Switching to sanitation: Understanding latrine adoption in a representative panel of rural Indian households

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June 25, 2017

Abstract

Open defecation, which is still practiced by about a billion people worldwide, is one of the most compelling examples of how place influences health in developing countries. Efforts by governments and development organizations to address the world's remaining open defecation would be greatly supported by a better understanding of why some people adopt latrines and others do not. We analyze the 2005 and 2012 rounds of the India Human Development Survey (IHDS), a nationally representative panel of households in India, the country which is home to 60% of the people worldwide who defecate in the open. Among rural households that defecated in the open in 2005, we investigate what baseline properties and what changes over time are associated with *switching to* latrine use between 2005 and 2012. We find that households that are richer or better educated, that have certain demographic properties, or that improved their homes over this period were more likely to switch to using a latrine or toilet. However, each of these effect sizes is small; overall switching to latrine use from open defecation is low; and no ready household-level mechanisms are available for sanitation programs to widely influence these factors. Our research adds to a growing consensus in the literature that the social context should not be overlooked when trying to understand and bring about change in sanitation behavior.

keywords: sanitation; health; India; latrine adoption

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1 Introduction

Sanitation is one of the characteristics of a person's physical environment that is most important for her health and human capital development. An accumulating body of research links open defecation to intestinal diseases which reduce the absorption of calories and nutrients, and lead to malnutrition and impaired cognitive development among children. Because poor sanitation has been linked to infant mortality, child stunting (Cutler and Miller, 2005; Headey, 2015), and other health outcomes (Nandi et al., 2017), better understanding the causes of open defecation and the prospects for its decline are priorities for research and policy, especially in rural India.

Indeed, according to WHO/UNICEF Joint Monitoring Programme estimates for 2012, 60 percent of the world's open defecation occurs in India. While the practice of open defecation is steadily decreasing in many other countries of the world, it remains stubbornly persistent in India. The decline in India's rate of open defecation is so slow that each year the fraction of the world's open defecation that remains in India increases. According to India's 2011 Census, 90% of open defecation in India takes place in rural areas.

Changing sanitation behavior is the primary challenge to reducing open defecation in rural parts of the developing world (Aboud and Singla, 2012; Bisung et al., 2014). This paper seeks to inform this pursuit by investigating the characteristics of households in rural India that built latrines between 2005 and 2012. In particular, we ask: among rural households that defecated in the open in 2005, what baseline properties and changes predict switching to a latrine or toilet during this period? Our analysis uses panel data that is uniquely suited for this question because it tracks the same households over time.

Our empirical analyses test four hypotheses suggested by the literature that we discuss in section 2:

Hypothesis 1. *Households that had greater economic resources at baseline or a greater improvement in economic status were more likely to switch to latrines.*

Hypothesis 2. *Households that had more education at baseline were more likely to switch to latrines.*

Hypothesis 3. *Switching to latrines is associated with certain household demographic structures: having a newly married woman join the household or having an older adult member was associated with an increased likelihood of switching to latrines.*

Hypothesis 4. *Switching to latrines often accompanied other investments in home construction: households that switched to formal (*pacca*) walls over this period were more likely to switch to latrines.*

By testing these hypotheses with panel data from rural India, we expand on the evidence in the literature on sanitation behavior in developing countries. We find support for each of these four hypotheses, but in each case, we find that the magnitude of the associations between the predictor and switching to latrine use is quantitatively small. In other words, what is notable about our results is not which variables are statistically significant, but how shallow their regression slopes are. To give an example of one such finding: being a household in which the most educated male completed ten years of schooling rather than six is linearly associated with that household being only about four percentage points more likely to switch to a toilet or latrine.

This research is related to studies from other countries that seek to understand motivations for sanitation adoption or non-adoption, such as Jenkins and Curtis (2005a) in Benin, Santos et al. (2011) in Brazil, Rheinländer et al. (2010) in Vietnam, and Guiteras et al. (2015) in Bangladesh. We particularly build upon prior theoretical literature about the adoption of water, sanitation, and hygiene behaviors (Bisung and Elliott, 2014), as well as on qualitative investigations of the social context which supports widespread open defecation in rural India and undermines government and NGO sanitation programs (O'Reilly et al., 2016; Coffey et al., 2017; Routray et al., 2015a). We study social and economic correlates of latrine adoption over time in the population, rather than reporting on sanitation interventions

(Waterkeyn and Cairncross, 2005; Evans et al., 2014; Jenkins and Scott, 2007a).

The quantitative facts of latrine adoption in rural India that we document present a striking challenge for policy-makers and health researchers who seek to reduce open defecation in rural India. Widespread open defecation is likely to persist until programs and policies by governments and agencies begin to focus less on whether or not an individual household owns the physical asset of a latrine, and more on the social context, which, for reasons we discuss in section 5, does not yet support the adoption of affordable latrines. Our results highlight a similar challenge for researchers: in order to document the effects of open defecation on health, researchers must first learn how to cause reductions in open defecation.

2 Background on sanitation adoption

What explains why some households adopted latrines over this period and others did not? Our paper tests several hypotheses suggested by the existing literature on sanitation adoption.

The first hypothesis is that households that had greater economic resources at baseline or a greater improvement in economic status were more likely to switch to latrines. Case (2002) finds that South African households that benefited from a government program that increased their incomes were more likely to invest in toilets than those that did not.

The second hypothesis is that households that had more education at baseline were more likely to switch to latrines. Barnard et al. (2013) find evidence that households in the Indian state of Orissa in which the female head had been to secondary school were more likely to use latrines provided by the government.

Several prior papers on sanitation relate to the third hypothesis, that households in rural India that have a newly married woman would be more likely to adopt latrines than those that do not. Stopnitzky (2016) studies the Haryana government's "No toilet, no bride" campaign and finds that households are more receptive to messages about latrine construction at times

when a young man is getting married – that is, when a new daughter-in-law is entering the household. It is noteworthy, though, that the effect size was quantitatively modest and that Haryana is a relatively wealthy state. The campaign increased latrine adoption primarily in places where brides were scarce due to skewed sex ratios. So, this result may not apply to poorer states, or to places with better sex ratios. Other research on gender and sanitation highlights the difficulties that some women face while defecating in the open (Sahoo et al., 2015; Khanna and Das, 2015).

The fourth hypothesis, that sanitation adoption might accompany other home improvements is supported by evidence from Brazil, presented by Santos et al. (2011), who find that sanitation adopters were more likely than non-adopters to express interest in modernizing their homes.

We find that each of these factors statistically significantly predicts switching to latrine adoption in rural India. The more striking result, though, will be that the magnitudes of the associations between these predictors, which have been found to be important in other countries and in localized parts of India, are small. Section 5 discusses reasons why sanitation adoption in rural India is so slow and what steps policy makers and researchers might take to speed it in light of these results.

3 Data and methods

3.1 Data sources

We use nationally-representative panel data from the India Human Development Survey (IHDS) (Desai and Vanneman, 2016). The IHDS asks households about consumption and poverty, health and education, women's status, marriage, work and migration, and other topics. The IHDS interviewed approximately 40,000 households in 1,503 villages and 971 urban neighborhoods in 2004-2005. The same households were interviewed again in 2011-2012.

These data provide a unique opportunity to explore how baseline characteristics and changes in household characteristics are associated with latrine adoption: other existing data on latrine use, such as Demographic and Health Survey data and Census of India data, are nationally representative, but do not allow researchers to observe the same households over time.

We focus on rural India because according to the 2011 Census, 90% of the households that lack a toilet or latrine are in rural, rather than urban, India. The IHDS stratified its sampling over rural and urban parts of Indian states, so using the rural sub-sample produces estimates that are representative of rural India. We limit our sample according to three inclusion criteria:

- We include only rural households.
- We include only households that appeared in both survey rounds, and did not split between survey rounds.
- We include only households that report open defecation in the 2005 round.

These inclusion criteria leave us with a sample of 13,739 households to test our hypotheses. Each table and figure uses this sample. Throughout the paper, every result uses the IHDS sampling weights and every standard error is computed with clustering by primary sampling unit (PSU) to reflect the two-stage survey design of the IHDS.

Summary statistics. Table 1 presents summary statistics describing our sample. The sample is split among households that did and did not switch to using a latrine or toilet by 2012. 23% of rural households without a latrine at baseline switched to sanitation over this period. Switching households are different from non-switchers, on average: they are richer, better educated, less likely to be Hindu, and have different demographic structures. Both sets of households experienced considerable economic growth over this period. Households that adopted latrines experienced an increase of 38% in monthly consumption per capita;

households that did not adopt latrines experienced an increase of 33% in monthly consumption per capita. This corresponds with annualized growth rates in consumption of 4.8% and 4.1%, respectively. (As is standard in economic surveys in developing countries, consumption per capita is measured for the month before the survey, not for the entire year. This means that any seasonality in annual consumption patterns cannot easily be separated from a household's economic growth. Here, we computed average, annualized, household-level changes, assuming constant growth, as $\left(e^{\ln(c_{2012})-\ln(c_{2005})}\right)^{\frac{1}{7}}$.)

Data limitations. One of the advantages of our research design is our data: the IHDS is a nationally representative sample of households and it is a panel dataset. However, there are also a few limitations of using the IHDS data to explore predictors of sanitation adoption. One is that, like the Demographic and Health Surveys and the Census of India, the IHDS asks only a single household-level question about sanitation, which combines latrine ownership and latrine use. In particular, the question asks "Does the household have a toilet of its own?" This question appears to refer to latrine ownership rather than use, but the negative option is written on the survey form as "No facility belonging to household (or open fields)," suggesting that some households which own a latrine but which use the "open fields" would have been coded as no.

Another limitation of the IHDS sanitation question is that it does not allow us to separate latrine use by person within the household. Recent surveys in rural India which do ask a person-specific question about sanitation behavior find a considerable amount of open defecation even in households that own latrines (Clasen et al., 2014; Coffey et al., 2014; Patil et al., 2014). Person-level open defecation is a better indicator of the disease environment than household level latrine ownership. This is especially true in rural India where prior literature has found that many people who live in a household that owns a latrine do not use it (Coffey et al., 2014).

Another potentially useful piece of information which the IHDS does not provide is whether the latrine was privately constructed or subsidized by the government. We prin-

cipally interpret a change in households' answers to the IHDS question to reflect private latrine construction by households for several reasons: a household survey in five states of rural north India found that 79% of households with latrines had constructed them using only private resources (Coffey et al., 2014), many government-constructed latrines are incomplete, "missing," or otherwise not usable (Hueso and Bell, 2013), and households in this context are most likely to use latrines that they construct for themselves with large pits or tanks. However, it is certainly true that some cases of change in the data will be due to government construction, or even to households beginning to use a previously unused existing latrine. A final limitation related to latrine construction is that we cannot observe when exactly within the 2005 to 2012 interval a household switched to a latrine. This means we cannot test precisely whether switching to latrines slightly preceded or followed the household-level changes that we study, such as a newly married woman joining the family or improving the building materials of the house's walls.

Finally, the IHDS measured only some variables of interest related to latrine adoption. It contains a large number of demographic and economic variables, but it did not collect information about whether sanitation policies were reaching households, nor about individual attitudes towards latrine use. Certainly, it would be useful to include these variables in our analysis of latrine adoption if they were available. Nevertheless, we believe that the IHDS panel data presents a unique opportunity to quantify associations between commonly discussed predictors and latrine adoption.

3.2 Empirical strategy

Our empirical strategy exploits the panel structure of our data. By holding constant that each household practiced open defecation in 2005, our study has the advantage that any cross-sectional property of households that predicts 2005 open defecation is controlled for in the comparisons.

For each hypothesis, we first investigate graphically how the variables of interest predict

switching to latrine use between 2005 and 2012. Although a correlation between religion and switching to latrines is not a hypothesis of this paper, we present descriptive results separately for Hindu and non-Hindu households. This is because prior studies of National Family Health Survey data find very large differences in latrine use between Hindus and non-Hindus (Vyas and Spears, 2017; Geruso and Spears, forthcoming). Using the IHDS data, we find that holding other variables constant, whether or not a household is Hindu is a strong predictor of latrine adoption.

After presenting descriptive results graphically, we present the results of a regression analysis. Our dependent variable is an indicator that is equal to 1 if a household that did not use a latrine in 2005 switched by 2012. Therefore, even though the data provide two observations per household, each household appears once in our regression data. We fit the following model of household behavior:

$$\Delta latrine_{hvs} = \theta_1 \Delta X_{hvs} + \theta_2 X_{hvs}^{2005} + \beta_1 Hindu_{hvs} + \beta_2 SC_{hvs} + \alpha_s + \varepsilon_{hvs}, \tag{1}$$

where h indexes households, v indexes villages (which in the IHDS are primary sampling units), and s indexes states. Our dependent variable, $\Delta latrine_{hvs}$, is an indicator for whether a household which defecated in the open in 2005 switched to any kind of latrine or toilet over the period studied. We include four categories of independent variables:

- ΔX: Variables describing change over time in the properties or demographic composition of households.
- X^{2005}: Variables describing baseline (2005) or fixed properties of households, such as consumption per capita and adult education.
- α: A set of indicators for each of the Indian states. These permit us to study variation across households holding state-level properties constant.
- SC: An indicator for whether or not a household is Scheduled Caste.

- *Hindu*: An indicator for whether or not the household is Hindu.

Our approach is not intended to estimate causal effects in the sense of econometric identification, but rather to describe which factors are associated with switching to sanitation, when considered together. Therefore, we do not claim that our independent variables represent quasi-random exogenous variation, but instead assess the fit of our regression model and its robustness or stability to changes in specification. Even without causal identification, such analyses can speak to theories of sanitation behavior, can be consistent or inconsistent with claims in the literature, and can help sanitation policy learn to target households or communities that are particularly likely or unlikely to switch to latrines.

3.3 Ethics approval

We analyze anonymized, publicly available secondary data. Therefore, the study did not require prior approval from an Institutional Review Board.

4 Results

4.1 State-level changes in latrine use

Most households in rural India lack a toilet or latrine, and the large majority of persons in rural India defecate in the open. Over the seven years we study, from 2005 to 2012, neither of these basic facts changed. However, there was some important variation in latrine adoption across states in India, which we study here before turning to household level analyses.

Figure 1 uses India Human Development Survey data to describe state-level changes in latrine use. In both panel A and panel B, each observation is the rural part of an Indian state. Panel A shows that there is considerable variation in levels of latrine use across states in 2005 and 2012. Over this period, state-level latrine use converged somewhat, but the rank order of reported latrine use was largely preserved (Spearman's rank $\rho = 0.89$). For

example, in 2005, Uttar Pradesh and Bihar, which together are home to 300 million people, ranked 5th and 10th respectively for the fraction of rural households that defecated in the open. The IHDS found that only 13% of rural households in Uttar Pradesh had a latrine; in Bihar, the fraction was 20%. By 2012, these states ranked 6th and 7th, respectively, for latrine coverage – about 23% of households in both states reported having a latrine.

Panel B of figure 1 shows that by 2012, states with less open defecation in 2005 eliminated a larger fraction of the open defecation that existed in 2005. In Kerala, for example, where 94% of households had a latrine in 2005, 92% of households that lacked a latrine at that time gained one between the survey rounds. Therefore, by 2012, 99% of rural Keralan households reported having a latrine. In contrast, states like Rajasthan, Madhya Pradesh, and Uttar Pradesh had relatively low latrine coverage in 2005 – between 11% and 14% – and saw only about a fifth of households without latrines in 2005 adopting latrines by 2012. Two notable exceptions to this trend are Haryana and Himachal Pradesh. In these states, only about a third of rural households used latrines in 2005, but by 2012, 68% and 75% of households, respectively, that did not own latrines in 2005 had adopted them. Future research about the policies that might support latrine adoption could investigate these states' experiences. It would, of course, be important to keep in mind that these states have small populations relative to states like Rajasthan, Madhya Pradesh, Uttar Pradesh, and Bihar, and are relatively prosperous.

4.2 Economic status

Were households that were richer in the baseline period, and households whose economic status increased by more, more likely to switch to latrines over the period studied? This is plausible considering that, as described above, most latrine adoption in this setting would be through privately constructed latrines with expensive pits or tanks, rather than affordable pit latrines such as those found in sub-Saharan Africa or other parts of Asia (Coffey et al., 2014).

The locally weighted regressions in figure 2 indicate that baseline consumption per capita is positively associated with household latrine adoption. Panel A shows that multiplying baseline consumption per capita by 2.7 (a one unit increase on a log scale) is linearly associated with households being approximately ten percentage points more likely to switch to latrine use. In panel B, the *increase* in consumption is less steeply correlated with latrine adoption among Hindus, and not at all for non-Hindus. However, this non-association could reflect the omitted variable bias of partial correlation: in particular, if baseline consumption and the increase in consumption are both important, then the slope of the increase in consumption will be (mechanically) biased negatively unless the baseline level is also accounted for. (This is because $\Delta c = c_2 - c_1$, so if c_1 has an independent positive effect, the fact that it is subtracted from c_2 to produce Δc (and therefore has a negative sign) will cause a negatively-signed omitted variable bias.)

The regression results in table 2 are consistent with this interpretation: both the initial level and the change between survey rounds in consumption per capita are robustly associated with households being more likely to switch to latrines over the period studied. However, the coefficients are small in magnitude, consistent with the fact that only 23% of the studied households switched. To illustrate the shallowness of these gradients, multiplying a household's 2005 consumption per capita by 10 would only be linearly associated with a 28 percentage point increase in the likelihood of switching over these seven years ($\ln(10) \times \hat{\beta} = \ln(10) \times 0.121 = 0.279$).

4.3 Education

As an illustration of the relationship between baseline adult education and switching to latrine use, figure 3 documents that households with higher female education in 2005 were more likely to switch to toilets or latrines: households in which a woman has a bachelor's degree or higher are about 50 percentage points more likely to switch, on average, than households with no educated females. However, the skewed distribution of education in

rural India in 2005 means that this graph must be interpreted with care: in fully 57% of households studied, no adult female had any education. Moreover, education is correlated with economic status and other key variables.

Regression table 2 studies this correlation in the context of the other hypotheses and variables, and finds a robust but much smaller association between adult education and switching to latrines than what was found in figure 3. Both female education and male education are entered linearly as years of education. The coefficient of approximately 0.01 on male education in columns 2-4 is small in magnitude. For example, in 49% of households the most educated male has 6 years of education or less and 81% have a most educated male with 10 years of education or less. This four-year difference – a large 32 point shift in the percentile rank of the household – is linearly associated with the household being only about four percentage points more likely to switch to a toilet or latrine. The coefficients on female education in these controlled regressions are similarly small in magnitude. Columns 2-4 show that conditional on the highest years of education among men and women, including an additional control for the household having a literate member does not add explanatory power.

4.4 Household demographic structure

Based on the literature and on formative qualitative fieldwork, we expected households to be more likely to switch to latrines if a married woman joined the household or if there were a newly elderly member, who may find it difficult to walk to the fields for open defecation. We operationalize the latter as members 70 years old or older. We found mixed support for these hypotheses. Figure 4 reports our descriptive findings. Panel A shows that Hindu households in which a married woman had joined between 2005 and 2012 were a few percentage points more likely to switch to latrines than households that did not. This association is not found among non-Hindu households.

We found no evidence that households with a newly elderly member (through aging above

this threshold) were more likely to switch to latrine use. Rather, what seems to matter is the total number of elder members at baseline. This could be because the age and health of household members who are just older than 70 after 2005 would be highly correlated with the age and health of household members who are just under 70 before 2005. Moreover, the average household had one-third as many newly elderly members (over 70) as it did newly married women. Thus, panel B of figure 4 shows that it is the count of elderly members, not the change, which predicts latrine adoption. Even this association, however, is found only for non-Hindu households: in the simple specification with no further controls corresponding to panel B of figure 4, Hindu interacts with the count of elders with $p = 0.060$.

These descriptive results are confirmed in table 2, where an additional one woman *increase* in the number of married women between 2005 and 2012, or an additional one person greater *count* in the 2005 number of elder household members, are each robustly associated with an approximately three percentage point increase in the chance of switching to latrine use. Thus, these demographic changes are associated with sanitation changes, but they do not radically change the likelihood of it. This is quantitatively consistent with Stopnitzky's (2016) analysis of a rural sanitation program in Haryana that used the occasion of daughters-in-law marrying into households to promote latrine adoption: each additional marriageable-age boy was associated with only a 4.5 percentage point increase in household latrine ownership.

Column 4 includes further demographic variables in the spirit of a placebo or falsification test of the results about demographic predictors. We add two categories similar to but distinct from those of interest: males and females age 18-30. An increase in females in this category which is not reflected among *married* women would indicate an aging into this group of daughters of the household, who had not yet been married into their husbands's household for adult residence. Because men and daughters of the village face different social expectations and mobility constraints than daughters-in-law in rural India (Jeffery et al., 1989; Jejeebhoy and Sathar, 2001). Families would likely see less of a reason to invest in latrines for these groups than for newly married women. As we expect, neither of

these variables statistically significantly predicts sanitation switching, which increases our confidence in our interpretation of our main result.

4.5 Contemporaneous construction investments

As we discuss in greater detail below, households in rural India tend to construct latrines with large, expensive substructures and superstructures out of formal materials such as bricks or cement. In a survey in rural north India, Coffey et al. (2014) found that the average adult male thought that a minimally useable latrine would cost over 20,000 rupees: about US$300 at market exchange rates, or almost US$1,500 at the 2011 ICP purchasing power parity rate for individual consumption. We expected that households would be more likely to make the considerable investment in building a latrine when they are otherwise also investing in improving their homes. Although we cannot observe exactly when households built walls or built latrines, we can test whether the households that improved their walls over this seven-year period were more likely to switch to latrines.

Figure 5 indicates that they were: households that improved their walls from informal (*kaccha*) to formal (*pacca*) walls were over 10 percentage points more likely to be among the 23% of households that switched to latrines over this period. Table 2 confirms that this association is statistically significant and robust as a partial correlation. Although, again, the association is small in magnitude: controlling for other factors, households that improved their walls were two to three percentage points more likely to switch from open defecation than households that did not. Another way of putting this is that even though newly constructing a house from bricks and cement is statistically significantly associated with building and using a latrine, 75% of the households that acquired brick and cement walls over this period did not invest in a latrine.

Column 4 includes a further falsification test about home amenities. It is common to claim in discussions of Indian sanitation that access to water is a constraint on switching from open defecation. However, there is little population-level evidence for this: Coffey and

Spears (2017) show that open defecation in India is much higher than most poorer countries with worse access to water, and that in the 2011 Census of India (Government of India, 2011), almost half of rural Indian households with piped water on their premises do not own a latrine. As column 4 shows, adding an indicator for change in access to piped water does not improve the model's ability to explain switching from open defecation.

4.6 Additional results

The regression results in table 2 find that holding other factors constant, Hindu households were 9 to 13 percentage points less likely to switch to latrines over this time period than non-Hindu households. The difference in latrine adoption between Hindus and non-Hindus is far larger than the difference in latrine adoption between scheduled caste (or "untouchable") households and non-scheduled caste households: conditional on the other predictors in the analysis, scheduled caste households were only about 4 percentage points less likely to adopt latrines than non-scheduled caste households. Finally, moving from column 2 to column 3 of the regression table, we find that adding a set of indicators for Indian states statistically significantly improves the fit of the model without substantially changing any of the estimates or conclusions we describe above.

5 Discussion

This paper adds to the literature on sanitation behavior in rural India by seeking to understand which households adopted latrines between 2005 and 2012. Using a panel data set, we ask: what explains why some households adopt latrines in rural India? And, what is the magnitude of the effect size associated with each of the predictors of latrine adoption?

We find support for four hypotheses: that economic status and education are associated with latrine adoption, that latrine adoption is associated with household demographic structure and its changes, and that toilet adoption is more likely to occur when homes are

being improved. However, we also find that despite a large average increase in monthly consumption per capita among the rural households we study, only a small minority switched to latrine use over this seven-year period. Indeed, the magnitudes of the associations that we document between latrine adoption and each of the economic, education, demographic, and home improvement investment characteristics that we study are quite small.

These shallow slopes are best understood in the context of very low latrine adoption rates: in the IHDS data only 23% of the 74% of rural households that did not have a latrine at baseline in 2005 adopted a toilet or latrine by 2012. Over the seven-year period studied, this corresponds with an annual rate of decline in household-level open defecation of 1.7 percentage points per year. To put these results in the context of an even longer time horizon, Indian Census and National Family Health Survey data agree that open defecation in India has been declining at an average rate of only about one percentage point per year over the last two decades. This is so slow compared to sanitation adoption in the rest of the developing world that our calculations from Joint Monitoring Programme for Water Supply and Sanitation (2012) data find that the fraction of remaining open defecation in the world that occurs in India increases each year.

The finding that factors that we would expect to strongly predict latrine adoption do so only weakly aligns with prior literature that seeks to understand why open defecation is so high there relative to other contexts. One reason for persistently widespread open defecation in rural India is that the culture of ritual purity and pollution that supports the caste system also complicates and discourages the use of affordable latrines with internationally-normal latrine pits (O'Reilly et al., 2016; Coffey et al., 2017). Latrines with pits such as those recommended by the WHO and the Indian government will fill and thus require emptying after a few years (WHO, 1996; Government of India, 2007). The fact that, subjectively for most Indian villagers, only people from "untouchable" castes can empty latrine pits, and the fact that resisting such work has been an important part of untouchables' struggle for equal treatment (Valmiki, 2003; Wilson, 2014), makes pit latrine adoption less attractive in

rural India than in other countries. Both qualitative and quantitative evidence support the claim that understanding social forces governing caste and untouchability are essential for understanding sanitation in rural India (Coffey et al., 2017; Routray et al., 2015b; Spears and Thorat, forthcoming).

The idea that social forces rooted in Hinduism are important for sanitation outcomes in India is further supported by cross-sectional findings about differences in latrine use by religion which have been explored elsewhere in the literature and by the panel analysis that we present here. Vyas and Spears (2017) use Demographic and Health Survey data from rural Bangladesh, India, and Nepal and project that open defecation in the region would be almost eliminated if Hindus in these countries had the same sanitation behavior as non-Hindus. Geruso and Spears (forthcoming) use 2005 National Family Health Survey data and find that within India, Muslims are 25 percentage points less likely to defecate in the open than Hindus, with important consequences for differences in child survival by religion. We found that Hindus are less likely to adopt latrines despite the fact that they are relatively advantaged compared to non-Hindus. For example, the average Hindu household in our sample had 6% more consumption per capita in 2005 than the average non-Hindu household; was 4 percentage points more likely to have a literate member; and was 7 percentage points more likely to have piped water.

We find only weak associations between latrine adoption and newly married women joining the household. Although development programs and existing research stress the higher demand for latrine use among women than among men, it is important to note that even if new daughters-in-law would like to use a latrine, they would not have the intra-household bargaining power to demand investment in one. Moreover, it is not necessarily the case that most young women would choose to build latrines even if they had the financial decision-making power to do so. Coffey and Spears (2017) find that many rural women have similar attitudes to those of men towards affordable latrines. Further, since women's movement is often limited, some have positive attitudes towards open defecation because it

gives them an opportunity to move around outside of the home.

Our findings on the relationship between home improvement investment and latrine adoption provide support for ideas about latrine investment and infrastructure that exist in the literature. Coffey et al. (2014) find that households in rural India typically privately finance the construction of a latrine with a large pit or tank out of formal building materials. This type of latrine pit, which is emptied mechanically or not at all, stands in sharp contrast to the relatively low-cost pit latrines that have been instrumental in reducing open defecation in other parts of the developing world. Unfortunately, the high cost of constructing a suitably large latrine pit likely contributes to the slow adoption of latrines in rural India.

Implications for policy. The slow pace of latrine adoption and the weak associations that we highlight between key predictors and latrine adoption pose challenges for sanitation policy makers. The time period of our study spanned two central-government sponsored rural sanitation programs – the Total Sanitation Campaign (2001-2011) and Nirmal Bharat Abhiyan (2011-2014) – which similarly emphasized the construction of pit latrines over sanitation behavior change (see Spears (2013)). Our findings suggest that the Indian government's policy of subsidizing pit latrines did not achieve large-scale behavior change, and may still represent a misguided focus. This policy essentially continues under the current Swacch Bharat Mission (2014-present). Despite evidence that understanding demand for latrines is important for understanding latrine adoption (Jenkins and Curtis, 2005b; Jenkins and Scott, 2007b), and that attitudes towards open defecation and latrine use are highly correlated with latrine use (Dreibelbis et al., 2015), sanitation programs pay little attention to sanitation behavior and social norms. If even the most educated and best-off households adopt latrines at such a slow pace, sanitation policy would likely be more successful if it addressed the underlying social environment in which decisions about where to defecate, and what sort of latrine is socially acceptable, take place.

If the government nevertheless continues to emphasize latrine construction over community engagement and social mobilization, one potentially useful policy shift would be to

concentrate resources on the communities where many households are of the types identified as likely to adopt latrines, such as non-Hindu households, or households with elderly or newly-married members. It is important to note, though, that targeting latrine construction may be controversial and may be perceived as inconsistent with the Government of India's stated goal to eliminate open defecation by 2019. Any post-2019 government sanitation policy would do well to shift the focus from construction to educating people about low cost latrine options, and changing social norms about using and emptying affordable pit latrines.

Implications for research. The facts that we document also present a challenge to researchers seeking to learn about the effects of open defecation on health through intervention studies. Like policy-makers, researchers are constrained in their ability to promote latrine adoption in rural India. Exploiting a sanitation intervention to learn the effect of open defecation on health requires a sufficiently large and statistically precise "first stage" effect of the intervention on open defecation (Spears and Haddad, 2015). Unfortunately, achieving such a large first stage change in latrine adoption has proven difficult in rural India. Arguably, recent intervention studies of the effect of open defecation on health (Clasen et al. (2014) is a recent example from rural Orissa; Patil et al. (2014) is an example from Madhya Pradesh) may have not detected the effects on health outcomes that are found in population-level studies (Hathi et al., 2017; Coffey et al., forthcoming) because too much open defecation remained in the villages they studied even after latrine promotion interventions.

Our primary recommendation to research funders, therefore, is to invest in studies that test interventions to promote latrine use, even if the funded research does not directly measure impacts on health. Studies that measure health impacts may be able to devote only limited attention to understanding what about an intervention did or did not promote latrine adoption. It could be useful to first focus on better understanding people's reasons for defecating in the open or using latrines, and how sanitation behaviors could be influenced by the sorts of programs that the government would have the capacity to implement; then this knowledge could be applied to facilitate more statistically powerful studies of effects on

health. Tests of existing models, which rightly focus on understanding potential latrine users' social and psychological context (Mosler, 2012; Dreibelbis et al., 2013; Devine, 2009), should be attentive to the special considerations posed by rural India's history of untouchability, which makes it a unique environment in which to attempt to influence sanitation behavior.

6 Conclusion

This study investigates the factors that are associated with latrine adoption in rural India between 2005 and 2012 using panel data. We find that latrine adoption over this period was very low and that economic status, education, demographic structure, and investments in home improvement are only weakly associated with latrine adoption. Our results point to the need to develop sanitation policies which address a social context that discourages the use of affordable latrines. Yet, exactly how social norms in rural India can be reshaped remains largely unexplored. This is a critical area for future research.

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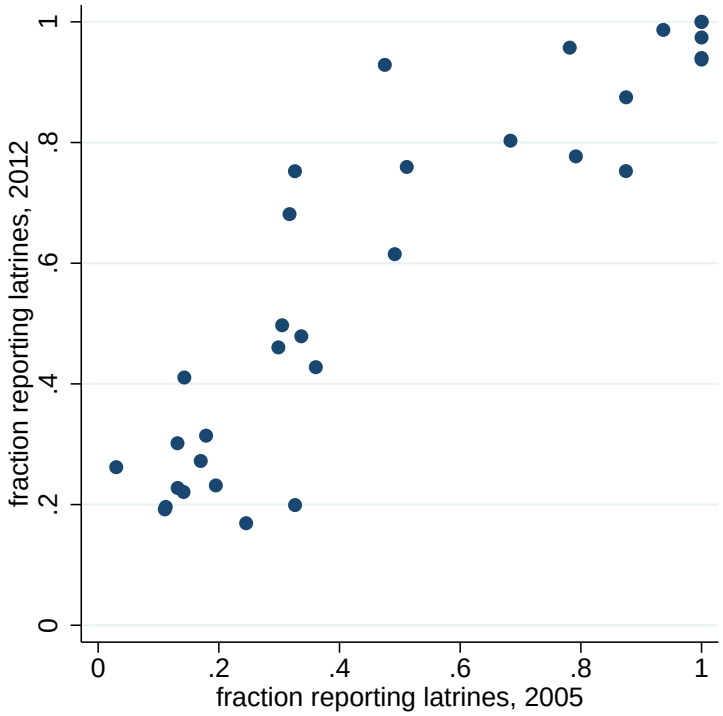
Figure 1: State level rural latrine adoption, IHDS 2005 and 2012

(a) states converged slightly, but ranks remained similar (Spearman $\rho = 0.89$)



(b) states with more baseline latrines covered more of their gaps (Spearman $\rho = 0.74$)

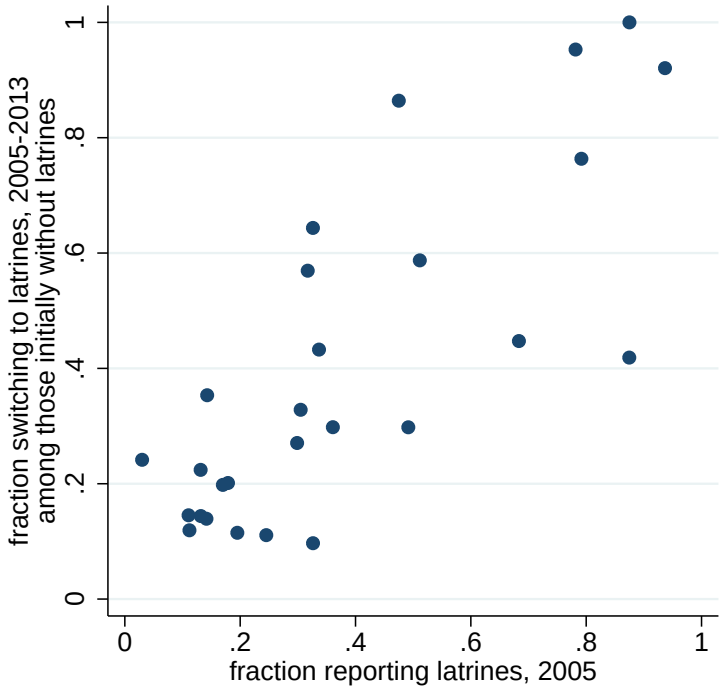
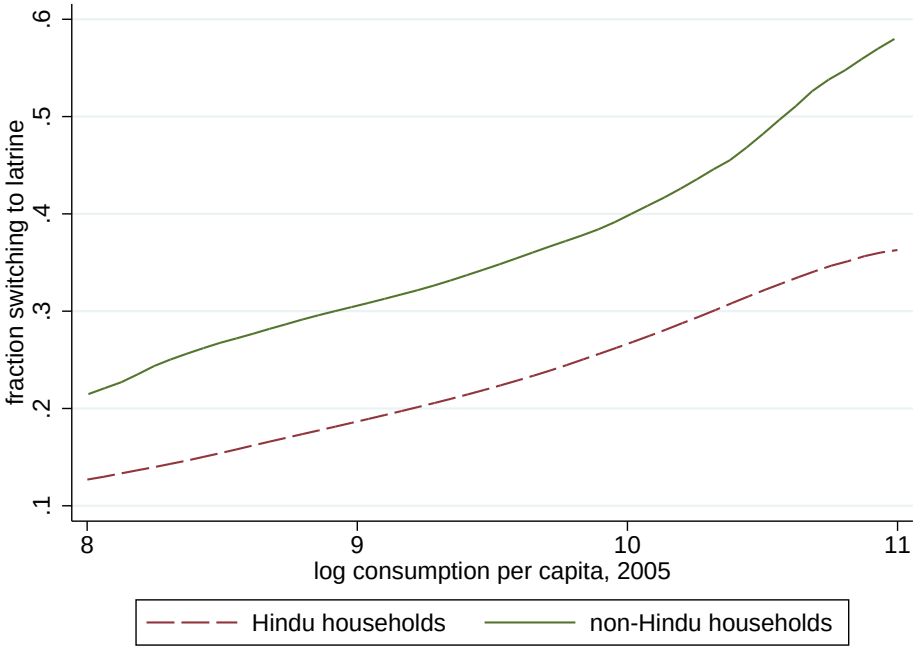
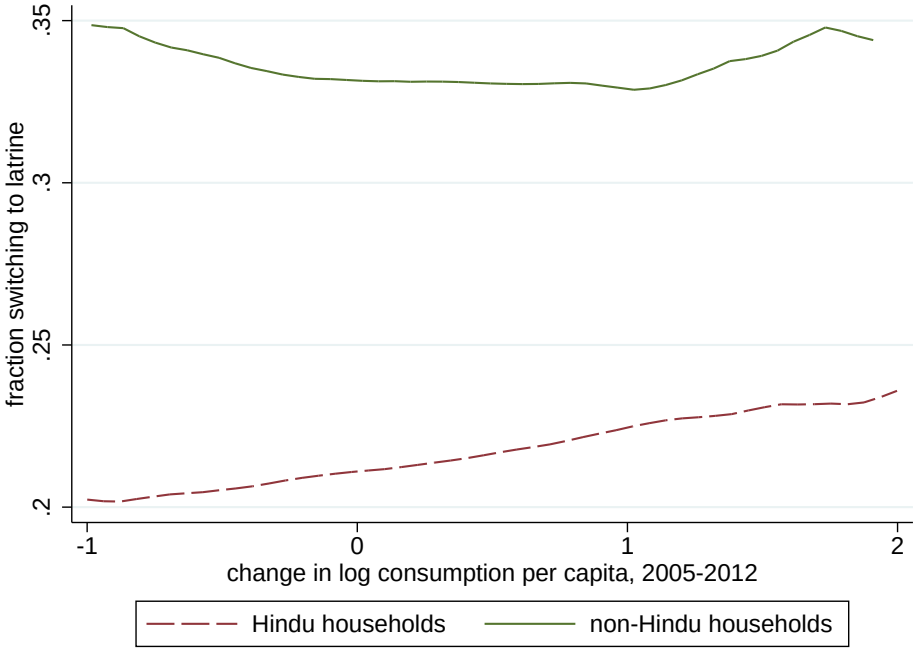


Figure 2: Household economic status and switching to latrines

(a) 2005 consumption per capita

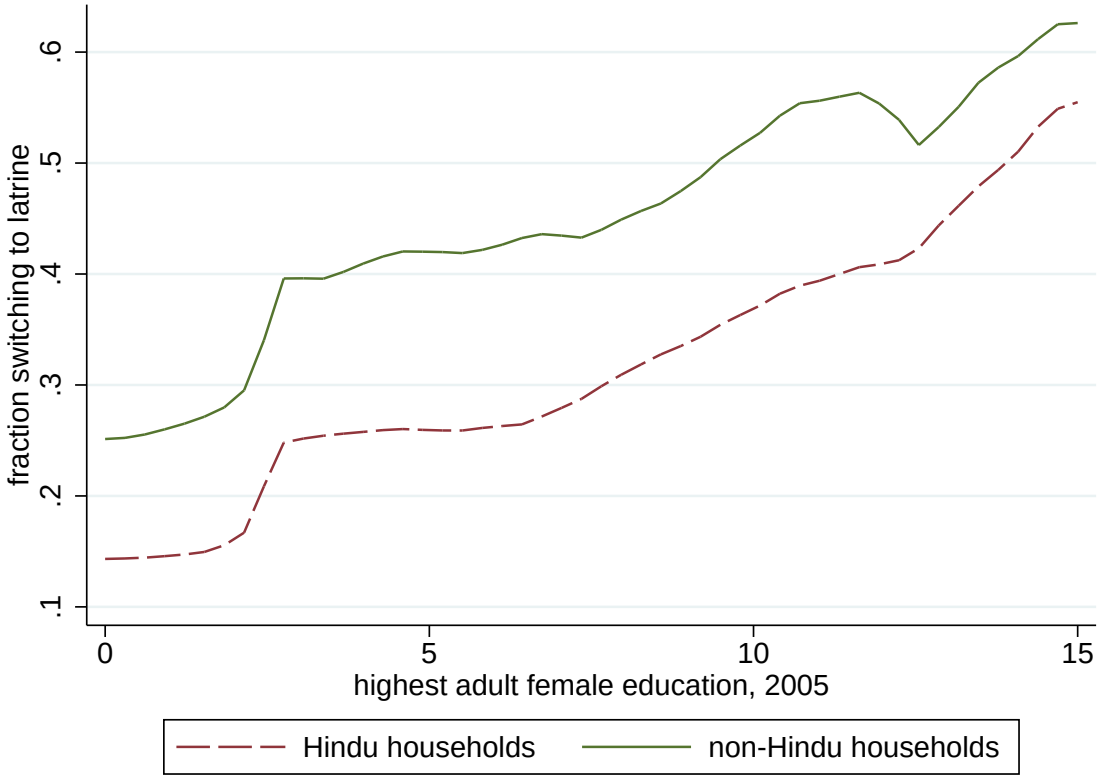


(b) change in consumption per capita, 2005-2012



Locally weighted regressions. Consumption is on a log scale, in rupees per capita per month. The sample corresponds to the main regression results in table 2.

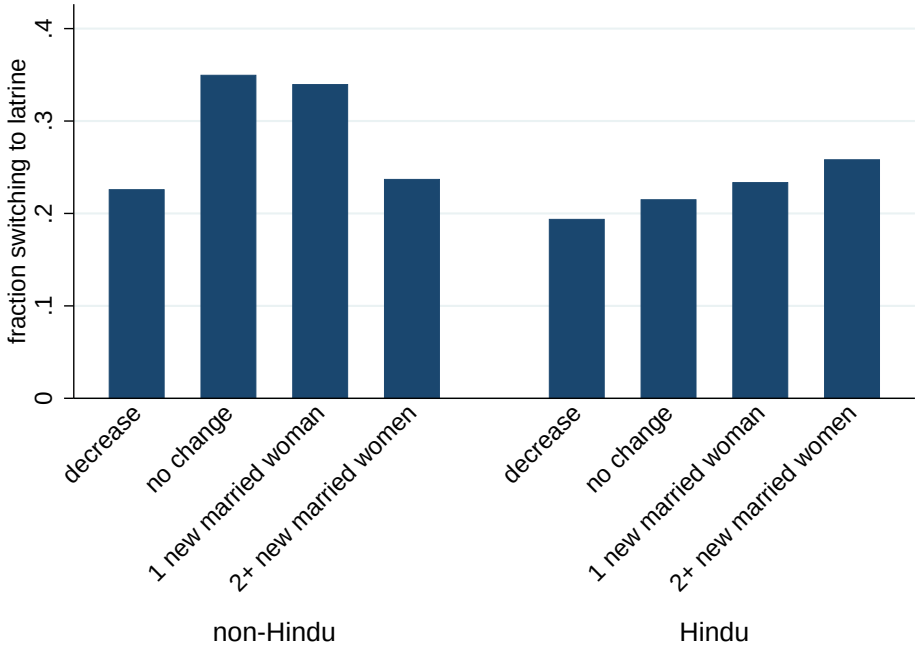
Figure 3: Baseline education and switching to latrines



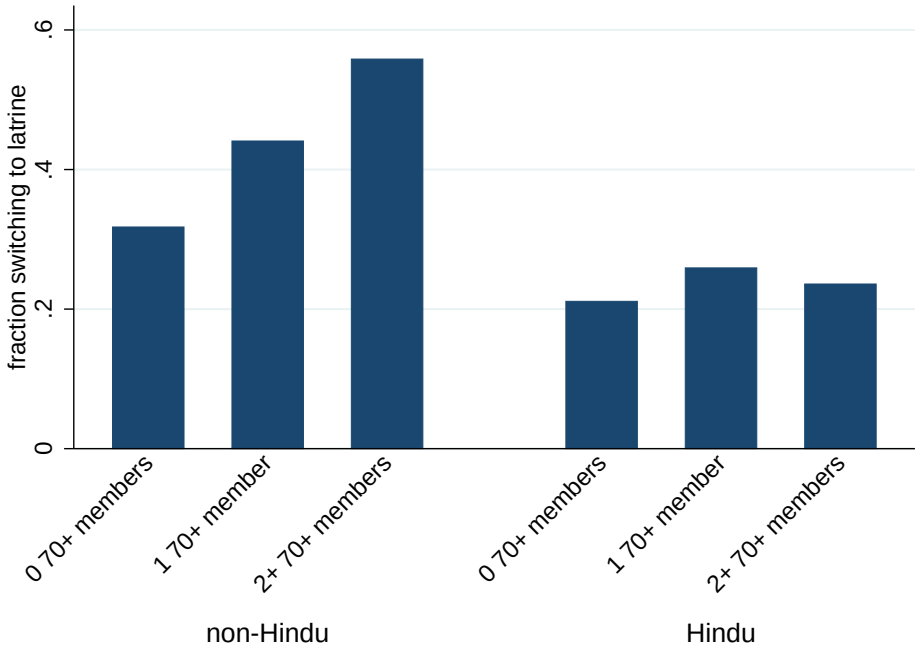
Locally weighted regressions. The sample corresponds exactly to the main regression results in table 2.

Figure 4: Hypothesis 3: Switching to latrines and household demographic structure

(a) change in married females, 2005-2012

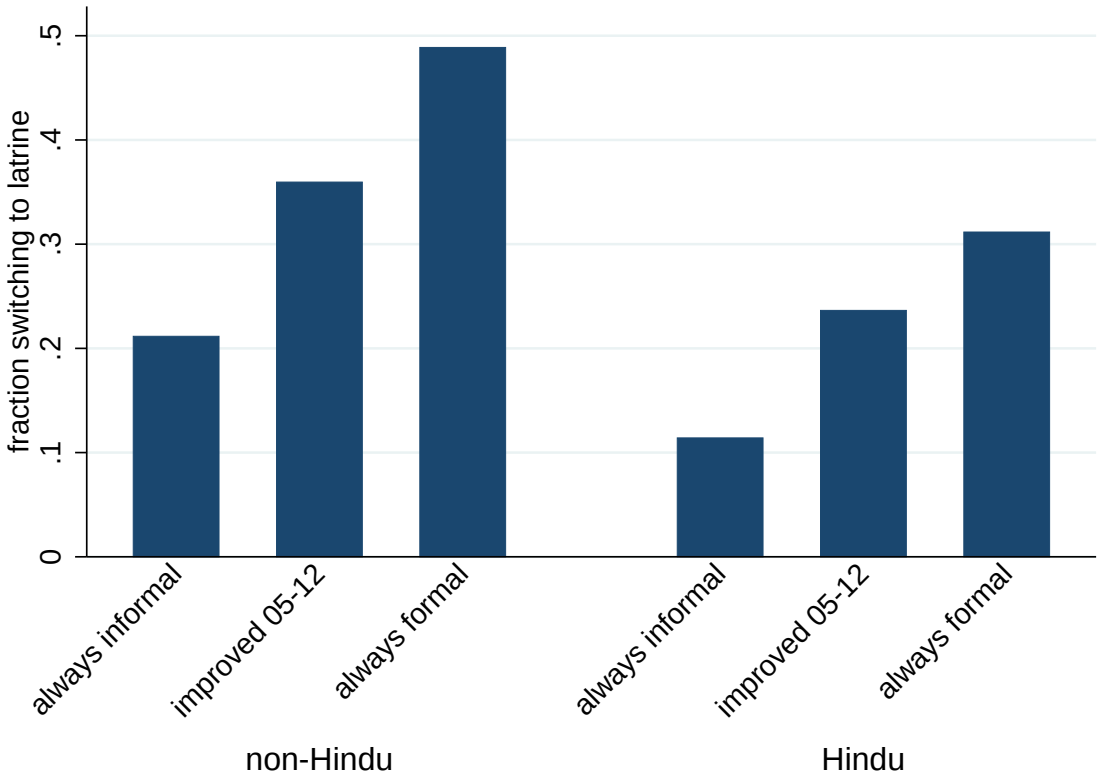


(b) elder residents (over 70 years old) at baseline, 2005



Locally weighted regressions. The sample corresponds exactly to the main regression results in table 2.

Figure 5: Contemporaneous home construction and switching to latrines



The sample used for this graph corresponds exactly to the main regression results in table 2. Data are from interviewers' observations of informal (*kaccha*) or formal (*pacca*) house walls. The bars labeled "improved 05-12" represent those households that changed from having informal walls to having formal walls between interviews in 2005 and 2012.

Table 1: Summary statistics, rural IHDS without latrines in 2005

	switched to latrine		did not switch		
	mean	s.e.	mean	s.e.	t-statistic
reported latrine use, 2005	0.000		0.000		
Hindu	0.826	(0.015)	0.896	(0.009)	-4.91
Scheduled Caste	0.206	(0.014)	0.281	(0.012)	-4.76
Δ ln(cons. per capita)	0.325	(0.023)	0.283	(0.015)	1.85
ln(cons. per capita), 2005	9.524	(0.020)	9.275	(0.014)	12.59
below poverty line, 2005	0.319	(0.015)	0.474	(0.011)	-10.21
Δ married females	0.176	(0.018)	0.123	(0.012)	2.51
married females, 2005	1.151	(0.019)	1.100	(0.009)	2.62
Δ members over 70	0.055	(0.011)	0.071	(0.006)	-1.37
members over 70, 2005	0.181	(0.012)	0.141	(0.007)	3.02
Δ household size	-0.010	(0.058)	0.074	(0.028)	-1.35
household size, 2005	5.158	(0.073)	5.076	(0.047)	1.21
Δ informal walls	-0.185	(0.017)	-0.142	(0.012)	-2.35
informal walls, 2005	0.444	(0.018)	0.615	(0.013)	-9.56
Δ piped water	0.090	(0.019)	0.055	(0.010)	2.09
piped water, 2005	0.352	(0.020)	0.221	(0.018)	6.03
any literate member, 2005	0.777	(0.012)	0.602	(0.008)	13.52
highest male education, 2005	6.715	(0.145)	4.466	(0.084)	15.33
highest female education, 2005	3.461	(0.116)	1.646	(0.060)	15.01
n (rural households)	3,605		10,134		

t-statistic tests whether the mean is the same for households that did or did not switch to latrine use; standard errors clustered by survey PSU. The sample corresponds exactly to the main regression results in table 2.

Table 2: Explaining household switching to latrines, 2005 to 2012

	(1)	(2)	(3)	(4)
dependent variable:	switched to latrine use, 2005-2012 (mean: 0.23)			
Hindu	-0.131***	-0.142***	-0.0948***	-0.0950***
	(0.0229)	(0.0234)	(0.0213)	(0.0213)
Δ ln(cons. per capita)	0.107***	0.0905***	0.0823***	0.0826***
	(0.0101)	(0.00971)	(0.0102)	(0.0104)
ln(cons. per capita), 2005	0.197***	0.158***	0.132***	0.131***
	(0.0119)	(0.0116)	(0.0123)	(0.0125)
Δ married females	0.0230**	0.0311***	0.0352***	0.0299***
	(0.00778)	(0.00749)	(0.00729)	(0.00832)
Δ members over 70	0.0101	0.00448	0.00807	0.00905
	(0.0110)	(0.0106)	(0.0101)	(0.0101)
Δ informal walls	-0.0214*	-0.0215*	-0.0277**	-0.0273**
	(0.0103)	(0.0103)	(0.00950)	(0.00945)
members over 70, 2005	0.0481**	0.0402**	0.0385**	0.0382**
	(0.0165)	(0.0154)	(0.0146)	(0.0148)
literate member, 2005		0.00769	-0.0124	-0.0120
		(0.0165)	(0.0158)	(0.0161)
highest adult education, 2005		0.00800***	0.0116***	0.0115***
		(0.00225)	(0.00217)	(0.00224)
highest female education, 2005		0.0162***	0.0115***	0.0120***
		(0.00230)	(0.00217)	(0.00216)
Scheduled Caste			-0.0379**	-0.0382**
			(0.0118)	(0.0119)
state indicators			$F = 84$	$F = 81$
			$p < 0.001$	$p < 0.001$
Δ females 18-30				0.00944
				(0.00689)
Δ males 18-30				0.0000689
				(0.00736)
Δ piped water				0.0190
				(0.0166)
n (rural households)	13,739	13,739	13,739	13,739

The sample is all rural households in the IHDS which did not split between 2005 and 2012 and which did not report a toilet or latrine in the 2005 baseline. F-statistics test whether indicators for 27 state and 5 caste categories (respectively) improve the fit of the model. Weights reflect the original 2005 sample design. Clustered standard errors in parentheses reflect the two-stage sample design; † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.