either selection into treatment based on time-varying factors, or anticipation effects, we will observe differential pre-trends in village-level outcomes. We focus on children's education outcomes, and adults' education and incomes. Appendix Figure A1 presents event study estimates. Across all outcomes, we consistently find little evidence of differential pretrends, with the pre-program coefficients being mostly small and insignificant. This provides supportive evidence that selection on time-varying factors or anticipation effects are unlikely to bias our estimates. It also helps rule out other contemporaneous shocks that coincided with both programs, such as changes in government policies or local industrial structures.

4.2 Stacked DiD: Effects on Education

We now report results on effects of sanitation programs on children's education. Panels A in Figure 5 show event-study estimates of dynamic effects of toilet construction and water improvement from Equation 1. In Panels C and D, we split the sample by gender; this is motivated by the literature that shows strong son preferences and son-biased parental investment behaviors (e.g: Qian 2008, Almond et al. 2019), as well as empirical evidence that shows girls' health is more responsive to WASH investments than boys (Abramovsky et al. 2019).[13] Post-treatment coefficients suggest that the effects of both toilet and water programs became significantly different for both boys and girls between 0 and 4 years after the introduction. Further, the effects increased progressively in magnitude. Notice that all Panels in Figure 5 show that coefficients on pre-program years remain small and statistically insignificant, providing supportive evidence for the parallel trend assumption.

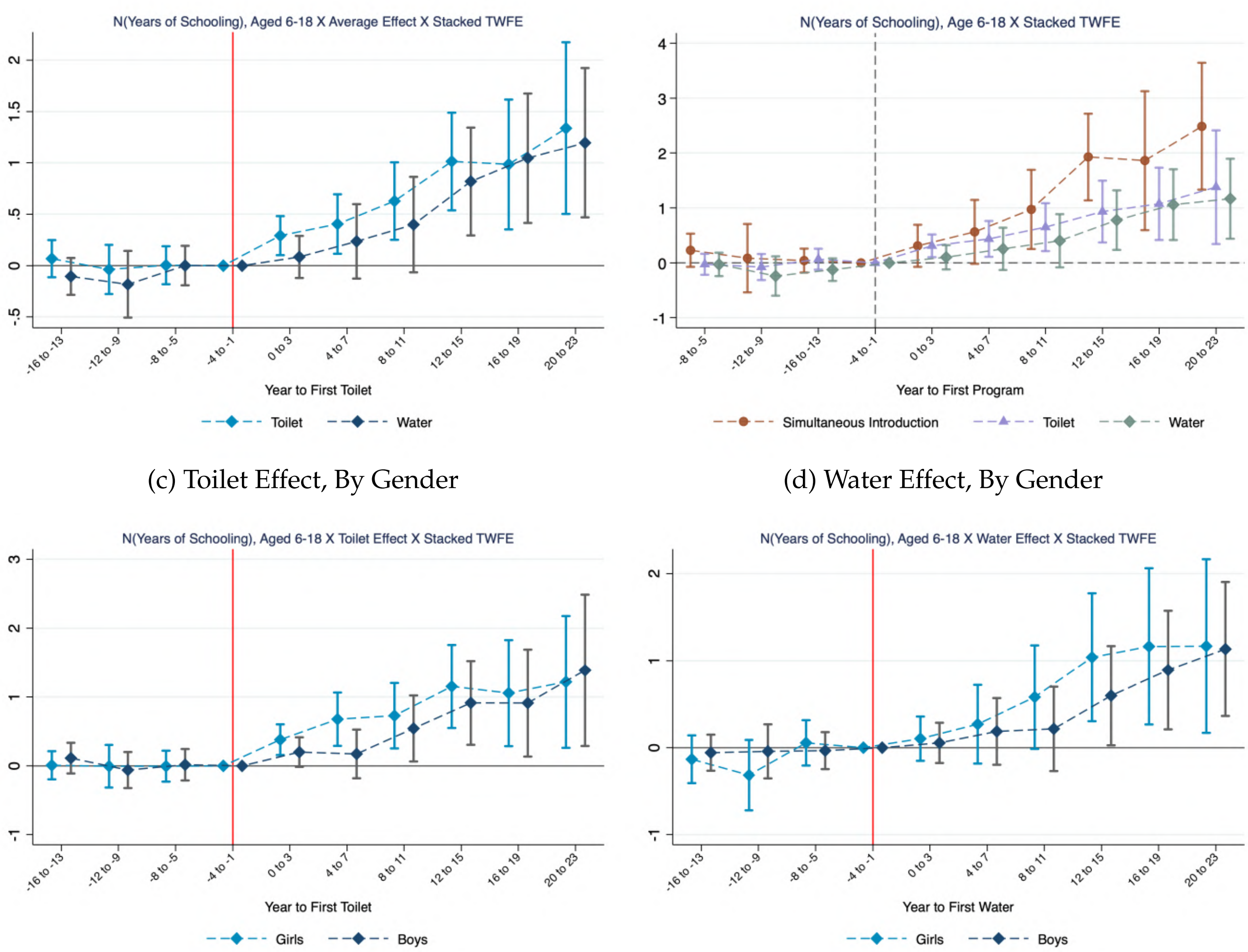
Panel A in Table 3 summarises the relative magnitude of the effects of each program. We find that toilet construction had a larger positive effect on years of schooling than water improvements children aged 6 to 18. Specifically, toilet construction increased 0.469 years whereas water improvements increased 0.341 years. One potential explanation for this is that water construction led to greater health improvements (which we provide evidence for in Section 5). Further, toilet construction had led to an increase in parents' labor supply, owing to the reallocation of housework time (Wang and Shen 2022). Increased household incomes from toilet construction may be a potential channel.

We also examine two other education outcomes for children to further check the robustness of the impact of WASH programs on child education. Figure A3 in the Appendix present estimated effects on school attendance and the probability of completing grade-for-age. They show similar qualitative patterns of a progressive increase, although they tend to have larger standard errors and are less likely to be statistically significant. As we find a smaller effect on school attendance for boys and girls than the overall effects on completed schooling, this suggests that some of the increased educational attainment could be driven by a reduction in the number of dropouts. Also, for these other education outcomes, most

[13]For instance, we believe that girls may benefit more from personal safety and privacy after having improved sanitation, or they may be more responsive to WASH improvements owing to prior underinvestments in their human capital. Prior work on water treatment programs in the China finds little evidence of significant heterogeneity in effects on cognitive test outcomes by gender (Chen et al. 2022).

Figure (5) Event-study for the effects on children's total years of schooling

(a) Average Effects (b) Effects by Program Timing



Note: Point estimates and 95% confidence intervals of OLS-TWFE event studies of heterogeneous effects on children's total years of schooling by gender. Panel A shows the average effects of toilet and water programs. Panel B shows heterogeneous effect of water, toilet programs in villages that did not introduce them simultaneously; and effects in villages that simultaneously introduced both programs. Panels C and D show the toilet and water program effects for boys and girls separately. The sample includes children who were 6- to 18 years old when they were surveyed.

of the graphs show a consistent pattern of gender heterogeneity, where the effects are larger on girls than on boys.

Taken together, our results show that the introduction of toilet and water programs improved boys' and girls' educational attainment, measured by completed years of schooling, school attendance, and the probability of completing grade-for-age. The increase in education was significant in the short run and persisted until 20 years after the program had been implemented. While the effects of each program in isolation are economically meaningful (from 6% to 9% of mean years of schooling in our sample), we find little evidence that the programs had positive interaction effects in villages that introduced both independently.

Table (3) Average Effects of Toilet & Water Programs on Education and Complementaries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Years(Schooling)			School Attendance			Grade for Age		
Panel A: Average Effects		Toilet	Water		Toilet	Water		Toilet	Water
Average Effects		0.469***	0.341**		0.082**	0.075		0.074**	0.030
		(0.130)	(0.166)		(0.039)	(0.057)		(0.033)	(0.039)
Control Mean Dep. Var.		5.315	5.236		0.787	0.775		0.400	0.399
N (Obs)		161158	161158		166829	166829		230623	230623
N (Clusters)		180	180		180	180		180	180
Panel B: Effects by Program Timing	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water
Average Effect	0.739***	0.476***	0.285*	0.093	0.090**	0.076	0.103*	0.074**	0.019
	(0.265)	(0.143)	(0.159)	(0.097)	(0.039)	(0.054)	(0.057)	(0.034)	(0.036)
Control Mean Dep. Var.	6.544	6.534	6.530	0.183	0.185	0.183	0.081	0.081	0.080
N (Obs)	150006	159158	159158	155888	164849	164849	216394	228095	228095
N (Clusters)	69	148	148	69	148	148	69	148	148
Panel C: Toilet Effect by Age of Water Plant	All	$<$ 10 Years	$>$ 10 Years	All	$<$ 10 Years	$>$ 10 Years	All	$<$ 10 Years	$>$ 10 Years
Toilet Effect	0.469***	0.453***	-0.068	0.082**	0.126**	0.008	0.074**	0.097**	0.050
	(0.130)	(0.170)	(0.185)	(0.039)	(0.051)	(0.066)	(0.033)	(0.049)	(0.058)
Control Mean Dep. Var.	6.550	6.530	6.528	0.184	0.183	0.184	0.082	0.080	0.080
N (Obs)	161158	155980	150041	166829	161751	155888	230623	224039	216492
N (Clusters)	180	120	54	180	120	54	180	120	54

Note: This table shows stacked OLS-TWFE estimates of the effects of toilet/water programs on educational attainment. Regression results from Equation 1. "Years of Schooling" means the number of completed years of schooling. "School Attendance" means the probability that the child was attending school in the survey year. Standard errors are clustered at the village level.

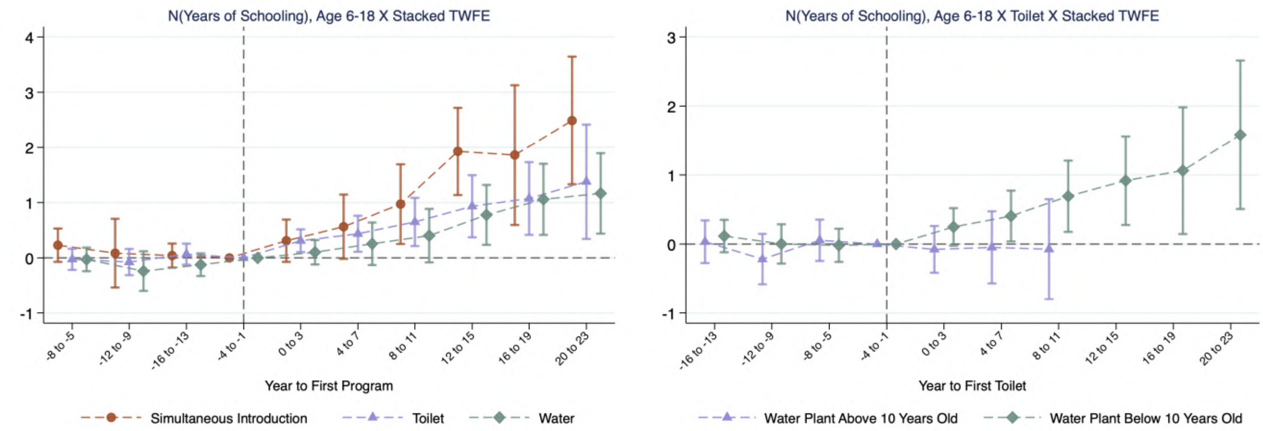
We next report results of our heterogeneous effects estimates to shed light on whether there are complementarities between water and toilet improvements in increasing children's education.

First, Figure 6 provides the dynamic effects by program timing, supporting the positive complementaries between these two programs; the effects of simultaneous introduction of toilet and water are larger than when they were not introduced at the same time. Note that the statistically insignificant pre-program years provide the supportive evidence on the parallel trend assumption. Panel B in Table 3 reports the magnitude of each effects. We find that if these two programs were introduced at the different timing, the toilet program increased children's years of schooling by 0.476 years and water program increased it by 0.285. However, once these two programs were implemented at the same time, the effects reached up to 0.739 years, almost doubled. The effects on children school attendance and their probability of completing grade for age (Columns 4 to 9 in Table 3) further support the robustness of the positive complementaries of toilet and water programs.

Next, Panel B in Figure 6 demonstrates the heterogeneous effects of the toilet program that varies from the age of the water plant. It shows that the effects of toilet program on years of schooling for children living in villages that toilet programs were introduced 10 years below the implementation of water program increased progressively. However,we find limited evidence on the effects of toilet program for children living in villages that toilet programs were introduced 10 years above water program's introduction. Panel C in Table 3 present the static results from the corresponding event study. For comparison, Columns 1, 4, and 7 replicate the effects of toilet program from Panel A. As can be seen, the effects in the villages that experienced toilet program 10 years below the water program are the most significant compared to

Figure (6) Event-study for the complementary effects on children's total years of schooling

(a) Effects by Program Timing (b) Toilet Effects by Age of Water Plant



Note: Point estimates and 95% confidence intervals of OLS-TWFE event studies of heterogeneous effects on children's total years of schooling by gender. Panel A shows the average effects by program timing, with "simultaneous introduction" being derived from one sample that villages introduced both programs at the same time and "toilet" and "water" being derived from the other sample that villages did not introduce them at the same time. Panel B shows the toilet effects by age of water plant, with "water plant above 10 years old" being derived from one sample that villages introduced toilet programs after water programs were introduced over 10 years and "water plant below 10 years old" being derived from the other sample that villages introduced toilet programs after water programs were introduced less than 10 years. The sample includes children who were 6- to 18 years old when they were surveyed.

either the average effects of water where we include all the villages or the effects in the villages that experienced toilet program 10 years above the water program, which have limited effects. Most of the additional educational outcomes perform consistence results.

Taken together, we conclude that the effects of toilet and water programs on children's educational attainments are positively complemented by investigating the effects by program timing and the toilet effects of age of water plant.

4.3 Effects on Intergenerational Persitence

Our prior results show that both toilet construction and water plant programs increased children's average educational attainment. We now investigate whether these programs also reduced the link between maternal education and children's development outcomes.

4.3.1 Effects on Intergenerational Education Persistence

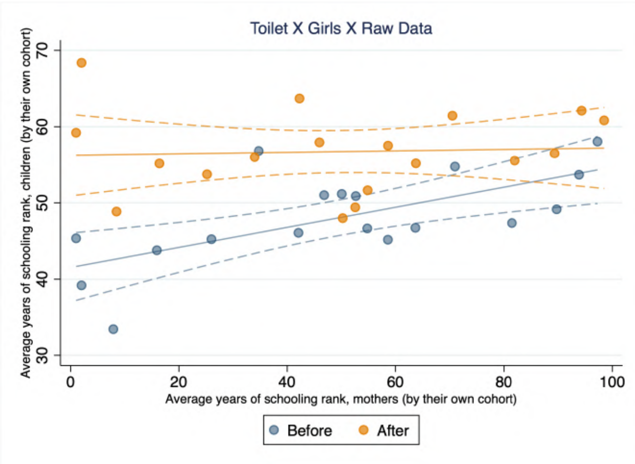
We begin with rank-rank education persistence between mothers and children. Figure 7 shows binned scatterplots of the raw mean (percentile) education ranks of children against their mothers' percentile ranks. We focus on children in villages that were affected by the toilet and/or water programs, splitting the sample by whether they were observed before or after each program.

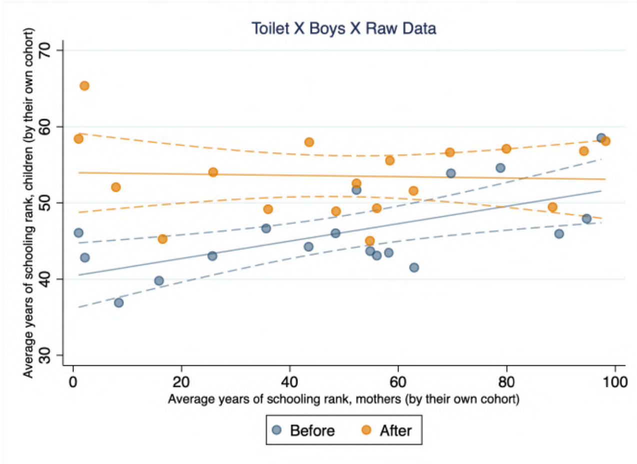
We have a few main findings. First, maternal education is positively associated with higher children's attainment. Second, the graphs show that at all ranks of maternal education, children had a higher average education rank after being exposed to toilet and water programs.[14] Combined with a higher estimated

[14] One may be concerned that this difference in the slope and level of rank-rank association is due to generic effects of younger cohorts having more education. Figure A4 in the Appendix presents the binned scatterplots for younger and older cohorts (defined as being of the same age as the average age of post-treatment and pre-treatment cohorts in

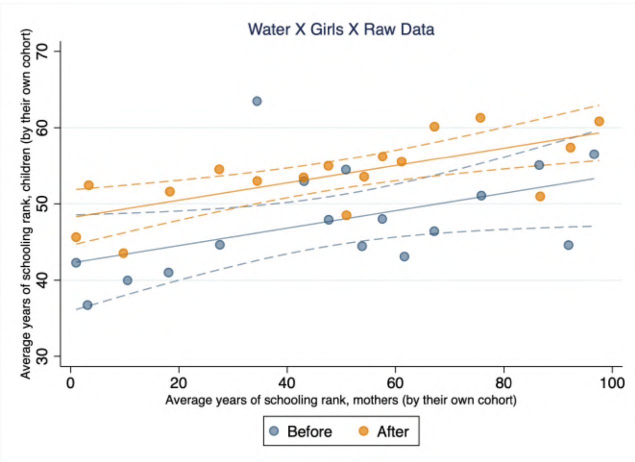
Figure (7) Associations between Children's and Mothers' Education Ranks by Villages

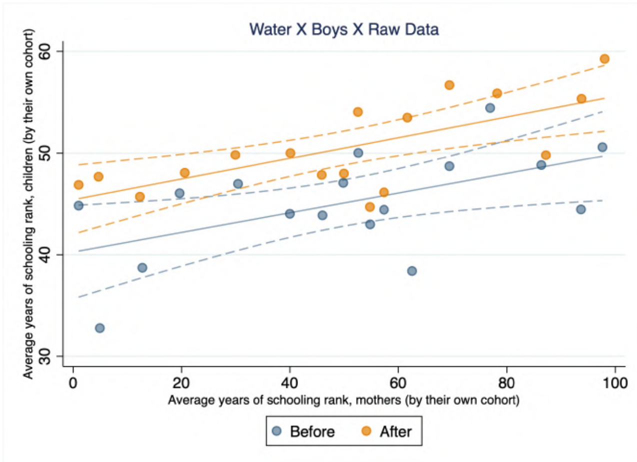
(a) Toilet





(b) Water





Note: The plots present binned scatterplots of the relationship between children's total years of schooling percentile ranks and their mothers' total years of schooling ranks in treated villages before and after being treated. Results for girls and boys are presented in Panel A and B, respectively. Children's and mothers' total years of schooling are ranked in their own birth cohort's education years distribution.

intercept of post-treated villages, this suggests that the education rank of children whose mothers are at the bottom of the education distribution was higher in villages after sanitation programs. This means that the education distribution of children in post-treated villages shifted to the right. Further, Panel A of Figure 7 shows that the relationship between a mother's rank and the child's rank was flattened in villages after toilet programs. The reduction in mother-child associations is larger for girls than for boys. This is consistent with our prior event-study findings that toilet construction programs increased children's educational attainment by more than water improvement programs.[15]

Table (4) Stacked OLS-TWFE, Education Rank Persistence (Time-Varying Rank)

	(1)	(2)	(3)	(4)
	Girls		Boys	
$PostToilet_{vt}$ ×MotherRank$_{iv}$	-0.074*	-0.050**	-0.084**	-0.060***
	(0.039)	(0.024)	(0.034)	(0.019)
$PostWater_{vt}$ ×MotherRank$_{iv}$	-0.006	-0.018	-0.002	0.002
	(0.035)	(0.025)	(0.033)	(0.025)
$MotherRank_{iv}$	0.039	0.098***	0.025	0.056**
	(0.029)	(0.026)	(0.037)	(0.024)
Constant	46.416***	44.252***	45.180***	43.975***
	(1.014)	(0.901)	(1.342)	(0.867)
N (Obs)	88685	88521	110185	110153
N (Clusters)	178	178	180	180
Village FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Cohort FE	N	Y	N	Y

Note: Regression results from Equation 3, showing the estimated associations between the mother's percentile education rank and the children's percentile education rank. All ranks are normalised relative to individuals' own birth cohorts. Standard errors are clustered at the village level.

Next, we present regression results from Equation 3 in Table 4, which estimates changes in mother-child rank-rank correlations before and after the introduction of each program. Our baseline specification (in Columns 1 and 3) controls for village and year fixed effects, while estimates are stable when including birth cohort fixed effects (Columns 2 and 4). The coefficients of the interaction terms of mother's education rank and *PostToilet* are negative and statistically significant, suggesting that the intergenerational persistence is significantly lower in these villages after toilet construction for both girls and boys. From Column 2, we observe that for girls, after the introduction of the toilet program, mother-child rank-rank correlation fell from 0.098 to 0.048, while the correlation fell to around zero for boys (in Column 4). However, we observe no significant changes in education persistence among children in those villages after water plant programs.

4.3.2 Effects on Upward Education Rank Mobility

We have shown that the introduction of the toilet improvements program weakened the link between mothers' and children's education. To better understand whether children born to mothers who have lower

the treated villages) in the control villages, which provides evidence that the difference in pre- and post-treatment rank persistence is not driven by general cohort effects.

[15]For completeness, Appendix Figure A5 presents the association between children's and mothers' education rank in pure control villages; the steeper slopes provide suggestive evidence that there was higher intergenerational education persistence in control villages. A simple regression shows that before treated villages have experienced toilet improvement, the correlation between the mother's and daughter's (son's) education rank is 0.181 (0.122), whereas after that treatment, the correlation is reduced to 0.120 (0.054).

Table (5) Change in Conditional Fraction of Children in Education Quintiles Given Mother Education in Toilet Treated Villages

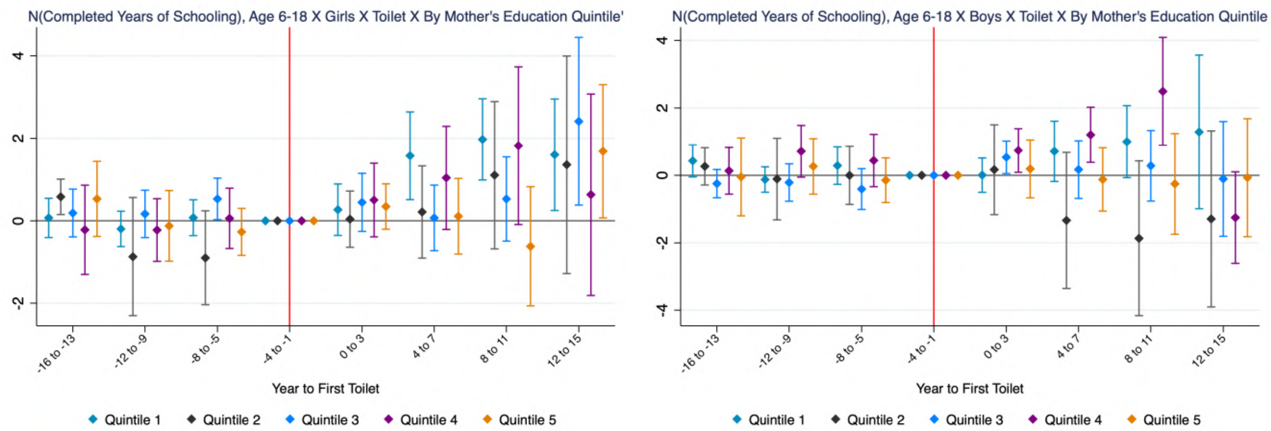
	Mother's Education in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Δ Fraction (Daughters) with Education in...					
Quintile 1	-0.144	0.037	0.047	0.091	0.021
Quintile 2	0.013	0.001	-0.108	-0.169	-0.071
Quintile 3	-0.058	-0.085	-0.085	-0.138	-0.028
Quintile 4	0.016	-0.302	-0.003	0.110	-0.282
Quintile 5	0.172	0.349	0.149	0.106	0.361
Δ Fraction (Sons) with Education in...					
Quintile 1	-0.062	-0.038	-0.006	-0.066	0.009
Quintile 2	-0.023	-0.089	-0.109	-0.182	0.027
Quintile 3	-0.022	-0.216	0.001	-0.130	-0.116
Quintile 4	-0.072	0.118	-0.100	-0.089	-0.086
Quintile 5	0.179	0.224	0.214	0.466	0.166

Table (6) Change in Conditional Fraction of Children in Education Quintiles Given Mother Education in Water Treated Villages

	Mother's Education in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Δ Fraction (Daughters) with Education in...					
Quintile 1	-0.062	-0.089	-0.033	-0.144	-0.130
Quintile 2	-0.082	-0.005	-0.126	0.057	0.065
Quintile 3	0.057	0.097	-0.014	-0.046	-0.013
Quintile 4	-0.010	-0.015	-0.028	0.002	-0.104
Quintile 5	0.097	0.012	0.200	0.131	0.182
Δ Fraction (Sons) with Education in...					
Quintile 1	-0.078	0.067	0.007	-0.079	-0.042
Quintile 2	-0.016	-0.087	-0.076	-0.107	-0.013
Quintile 3	-0.004	-0.031	-0.001	-0.014	-0.129
Quintile 4	0.020	-0.098	-0.016	0.071	0.091
Quintile 5	0.078	0.150	0.086	0.129	0.093

education ranks benefited more from the toilet improvements, we use âtransition matricesâ to measure upward rank mobility. This is a clear and interpretable way to measure whether children were more likely to move up to higher relative positions in the education distribution after being exposed to toilet construction programs. Table 5 presents the intergenerational transition matrices for children in villages affected by toilet improvements. Each element shows the *change* in the fraction of children whose mothers were in a given quintile that moved into each quintile in their birth cohort's education distribution. We find that after toilet construction programs, there was a 17.2% (17.9%) increase in the fraction of daughters (sons) whose mothers' education was in the bottom quintile, and whose education was in the top quintile. Before toilet programs, 4.4% (7.6%) of girls (boys) with mothers in the bottom quintile moved into the top quintile. After toilet improvements, the fraction increased to 21.6% (25.5%) of girls (boys).[16] This indicates increased upward education mobility, defined by the increased probability that children who were born to mothers with low levels of education completed higher levels of schooling.[17] Table 6 presents the transition matrix for boys and girls in villages affected by the water program. We find a much smaller increase in the fraction of daughters (9.7%) and sons (7.8%) whose mothers were in the bottom quintile of the education distribution and who made it to the top quintile. This suggests that the water program also increased upward education mobility, albeit at a much smaller magnitude.

Figure (8) The Effects of Toilet Improvement on Children's Education by Mother's Education Quintile



Note: Event studies of heterogeneous effects on the probability of children's completing grade for age by gender. Stacked TWFE estimators of Equation 1 and their 95% confidence intervals are given. Standard errors are clustered at the village level. The sample includes children who were 6-18 years old when they were surveyed.

To probe the robustness of our prior findings on the effects of toilet programs on intergenerational education persistence, we examine the heterogeneous effects of toilet improvement on children's total years of schooling by mother's educational attainment. This approach makes minimum functional form assumptions about the linearity of program effects based on the mother's education, while allowing us to control for child and year fixed effects. To be consistent with the measurements for upward rank mobility, we look at the heterogeneous effects by the mother's education quintile and estimate our baseline model with the sample of children in each quintile. This helps us answer whether changes in the education mobility pattern we observed can be explained by differential effects on education for children with mothers in different quintiles of the education distribution. Figure 8 plots the event-study estimates, showing a similar pattern to that in the transition matrices. For mothers in the lowest quintile, toilet programs

[16] In the Appendix Table A2, we show the matrices separately for the treated villages before and after toilet improvements.

[17] In Appendix Table A4, we show that the level of upward education mobility implied by the transition matrix for boys and girls in the pure control villages (which didn't experience toilet or water programs) was qualitatively similar to that in toilet treated villages prior to the programs.

increased their children's total years of schooling and the effects are of great magnitude, compared to the effects on children born to mothers who belong to other quintiles, where the effects are not significant and are of small magnitude.

4.3.3 Effects on Intergenerational Education Persistence Across Cohorts

Table (7) Stacked OLS-TWFE, Effects of Early-Life Exposure on Intergenerational Education Persistence

	(1)	(2)	(3)	(4)	(5)	(6)
		Girls			Boys	
Aged	12-50	16-50	18-50	12-50	16-50	18-50
Panel A: Under 18 Exposure						
MotherRank$_{icvt}$ $\times$ $1[AgeToilet \leq 18]$	-0.104*	-0.137	-0.316***	-0.106***	-0.115**	-0.101*
	(0.053)	(0.085)	(0.104)	(0.037)	(0.045)	(0.054)
MotherRank$_{icvt}$ $\times$ $1[AgeWater \leq 18]$	-0.047	-0.105	0.089	-0.060*	-0.037	-0.020
	(0.058)	(0.091)	(0.100)	(0.033)	(0.036)	(0.040)
MotherRank$_{icvt}$	0.207***	0.418***	0.453***	0.181***	0.170***	0.182***
	(0.072)	(0.116)	(0.131)	(0.038)	(0.047)	(0.051)
Panel B: Under 6 Exposure						
MotherRank$_{icvt}$ $\times$ $1[AgeToilet \leq 6]$	-0.158*	-0.245	-0.403*	-0.110**	-0.086	-0.054
	(0.081)	(0.150)	(0.221)	(0.050)	(0.065)	(0.064)
MotherRank$_{icvt}$ $\times$ $1[AgeWater \leq 6]$	-0.041	0.027	0.274*	-0.148***	-0.134**	-0.121**
	(0.090)	(0.105)	(0.152)	(0.047)	(0.054)	(0.058)
MotherRank$_{icvt}$	0.206***	0.412***	0.446***	0.180***	0.169***	0.182***
	(0.071)	(0.117)	(0.132)	(0.038)	(0.047)	(0.051)
Village FE	Y	Y	Y	Y	Y	Y
Cohort FE	Y	Y	Y	Y	Y	Y
Age Quadratic	Y	Y	Y	Y	Y	Y
N (Obs)	12626	8897	7020	30352	25219	22779
N (Clusters)	157	141	128	171	168	167

Note: Regression results from Equation 4, showing the estimated associations between the mother's percentile education rank and the children's percentile education rank. All ranks are normalised relative to individuals' own birth cohorts. *AgeToilet* and *AgeWater* are individuals' age in the years the toilet & water programs were introduced. Standard errors are clustered at the village level.

We next report results from Specification 4, which uses a cohort DiD strategy to estimate the relative effects of being exposed to toilet and water programs at an earlier age (relative to being exposed older) on intergenerational education rank persistence. Table 7 shows the estimated effects of being exposed under the age of 18 (in Panel A) and under the age of six (Panel B) on rank-rank correlations in years of schooling, for individuals who were at least 12, 16, or 18 years old when last observed in our data. In line with prior results using time-varying education ranks, we find that being exposed to toilet programs, aged either under 18 or under 6, significantly reduced correlations between mother and child education rank. The effects are larger in magnitude for girls than for boys, and are larger in magnitude (although much less precisely estimated) for under-6 exposure than for under-18 exposure. For instance, for girls aged 18 to 50, being exposed to a toilet program under the age of 6 reduced mother-child rank correlation from 0.446 to 0.043, while for boys the correlation reduced from 0.182 to 0.128, with the effect of a toilet program being insignificant at conventional levels.

For the safe drinking water programs, we find larger reductions in education rank persistence for boys, with the effects for girls mostly being statistically insignificant. For boys, we continue to find larger effects of under-6 exposure, relative to under-18 exposure. For boys aged 18 to 50, under-6 exposure to water programs reduced rank correlations from 0.182 to 0.061, while it had an insignificant effect for girls. Finally, for the toilet program, we find that the effects are largest when we use the sample of 18- to 50-year-olds who were last observed. As most individuals in rural China finish their schooling before or by the age of 18, this sample is most likely to yield estimates of mother-child correlations in the lifetime stock of human capital.

4.3.4 Effects on Intergenerational Health Persistence and Upward Health Rank Mobility

We find that toilet improvement programs reduced intergenerational education persistence and increased upward education mobility. This may be because the program also affected intergenerational health persistence. A better sanitary environment may break the genetic transmission of the mother's physical health on the child, which, through the causal effect of health on education, could break the mother-child education link (Bhalotra and Rawlings 2013). We directly test this hypothesis by examining changes in intergenerational persistence of an individual's height, which is regarded as a summary measure of child nutrition and disease incidence (Bozzoli et al. 2009). Table 8 estimates changes in rank-rank height persistence (where we use standardised height ranks for mothers' and children's own birth cohorts) using Equation 3. We find that the toilet program had weakened the intergenerational rank persistence of height for girls, indicated by the negative and statistically significant coefficient on $PostToilet \times \text{MotherRank}_{ivt}$. We find little evidence of a similar reduction in intergenerational height persistence between mothers and children after water programs.

Table (8) Stacked OLS-TWFE, Height Rank Persistence (Time-Varying Rank)

	(1)	(2)	(3)	(4)
	Girls		Boys	
$PostToilet \times \text{MotherRank}_{ivt}$	-0.084**	-0.027	0.010	0.024
	(0.037)	(0.026)	(0.034)	(0.018)
$PostWater \times \text{MotherRank}_{ivt}$	0.025	-0.000	0.024	0.014
	(0.031)	(0.021)	(0.033)	(0.020)
$MotherRank_{it}$	0.118***	0.118***	0.082***	0.087***
	(0.033)	(0.025)	(0.031)	(0.023)
Constant	41.865***	41.881***	48.601***	48.401***
	(1.448)	(1.105)	(1.358)	(1.018)
N (Obs)	85619	85619	102998	102998
N (Clusters)	180	180	181	181
Village FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Cohort FE	N	Y	N	Y

Note: Regression results from Equation 3, showing the estimated associations between the mother's percentile height rank and the children's percentile height rank. All ranks are normalised relative to individuals' own birth cohorts. Standard errors are clustered at the village level.

Next, we use transition matrices to study potential changes in the upward mobility of height, without imposing linearity assumptions as our regression specifications do. Table 9 presents transition matrices in villages exposed to toilet programs, which measure the change in the fraction of sons (daughters) in each quintile (given the mothers' height quintile) after the toilet program. When using this approach, we find evidence of an increase in the upward mobility of height after the program for both boys and girls. In particular, there was a 25.0% increase in the fraction of girls who made it to the top quintile of height distribution, given their mothers were in the bottom quintile; similarly, there was a 20.9% increase in the fraction of boys whose mothers were in the bottom quintile and who made it to the top quintile.[18]

[18]Appendix Table A5 presents transition matrices in villages exposed to toilet programs, before and after their

Table (9) Change in Conditional Fraction of Children in Height Quintiles Given Mother Height in Treated Villages

	Mother's Height in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Δ Fraction (Daughters)					
Quintile 1	-0.272	0.138	-0.121	0.093	-0.038
Quintile 2	-0.067	-0.188	-0.159	-0.045	-0.140
Quintile 3	0.031	-0.138	-0.053	-0.151	-0.135
Quintile 4	0.059	0.004	0.174	-0.163	-0.046
Quintile 5	0.250	0.184	0.159	0.266	0.358
Δ Fraction (Sons)					
Quintile 1	-0.175	-0.137	0.018	-0.159	-0.258
Quintile 2	-0.163	-0.027	-0.158	-0.011	-0.055
Quintile 3	0.000	-0.115	-0.047	0.035	-0.024
Quintile 4	0.128	0.083	-0.021	0.014	-0.086
Quintile 5	0.209	0.196	0.208	0.121	0.423

Table (10) Conditional Fraction Change of Children in Height Quintiles Given Mother Height in Water Treated Villages

	Mother's Height in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Δ Fraction (Daughters) with Height in...					
Quintile 1	-0.008	-0.065	-0.130	-0.026	-0.187
Quintile 2	-0.113	-0.004	-0.070	-0.008	-0.074
Quintile 3	0.001	-0.033	-0.022	-0.024	-0.022
Quintile 4	0.071	0.058	0.067	-0.068	-0.018
Quintile 5	0.050	0.044	0.155	0.126	0.302
Δ Fraction (Sons) with Height in...					
Quintile 1	-0.075	-0.090	-0.185	-0.108	-0.042
Quintile 2	0.003	-0.202	0.017	0.026	-0.026
Quintile 3	-0.033	0.009	0.010	0.019	0.059
Quintile 4	0.020	0.024	0.003	0.003	-0.008
Quintile 5	0.085	0.258	0.154	0.060	0.017

Table 10 shows a similar transition matrix for changes in conditional fractions after children were exposed to water programs. In line with the education transition matrices, we find a much smaller, albeit positive, increase in the fraction of children whose mothers were in the bottom height quintile and who made it to the top height quintile. This was a 5.0% increase for girls and an 8.5% increase for boys. In summary, for the toilet program, we find evidence of a reduction in intergenerational height persistence, and an increase in the upward mobility of height, between mothers and daughters, although we find less conclusive evidence for boys. For the water program, we find less support for a reduction in intergenerational height persistence. Based on this, we conclude that the breaking of the link between maternal and child

introduction. Prior to the program, in treated villages, the fraction of daughters (sons) born to mothers in the lowest height quintile remaining in the lowest quintile was 43.9% (32.9%), whereas 2.1% (11.8%) could move into the top quintile. After the program, the fraction of daughters (sons) born to mothers in the lowest education quintile remaining in the lowest quintile changed to 16.7% (27.1%), and 15.4% (32.7%) had reached the top quintile.

health is a potential mechanism through which toilet improvement programs had weakened intergenerational education persistence.

5 Mechanisms

We now investigate potential mechanisms underlying the positive long-term effects on educational attainment up to 20 years after program introduction. First, we examine whether water & sanitation programs affected adult labour supply and led to a reallocation of labour out of agriculture, affecting household income.[19] We focus on both the average program effects and the heterogeneous effects based on whether villages introduced both programs simultaneously. Next, we investigate whether both programs affected children's time use, by reducing the amount of time needed to do housework. Finally, we examine the impacts of both programs on children's health.

5.1 Sanitation Program Effects on Adult Income & Labour Supply

Table (11) Effects of Toilet & Water Programs on Adult Wage Income

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Monthly Wage & Bonus Income			Monthly Wage Income (Excl. 0s)			Average Hourly Wage & Bonus		
Panel A: Average Effect		Toilet	Water		Toilet	Water		Toilet	Water
Average Effect		398.174***	132.944		296.661**	171.298		1.694*	2.210*
		(115.284)	(100.132)		(148.034)	(109.893)		(0.985)	(1.254)
Control Mean Dep. Var.		257.926	213.265		372.554	315.487		1.790	1.316
N (Obs)		176871	176871		66495	66495		158563	158563
N (Clusters)		180	180		176	176		180	180
Panel B: Effect by Program Timing	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water
Average Effect	653.522***	366.185***	61.639	585.140***	277.977*	83.951	2.881***	1.886*	2.055
	(203.885)	(125.486)	(89.074)	(193.318)	(164.967)	(110.491)	(0.726)	(1.015)	(1.299)
Control Mean Dep. Var.	438.233	441.149	426.684	1140.989	1131.366	1127.533	2.622	2.658	2.548
N (Obs)	166011	173702	173702	60598	64133	64133	148913	155652	155652
N (Clusters)	69	148	148	69	144	144	69	148	148

Note: This table shows stacked OLS-TWFE estimates of the effects of toilet/water programs on educational attainment. Regression results from Equation 1. "Hourly wage" is calculated by dividing the annual income by total hours of work per day and total days of work per month in one year. Sample includes adults aged 26 to 50 years old. Standard errors are clustered at the village level.

Improved sanitation facilities can have a positive effect on adult labor supply, by reducing the amount of time spent on housework, water collection, and by shifting households out of livestock rearing and other agricultural activities (Wang and Shen 2022). Indeed, field observations by the World Bank during its collaboration for the water program suggest that the program had transformative economic impacts: "Small businesses, mostly food related, proliferated in all areas, many operated by women who have been relieved of water carrying. Larger scale commercial and industrial development has also accelerated with the availability of water and new construction was visible everywhere(World Bank Group 2010)."

If the programs increased adult incomes, this could then raise their investments in education.[20] We use individuals' reported monthly wage and bonus income to investigate this. We limit our analysis to working-age (aged 26-50) individuals aged.[21] Results in Panel A of Table 11, we report average effect of

[19]We are unable to examine the impacts on educational expenditures with the current dataset, but we hope to conduct such analysis in future.

[20]Ideally, we would have also examined the impact on educational investments; however, due to data limitations, we were unable to do so.

[21]The age range of 18 and 25 is a period in which individuals are in a school-to-work transition for rural youth in China (Zhang and Xu 2016). Additionally, we restrict the sample to individuals below the age of 50, as the income profile may systematically differ between retired and non-retired individuals, and the retirement age for men is 60, while for women working as civil servants is 55 and other working women is 50 in China. Therefore, we restrict to individuals aged 26-50.

toilet and water programs on monthly wage income, and on hourly wage. We find a large and significant increase in monthly and hourly wage. We focus on estimates excluding zeros and separately investigate changes in labour supply. On average, when excluding zeros, toilet program increased monthly wage by almost 300 RMB (80% of control mean). Hourly wage also increased by 1.7 RMB per-hour (95% of control mean), indicating an increase in labour productivity. In Panel B, we examine potential complementarities by comparing the magnitude of income effect in simultaneous introduction villages *vis a vis* non-simultaneous villages. We consistently find larger income effects in simultaneous introduction villages (larger effects on both monthly and hourly wages), suggesting positive complementarity in income effects.

Table (12) Effects of Toilet & Water Programs on Adult Labour Supply

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Hours Worked/Week			Pr(Farmer)			Pr(Manual Job)			Pr(Service Jobs)		
Panel A: Average Effect		Toilet	Water		Toilet	Water		Toilet	Water		Toilet	Water
Average Effect		6.009***	2.068		-0.050*	-0.062**		0.051**	0.021		0.031*	0.018
		(1.654)	(2.222)		(0.026)	(0.028)		(0.026)	(0.021)		(0.017)	(0.014)
Control Mean Dep. Var.		39.453	40.960		0.660	0.727		0.155	0.123		0.058	0.036
N (Obs)		146444	146444		336506	336506		336506	336506		336506	336506
N (Clusters)		180	180		180	180		180	180		180	180
Panel B: By Program Timing	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water
Average Effect	8.356***	5.906***	1.772	-0.018	-0.078***	-0.076***	-0.037	0.082***	0.039**	-0.004	0.045**	0.024*
	(3.009)	(1.692)	(2.097)	(0.034)	(0.028)	(0.027)	(0.052)	(0.026)	(0.018)	(0.026)	(0.019)	(0.014)
Control Mean Dep. Var.	35.560	35.703	35.410	0.710	0.704	0.715	0.125	0.128	0.123	0.046	0.047	0.045
N (Obs)	137839	143849	143849	316978	332100	332100	316978	332100	332100	316978	332100	332100
N (Clusters)	69	148	148	69	148	148	69	148	148	69	148	148

Note: This table shows stacked OLS-TWFE estimates of the effects of toilet/water programs on adult labour supply and probability of working in different occupations. Regression results from Equation 1. "Hours Worked/Week" refer to reported hours worked last week. Sample includes adults aged 26 to 50 years old. Standard errors are clustered at the village level.

To further explore the drivers of complementarities in income effects, we test for complementarities in the effects on individual labour supply and on occupational choice. If the combination of toilet and water improvements substantially reduced the amount of time spent on collecting water, cleaning house, we would expect a bigger increase in labour supply from the simultaneous introduction. Similarly, if the combination of sanitary toilets and tap water supply was essential to free up individuals' time for non-agricultural activities (which had more stable time commitments), we should expect larger effects on shift outside of agriculture from their simultaneous introduction.

Panel A of Table 12 presents the average effects of both programs on labour supply and occupational choice (agriculture, manual, and service jobs). We find that the toilet program had much larger positive effect on individual labour supply and on the probability of working in manual or service jobs on average. Panel B shows heterogeneous effects by timing of program introductions. We find positive complementarities in labour supply, but we find no evidence of larger effect on non-agricultural occupational change in villages that introduced both programs simultaneously. This suggests the main margin of complementarity (that helps explain complementarity in positive income effects) is via the role of joint provision of toilet and water improvements in freeing up individuals' time and allowing them to increase their labour supply.

5.2 Changes in Children's Time Use

Another potential driver of observed effects is a change in child work. If household incomes increased from higher adult earnings, this could reduce the need for children to work. Further, the general reduction in time required to collect water & engage in cleaning could reduce time spent on housework. Reduction in child work could raise the amount of time available for study, hence improving learning.

To test this, we use an extensive margin variable of child labor supply, which indicates whether a child is currently working or not, to examine the impact of toilet and water programs on child labor.[22] To align

[22]Since data on children's work time is only available for those who are working, we are unable to assess the intensive margin of child labor due to limited observations.

with our main results, we define child labor as work performed by children aged 6-18 years. Columns 2 and 3 of Panel A in Table 13 present the average effects of toilet/water programs on child labor, estimated using our baseline specification with an indicator of current child employment as the dependent variable. The results indicate that toilet improvement significantly reduces children's labor force participation by 32 percentage points, while water improvement had little significant impact on child labor.[23] We then examine examine children's domestic work, often considered a hidden form of child labor (Webbink et al. 2012). We define an indicator for children's housework, including activities such as buying or preparing food, cleaning the house, or washing clothes. Columns 5 and 6 display the results, indicating that neither toilet nor water improvement has a significant effect on children's housework. To gain insights into children's overall time and effort allocation, we further assess changes in their leisure activities. We employ children's participation in exercises or activities either in or outside of school as a proxy for their leisure. Once again, we do not observe a significant change in leisure (Coloumns 7 and 8). Taken together, these findings suggest that the programs' effects on education can be partly attributed to a shift away from their labor force participation rather than changes in their involvement in housework or leisure activities. This could explain the absence of complementarities in reduction in child work from the simultaneous introduction of both programs (in Panel B): the toilet program (rather than water program) may have been critical at increasing adult labour supply and crowding out child work.

Table (13) Effects of Toilet & Water Programs on Child Time Use

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Currently Working			Housework			Exercise/Activities		
Panel A: Effect of Each Program		Toilet	Water		Toilet	Water		Toilet	Water
Average Effect		-0.324***	0.042		-0.084	0.171		0.012	0.053
		(0.070)	(0.067)		(0.099)	(0.128)		(0.040)	(0.048)
Control Mean Dep. Var.		0.742	0.759		0.883	0.901		0.951	0.939
N (Obs)		40044	40044		21229	21229		68029	68029
N (Clusters)		147	147		142	142		175	175
Panel B: Effect by Program Timing	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water
Average Effect	-0.184*	-0.349***	0.006	0.056	-0.074	0.105	0.120	0.005	0.030
	(0.107)	(0.088)	(0.071)	(0.263)	(0.094)	(0.096)	(0.126)	(0.037)	(0.041)
Control Mean Dep. Var.	0.780	0.781	0.781	0.972	0.972	0.972	0.922	0.922	0.921
N (Obs)	37113	39519	39519	19658	20953	20953	63809	67202	67202
N (Clusters)	48	133	133	55	124	124	68	144	144

Note: This table shows stacked OLS-TWFE estimates of the effects of toilet/water programs using 1. The sample includes children aged 6-18 in the survey year. "currently working" indicates whether the child either is employed in former labour market or in household business; "Housework" indicates whether the child does housework such as buying/preparing food, cleaning house, or washing clothes. "Exercise/Activities" indicates whether the child does any exercise or activities either in school or outside of school. Standard errors are clustered at the village level.

5.3 Changes in Child Health

Another potential channel underlying the long-term effects of water and sanitation programs is that they persistently improved children's health, which then led to increased formation of human capital. Prior work has established the role early-life access to better drinking water in improving later-life cognitive and education outcomes (Chen et al. 2022, Zhang and Xu 2016).

We measure child health using parents' reported sickness over the last two weeks of each survey wave (any sickness, any infection, any fever/diarrhea symptoms). These provide measures of direct impacts on children's disease burdens and are extensively studied in prior evaluations of WASH programs (e.g: Alsan and Goldin 2019). We then look at children's standardized height for age. Child height has been identified as a predictor of cognitive skills, education (Case and Paxson 2008, Spears 2012), and earnings, and is viewed as a summary measure that reflects disease and nutrition burden in childhood (Bozzoli et al. 2009).

[23]It is worth noting that the relatively high mean of child labor in our control sample, around 0.7, is attributed to the inclusion of children's work within household businesses, both on and off the farm, which is common in rural China. This measure does not contain housework.

We also look at children's weight for age and BMI indices as additional measures of a child's nutritional status (and an indicator of whether the child had a healthy weight).

Table (14) Effects of Toilet & Water Programs on Children's Health, Aged 6-18

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Height for Age			Weight for Age			Recently Sick			Fever/Diarrhea		
Panel A: Effect of Each Program		Toilet	Water		Toilet	Water		Toilet	Water		Toilet	Water
Average Effect		0.0008	0.026**		0.007	0.028		0.022	0.014		-0.043	0.012
		(0.010)	(0.012)		(0.030)	(0.034)		(0.020)	(0.023)		(0.037)	(0.046)
Control Mean Dep. Var.		0.453	0.456		0.474	0.550		0.046	0.036		0.119	0.120
N (Obs)		127622	127622		128692	128692		155236	155236		47002	47002
N (Clusters)		180	180		180	180		180	180		175	175
Panel B: Effect by Program Timing	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water	Simult.	Toilet	Water
Average Effect	0.008	0.005	0.024**	0.067	-0.001	0.026	0.053	0.016	0.011	0.078	-0.050	-0.006
	(0.024)	(0.010)	(0.011)	(0.062)	(0.032)	(0.032)	(0.065)	(0.021)	(0.022)	(0.066)	(0.037)	(0.037)
Control Mean Dep. Var.	-0.001	0.000	-0.001	0.001	0.000	0.001	0.078	0.078	0.078	0.100	0.100	0.099
N (Obs)	119658	126148	126148	120618	127212	127212	145595	153457	153457	44243	46507	46507
N (Clusters)	69	148	148	69	148	148	69	148	148	69	143	143

Note: This table shows stacked OLS-TWFE estimates of the effects of toilet/water programs on children's anthropometrics (height for age, weight for age) and reported sickness. Regression results from Equation 1. Sample includes children aged 6 to 18 years old. Standard errors are clustered at the village level.

Table 14 presents the static stacked DiD estimates. We find limited evidence of a significant reduction in child sickness (Column 1). We indeed find a significant increase in standardised height for age from the water program, but find no significant increase in height for age index from the toilet program.

Further, we find little change in probability of being sick and an insignificant reduction in the probability of having fever or diarrhea after the toilet program. Taken together, improvements in child health may not be the main mechanism behind our observed effects on education. An alternative explanation, which rhymes with Chen et al. (2022), is that the health benefits of exposure to water and sanitation are limited to those during early-life.[24]

6 Robustness Checks

Migration Concern.— Our research period spans from the 1980s to the 2010s, during which China witnessed an unprecedented urban-rural migration phenomenon. Considering that migration might be systematically correlated with water and sanitation programs, it is crucial to address the potential bias in our estimates. To account for the confounding effect of migration, we employ two indicators. First, we use whether the child is now living in the household, which captures whether the child is living with any household members, such as adults. Second, we consider whether the child is living with the mother in the household, recognizing the significant role the mother plays in investing in children's human capital. The statistically insignificant coefficients for both toilet and water improvements, as presented in Table 15, provide evidence that neither toilet improvement nor water improvement influences the probability of children's migration and, consequently, do not bias our estimates.

Alternative Cutoffs.—Our baseline definition of village-level program exposure is based on two conditions: Either a village reached a 75% coverage rate of sanitary toilets/safe drinking water in the first survey year or there was a 15% increase in coverage rate over a period of a year. To check the robustness of treatment definitions and confirm that our results are not driven by arbitrary cutoffs, we estimate our baseline specification (1) using alternative definitions. We test 6 treatment definitions, which are combinations of a 50% or a 90% coverage rate in the first survey year, and a 10, 15, and 20 percentage point increase per year. Table A6 reports the corresponding results. Reassuringly, across different combinations of our

[24] In an earlier version of our working paper, we adopted a cohort DiD estimator to look at the effect of being exposed early in life (under 5 years old) on children's probability of falling sick and their anthropometric outcomes, we indeed find significant reduction in sickness, increase in height for age index, and a significant increase in calories and protein intake.

Table (15) Stacked DID for the effects on child migration

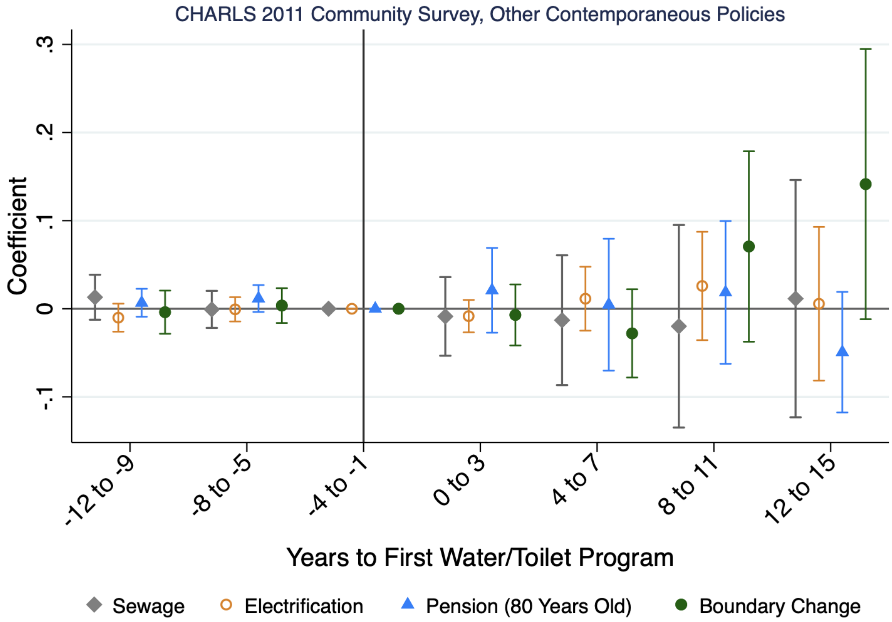
	Child's living in the house		Child's living with mother	
	(1)	(2)	(3)	(4)
	Girls	Boys	Girls	Boys
Toilet Effect	0.014	-0.028	-0.002	-0.042
	(0.043)	(0.033)	(0.037)	(0.035)
Water Effect	0.014	-0.028	-0.035	-0.006
	(0.043)	(0.033)	(0.030)	(0.031)
Mean of Dep. Var.	0.787	0.815	0.736	0.756
N (Obs)	59114	72010	107132	131531
N (Clusters)	175	175	178	179

Note: This table shows stacked OLS-TWFE estimates of the effects of toilet/water programs using 1. The sample includes children aged 6â18 in the survey year. Dependent variables are a dummy variable for childrenâs currently living in the house in Columns 1 and 2, a dummy variable for living with mother in the house in Columns 3 and 4. Standard errors are clustered at the village level. ***p¡0.01, **p¡0.05, *p¡0.1.

alternative treatment exposure either changing the baseline coverage rate requirement, changing the size of the annual increase, or both had little effect on the size or statistical significance of our results on education.

Contemporaneous Policies.—We assess the possibility that our estimated program effects are confounded by the implementation of other government policies that happened around the same time and targeted the same villages. This is a reasonable concern if the government used a multi-pronged approach to improve local sanitation. We first address the concern that the timing of water and sanitation programs may be correlated with introductions of other government policies at the village level, which will bias our estimates. Using the 2011 CHARLS community data, we estimate Sun and Abraham (2021) event studies of the changes in the probabilities that a village was exposed to other programs after it introduced water and toilet programs. The reference group is villages that never had water and toilet programs up to 2011 (survey year). Figure 9 presents the results, which clearly show no evidence of differential trends in program implementation either before or after the water and toilet programs were introduced. These provide evidence that our estimates are unlikely to be confounded by other contemporaneous policies.

Figure (9) Sun-Abraham (2021) Event Study Estimates of Effects of Toilet & Water Programs on Other Programs



Note: Event-study coefficients estimated using the Sun-Abraham (2021) estimator. The parameter of interest is the effect of the introduction of toilet and water programs on the probability that a village had introduced any of the four other programs. The "control"/comparison group is villages that were never affected by the toilet and water program up to the survey year. The sample includes 450 communities (rural villages or near rural towns) surveyed by the China Health and Retirement Longitudinal Study in 2011. Source: CHARLS 2011 Community Survey

Table (16) Stacked OLS-TWFE, Changes in other City-level Public Goods

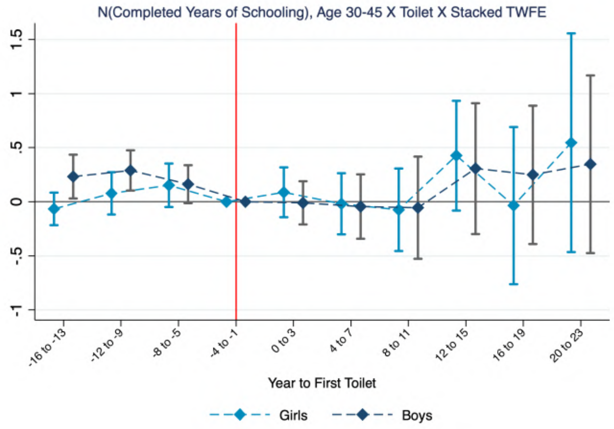
Outcome (in Logs)	Hospital Beds	Health Centres	Health Workers	Doctors	Preschools	Primary	Secondary
Toilet	-0.040*	0.066	0.010	0.029	-0.512	-0.094	0.013
	(0.022)	(0.065)	(0.028)	(0.033)	(0.586)	(0.078)	(0.088)
Water	-0.031	-0.011	-0.025	0.025	0.428	0.024	-0.009
	(0.025)	(0.097)	(0.035)	(0.019)	(0.404)	(0.063)	(0.135)
N (Obs)	1669	2949	1238	1697	2659	2423	8999
N (Clusters)	26	26	20	24	30	24	42
Adjusted R^2	0.995	0.878	0.997	0.997	0.742	0.988	0.910
City FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y

Note: The table shows stacked OLS-TWFE DiD regression results on changes in the supply of other city-level public goods following the implementation of toilet or water programs. The sample is a city-year panel data set, where we define city-level program exposure based on the first year any village in the city had introduced water/toilet programs. Heteroskedasticity-robust standard errors are clustered at the city level

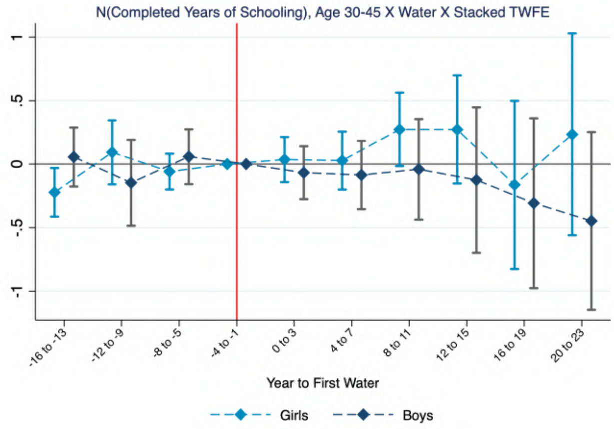
We then test changes in public goods provision after the introduction of these two programs. We use annual statistical yearbooks to construct a district-level imbalanced panel data set covering 1989 to 2015. We have measures on school supply (number of preschools, primary, and secondary schools), and health infrastructures (number of hospital beds, doctors and nurses, and health centers). Given the level of statistical records, we observe these variables at the city level, which is higher than our level of program exposure definition. We thus take the first year any village in a given city was affected by the water or toilet program as the city's treatment year. We estimate the same stacked DiD specification on the city-level panel data set to test for potential changes in the supply of these public goods that could have affected children's human capital. As reported in Table 16, we find little evidence of significant changes in these two types of public goods supply in cities after they implemented the water and sanitation program. Although there was a small decline in the supply of hospital beds, this was not reflected in changes in healthcare sector staff or health centers.

Figure (10) Event-study for the effects on years of schooling for cohorts aged 30-45

(a) Panel A



(b) Panel B

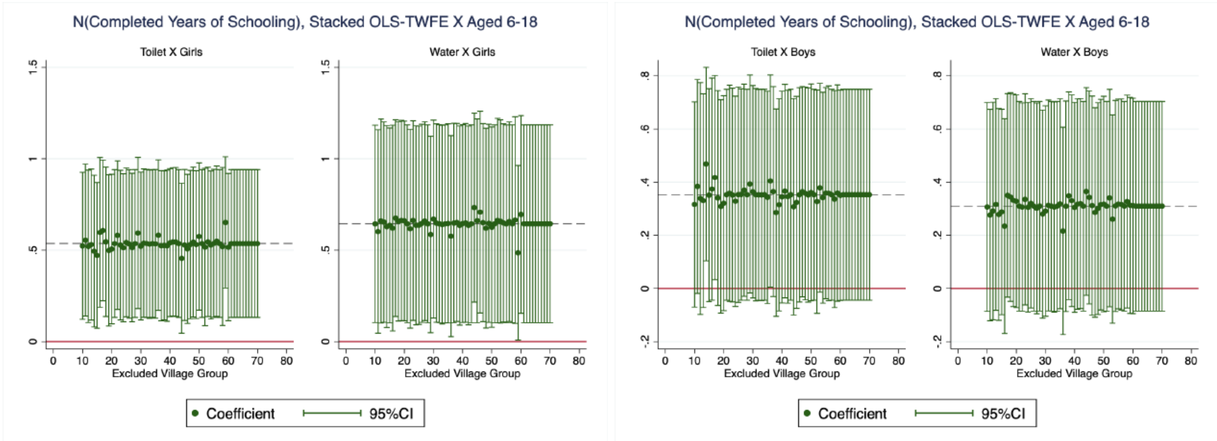


Note: Event studies of heterogeneous effects on the probability of children's years of schooling. Stacked TWFE estimates from Equation 1 and their 95% confidence intervals are given. Panels A and B plot for coefficients for the toilet program and water program, respectively. Standard errors are clustered at the village source. The sample includes children who were 30-45 years old when they were surveyed.

Placebo Tests for Older Cohorts.—Our generalized difference-in-differences strategy accounts for individual- and village-level time-invariant heterogeneity (through the inclusion of individual fixed effects) and common shocks (through year fixed effects). Key threats to our identification come from other time-varying shocks correlated with both the timing of the introduction of sanitation programs and children's long-run outcomes. We perform a placebo test to check for the presence of other time-varying unobservables. Specifically, we use a sample of individuals aged 30 to 45 in each survey year, who were too old (at the time of the programs' introduction) to have their educational attainment affected. This makes them a plausible placebo sample, as we can see whether the treated villages exhibited significant differences in *education trends*, which would inform us of the presence of unobservable time-varying shocks likely biasing our estimates. We rerun our baseline event-study models using this placebo sample, and the results are reported in Figure 10. Event-study graphs show no evidence of significant effects of toilet and/or water programs on the educational attainment of this sample of older individuals, providing evidence against potential unobservable shocks that bias our estimates.[25]

[25] We do not examine school attendance and the probability of completing grade for age with a placebo sample, because these two variables are not available for nonschool-age individuals.

Figure (11) Stacked OLS-TWFE Estimate, Dropping One Village Group at a Time



Note: Average treatment effect estimates (formed by summing up event-study coefficients) from stacked OLS-TWFE specifications. Each panel compares boys/girls in villages that implemented only water/toilet programs with those in villages that had neither program. Each coefficient is from a sample dropping one group of villages that introduced water/toilet programs in a given year. There are 61 "event-source" groups in total. The black dashed line is the average point estimate across all leave-out samples. The sample includes children aged 6 to 18 at the time they were surveyed.

Table (17) Stacked OLS-TWFE, Effects on Education for Placebo Cohorts

	Toilet		Water	
	Girls	Boys	Girls	Boys
	Placebo 1: Exposed Post-18			
Post	0.027	0.011	-0.071	0.020
	(0.086)	(0.073)	(0.086)	(0.069)
	Placebo 2: Exposed 18-22			
Post	0.616	0.436	0.141	-0.149
	(0.436)	(0.433)	(0.407)	(0.526)
N (Obs)	457210	453740	457210	453740
Individual FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y

Note: The table shows stacked OLS-TWFE DiD regression results (from Equation 1), using a sample of individuals who were (1) exposed to either program after the age of 18, and (2) exposed between the ages of 18 and 22. Heteroskedasticity-robust standard errors are clustered at the village level.

We conduct a second placebo test by estimating the same stacked DiD specifications for two cohorts too old to be affected: all individuals who were exposed to both programs after they turned 18, and those exposed to programs between the ages of 18 and 22. If there are other time-varying unobservable shocks affecting treated villages, we would expect this to be reflected in changes in educational outcomes for those cohorts too old to have their education affected. While those exposed between the ages of 18 and 22 could still be at university (and thus continue to experience increased education effects), we believe this is unlikely in the rural Chinese setting. This placebo test is also useful for testing potential changes in migration following the two programs: If there were significant migration flows, we should expect this to be reflected in changes in the composition of the village-level population, such as significant changes in the education of village members. Our results, reported in Table 17, show there were small and statistically insignificant changes in educational outcomes for both placebo cohorts (all individuals exposed post-18, and those exposed between the ages of 18 and 22). This further helps address concerns regarding unobservable time-varying shocks and migration responses.

Leave One Out Estimates.—We next show that our estimates are not dependent on any group of villages that implemented their water and sanitation programs in a given year. We estimate our baseline stacked OLS-TWFE specifications, each time dropping one group (defined by ”event source”) of villages based on when they introduced their water/toilet construction programs (there are 61 groups in total). Figure 11 plots estimated coefficients on the toilet and water programs and their 95% confidence intervals, which provides evidence that our estimates are highly robust to dropping any single village group.

7 Conclusion

In rural China, children are at risk of not reaching their full potential due to malnutrition and adverse health conditions. As a result, more than a third of children under the age of three are at risk of developmental delay (UNICEF 2018). Among the causes of adverse health, unimproved water and sanitation systems are important factors. In this paper, we leverage the staggered introduction of nationwide public programs to subsidize household sanitary toilets and increase access to safe drinking water (primarily through building water plants), to estimate the long-run effects of improved sanitation and safe drinking water access on children’s long-run human capital, which we measure through educational attainment, physical health, anthropometric outcomes, and nutritional status. One key contribution of our study is that we not only investigate the average effects of each program but also probe their interaction effects. We find that the toilet and water program have positive complementarities, where the simultaneous implementation of these two programs have larger effects on children’s educational attainment, compared to different program introduction timing. Further, we also provide evidence that if effects of toilet program was the most significant if it was introduced 10 years below the age of water plant.

Another novel contribution is to establish that the programs not only benefited a child on average, but had strong distributional effects by weakening the intergenerational education and height persistence between mothers and children. Our results indicate that both toilet and water programs increased children’s educational attainments, with larger effects for girls than for boys. Moreover, toilet improvements reduced intergenerational education persistence for children born to mothers in villages that have experienced toilet construction subsidies. We provide supportive evidence that this was potentially driven by improved child health, irrespective of the mother’s health, which weakened intergenerational health persistence, and by differential improvements in child health after being exposed to the program below the age of 6.

Putting our results into perspective, our finding that a sanitation program can change intergenerational mobility corresponds well with the existing literature. For instance, Bütikofer et al. (2018) find that the Norwegian oil boom shock increased intergenerational mobility for cohorts entering the labor market at the beginning of the boom in the most affected labor markets, and Feigenbaum (2015) finds that the Great Depression lowered intergenerational mobility for the sons that grew up in the cities, with severe downturns in the US. A key difference in our context is that we show the importance of public sanitation programs, which have largely been advocated on the grounds of improving child health and as a kind of fundamental necessity, and can be quantitatively important in shaping intergenerational mobility in socioeconomic outcomes. While the programs we study are unique in that they were gradually rolled out across almost 20 years, an important question we wish to address in ongoing work is whether more recent sanitation programs implemented in other countries had similar effects on intergenerational mobility. This will contribute to building a body of empirical evidence that improves our understanding of the net benefits of WASH programs across generations.

In 2020, 74% of the global population still lacked safely managed drinking water services and 46% of the worldâs population lacked safe sanitation. On a global scale, there is a collaborative effort among governments and organizations to ameliorate the WASH infrastructure, with the ultimate goal of ensuring universal access to safe drinking water and adequate sanitation. Our finding that WASH programs can have long-term health and educational benefits can serve as additional motivation for policymakers to subsidize WASH programs. Furthermore, our study reveals that WASH programs can have a positive impact on intergenerational mobility, implying that once up and running, public WASH programs can significantly level the playing field in socioeconomic outcomes across generations.

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A Appendix: Additional Figures and Tables

Table (A1) Village-level Summary Statistics, Children Aged 6-18

	Treated			Control			Regression		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Coef.	Std. Err.	P-Val
Panel A: Villages with Only Toilet Programs VS Never Treated Villages									
Total years of schooling	5.23	1.30	114	5.38	1.74	263	0.06	0.25	0.82
School attendance	0.77	0.19	114	0.80	0.21	264	-0.02	0.03	0.50
Prob(Completing grade-for-age)	0.35	0.17	114	0.33	0.22	272	0.02	0.03	0.51
Mother total years of schooling	5.63	2.10	99	6.74	2.27	241	-0.66	0.60	0.28
Prob(Sickness)	0.09	0.17	111	0.07	0.17	261	-0.04	0.02	0.03
Prob(Contagious diseases)	0.39	0.43	79	0.20	0.35	188	-0.01	0.05	0.86
Height	136.18	11.76	108	141.33	12.99	259	1.39	1.34	0.30
Weight	32.05	8.56	110	37.19	10.75	258	3.20	1.03	0.00
BMI	16.67	1.77	108	17.77	2.39	258	1.04	0.20	0.00
Household income	11861.11	14231.28	114	15357.42	21461.53	272	8906.59	2612.44	0.00
Panel B: Villages with Only Water Programs VS Never Treated Villages									
Total years of schooling	5.13	1.54	136	5.38	1.74	263	-0.49	0.28	0.09
School attendance	0.76	0.16	137	0.80	0.21	264	-0.01	0.02	0.62
Prob(Completing grade-for-age)	0.36	0.17	137	0.33	0.22	272	-0.03	0.03	0.36
Mother total years of schooling	4.62	2.48	109	6.74	2.27	241	-1.31	0.54	0.02
Prob(Sickness)	0.05	0.14	128	0.07	0.17	261	-0.02	0.03	0.39
Prob(Contagious diseases)	0.30	0.42	61	0.20	0.35	188	-0.16	0.06	0.01
Height	136.39	13.52	128	141.33	12.99	259	0.44	1.86	0.81
Weight	34.15	8.41	129	37.19	10.75	258	1.36	1.40	0.34
BMI	17.67	1.82	128	17.77	2.39	258	0.64	0.43	0.14
Household income	6563.60	8403.42	137	15357.42	21461.53	272	1322.79	2311.81	0.57

Note: The table shows summary statistics (at the village-year) level, using a sample of 6-18 years old at each survey year. The summary statistics are based on the sample of observations prior to the introduction of water/toilet programs. In Panel A, we compare the toilet-only to never either villages; in Panel B, we compare water-only to never either villages. Regression coefficients, standard errors and p-values on the right are from regressions of outcomes on treatment indicators, controlling for county and year fixed effects. Heteroskedasticity-robust standard errors are clustered at the village level.

Table (A2) Conditional Fraction of Children in Education Quintiles Given Mother Education in Toilet Treated Villages

Panel A: Treated Villages Prior to Treatment					
			Mother's Education in...		
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Education in...					
Quintile 1	0.306	0.224	0.224	0.225	0.137
Quintile 2	0.203	0.172	0.244	0.169	0.157
Quintile 3	0.247	0.216	0.220	0.191	0.235
Quintile 4	0.200	0.302	0.201	0.258	0.392
Quintile 5	0.044	0.086	0.110	0.157	0.078
Fraction (Sons) with Education in...					
Quintile 1	0.254	0.278	0.253	0.166	0.222
Quintile 2	0.193	0.209	0.232	0.182	0.127
Quintile 3	0.256	0.296	0.232	0.230	0.254
Quintile 4	0.221	0.122	0.196	0.289	0.286
Quintile 5	0.076	0.096	0.088	0.134	0.111
Panel B: Treated Villages Post-treatment					
			Mother's Education in...		
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Education in...					
Quintile 1	0.162	0.261	0.272	0.316	0.159
Quintile 2	0.216	0.174	0.136	0.000	0.085
Quintile 3	0.189	0.130	0.136	0.053	0.207
Quintile 4	0.216	0.000	0.198	0.368	0.110
Quintile 5	0.216	0.435	0.259	0.263	0.439
Fraction (Sons) with Education in...					
Quintile 1	0.191	0.240	0.247	0.100	0.231
Quintile 2	0.170	0.120	0.123	0.000	0.154
Quintile 3	0.234	0.080	0.233	0.100	0.138
Quintile 4	0.149	0.240	0.096	0.200	0.200
Quintile 5	0.255	0.320	0.301	0.600	0.277

Table (A3) Conditional Fraction of Children in Education Quintiles Given Mother Education in Water Treated Villages

Panel A: Treated Villages Prior to Treatment					
			Mother's Education in...		
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Education in...					
Quintile 1	0.311	0.225	0.218	0.223	0.208
Quintile 2	0.267	0.174	0.265	0.107	0.221
Quintile 3	0.177	0.208	0.184	0.289	0.195
Quintile 4	0.180	0.270	0.286	0.215	0.260
Quintile 5	0.066	0.124	0.047	0.165	0.117
Fraction (Sons) with Education in...					
Quintile 1	0.314	0.231	0.277	0.243	0.158
Quintile 2	0.229	0.231	0.251	0.189	0.263
Quintile 3	0.189	0.185	0.199	0.288	0.289
Quintile 4	0.189	0.269	0.210	0.189	0.105
Quintile 5	0.080	0.085	0.063	0.090	0.184
Panel B: Treated Villages Post-treatment					
			Mother's Education in...		
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Education in...					
Quintile 1	0.249	0.136	0.185	0.079	0.078
Quintile 2	0.185	0.169	0.139	0.164	0.286
Quintile 3	0.234	0.305	0.170	0.243	0.182
Quintile 4	0.170	0.254	0.259	0.217	0.156
Quintile 5	0.162	0.136	0.247	0.296	0.299
Fraction (Sons) with Education in...					
Quintile 1	0.236	0.297	0.284	0.164	0.116
Quintile 2	0.213	0.144	0.175	0.082	0.250
Quintile 3	0.185	0.153	0.198	0.274	0.161
Quintile 4	0.209	0.171	0.195	0.260	0.196
Quintile 5	0.157	0.234	0.149	0.219	0.277

Table (A4) Conditional Fraction of Children in Education Quintiles Given Mother Education in Pure Control Villages

	Mother's Education in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Education in...					
Quintile 1	0.254	0.199	0.235	0.124	0.117
Quintile 2	0.237	0.204	0.224	0.152	0.105
Quintile 3	0.192	0.230	0.205	0.215	0.175
Quintile 4	0.229	0.231	0.211	0.313	0.314
Quintile 5	0.088	0.137	0.124	0.195	0.288
Fraction (Sons) with Education in...					
Quintile 1	0.268	0.259	0.249	0.127	0.205
Quintile 2	0.194	0.195	0.208	0.186	0.176
Quintile 3	0.214	0.227	0.222	0.225	0.186
Quintile 4	0.228	0.204	0.218	0.310	0.216
Quintile 5	0.095	0.114	0.103	0.152	0.217

Table (A5) Conditional Fraction of Children in Height Quintiles Given Mother Height in Toilet Treated Villages

Panel A: Treated Villages Prior to Treatment					
	Mother's Height in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Height in...					
Quintile 1	0.439	0.206	0.280	0.193	0.102
Quintile 2	0.213	0.250	0.227	0.217	0.203
Quintile 3	0.199	0.294	0.235	0.265	0.390
Quintile 4	0.129	0.184	0.189	0.277	0.237
Quintile 5	0.021	0.066	0.068	0.048	0.068
Fraction (Sons) with Height in...					
Quintile 1	0.329	0.286	0.205	0.266	0.258
Quintile 2	0.259	0.176	0.241	0.190	0.180
Quintile 3	0.153	0.221	0.186	0.215	0.180
Quintile 4	0.141	0.151	0.132	0.165	0.180
Quintile 5	0.118	0.166	0.236	0.165	0.202
Panel B: Treated Villages Post-treatment					
	Mother's Height in...				
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Fraction (Daughters) with Height in...					
Quintile 1	0.167	0.344	0.159	0.286	0.064
Quintile 2	0.146	0.062	0.068	0.171	0.064
Quintile 3	0.229	0.156	0.182	0.114	0.255
Quintile 4	0.188	0.188	0.364	0.114	0.191
Quintile 5	0.271	0.250	0.227	0.314	0.426
Fraction (Sons) with Height in...					
Quintile 1	0.154	0.149	0.222	0.107	0.000
Quintile 2	0.096	0.149	0.083	0.179	0.125
Quintile 3	0.154	0.106	0.139	0.250	0.156
Quintile 4	0.269	0.234	0.111	0.179	0.094
Quintile 5	0.327	0.362	0.444	0.286	0.625

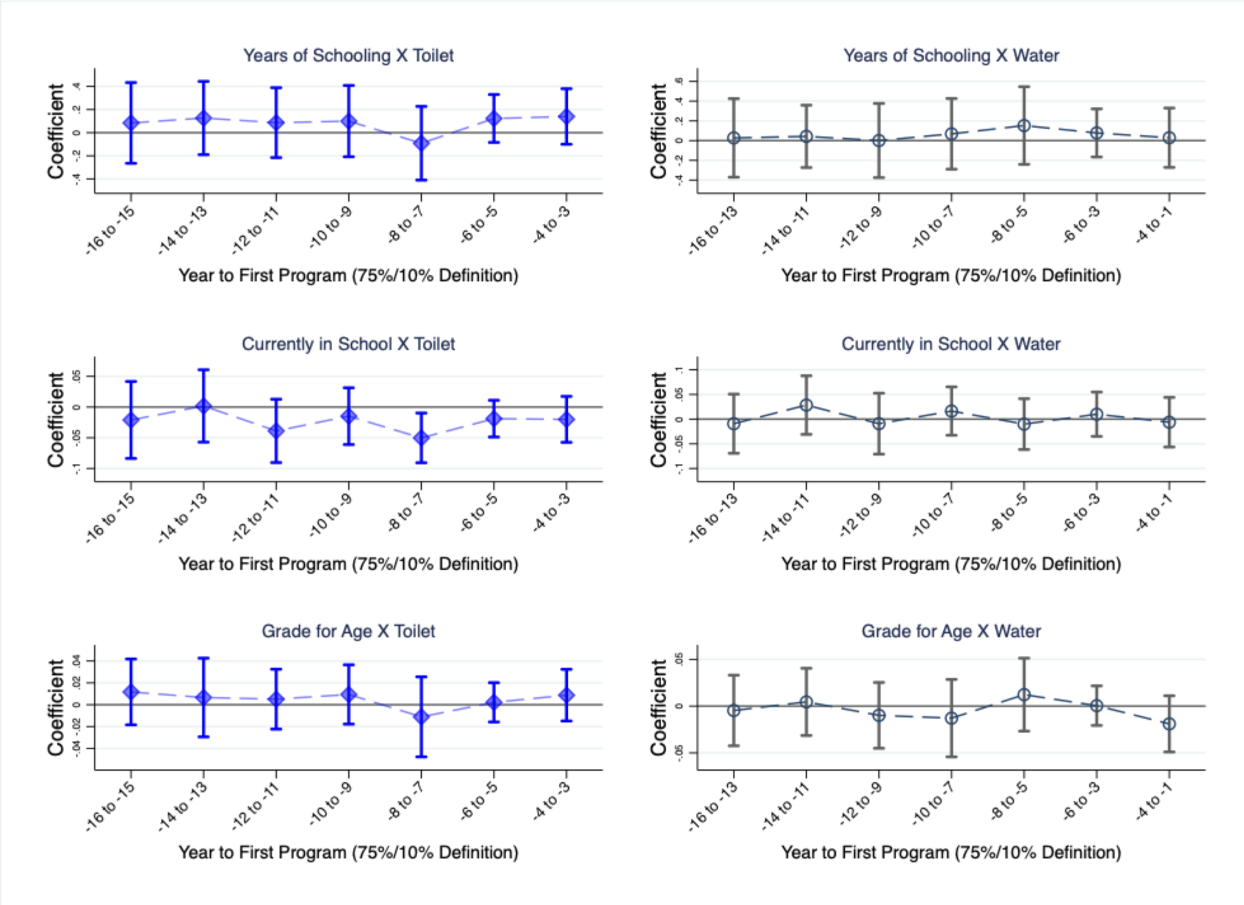
Table (A6) Effects of Toilet, Water on Educational Attainments with Alternative Cutoffs

Panel A: Schooling					
		50%		90%	
	percentage point	Girls	Boys	Girls	Boys
Toilet	10	0.559***	0.426**	0.593***	0.333**
		(0.177)	(0.182)	(0.173)	(0.161)
	15	0.383*	0.536***	0.514**	0.481**
		(0.207)	(0.185)	(0.198)	(0.186)
	20	0.471*	0.681***	0.588**	0.787***
		(0.270)	(0.191)	(0.251)	(0.182)
Water	10	0.465*	0.136	0.335	0.261
		(0.248)	(0.194)	(0.217)	(0.170)
	15	0.689**	0.418**	0.436*	0.335**
		(0.269)	(0.186)	(0.242)	(0.164)
	20	0.675***	0.262	0.361	0.151
		(0.242)	(0.175)	(0.224)	(0.159)
Panel B: School Attendance					
		50%		90%	
		Girls	Boys	Girls	Boys
Toilet	10	0.049	0.091*	0.064	0.103**
		(0.058)	(0.052)	(0.060)	(0.051)
	15	0.138**	0.163***	0.170***	0.173***
		(0.059)	(0.048)	(0.054)	(0.053)
	20	0.164**	0.121	0.195***	0.169**
		(0.067)	(0.075)	(0.062)	(0.078)
Water	10	0.140	0.042	0.084	0.035
		(0.091)	(0.071)	(0.080)	(0.060)
	15	0.091	0.082	0.053	0.068
		(0.068)	(0.060)	(0.064)	(0.050)
	20	0.146**	0.064	0.103*	0.072
		(0.066)	(0.059)	(0.058)	(0.054)
Panel C: Prob(Grade for Age)					
		50%		90%	
		Girls	Boys	Girls	Boys
Toilet	10	0.086**	0.075*	0.100**	0.069*
		(0.039)	(0.040)	(0.041)	(0.037)
	15	0.113**	0.099**	0.102**	0.071*
		(0.051)	(0.044)	(0.043)	(0.042)
	20	0.121*	0.211***	0.140**	0.198***
		(0.070)	(0.058)	(0.062)	(0.045)
Water	10	0.062	0.004	0.026	-0.001
		(0.052)	(0.047)	(0.045)	(0.041)
	15	0.102*	0.024	0.051	0.034
		(0.052)	(0.039)	(0.046)	(0.038)
	20	0.122**	0.036	0.097**	0.039
		(0.055)	(0.050)	(0.047)	(0.041)

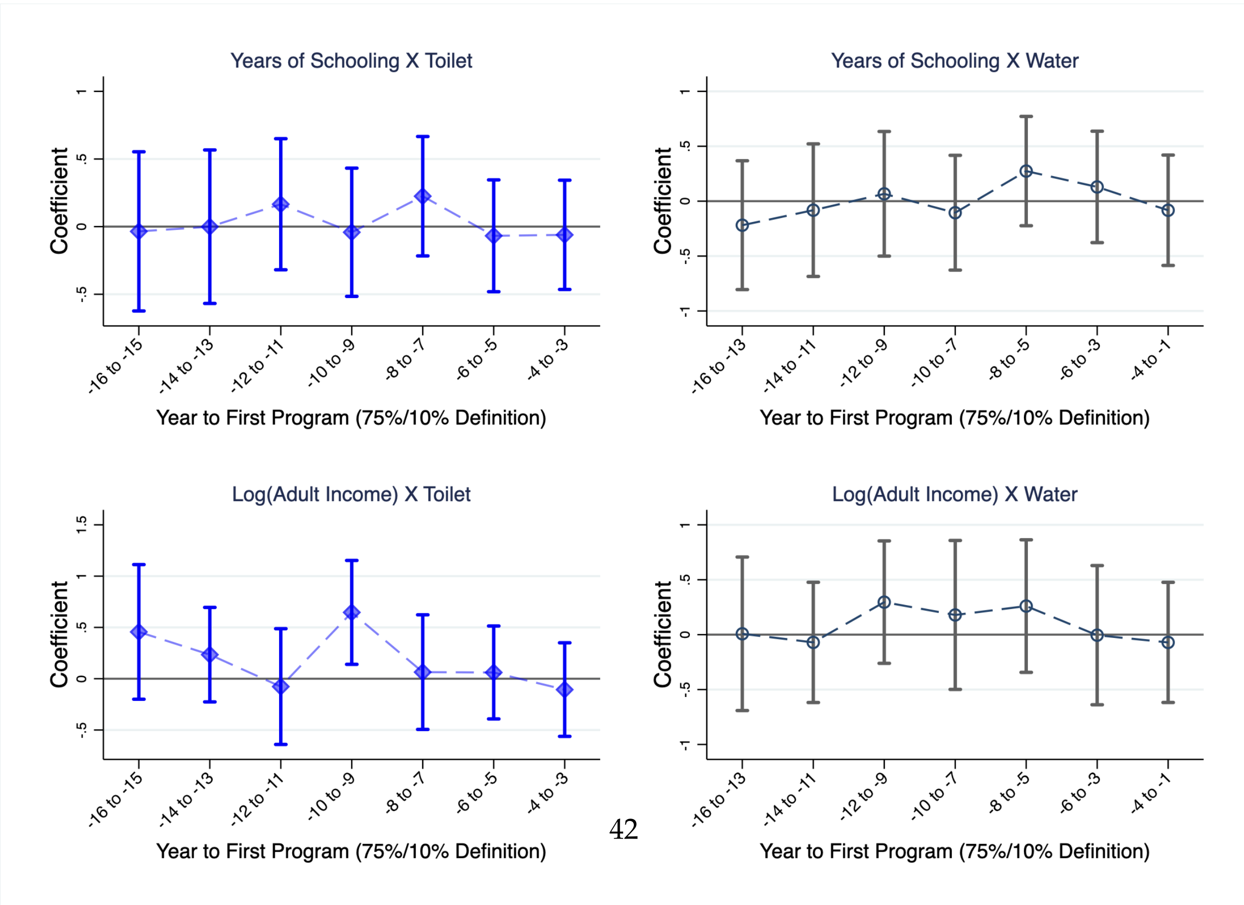
Note: 50% and 90% indicate that the village has more than 50% and 90% coverage rate of flush toilet/water plant in the first survey wave; 10, 15, and 20 percentage points indicate that a 10, 15, and 20 percentage points increase in flush toilet/water plant for each year between two survey waves. "Schooling" means the number of completed years of schooling. "School Attendance" means the probability that the child was attending school in survey year. Standard errors are clustered at the village level.

Figure (A1) Event-study for pre-program trends in village-level outcomes

(a) Children's Outcomes (6-18 Years Old)



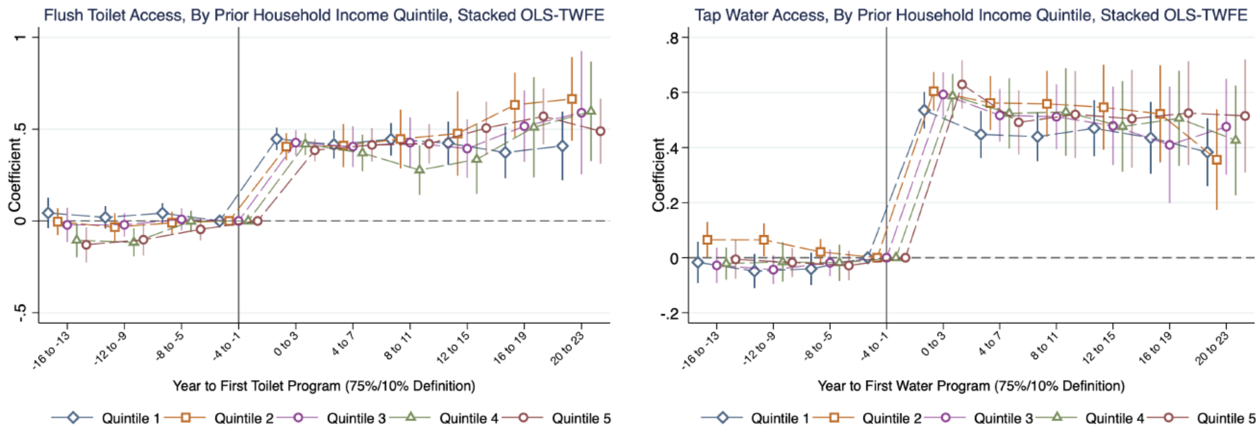
(b) Adult Outcomes (26-50 Years Old)



Note: Point estimates and 95% confidence intervals of OLS-TWFE event studies of pre-program trends in children and adult outcomes. Standard errors are clustered at the village level. The sample includes children who are 6-18 years old when they are surveyed.

Figure (A2) Effects of Water & Sanitation Programs on Household-level Access, by Household Income Quintile

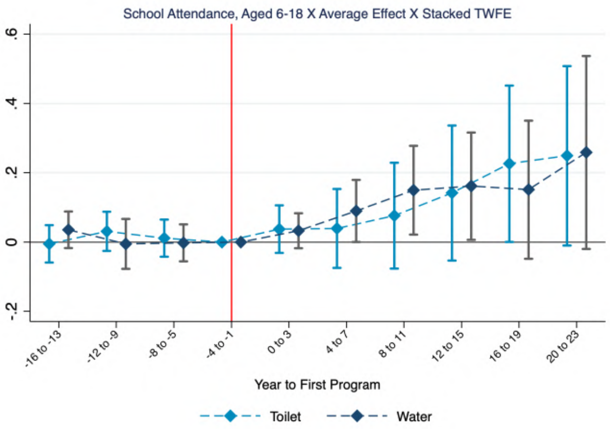
(a) Toilet Access   (b) Tap Water Access



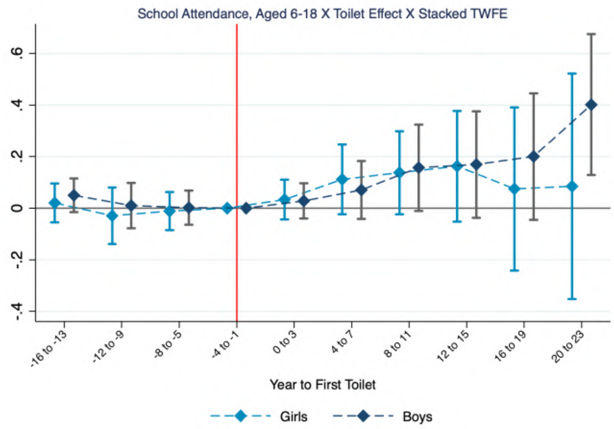
Note: Panels A and B show the average effect of toilet & water programs on household access to flush toilet and tap water, splitting households by their pre-existing income quintiles. Panels C and D show binned scatterplots of toilet & water access by household income, separately, for households observed before and after each program.

Figure (A3) Event-study for the effects on children's school attendance and the probability of completing grade for age

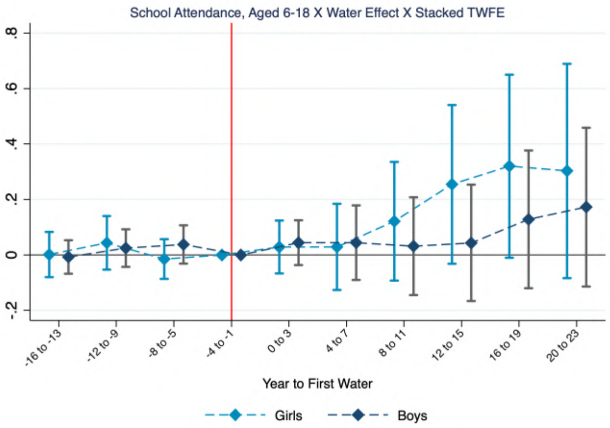
(a) Average Effect



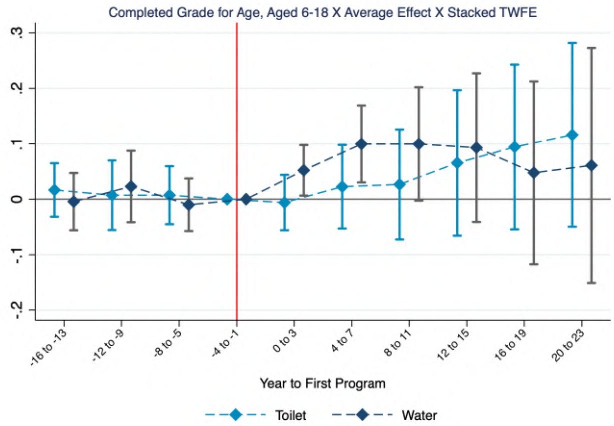
(b) Toilet Effect, By Gender



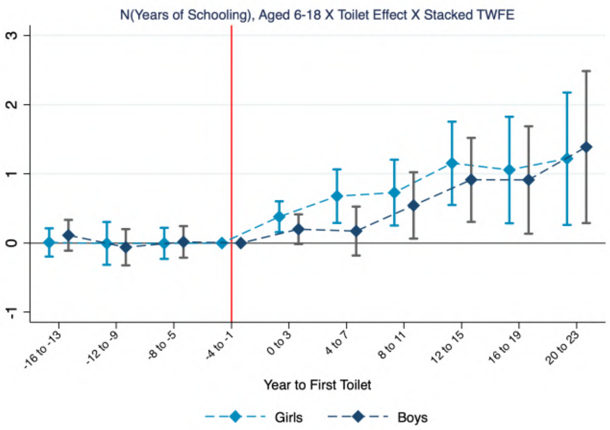
(c) Water Effect, By Gender



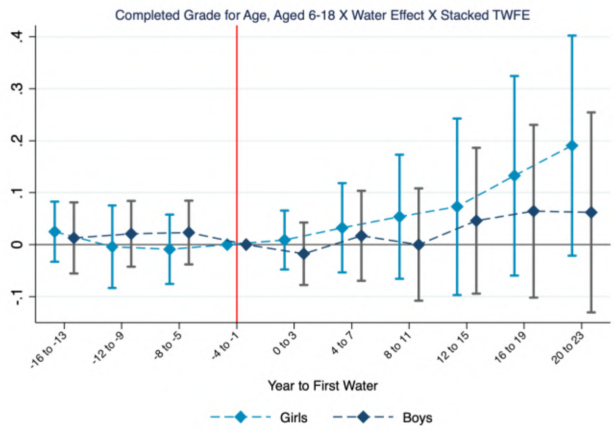
(d) Average Effect



(e) Toilet Effect, By Gender

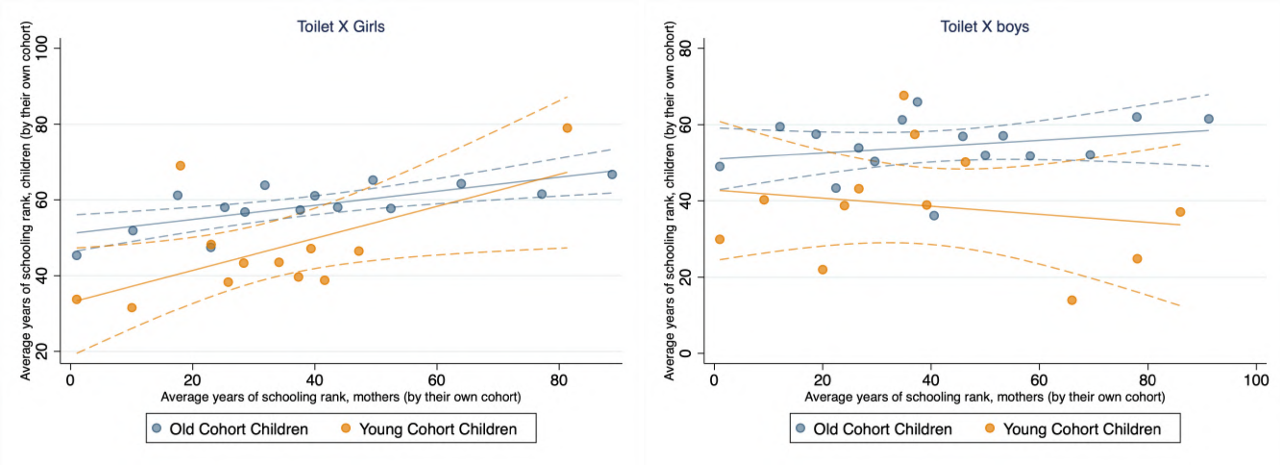


(f) Water Effect, By Gender



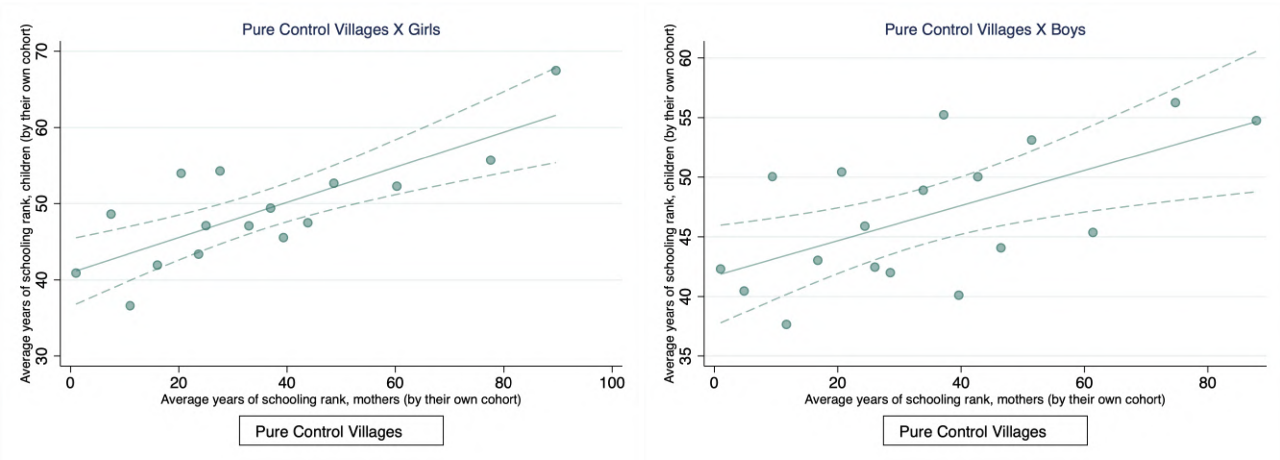
Note: Point estimates and 95% confidence intervals of OLS-TWFE event studies of heterogeneous effects on children's school attendance by gender. Panels A to C present the effects on children's school attendance and Panels D to F show the effects on the probability of completing grade for age; Panel A (Panel D) demonstrates the average effects of toilet/water programs and Panels B and C (Panels E and F) look at the heterogeneous effects by gender for toilet and water program respectively. Standard errors are clustered at the village level. The sample includes children who are 6-18 years old when they are surveyed.

Figure (A4) Association between Children's and Mothers' Education Ranks in Toilet Treated Villages for Younger and Older Cohorts



Note: The plots present binned scatterplots of the relationship between children's total years of schooling percentile ranks and their mothers' total years of schooling ranks in treated villages before and after treated. Children's and mothers' total years of schooling are ranked in their own birth cohort's education years distribution.

Figure (A5) Association between Children's and Mothers' Education Ranks in Pure Control Villages



Note: The plots present binned scatterplots of the relationship between children's total years of schooling percentile ranks and their mothers' total years of schooling ranks in pure control villages, i.e., neither have toilet nor water programs. Children's and mothers' total years of schooling are ranked in their own birth cohort's education years distribution.