Research Paper

Sanitation dynamics: toilet acquisition and its economic and social implications in rural and urban contexts

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ABSTRACT

This paper uses primary micro-data from Indian households residing in rural villages and poor urban neighbourhoods to shed light on household sanitation decision-making. We use a theoretical economic model to reduce the dimensionality and complexity of this process. Beyond the most commonly analysed motivator, health, we consider economic and non-pecuniary benefits. We provide empirical evidence that each of these margins matter, and do so in both rural and urban contexts, and discuss how our findings can be explored in sanitation policy and programme design.

Key words | economic drivers, household investment, India, sanitation, WASH

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HIGHLIGHTS

- Health is but one motivating factor for households to invest in sanitation in the context of India.
- Households that own sanitation exhibit higher consumption expenditures.
- An increase in productive asset ownership and a shift in time allocation are potential drivers behind increased consumption expenditures.
- Sanitation shifts children's time allocation within the household away from domestic chores and collection of water.
- Sanitation seems to serve as a pre-marital investment strategy.

INTRODUCTION

Safe sanitation, a means of isolating human waste, has been recognised as an indispensable element of disease prevention and primary health care programmes (e.g. the Declaration of Alma-Ata, 1978). The worldwide consensus of its importance led to 'access to adequate and equitable sanitation' becoming part of the Sustainable Development Goals (UN 2015). Yet, with an estimated 1.3 billion people lacking basic sanitation, the scale of the problem is huge (Mara & Evans 2018).

An important challenge to increasing sanitation coverage is its costly provision. According to the World Bank, an estimated US$19.5 billion a year is needed globally to meet nationally defined WASH targets (Hutton & Varughese 2016). An under-acknowledged contributor to investments is households themselves: based on survey responses by 35 national governments in 2018/2019, households contribute an estimated 66% of US$52 billion of annual WASH expenditures (WHO 2019). These figures have triggered calls for a stronger emphasis on research that enables a better understanding of household investment in WASH (Danert & Hutton 2020). Novotný *et al.* (2018) highlight that research aimed at understanding how contextual factors and

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motivations affect different sanitation outcomes is currently underdeveloped and that the current programmatic focus provides a narrow understanding of sanitation dynamics.

In this paper, we respond to this identified gap. We use primary micro-data from households residing in two Indian states to shed light on household sanitation decision-making, exploring the association of household characteristics with revealed preference for toilet uptake as well as outcomes resulting from the acquisition choice. Since such sanitation dynamics are characterised by complex human–environment interactions (Novotný *et al.* 2018), we present and structure our analysis around a theoretical economic model, which helps to reduce dimensionality and complexity. In addition to health and non-pecuniary benefits, the model highlights the importance of economic factors as motivators, a category that Novotný *et al.* (2018) identify as under-represented in the sanitation literature.

Our data include two survey rounds implemented in both rural villages and poor urban neighbourhoods, allowing us to provide a rich picture of the main correlates with, and potential outcomes of, sanitation uptake in different environmental contexts. We clarify the distinct socio-economic-cultural contexts and resulting differences in motivations for, and impacts of, toilet construction throughout our analysis but do not intend to use aggregates to inform policy or programming.

India is a particularly apt context to study household investment in sanitation, having contributed over 50% of the close to 700 million people who defecate in the open globally in 2017 (UNICEF and WHO 2019). The Government of India has shown a significant commitment to achieving SDG 6 of clean water and sanitation for all by 2030, including its ambitious Clean India Movement.

METHODS

Data and study population

We use data collected as part of an evaluation effort for a sanitation intervention. The original study's baseline and endline reports (Augsburg & Rodríguez-Lesmes 2015) provide detailed information on the selection of study communities and respondents and on survey instruments, attrition, etc. Data collection followed *The Netherlands Code of Conduct for Scientific Practice*. Clearance to collect data was given by the United Nations University-MERIT, The Netherlands. Approval for the second round in Tamil Nadu was separately given by UCL IRB (project code 2168/010). Two rounds of data were collected in 2009/2010 and 2013/2014. We include in our analysis those households that were interviewed twice, allowing us to apply panel data models with household fixed effects in our analysis. We worked with a sample of 1,035 households in 39 poor urban neighbourhoods, 764 households in 17 peripheral rural villages of Gwalior city, Madhya Pradesh and 869 households in 46 GPs (GPs constitute the smallest administrative unit in India) in Thiruvarur, Tamil Nadu (henceforth we refer to peripheral villages and GPs combined as 'rural villages/areas' and to the poor urban neighbourhoods, which are characterised by substandard housing and infrastructure, as 'slums'). Appendix A1 provides further information on survey locations and data collection (timings and sample sizes). The main survey instruments were a general household survey and an individual survey with the head of household, if female, or the spouse, if male and married (whom we refer to as the 'main woman'). Apart from household general characteristics, the survey instruments include detailed information on living standards, assets, consumption expenditures (including 21 food items), income, risk perceptions, credits, savings and insurance and demand for health care. A distinguishing feature of the data is an extensive module on sanitation and hygiene facilities, practices and perceptions. The interview with the main woman of the household covered information on time utilisation, hygiene practices and knowledge, cultural background and measures of empowerment. The women were also asked about children in their household, particularly providing information on their health status, time utilisation and nutrition. Survey questions were consistent across contexts with respect to variables used in this analysis, with response options covering both contexts; the Gwalior survey included additional modules on time use and detailed distance data.

Table 1 provides a set of descriptive statistics of study households. Descriptive statistics on further variables, including outcomes considered in the subsequent analysis,

Table 1 | Descriptive statistics of study households

		Round 1		Round 2	
		Rural	'Slums'	Rural	'Slums'
Religion & caste					
Muslim		9.9%	25.8%	9.8%	25.8%
Hindu		87.7%	74.0%	87.7%	74.0%
Forward caste		12.0%	30.8%	12.3%	30.8%
Most backward caste		12.7%	7.3%	12.7%	7.3%
Backward caste		46.1%	35.0%	45.3%	35.0%
Scheduled caste		27.1%	24.8%	27.7%	24.8%
Scheduled tribe		2.1%	2.2%	2.0%	2.2%
Household (HH) demographic composition					
No. of HH members		5.1	5.4	5.3	5.9
No. of male HH members		2.7	2.9	2.7	3.0
HH has at least one child <6 years old		30.9%	37.1%	30.9%	39.1%
Main woman: married		91.6%	91.7%	91.5%	88.8%
Main woman: age		37.8	36.6	38.1	37.98
Main woman: no formal education		44.7%	56.1%	45.6%	55.0%
Dwelling characteristics & location					
Dwelling is owned		93.6%	83.4%	94.9%	86.6%
Dwelling has a bathroom		38.2%	70.0%	63.8%	78.9%
Pucca (strong)		23.9%	40.3%	50.4%	75.1%
Semi-pucca (semi-strong)		41.0%	46.9%	23.4%	18.6%
Value of the dwelling (INR 1,000)		142.1	184.1	265.4	245.6
In Gwalior area		46.8%	100.00%	46.8%	100.00%
'Slum'		0.00%	100.00%	0.00%	100.00%
Sanitation & hygiene					
Main source of drinking water is HH service connection		16.5%	29.8%	24.1%	36.5%
HH has a toilet		24.6%	53.7%	42.0%	71.7%
Type of toilet:	Pour/flush to pit or septic tank	88.5%	40.8%	77.7%	42.2%
	Pour/flush to drainage	0.7%	14.0%	0.3%	13.2%
	Pour/flush to other	2.0%	31.2%	5.2%	24.9%
	Simple pit	7.0%	3.2%	16.2%	19.3%
	Don't know/No answer	1.7%	10.8%	0.6%	0.4%

Notes: Means for rounds 1 and 2, in rural and 'slum' areas. 'Rural' is peripheral villages of Gwalior and villages in rural Tamil Nadu; 'slums' are in the city of Gwalior. 'Value of the dwelling' is in 1,000 Indian Rupees of 2013 (i.e. round 1 numbers were adjusted by a factor of 1.32, which was calculated based on national figures for 2011, 2012 and 2013).

are provided in Appendix A2. Most households are Hindu (83%) and about 16% are Muslim; 19% report belonging to forward castes, 42% to backward castes, 26% to scheduled castes, 2% to scheduled tribes and 11% to most backward castes. A typical household comprises five members, three of whom are male, and around 33% have at least one child under the age of 6 years. The main woman in the household was on average 37 years of age and married (91%), and almost half (49%) had no formal education. Compared with rural villages, urban 'slums' are characterised by a higher percentage of Muslim and forward caste households. Households are slightly larger and the main woman less educated.

Dwelling ownership rates are lower, but dwellings are of stronger structure and of higher value.

Households had an average income of US$0.97 per member per day, considerably below the commonly used international poverty line of US$1.25. About a fifth of households had piped water access. A bit more than one-third of the sample has a toilet and almost half a bathroom. Toilet ownership was verified by the interviewer, alleviating concerns that households misreport their sanitation ownership status, possibly due to embarrassment about not having sanitation facilities. Verification was not possible for 6% of the sample, in remaining cases, respondents' reports were confirmed in 95–98% of cases. Toilet ownership rates varied considerably across study locations, being significantly higher in urban 'slums' (54%) than rural (25%) areas. Ownership rates increased significantly over time, with a bit more than half of study households owning a toilet after about three years (72% for 'slums', 42% for rural). In both survey rounds, pour/flush to pit or septic tanks were the most common toilet types available in rural settings. In contrast, pour/flush to drainage/others were slightly more common types in urban settings. Simple pit toilets became more common in round 2, especially in 'slums'.

Theoretical framework

In order to understand how households make sanitation investment decisions within this context, and the consequences these decisions might have, we present a simple theoretical model. The model is developed in detail in Appendix A3. Here we present its main elements and implications that link to our empirical analysis.

Within the simple two-period framework we consider, households care about consumption, leisure and health. They must decide who works and for how long, how many resources to consume today, how much to save for the future and whether to invest in a toilet today. Toilets are modelled as a one-off durable and indivisible investment, which can be expensive relative to household income. In the context of this study, households spend up to 20% of their annual income to construct toilets. Households benefit from owning a toilet through three channels. First, toilets add value to the household's dwelling, which can be sold or serve as collateral, hence increasing a household's asset wealth and ability to borrow. Second, toilets increase a household's utility through intangible benefits, such as comfort, status and even marriage market prospects for grooms-to-be. Third, toilets improve future health, which the household values in itself and which furthermore increases household productivity. While there is, to date, no clear evidence on the link between sanitation ownership and productivity, health is increasingly seen as an important part of human capital. An active literature demonstrates the link between health and human capital and productivity (Strauss & Thomas 1998; Currie & Hyson 1999; Currie & Madrian 1999; Cunha & Heckman 2007). The model also incorporates health externalities, i.e. that health benefits derived from improved sanitation depend not only on a household's own ownership status but also on the status of its neighbours (Kresch *et al.* 2020).

This set-up guides our empirical analysis, which is split into two parts. For the first part – an analysis of toilet acquisition – we consider, for example, the role of the household's current wealth/income, sanitation ownership of its neighbours and proxies for anticipated marriage decisions. For the second part of our empirical analysis – understanding potential benefits of owning a toilet – the model provides testable hypotheses for households that are not liquidity constrained and hence are able to make the sanitation investment. For these households, the investment moves resources from the present into the future. As a result, according to the model, we should observe an increase in the value of assets owned, either because the investment itself adds value or because additional assets are purchased. This part of the model leads us to look at the information on owned assets as outcomes. As mentioned above, such an increase in assets might allow households to obtain access to credit markets, which we consider through information on household borrowing. Additionally, improved health and productivity (potentially in combination with productive investments) can increase household income. Changes in the household's permanent income and wealth have, in turn, implications for consumption patterns, leading us to look at households' consumption expenditures. Finally, sanitation investment might affect the balance between consumption and labour in two ways: via productivity or via the marginal utility of labour and consumption, induced directly

through the impact on health. This implies that the impact of sanitation investment on labour supply is ambiguous. We will bring it to the data through information on children's time use. The analysis section will discuss the full set of outcomes that we consider.

Finally, although households in this model can borrow and save, some might remain liquidity constrained given imperfect financial markets with borrowing limits that depend on a household's wealth, and hence only indirectly on its income potential (Gautam 2018).

Empirical strategy

Our analysis is structured around two main objectives of (1) assessing determinants (correlates) of toilet acquisition and (2) understanding the potential benefits of toilet ownership for several outcomes.

We analyse *correlates of toilet acquisition* through a logistic regression where we constrain our sample to households that had no toilet at the time of the first survey round. It establishes the conditional correlation between a set of covariates X and toilet ownership status T.

$$T_{i,j,t=2} = g(X'_{i,j,t=1}\,\beta_1 + u_{i,j,t=2}) \tag{1}$$

Variables are at the level of the household i, the community j and time t, with $t = \{1,2\}$ representing the two survey rounds. The vector of estimated parameters $\hat{\beta}_1$ gives us an idea of the correlation between each variable on the right-hand side and toilet ownership. We cluster the error term u at the community level. We run this regression for the entire sample, as well as separately for rural and urban 'slum' areas. We confirm the robustness of our findings by, first, assessing the sensitivity of estimates to the inclusion of a different set of covariates, X, and, second, using a linear instead of a logistic regression model.

For our analysis of the *link between toilet ownership and outcomes*, we can consider potential impacts by regressing outcomes on toilet ownership, conditional on the above determinants, which include confounding factors, such as income and education. We use a linear panel model, which includes a time (survey round) dummy (γ_t) and household fixed effects (α_i).

$$Y_{ijt} = \delta\, T_{ijt} + X'_{ijt}\omega_2 + \alpha_i + \gamma_t + u_{ijt} \tag{2}$$

Other variables and subscripts are defined as above. Monetary outcomes are transformed using the inverse hyperbolic sine transformation (IHS), which is similar to a logarithmic transformation but allows for zeros in its domain. The resulting coefficients $\hat{\delta}$ and $\hat{\omega}_2$ are to be interpreted as semi-elasticities. While this model eliminates time-invariant confounding factors, we avoid overstating the substantive importance of the variable's effect. In addition to potential omitted time-*varying* variable bias, another point to be aware of is that two rounds of data do not allow us to analyse sequencing. For example, investing in a toilet could improve the asset value of the house, allowing households to get more resources in the financial market. As a result, households can invest in productive assets and increase their income and consumption. However, toilets could be the result of an unobserved shock that increased the household's income, which allows it to invest both in toilets and in other assets. To get a step closer to establishing causality, we estimate a difference-in-difference linear probability model on a subsample of households matched based on the probability that they will construct a toilet in the future (Rosenbaum & Rubin 1983; Heckman *et al.* 1997) for further discussion on propensity score matching (PSM). The procedure was implemented using kernel matching on the propensity score with the statistical software Stata (Leuven & Sianesi 2014).). Although findings are in line (as discussed later), Equation (2) remains our preferred specification since the matching exercise results in a significantly reduced sample size.

RESULTS

Correlates of toilet acquisition

Table 2 presents the results of the analysis of determinants of toilet acquisition. Our sample is households that changed toilet ownership status from having no toilet at survey round 1 to having one at round 2, 3–4 years later. These

Table 2 | Toilet acquisition determinants

	Base mean			Average marginal effects			
Independent variable *X*	(1) Rural	(2) 'Slums'	(3) Toilet	(4) All	(5) Rural	(6) 'Slums'	(7) Difference
Household income (past year) per household member							
Belongs to quartile 2 or above	74.2%	69.2%	39.8%	3.32	–0.01	10.54**	8.81*
				(2.51)	(2.67)	(5.34)	(5.35)
Belongs to quartile 3 or above	44.9%	37.5%	46.7%	7.10**	8.95***	4.68	–5.86
				(2.92)	(3.42)	(6.07)	(6.23)
Belongs to quartile 4	19.4%	13.5%	55.5%	–1.91	–0.86	–9.71	–7.17
				(3.75)	(4.21)	(8.44)	(8.40)
Social background							
Religion: Muslim	10.0%	28.4%	44.9%	–6.41	–5.55	–3.50	3.13
				(4.83)	(5.59)	(8.47)	(9.30)
Most backward caste	12.1%	30.6%	29.5%	6.60	11.11	4.23	–8.60
				(4.93)	(7.22)	(7.87)	(10.16)
Backward caste	41.3%	8.2%	43.4%	0.64	7.02	–7.91	–14.27
				(5.52)	(7.73)	(8.83)	(11.17)
Scheduled caste or tribe	34.8%	29.0%	22.0%	–14.91***	–8.75	–19.86**	–7.04
				(5.51)	(7.78)	(8.44)	(11.23)
Household demographic composition							
Number of members	5.0	5.4		1.22	2.76**	–2.23	–4.87*
				(1.23)	(1.25)	(2.91)	(2.77)
Number of male members	2.7	2.9		–4.28**	–4.93***	–2.12	3.61
				(1.66)	(1.79)	(3.46)	(3.44)
HH has at least one child under 6 years old	32.0%	40.4%	38.1%	–1.58	–2.74	3.33	5.77
				(2.84)	(3.56)	(5.02)	(5.68)
There is an unmarried boy aged 17–24 years	33.4%	28.6%	39.7%	9.57***	7.75***	12.06	1.61
				(2.60)	(2.25)	(7.88)	(7.04)
There is an unmarried girl aged 13–20 years	32.6%	31.3%	38.2%	–4.63	–5.41	–0.22	5.72
				(3.56)	(3.73)	(7.97)	(7.72)
Main woman completed grade VI, VII or VIII	15.0%	9.5%	39.6%	3.93	5.36	3.20	–3.18
				(3.74)	(3.90)	(9.16)	(8.65)
Main woman completed grade IX or above	11.3%	5.1%	48.1%	3.94	4.32	4.14	–1.26
				(4.77)	(5.16)	(13.38)	(12.44)
Sanitation reported as a decision factor for marriage	26.3%	39.2%	50.9%	4.28	–1.07	11.76**	11.00**
				(2.71)	(2.79)	(4.76)	(5.09)
Dwelling characteristics							
Strong structure (pucca)	18.0%	22.8%	59.8%	5.51	4.88	4.80	–1.33
				(3.50)	(4.03)	(7.08)	(7.32)
Semi-strong structure (semi-pucca)	41.6%	57.0%	35.5%	7.24**	6.69**	7.67	–0.89
				(2.84)	(3.20)	(5.42)	(5.77)

(*continued*)

Table 2 | continued

	Base mean			Average marginal effects			
Independent variable *X*	**(1) Rural**	**(2) 'Slums'**	**(3) Toilet**	**(4) All**	**(5) Rural**	**(6) 'Slums'**	**(7) Difference**
Community characteristics							
Coverage: water service connections	5.1%	19.5%		–0.22*	–0.43**	–0.20	0.30
				(0.13)	(0.20)	(0.14)	(0.25)
Coverage: toilet ownership	8.8%	38.2%		0.52***	0.79***	0.49***	–0.45
				(0.12)	(0.22)	(0.14)	(0.28)
Total number of HHs surveyed in the village/'slum'	52.7	53.3		0.14**	–0.15***	0.06	–0.12
				(0.05)	(0.06)	(0.05)	(0.08)
In Gwalior area	51.7%	100.0%	54.0%	–15.86**	–16.47*		
				(6.42)	(8.47)		
Total observations				1,509	1,058	451	1,509
Total villages/'slums' (clusters)				96	62	34	96

Notes: Columns 1 and 2 present the mean at survey round 1, in rural and 'slum' areas, respectively, of each of the independent variables in the rows for households that did not have a toilet in their home at the first round (base mean). 'Rural' is peripheral villages of Gwalior and villages in rural Tamil Nadu; 'slums' are in the city of Gwalior. As a reference, column 3 presents the percentage of households that own a toilet conditional on the specific category (for discrete variables only). Columns 4–7 correspond to average marginal effects (AME), for each of the independent variables, after logistic regressions where the dependent variable is having a toilet in the house at the second round, conditional on not having one in the first round. Column 4 is for the entire sample, and columns 5 and 6 for rural areas and 'slums', respectively. Column 7 presents the difference between the estimates in columns 5 and 6, obtained by interacting 'toilet ownership' (as well as all other independent variables) with the 'slum' indicator. The four regressions include as controls all the variables presented in the table plus: a binary variable for the presence of any major shock to the household in the last 12 months; the age of the woman who is the household head or the spouse of the household head; an indicator of whether she lives with her in-laws; an indicator of whether the dwelling is owned by the household; and the value of household elements. Standard errors, clustered at the village/'slum' level, are shown in parentheses. Significance: *10%, **5%, ***1%.

are 17% of the rural and 18% of our 'slum' sample. The majority of these newly acquired toilets were funded through households' own money/savings (80%), followed by government subsidies (8%) and informal loans (9%); remaining categories are formal loans (1%) and 'other' (2%). The data reveal a clear wealth gradient in the type of funding used by households, with richer households more likely to use their own money/savings to construct a toilet (highest income quartile (Q4) 90%; 'slums': 92%; rural: 89%) and poorer households more likely to get government support (Q1 13%; 'slums': 21%; rural: 10%) and informal loans (Q1 12%; 'slums': 11%; rural 14%). Columns 1 and 2 provide sample averages of the considered variable for the subsample of households without a toilet in the first survey round in rural and urban 'slum' areas, respectively. As a reference for the analysis, column 3 gives the average toilet ownership rate at round 1 for the respective variable, if binary. Columns 4, 5 and 6 present our estimated coefficients of interest, $\hat{\beta}_1$, as specified in Equation (1). Column 7 presents the difference between the estimates in columns 5 and 6, obtained by interacting toilet ownership (as well as all other independent variables) with the 'slum' indicator.

The first two panels provide results on wealth and status determinants. We observe a positive gradient of toilet ownership and social standing: the means of toilet ownership presented in column 3 show that households with higher income and higher caste are more likely to own a toilet. In terms of acquisition, our results reveal that those from the third income quartile are significantly more likely to invest in a toilet between the two survey rounds. Rural areas, where toilet ownership rates are generally much lower than in urban 'slums', drive this result. Interestingly, we also find that in 'slums', it is those in the second income quartile or above that are significantly more likely to acquire a toilet over time. At the same time, households in a scheduled caste or tribe are less likely to improve their sanitation ownership than those in a forward caste – a finding that is more pronounced in 'slums' than in rural areas.

Correlations of toilet acquisition with other proxies of household wealth are in line with those of income:

households with dwellings of semi-strong (rather than strong or weak) structures are significantly more likely to invest in a toilet between the two survey rounds, again driven by rural areas.

We further find that certain household compositions and changes are driving sanitation investments. Specifically, the arrival of a new female (an increase in household size, conditional on the number of males) in a rural household increases the likelihood of constructing a toilet significantly, a finding not driven by a newborn member. Further, a male close to the legal marriage age (21) in the household makes investment more likely.

Finally, we find that conditional on contextual characteristics, such as wealth or income, an increase in sanitation coverage is positively associated with greater sanitation uptake in the village, as predicted by the theoretical model. We also find a negative association between the coverage of water service connections in rural villages and toilet ownership, in line with Bennett's (2011) results, which are consistent with the hypothesis that clean water can serve as a substitute for sanitation.

Toilet ownership and outcomes

Table 3 shows estimates of parameter δ (Equation (2)) in columns 4–6. Column 7 shows the difference between rural and 'slum' associations, similar to column 7 of Table 2. Inspired by the model, we group outcomes around health, household consumption, wealth and finances and time allocation.

Health

Health is typically considered a key motivator for improved sanitation and also highlighted in our model as one margin along which households might benefit. Within this analysis, we do not find evidence for reduced illness associated with sanitation, measured by diarrhoea incidence among children in the last week. We do, however, find evidence that households perceive health benefits of owning a toilet, particularly in urban 'slums', where the main respondent is 11 percentage points more likely to perceive herself as healthier than peers in the community and 10 percentage points more likely to perceive her family as healthier than other families in the community (significant at the 5 and 1% level, respectively).

Consumption

The model predicts that toilet ownership can result in increased income. Since income is an important confounding factor, which we account for throughout our analysis, we consider consumption expenditure, rather than income, as an outcome variable. A change in consumption expenditures is typically a result of a permanent change in income (Jappelli & Pistaferri 2010) and hence a valid proxy. We find a large, positive and significant correlation between sanitation ownership and household consumption, observed in rural and urban 'slum' areas alike. Particularly, non-durable consumption (such as transport, utilities, fuel, education and cosmetics) is higher for those with a toilet. We stress that this relationship holds despite accounting for income in our analysis, which in fact could downward-bias estimates. The higher expenditures are suggestive that households with a toilet are more productive, potentially driven by better health, ownership of more productive assets or differing time allocation.

Wealth and finances

And indeed, we find significant relationships between sanitation and likely productive assets the households own, including vehicles (bicycle, scooter, motorbike, four-wheeler) and other household items. We also observe an increase in the value of agricultural assets for 'slum' households. Further analysis reveals that these assets are uncommon and small, with the results driven by about 2% of the sample.

We further find that sanitation investments are reflected in the value of the dwelling, much above the investment needed to construct the toilet. The average reported value of the toilet is INR 20,000, whereas the estimated coefficient suggests an increase in value of INR 42,926; houses without a toilet were on average worth INR 103,900 in 2013. We acknowledge that housing valuations are notoriously difficult in the setting and self-reported, but even if misreported, a perceived increase in value would be an important investment motivation.

Table 3 | Toilet ownership and outcomes

	Base mean		Full sample linear fixed effects panel		Linear fixed effects panel rural versus 'slums'		
Outcome variables *Y*	**(1) Rural**	**(2) 'Slums'**	**(3) Obs.**	**(4) Coeff.**	**(5) Rural**	**(6) 'Slums'**	**(7) Difference**
Health							
At least one child had diarrhoea last week	7.3%	13.2%	1,732	1.44	1.42	1.14	–2.33
				(2.50)	(5.14)	(2.90)	(6.30)
Perceives herself as healthier than others	33.8%	23.8%	1,709	9.18**	5.63	11.27**	7.78
				(3.72)	(6.77)	(4.26)	(9.67)
Perceives family as healthier than others	30.8%	21.6%	1,701	7.13	1.33	10.36***	11.53
				(4.50)	(10.13)	(3.75)	(11.74)
Annual consumption (previous year) per household member (1,000 INR)							
(IHS) Total consumption expenditures	91.4	96.3	2,505	14.60%***	15.90%**	13.09%***	–6.20%
				(3.94)	(6.81)	(3.62)	(8.10)
(IHS) Food consumption	56.6	74.4	2,505	5.48%	6.70%	4.89%	18.52%
				(6.56)	(11.54)	(3.85)	(11.61)
(IHS) Non-durable consumption	23.2	16.8	2,496	22.05%***	25.29%***	18.60%**	–14.69%
				(5.07)	(7.09)	(7.60)	(10.21)
(IHS) Alcohol and tobacco consumption	0.8	0.9	2,505	–4.05%	–8.93%	1.41%***	–5.61%
				(3.67)	(6.51)	(0.46)	(6.25)
Household asset values (INR 1,000)							
(IHS) Dwelling	104.3	103.9	1,980	41.34%***	46.67%***	34.98%**	–29.03%
				(8.17)	(10.30)	(13.67)	(19.17)
(IHS) Vehicles	5.2	3.0	2,505	38.92%***	43.47%***	32.63%***	–12.36%
				(8.00)	(12.26)	(9.81)	(15.27)
(IHS) Household items	47.0	55.9	2,505	39.81%***	56.02%***	16.91%*	–57.38%***
				(9.35)	(15.87)	(9.15)	(19.49)
(IHS) Agricultural assets	25.3	6.8	2,505	10.16%	6.95%	15.47%**	–17.24%
				(6.66)	(10.52)	(7.52)	(12.95)
Credit							
Household has debt outstanding	43.1%	22.2%	1,972	–0.45	–3.19	3.39	10.06
				(4.11)	(4.57)	(7.16)	(8.13)
(IHS) Amount of debt outstanding (INR 1,000)	14.5	5.4	1,884	20.18%	30.45%	2.60%	–66.83%*
				(17.77)	(27.60)	(25.54)	(40.22)
Children aged 3–15, time allocation (Gwalior only) – % with more than 0 h							
Domestic housework	47.3%	52.1%	1,266	–11.84***	–5.50	–14.64***	–15.49*
				(3.98)	(7.35)	(3.38)	(8.14)
Carrying water	46.2%	49.6%	1,259	–15.18**	–12.82*	–15.19***	–12.60
				(5.72)	(6.00)	(7.07)	(8.46)
Work in household business	4.9%	1.8%	1,258	–1.28	–2.62	0.78	–6.43
				(2.29)	(4.51)	(2.08)	(5.52)

(*continued*)

Table 3 | continued

	Base mean		Full sample linear fixed effects panel		Linear fixed effects panel rural versus 'slums'		
Outcome variables *Y*	**(1) Rural**	**(2) 'Slums'**	**(3) Obs.**	**(4) Coeff.**	**(5) Rural**	**(6) 'Slums'**	**(7) Difference**
Play	83.2%	83.2%	1,260	2.04	–3.79	6.45*	2.69
				(2.67)	(3.65)	(3.23)	(5.06)
Taking care of elders or sick household members	43.0%	45.4%	1,261	–1.82	–2.32	–0.73	–7.59
				(4.95)	(6.72)	(6.45)	(8.56)
Extracurricular study	13.6%	14.8%	1,266	2.81	–1.22	5.14	–2.71
				(3.84)	(6.86)	(4.83)	(8.81)

Notes: Each row represents the dependent variable of a set of fixed effects linear panel models. Columns 1 and 2 present the mean at survey round 1, in rural and 'slum' areas, respectively, of each of the dependent variables in the rows, for households that did not have a toilet in their home at the first round (base mean). 'Rural' is peripheral villages of Gwalior and villages in rural Tamil Nadu; 'slums' are in the city of Gwalior. Column 3 presents the number of observations of the regression in the 'full' sample. Columns 4, 5 and 6 present the coefficient estimate for the independent variable 'toilet ownership' when considering the full, rural and 'slums' sample, respectively. Column 7 presents the difference between the estimates in columns 5 and 6, obtained by interacting 'toilet ownership' (as well as the other independent variables) with the 'slum' indicator. All regressions include as controls: log of income, the presence of any major shock to the household in the last 12 months, the numbers of total and male household members, dummies for the presence of marriageable-age-male/marriageable-age-female/under-5 members, and the proportion of water that comes from piped drinking water in the community. Consumption expenditure, amount of debt and asset values are in 1,000 Indian Rupees of 2013 (i.e. round 1 numbers were adjusted by a factor of 1.32, which was calculated based on national figures for 2011, 2012 and 2013). For the regressions, these values were transformed using the inverse hyperbolic sine (IHS), which for interpretation is similar to the logarithmic transformation. Standard errors, clustered at the village/'slum' level, are shown in parentheses. Significance: *10%, **5%, ***1%.

Interestingly, the significant associations of toilet ownership and consumption and wealth are relevant in both rural and 'slum' contexts but are generally quantitatively larger in rural communities.

Finally, results on credit outcomes suggest no changes in borrowing on either the extensive or intensive margin.

Time allocation

Our model predicts a potential change in labour supply. We do not have the relevant data to analyse this prediction. We can, however, check whether time allocation within the household differs depending on toilet ownership. In particular, we have data on the time use of children aged 3–15 years in Gwalior (adult time-use data are not available and no time use was collected in Tamil Nadu). The last panel of Table 3 shows associations between toilet ownership and indicators for a positive amount of time reported on a specific activity by at least one child within the considered age range when data were collected 3–4 years after the base year. As a robustness check, we also estimated the relationship with the reported average hours of all the children in the household. The findings are in line. We find evidence that especially children living in urban 'slums' are significantly less likely to spend time on domestic housework and carrying water and instead more time on play when they live in a dwelling with a toilet. Children living in households with a toilet in rural areas are less likely to spend time carrying water.

Robustness checks: matching

As stressed previously, while the presented data account for a large set of covariates and we consider consistency across time and context, results might still be driven by pre-existing trends. In other words, households that were already improving along several margins for reasons that we cannot observe might acquire toilets. We, therefore, employ as a robustness check a PSM exercise, which ensures we compare households that were as similar as possible along observable characteristics. Appendix A4 presents evidence of a successful PSM procedure (Figure A2), providing us with a comparable sample. We find that our main conclusions hold true and also that cross-sectional analysis with both survey rounds confirms our conclusions: coefficients remain in line (Table A3), but at times with reduced

significance driven by the reduced sample (the matching procedure reduced the analysis sample by almost half) and hence larger standard errors. We lose significance altogether for the perceived health of the family in urban 'slums', consumption and the value of transport assets in rural settings, dwelling value, the value of household items and some time-use variables.

DISCUSSION

The theoretical model has provided a useful foundation to support our analysis. Here, we use it to guide the discussion of our results and explain their broader relevance. We start with the motivating factor of health for sanitation investment.

While our analysis does not provide evidence of improved health associated with *private* toilet ownership, we know from Augsburg & Rodríguez-Lesmes (2018) that children's height for age improves in our Gwalior sample with higher *community* sanitation coverage. The strong association with health perceptions present in our data suggests that households internalise such health impacts, which have also been shown in other studies (see, for example, Prüss-Ustün *et al.* (2014), Pickering *et al.* (2015) or, for an overview, UN (2016)). The finding that these are primarily driven by 'slum' dwellers' perceptions is possibly a result of higher population density in these areas, and hence higher vulnerability to negative externalities of poor sanitation, as discussed in Hathi *et al.* (2017). Our findings show that toilet acquisition increases with community toilet coverage. Potential drivers of this finding include that households internalise the sanitation externality (Guiteras *et al.* 2019), or social network effects (Shakya *et al.* 2015).

Our results provide further contributions to this literature stream conducting benefit analysis of improved sanitation (see, for example, Hutton & Haller 2004) in three ways. For one, we are able to document an increase in consumption expenditures, which provides empirical evidence for the hypothesis that sanitation ownership can induce an income effect. Second, we find that households that own a toilet also acquire more other assets than households without a toilet. Some of these are likely productive (such as transport), a potential driver behind higher consumption expenditures. Others can be once again linked to social status and/or non-pecuniary benefits driving sanitation investment: despite having a similar income, households with sanitation might also have a better quality of life in general. Third, recent literature argues that sanitation has an important role to play in the formation of human development, such as cognitive skills and learning (Spears & Lamba 2016; Britto *et al.* 2017; Sclar *et al.* 2017). While in this literature improved health is typically seen as the driving factor, our analysis shows that improved sanitation can lead to children shifting time from household chores to play, and potentially education. Such changes in time use are typically encompassed in calculations of the economic benefits of sanitation. OECD (2011), for example, uses the estimate that improved sanitation gives a household up to 1,000 additional hours a year to work, study, care for children and so on.

Our analysis also reveals further insights into non-pecuniary benefits of sanitation. A body of literature highlights that latrine adoption is motivated by factors, such as convenience, comfort, cleanliness, privacy, safety and prestige (WSP 2004; Pearson & McPhedran 2008). Our finding of higher sanitation investment with the presence of a male close to marriageable age and with the arrival of an adult female member suggests that toilet construction might further serve as a pre-marital investment strategy and/or that the bride-to-be brings additional resources that allow the investment in a toilet to be made.

Finally, while our model suggests that increased wealth can improve access to borrowing, we do not find any statistically significant evidence for this. While we show a catch-up in toilet acquisition along income and caste gradients, our study also reveals that a large percentage of the population, in particular, those at the lower end of the income distribution in rural areas and those of lower caste, do not invest in sanitation. Households' own reporting that toilets are too expensive hints at liquidity constraints being important drivers.

CONCLUSIONS

Gaining a deeper understanding of contextual factors and motivations that affect sanitation outcomes is important

given the current push and aim to provide safe sanitation for all, as manifested in Sustainable Development Goal 6.2.

While not experimental, our findings can be used to contextualise interventions better and to find different angles to promote sanitation. The most commonly adopted strategy to combat open defecation, Community-Led Total Sanitation (CLTS), relies on information and collective action mechanisms. This intervention can have substantial impacts on households' sanitation investments (Pickering *et al.* 2015; Briceno *et al.* 2017; Abramovsky *et al.* 2020). Yet, it is not a silver bullet to achieve open-defecation-free status and policymakers working towards meeting the sanitation-related sustainable development goals are advised to consider alternative or complementary policies (Abramovsky *et al.* 2020). The finding that a significant part of the population we consider seems to be lacking funds to make the investment suggests that complementary policies can be a fruitful angle. Programmes, such as microcredit for sanitation (Augsburg *et al.* 2019, 2020) and subsidy provision (Patil *et al.* 2014; Guiteras *et al.* 2015; Andrés *et al.* 2020), have been successful and are worth considering. Subsidy provision is costly, but the productivity and income gains suggested by our results support further resource allocation to sanitation.

It is interesting to note, though, that a significant percentage of the richest households in our context still do not own a toilet at the time of the second survey round (46% in rural areas and 16% in urban 'slum' areas). It is likely that these households do not perceive a high enough benefit from making the investment, rather than them being liquidity constrained. At the same time, Abramovsky *et al.* (2020) show that CLTS is not effective in richer areas, making this a potentially challenging part of the population to motivate for sanitation investment.

Our findings suggest that a policy addressing non-pecuniary benefits, such as the 'No Toilet No Bride' campaign successfully implemented by the Government of Haryana, India (Stopnitzky 2017), might work well in our study context, particularly the urban 'slums'.

Identifying and assessing which policies are effective in further closing the sanitation gap, particularly when working at scale, should be a priority for researchers, policymakers and implementers in the field.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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