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

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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. In this study, 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 sanitation behavior. It also contributes to better research on the health consequences of poor sanitation: in order to conduct intervention studies, such as randomized experiments to learn about effects of open defecation on child height, researchers must first learn how to cause reductions in open defecation.

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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; Spears, 2012; Headey, 2015), and other health outcomes (Nandi et al., 2016), 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.

Reducing open defecation in rural parts of the developing world principally entails the difficulty of many households changing their sanitation behavior (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.

We 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. One implication of this central fact is that the magnitudes of the associations

that we document between latrine adoption and economic characteristics, education, demographic characteristics, and home improvement investments are quite small. For example, 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.

This paper expands the evidence in the literature on sanitation behavior in developing countries by studying 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, 2007). It is related to papers which seek to understand motivations for sanitation adoption or non-adoption across groups (see, for example, Jenkins and Curtis (2005) in Benin, Santos et al. (2011) in Brazil, Rheinländer et al. (2010) in Vietnam, and Guiteras et al. (2015) in Bangladesh). Like other recent papers on sanitation adoption in developing countries, it includes an explicit focus on group identity (in this case, Hindu and non-Hindu) and on gender (Sahoo et al., 2015; Khanna and Das, 2015; O'Reilly and Louis, 2014).

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 (Coffey et al., 2016; O'Reilly et al., forthcoming). Our results suggest that challenges to accelerating latrine adoption are likely to persist until programs and policies by governments and agencies, on the one hand, and intervention studies by researchers, on the other, 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 will explore in the discussion, does not support the adoption of affordable latrines.

2 Setting & context

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 variation in switching to latrines across and within places in India, which we study here.

Figure 1 uses the India Human Development Survey, which we introduce in section 3.1, to present data on 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 $\rho = 0.89$). Panel B shows that by 2012, states with less open defecation in 2005 eliminated a larger fraction of the open defecation that existed in 2005.

One important reason why open defecation in rural India remains persistently widespread 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. 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, makes pit latrine adoption less attractive in rural India than in other countries. Qualitative and quantitative evidence for the importance of social forces for Indian sanitation outcomes have been presented elsewhere in the literature (Coffey et al., 2016; Routray et al., 2015; Spears and Thorat, forthcoming). This paper, in contrast, seeks to quantitatively understand the minority of households that do switch from open defecation to latrine use.

In general, households that adopt latrine use in rural India privately finance the construc-

tion 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 (Coffey et al., 2014). Most villagers in the parts of rural India where open defecation is most common believe that an expensive latrine with a large pit or tank is an appropriate, although not necessary, addition to a house that is made out of bricks and cement. These latrines are considered convenient for occasions when someone has diarrhea; at night when it is difficult to walk far from the house; or when the household has an elderly or handicapped member who cannot defecate in the open. Some households may be more receptive to messages about latrine construction at times when a new daughter-in-law is entering the household (Stopnitzky, 2016). Due to their high cost, however, these latrines are considered a luxury item that only wealthy people can afford.

Unfortunately, the high cost of constructing a suitably large latrine pit may contribute to the slow adoption of latrines in rural India. Qualitative interviews by Coffey et al. (2016) suggest that the ways in which a small group of wealthy and influential villagers build latrines reinforces open defecation among the many poor. Although analysis of the importance of social networks for latrine adoption (see, for example, Shakya et al. (2015)) is outside the scope of this paper, we note that the fact that social networks in Indian villages are largely caste-based is likely to be another way in which intra-village social forces may slow latrine adoption in this context (Lamba and Spears, 2013).

Our paper tests several hypotheses suggested by the existing literature. We investigate how common it was for rural households who practiced open defecation in 2005 to switch to latrines by 2012, and whether such switching is statistically explained by household socioeconomic status, by demographic properties such as elderly household members and new married women, and by contemporaneous improvements in the home construction.

3 Data and methods

3.1 Data

We study nationally-representative panel data from the India Human Development Survey (IHDS), which interviewed approximately 40,000 households across India in 2004-2005 and again in 2011-2012. These data provide a unique opportunity to explore how changes in individual 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 study 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 focusing on 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 that permits us to study our question of interest: what baseline properties and changes over time are associated with switching to latrines among rural households without a latrine at baseline? 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.

3.2 Summary statistics

Table 1 presents summary statistics describing our rural 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.[1] Using a linear probability regression model, our main results investigate the statistical significance and robustness of these differences. Some of the differences in table 1 – such as access to piped water, for example – will prove to reflect omitted variables.

3.3 Hypotheses

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: acquiring married women or older adults was associated with an increased likelihood*

[1] 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 $\left(e^{\ln(c_{2012})-\ln(c_{2005})}\right)^{\frac{1}{7}}$.

of switching to latrines.

Hypothesis 4. *Switching to latrines often accompanies other investments in home construction: households that switched to improved walls over this period were more likely to switch to latrines.*

3.4 Empirical strategy

Our empirical strategy exploits the panel structure of our data. Unlike other quantitative studies of latrine use survey data in the literature, which investigate cross-sectional differences across households (Barnard et al., 2013; Coffey et al., 2014; Routray et al., 2015), our data hold constant that each household practiced open defecation in 2005. Thus, our study has the advantage of a fixed effects specification: any cross-sectional property of households that predicts 2005 open defecation is controlled for in our comparisons.

For each hypothesis, we first investigate how the variables of interest unconditionally predict switching to latrine use over the period studied. Then, we present our main result, a regression analysis of the first difference in household latrine adoption. Our dependent variable of interest is whether or not a household that did not use a latrine in 2005 has 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:

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

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 adult education.

- α: A set of indicators for each of the Indian states which permit us to study variation across households holding state-level properties constant.

- γ: A set of indicators for each of five caste and population group categories: Adivasi, Dalit, Other Backwards Classes, Brahmin, and other forward castes.

- *Hindu*: The existing qualitative and quantitative literature on latrine use in rural India highlights the role of religion and culture in sanitation adoption (Spears and Vyas, 2016; Geruso and Spears, 2015; Coffey et al., 2016). Therefore, all of our analyses test for the possibility that Hindu households were less likely to switch to latrines than non-Hindu households. It is noteworthy that Hindus are less likely to adopt latrines because they are relatively advantaged in socioeconomic status and access to public resources compared to non-Hindus.[2]

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 descriptive analysis 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. Nev-

[2]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.

ertheless, it is important to emphasize that our study has limits even for this more modest goal.

One of the advantages of our research design is our data: the IHDS is a nationally representative sample of households and it is panel data, visiting the same household twice. However, one limit 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 therefore combines latrine ownership and latrine use and which cannot separate latrine use among persons within a household.[3] Other recent surveys in rural India which distinguish between latrine use and ownership demonstrate the importance of these aspects of questionnaire design (Coffey et al., 2014; Clasen et al., 2014; Patil et al., 2014). Because many government-constructed latrines are incomplete, "missing," or otherwise not usable (Hueso and Bell, 2013), and because households in this context are most likely to use latrines that they construct for themselves with large pits or tanks, we principally interpret a change in households' answers to the IHDS question to reflect private latrine construction by households. 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.

Finally, 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 acquiring a daughter-in-law or upgrading the building materials of the house's walls.

[3]In particular, the question asks "Does the household have a toilet of its own?," which appears to be about 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. This question also is not clear on the categorization of apparent latrines which in fact are missing key parts or otherwise could not be used for defecation.

4 Results

For each hypothesis, we present results in two formats. First, we graphically explore the unconditional correlations of the independent variables described above with switching to latrine use. Then, because the independent variables in our hypotheses are correlated with one another, we present our main results in table 2 using the linear probability regression model described above in equation 1. Thus, throughout this section, we repeatedly refer back to table 2 to discuss each hypothesis in turn. The table presents a series of nested regression models to test the stability and robustness of our coefficients of interest. In particular, moving from column 2 to column 3, we see that adding a set of indicators for Indian states and for household caste category both statistically significantly improve the fit of the model without substantially changing our estimates or conclusions.

A prior cross-sectional literature, studying data from other surveys, finds that Hindu households in South Asia are more likely to defecate in the open, on average, than non-Hindu households. Consistent with this literature, we find that holding other variables equal, Hindu households were 8 to 14 percentage points less likely to switch to latrines over this time period than non-Hindu households. Although a correlation between religion and switching to latrines is not a hypothesis of this paper, we will present descriptive results for Hindu and non-Hindu households to ensure that religion is not an omitted variable.

4.1 Hypothesis 1: 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.

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.[4]

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.[5]

4.2 Hypothesis 2: Education

Figure 3 documents that households with higher education at baseline[6] (here represented as adult female education) 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 2005 rural India means that this graph must be interpreted with

[4]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.

[5]$\ln(10) \times \hat{\beta} = \ln(10) \times 0.121 = 0.279$.

[6]Because we are studying changes over time in the sanitation choices of households that remain intact, adult education would not be expected to importantly change in most cases.

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 be linearly associated with the household being only about four percentage points more likely to switch to a toilet or latrine. Columns 2-4 show that conditional on controlling for 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.

4.3 Hypothesis 3: Household demographic structure

Based on the literature and on formative qualitative fieldwork, we expected households to be more likely to switch to latrines if they gained married women (typically, in patrilocal rural India, a young, newly-married daughter-in-law) or if they gained elder members who may find it difficult to walk to the fields for open defecation, which we operationalize as members 70 years old or older. We found mixed support for these hypotheses. Figure 4 reports our descriptive findings. Panel (a) shows that, conditional on their change in consumption, households that gained a married woman were a few percentage points more likely to switch to latrines than households that did not.

We found no evidence that households that gained an elder (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 gained about one-third as many members over 70 as it did married women. Thus, panel (b) of figure 4 shows that it is the count of elder members, not the change, which predicts latrine adoption. Even this association, however, is found only for non-Hindu households.[7]

These descriptive results are confirmed in table 2, where an additional one woman *increase* in 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 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. It is widely accepted that men and daughters of the village face different social expectation and mobility constraints than daughters-in-law in rural India (Jeffery et al., 1989; Jejeebhoy and Sathar, 2001). Therefore, 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

[7]In the simple specification with no further controls corresponding to panel (b) of figure 4, Hindu interacts with the count of elders with $p = 0.060$.

confidence in our interpretation of our main result.

4.4 Hypothesis 4: Contemporaneous construction investments

As discussed above, when households in rural India build latrines, they tend to construct large, expensive substructures and superstructures out of improved 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 therefore 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 transitioned from unimproved to improved 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 had improved walls were two to three percentage points more likely to switch from open defecation than households that did not.

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, 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.

5 Discussion

Indian Census and Demographic and Health Survey data agree that open defecation in India has been declining at an average rate of 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 the fraction of remaining open defecation in the world that occurs in India increases each year.[8] The India Human Development Survey data also reflect this slow decline: only 23% of the 74% of rural households that did not have a latrine at baseline in 2005 adopted a toilet or latrine by the endline in 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.[9]

This paper adds to the literature on sanitation behavior in rural India by seeking to understand the minority of households that do adopt latrines. Using a panel data set, we ask: what explains why some households adopt latrines in rural India? We find support for four hypotheses: that economic status and education are associated with latrine adoption, that toilet adoption is more likely to occur when homes are being improved, and that latrine adoption is associated with household demographic structure and its changes.

It is, of course, not surprising that education, economic status, and demographic differences matter for sanitation adoption. But the *quantitative* facts of latrine adoption in rural India that we document present a striking challenge for policy-makers and health researchers. In other words, what is notable about our results is not which variables are statistically significant, but how shallow their regression slopes are. To illustrate this: 30% of our sample

[8]The source for this figure is the author's calculations from Joint Monitoring Programme for Water Supply and Sanitation (2012) data.

[9]The decline in person-level open defecation, which is a better indicator of improvement in the disease environment, is surely slower. Unfortunately, we could not examine this indicator because the IHDS does not record person-level open defecation within latrine-adopting households.

of rural households without a latrine in 2005 are Hindu, had below-median consumption in 2005, and have a below-median level of adult education; these represent hundreds of millions of people and 15% of the persons worldwide who defecated in the open in 2005.[10] Only 11.4% of these households switched to latrines between 2005 and 2012.

In addition to highlighting the slow pace of latrine adoption in rural India, it is also important to point out that the factors that we identified as associated with latrine adoption may be difficult for policy-makers to influence: even tripling consumption has a quantitatively small effect on latrine adoption, as do major household-level investments in brick and concrete walls. Economic growth will certainly allow more rural Indian households to switch from open defecation to expensive latrines with large pits in the next several decades. But in the meantime, open defecation poses an important threat to health in rural India, and particularly to the health and human capital accumulation of children.

The time period of our study spanned two central-government sponsored rural sanitation programs – the Total Sanitation Campaign and Nirmal Bharat Abhiyan – which similarly emphasized the construction of pit latrines over sanitation behavior change. Our findings suggest that the Indian government's policy of subsidizing pit latrines did not achieve large behavior change, and may still represent a misguided focus. This policy essentially continues under the current Swacch Bharat Mission. If even the most educated and best-off households and those who are already making home improvements adopt latrines at such a slow pace, then our results suggest that perhaps sanitation policy could be more successful if it did more to address the underlying social environment in which decisions about where to defecate, and what sort of latrine is socially acceptable, take place.

The facts that we document here also present a challenge to researchers seeking to learn about the effects of open defecation on health through intervention studies. Like policy-

[10]According to UNICEF-WHO Joint Monitoring Program statistics, in 2005 581 million people in rural India defecated in the open, and 1.135 billion people worldwide did. Because the decline in open defecation in rural India has been so relatively slow, this percent would only be greater for present-day data. http://www.wssinfo.org accessed 11 December 2016.

makers, such 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. Intuitively, it is difficult to advance our understanding of the consequences of changing open defecation behavior without successfully changing open defecation behavior.

Unfortunately, achieving such a large first stage change in latrine adoption has proven difficult in rural India. Recent studies of the effect of open defecation on height (Clasen et al. (2014) is a recent example from rural Orissa; Patil et al. (2014) is an example from Madhya Pradesh), do not identify effects on health outcomes in large part because too much open defecation remained in the villages they studied even after latrine use promotion interventions.

Despite such challenges, it is no solution to abandon attempts to learn the effects of open defecation in India. This is because rural India is where much of the world's open defecation remains, and because the literature suggests that due to high population density the effects of open defecation on health are likely to be especially large in South Asia (Hathi et al., forthcoming). So, if intervention studies cannot achieve a large first stage change in open defecation behavior in rural India, then the set of estimates in the experimental literature may systematically overlook its potentially large consequences for rural Indians – at least until better strategies for promoting latrine adoption and use can be developed.

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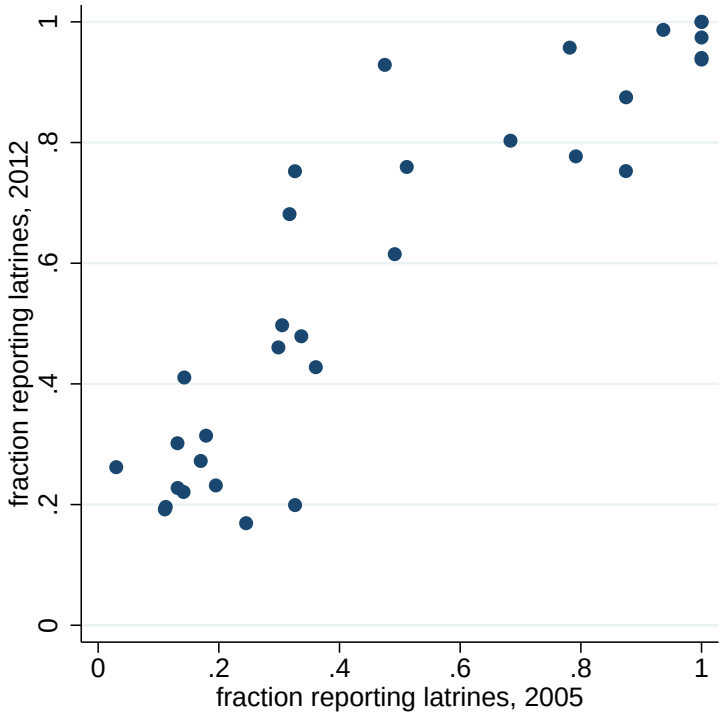
Figure 1: State level rural latrine adoption, IHDS 2005 and 2012

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



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

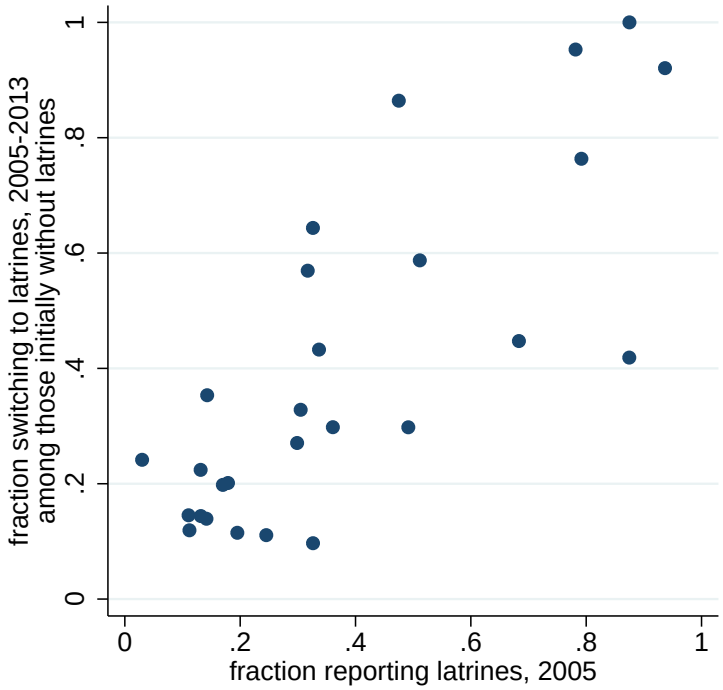
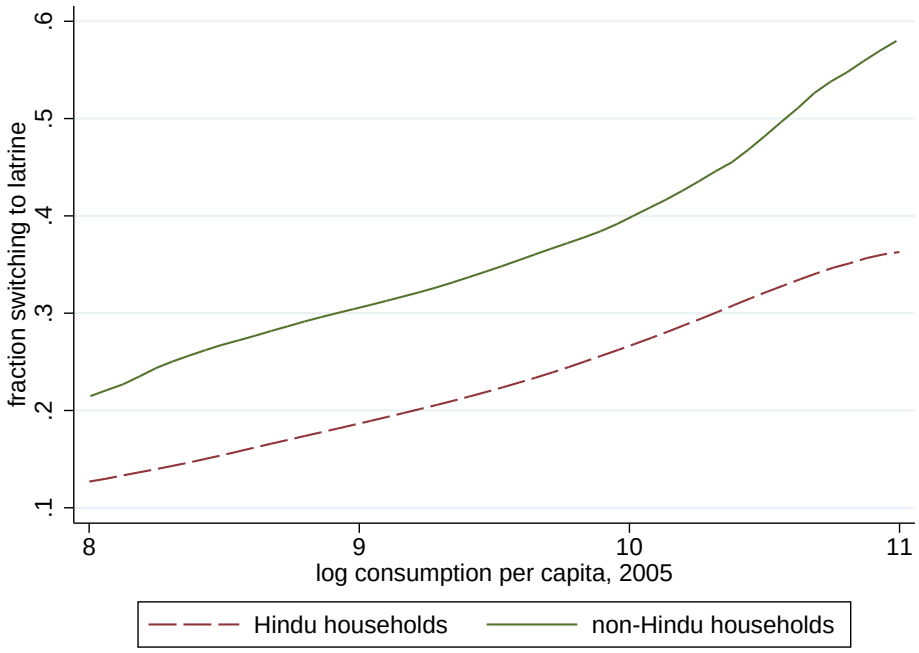
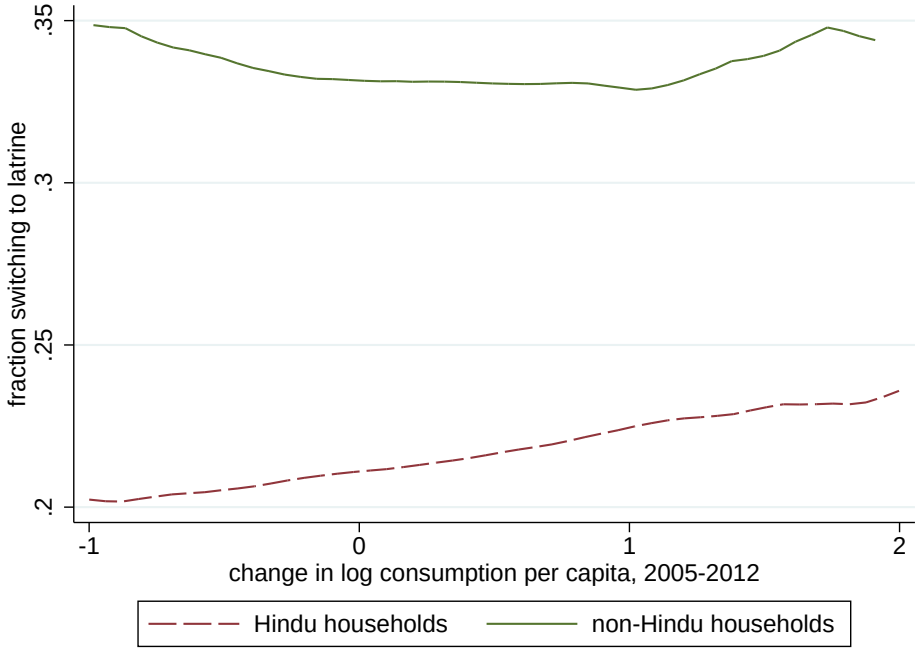


Figure 2: Hypothesis 1: Switching to latrines and household economic status

(a) 2005 consumption per capita

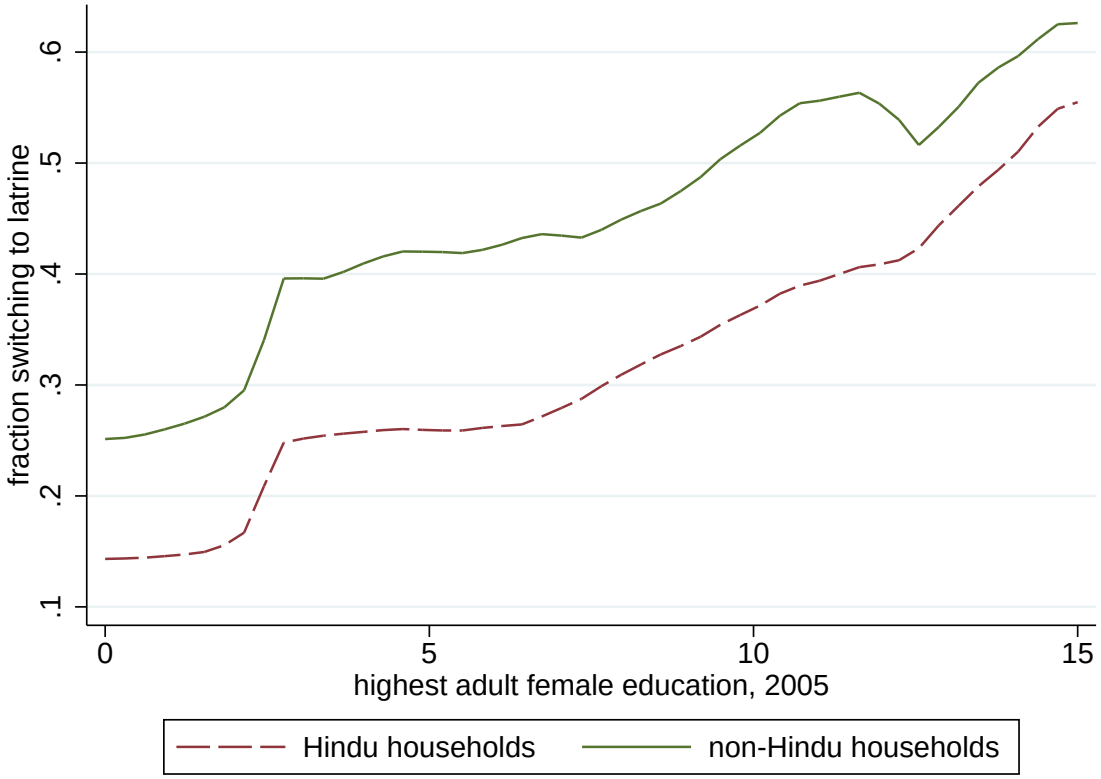


(b) change in consumption per capita, 2005-2012



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.

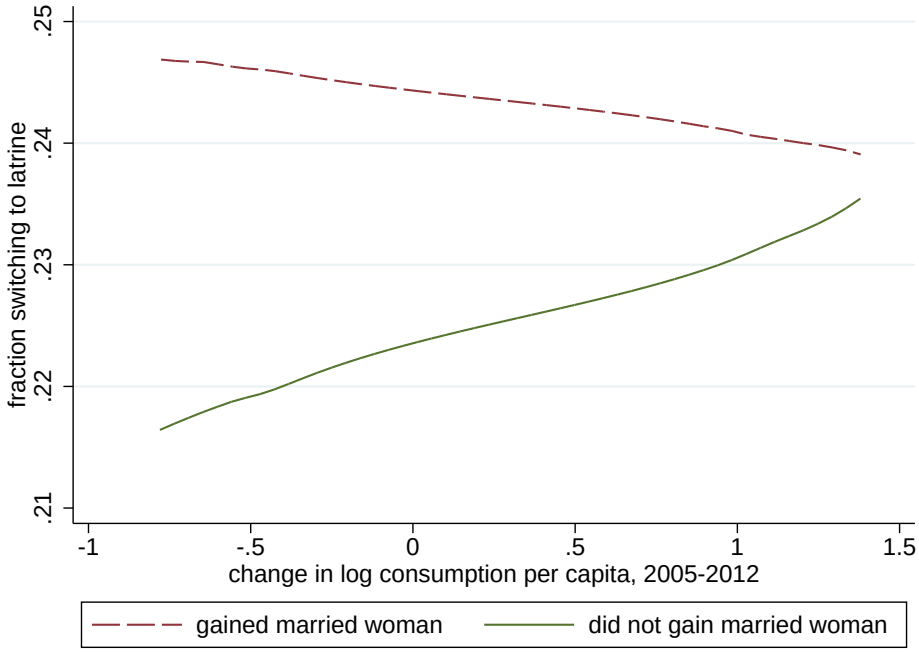
Figure 3: Hypothesis 2: Switching to latrines and baseline education



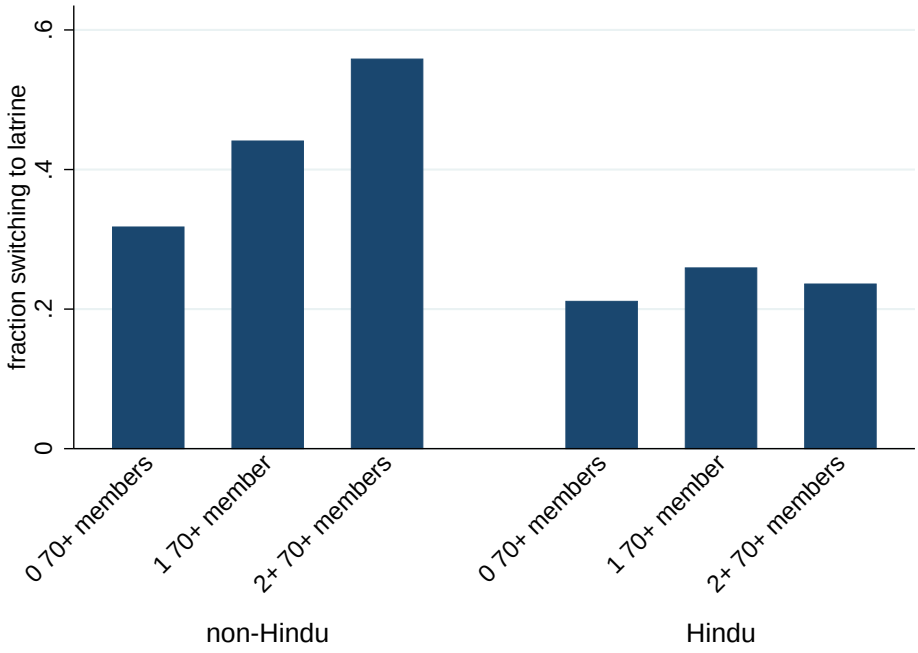
Locally weighted regressions. The sample corresponds exactly to the main regression results in table 2.

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

(a) change in married females, 2005-2012

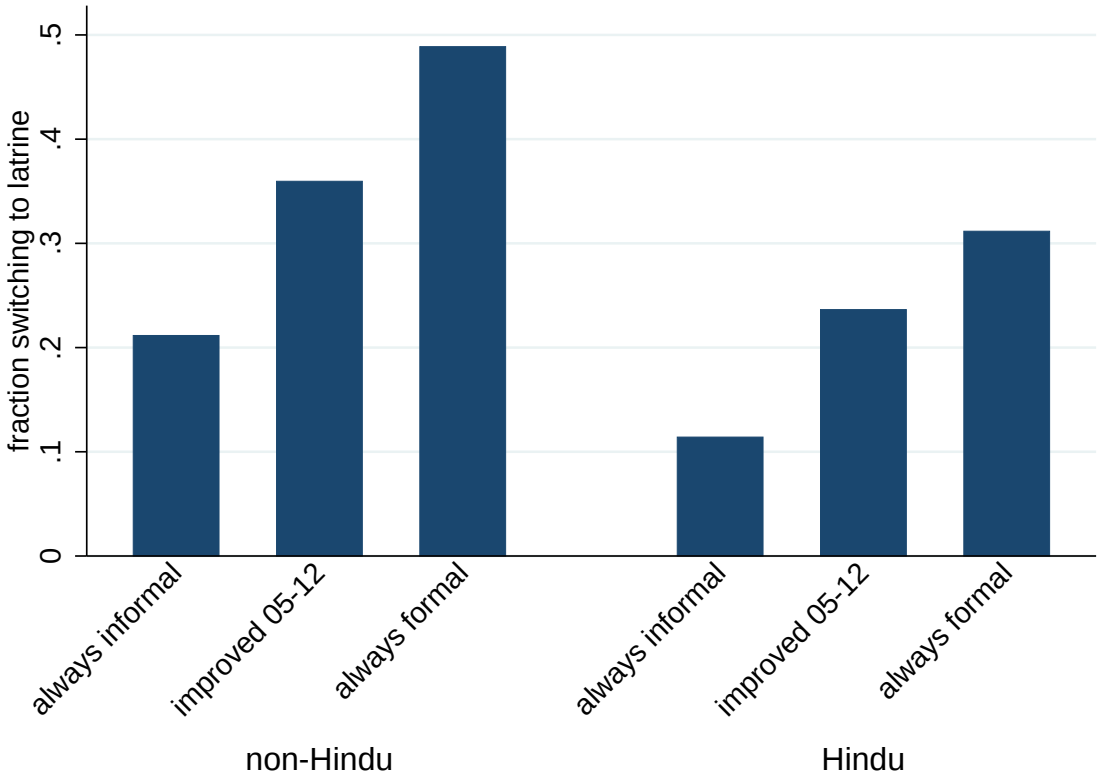


(b) elder residents (over 70 years old) at baseline, 2005



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

Figure 5: Hypothesis 4: Switching to latrines and contemporaneous home construction



Locally weighted regressions. Data are from interviewers' observations of *kaccha* (unimproved) or *pacca* (improved) house walls. The sample corresponds exactly to the main regression results in table 2.

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
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 unimproved walls	-0.185	(0.017)	-0.142	(0.012)	-2.35
unimproved 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***	-0.0882***	-0.0882***
	(0.0229)	(0.0234)	(0.0209)	(0.0209)
Δ ln(cons. per capita)	0.107***	0.0905***	0.0766***	0.0767***
	(0.0101)	(0.00971)	(0.0102)	(0.0104)
ln(cons. per capita), 2005	0.197***	0.158***	0.122***	0.121***
	(0.0119)	(0.0116)	(0.0124)	(0.0126)
Δ married females	0.0230**	0.0311***	0.0348***	0.0296***
	(0.00778)	(0.00749)	(0.00727)	(0.00833)
Δ members over 70	0.0101	0.00448	0.00542	0.00645
	(0.0110)	(0.0106)	(0.0101)	(0.0101)
Δ improved walls	0.0214*	0.0215*	0.0275**	0.0270**
	(0.0103)	(0.0103)	(0.00946)	(0.00943)
members over 70, 2005	0.0481**	0.0402**	0.0348*	0.0344*
	(0.0165)	(0.0154)	(0.0149)	(0.0151)
literate member, 2005		0.00769	-0.0150	-0.0146
		(0.0165)	(0.0158)	(0.0161)
highest male education, 2005		0.00800***	0.0114***	0.0114***
		(0.00225)	(0.00218)	(0.00225)
highest female education, 2005		0.0162***	0.0112***	0.0117***
		(0.00230)	(0.00217)	(0.00216)
state indicators			$F = 81.92$	$F = 78.22$
			$p < 0.001$	$p < 0.001$
caste group indicators			$F = 5.78$	$F = 5.92$
			$p < 0.001$	$p < 0.001$
Δ females 18-30				0.00924
				(0.00684)
Δ males 18-30				0.000368
				(0.00740)
Δ piped water				0.0212
				(0.0165)
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; † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.