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Of Flies, Mosquitoes, and Hygiene: Role of Public and Private Avoidance Measures in Indian

Althaf Shajahan

althaf@nitc.ac.in

National Institute of Technology Calicut

Arnab Mukherji

Indian Institute of Management Bangalore

Article

Keywords:

Posted Date: June 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9126401/v1

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Additional Declarations: No competing interests reported.

Abstract

One of the major risks of living in a slum without adequate public services is the elevated risk of infectious disease. This paper considers the association between exposure to public preventive efforts and morbidity levels due to environmental diseases in Indian slums. Using the slums and urban sub-sample from the nationally representative data from the 2012 wave (69th Round) and 2018 wave (76th round) of National Sample Survey on Drinking Water, Housing and Hygiene Conditions, we test whether local or state governments are more or less successful than private households in reducing morbidity from diseases caused by flies and mosquitoes. After controlling for a range of attributes, we found that government efforts to tackle flies and mosquitoes had a considerably larger positive impact than for private efforts, although the effect was found only in slum areas; there was no effect in urban localities outside the slum settlements. These results suggest that public health efforts targeted towards improving drinking water and hygiene are highly effective and not easily duplicated by private efforts.

Introduction

Urbanization and congestion are key aspects of the modern city today. Estimates suggest that over 68% of the world's population will live in urban areas by 2050 (United Nations, 2018). Slums are the first place of habitation for new migrants into the city. In this context, the policy environment for slums have been surprisingly unfriendly, ranging from a benign lack of governing policies to policies designed to evict slum residents (Yelling, 2012; Krishna et al. 2014; Frumkin and Haines, 2018). Urbanization and the parallel growth of slums, particularly in developing countries, implies that people live with poor infrastructure and limited access to water and sewage systems. This also implies that the micro-environment within which they live can easily play host to disease carrying flies and mosquitoes so that slums may be characterized as hotspots for infectious diseases (Eisenstein, 2016; Ezeh et al. 2017). In this paper, we explore the role of the state in managing such city-wide hotspots through public vector control interventions and its impact on health outcomes on two axis – a) across slum and non-slum urban areas and b) the relationship between public and private investments in vector control strategies.

The literature on the efficacy of interventions that control disease, such as malaria and stomach disorders, in slums is limited. Not only is such data infrequently collected, what data exists has rarely been used to investigate how households engage with the micro-environment they live in and how this may affect their health. A household's micro-environment is influenced by the household's choices as well as the slum's access to infrastructure, hygiene, and their use of vector control strategies. Public investments are likely to have large positive externalities and reduce the likelihood of diseases such as stomach disorders and malaria whose mitigation is particularly dependent on access to clean water and good hygiene; only a few studies study this relationship (Armand et al., 2017; Cohen et al., 2012; Lengeler, 2004; Packard, 2009). Community-based interventions against infectious diseases in urban informal settlements across Asia, Latin America, and sub-Saharan Africa confirm that while the evidence base is growing, it remains unevenly distributed, and that multi-pronged public interventions consistently demonstrate greater effectiveness than household-level action alone in reducing disease burden in such

settings (Shafique et al., 2024). We add to this literature by estimating the health externality associated with public interventions compared to the impact of private household-level inputs to combat poor micro-environments. To do so, we draw on the NSSO 69th and 76th Round surveys on Drinking Water, Sanitation, Hygiene and Housing Condition — among the only nationally representative instruments in India that simultaneously capture settlement-level public vector control efforts, household-level private avoidance behaviour, and self-reported disease outcomes. This makes them uniquely suited to investigating a research question that sits at the intersection of two underexplored themes in the public health literature: the behavioural channels through which preventive health inputs operate in informal settlements, and the extent to which those channels are shaped by public or private externalities. While the broader literature has tended to treat public and private health investments as substitutes or complements in aggregate, the structure of these surveys allows us to disaggregate the two and trace their differential effects through the specific epidemiological pathways — drinking water and hygiene — that are most salient in slum environments.

While municipalities are usually responsible for ensuring fumigation, provision of drinking water, collecting and treating sewage at the settlement level, very frequently, such public investments are often inadequately provided in slums. Households often try to reduce their exposure to poor quality water, air, and disease carrying flies and mosquitos by investing in household level water treatment, adopting clean hygiene practices and bed-nets to limit their personal exposure to disease causing pathways. We look at the association of public investments and health risk in contrast to the association between private investments and health risk to understand the health externality associated with the public provision of settlement level clean water, strong hygiene and by tackling the problem of mosquitoes and flies. The richness of the covariates in our dataset allows us to explore two specific disease progression channels that may influence the settlement micro-environment and the health of its residents: a) drinking water and b) hygiene and its impacts on two common vector borne illnesses – stomach disorders and malaria

The data shows that both slum and non-slum resident households invest in improving quality of water and the level of hygiene in their homes; further, such investments reduce the incidence of stomach problems and malaria. However, the impact of private efforts is much smaller than the health effects generated by public investments in vector control. This suggests that public investments in these activities can not only have a larger effect, but that this effect may be equity promoting and protect even those who are unable to invest in their own protection.

The rest of the article is organized as follows: we discuss the literature around disease transmission pathways operating in urban areas in section 2; in section 3, we discuss the data we use, while in section 4 we present the estimation strategy in section 4, and in section 5, we present our results, and we conclude in section 6.

Background

Over 2000 years ago Hippocrates, in his treatise on Air, Waters and Places, advised the itinerant physician to be mindful of the qualities of the local air and water as they travelled from place to place. This advice is still relevant as poor public infrastructure in urban areas often leads to poor water and hygienic environments for their residents. Such environments are known to provide favourable pathways for the spread of a wide range of infectious diseases (Riley, 2007; Eisentien, 2016). An individual's microenvironment is determined by both household specific factors and community settlement factors. Individual factors not only reflect income and socio-economic status of the household, but also behaviour and actions taken within the home to improve the household disease micro-environment. Thus, while income and socioeconomic status could determine the ability to make an investment in superior sewage and water purification systems, a household's care at storing water, or using bed-nets would reduce the chances of individuals falling sick. Community settlement specific factors such as the quality of water received, or regular clearance of garbage can reduce the exposure to communicable diseases significantly (Belmaker et al., 2006; Mayo, 2007; Rego et al., 2005; Skudarnov & Kurkatov, 2011) The epidemiological basis of vector borne and congestion related diseases in urban areas is a rapidly burgeoning research field that not only deals with existing communicable diseases, but also new ones such as the Zika virus (Schwarz and Pruyt, 2016; Unger and Riley, 2008). The COVID-19 pandemic additionally underscored how slum micro-environments can dramatically amplify disease transmission, reinforcing the urgent case for sustained public investment in settlement-level vector control and sanitation (Shafique et al., 2024). While the epidemiological basis for reducing the spread of communicable diseases is widely known, their use in household strategies or as a part of policy is less well understood. For example, Galiani et al.'s (2005) work shows that when water services are privately provided then child mortality declines in contrast to when they are provided directly by the municipality. Thus, not only does the epidemiological pathways matter, but so does a range of contextual factors that drive the efficacy of attempts to disrupt epidemiological pathways. Inherent norms of monitoring and incentivizing routine activities, diligence at home, and in provision of public service, etc. all matter in reducing the spread of communicable diseases (Pattanayak, 2007; Wagner and Lanoix 1958).

In the context of reducing the spread of communicable diseases due to the breeding of flies and mosquitoes it is possible to look at two disease transmission channels: a) drinking water and b) hygiene (A schematic depiction is in Fig. 1). The drinking water channel accounts for diverse types of privately purchased inputs that can improve the quality of drinking water. Some examples of such privately purchased inputs include the filtration or other physical or chemical treatment of water prior to drinking or ways of handling and storing water in the household. The hygiene channel accounts for household-level efforts to tackle the spread of disease by exposure to flies and mosquitoes and efforts in draining the wastewater from the premises and municipal mechanisms of garbage disposal. The efficacy of these channels is in principle affected by public provision of vector, and we try to find empirical support for this in this article.

There are many transmission points at which interventions may disrupt the transmission of diseases, especially for stomach-disorders via the drinking water channel. Water may become re-contaminated after at-source treatment, either during transportation, or storage, or even after collection, or through

poor storage practices. A systematic review of the literature on interventions in developing countries found that household interventions on water quality were twice as likely as at-source interventions in reducing the incidence of diarrhoea among children five or less (Clasen et al. 2007). Evidence from urban slums in Indian metropolises confirm that even when water is sourced from nominally safe municipal supply, point-of-use contamination during household storage and handling remains a critical driver of diarrhoeal disease transmission, pointing to the limits of infrastructure provision alone (Palit et al., 2012; Kanungo et al., 2021). Globally, a landmark analysis estimates that unsafe drinking water, sanitation, and hygiene together account for 1.4 million deaths and 74 million disability-adjusted life years annually, with diarrhoeal diseases contributing the largest share of this preventable burden (Wolf et al., 2023). While most of these methods are relatively inexpensive and easy to use, they do require time, discipline and motivation – all of which is likely to be in short supply for households in living in slums.

Investments in sanitation by a household will not only reduce morbidity for that household but also contribute to improving sanitation and morbidity in the neighbourhood. The greater the density of the neighbourhood, the larger the gains that are possible (Cutler and Miller 2005; Watson, 2006). A household's investment in sanitation and hygiene reduces the level of infectious disease in the community. This effect is predicted to be most important in communities with low levels of sanitation and reflects in the spread through fecal–oral transmission such as stomach-disorders (Watson, 2006; Chin, 2000). Sanitation and hygiene as determined by how water is stored, solid garbage and wastewater is disposed, the type of toilet used, drainage systems at the household and settlement level all are important intervention points in controlling disease progression channels.

Yet, traditionally there has been an emphasis on household-level efforts to prevent mosquito bites, such as, fixing mosquito nets, preventing water from accumulating in the surrounding, using smoke or mosquito repellents or more importantly using insecticide treated nets and curtains (Nabarro and Taylor, 1998; Deuchert, and Wunsch, 2014; Tozan and Derya Uysal, 2014). An alternate approach is to engage local governments in vector-control efforts at the settlement level through a broad range of interventions including through regular fumigation or fogging activities.

Data and Methods

In this paper we use household data from 2012(69th round) and 2018(76th round) collected by the National Sample Survey of the Government of India that collected data on housing for urban households. This is a nationally representative survey that was designed to collect data on housing conditions, drinking water, sanitation and hygiene conditions. In addition to standard household survey modules, the 2012 and 2018 surveys also had questions on the quality of drinking water, method of treatment of drinking water, material of the main container in which drinking water is stored, how drinking water is taken out from the storage container, how local bodies/state government (or the household) tackled the problem of flies/mosquitoes and on the incidence of specific types of hygiene-related illness. This provides a unique opportunity to study the health impact of disrupting two different epidemiological channels of disease propagation, the drinking water and hygiene channels, through public and private

investments. Our sample shows that 10.89% of all slum-dwellers report that their drinking water tastes or smells bad in 2012. Further, 46.56% and 51.49% of all slum household report either physically or chemically treating water before consumption in 2012 and 2018 respectively; about 70% report handling water hygienically (using a tap or a vessel with handle to draw water) while nearly 98.8% store their drinking water in an earthen or metal container with a lid.

In this paper, slum and non-slum households are identified based on the definition adopted by the Census of India 2011, which also forms the sampling framework for the National Sample Survey. The Census 2011 recognises three categories of urban slums: (i) notified slums — all areas formally notified as “slum” by the State or Union Territory administration or local government under any Act, including a Slum Act; (ii) recognised slums — areas acknowledged as slums by State, Union Territory administration or local government, Housing and Slum Boards, which have not been formally notified under any legislation; and (iii) identified slums — compact areas of at least 300 population, or roughly 60–70 households, of poorly built and congested tenements, in an unhygienic environment usually characterised by inadequate infrastructure and lacking proper sanitary and drinking water facilities (Census of India, 2011; Report of the Committee on Slum Statistics/Census, 2011). It is worth noting that the NSS operationalises the slum threshold somewhat differently: in the 69th and 76th Round surveys, a slum is defined as any compact settlement of at least 20 households of poorly built tenements in unhygienic conditions, with inadequate sanitary and drinking water facilities, covering both notified and non-notified slum areas. A household surveyed within such a settlement is classified as a slum household; all other urban households residing in statutory towns but falling outside any of these Census-defined slum settlement boundaries are treated as non-slum urban households. This slum/non-slum distinction forms the basis of the two sub-samples used throughout the analysis.

Table 1
Summary Statistics for Slum and Non-Slum Households (2012- 69th round)

	Slum		**Non-slum**		**Non-Slum Matched**	
	(N = 5,318)		***(N = 36,813)***		***(N = 5,318)***	
	Mean	SD	Mean	SD	Mean	SD
Health-outcomes						
Incidence of a stomach disorder	21.43%	41.03%	15.79%	36.46%	16.68%	37.28%
Incidence of malaria	4.33%	20.35%	3.31%	17.89%	4.78%	21.33%
Household variables						
Has a secondary educated female	36.25%	48.08%	61.23%	48.72%	39.09%	48.80%
Head is self-employed	34.61%	47.58%	36.86%	48.24%	33.91%	47.34%
Muslim	19.45%	39.59%	14.85%	35.56%	18.41%	38.76%
Scheduled Caste	25.77%	43.74%	13.53%	34.21%	29.64%	45.67%
Owns house?	61.40%	48.69%	67.62%	46.79%	59.14%	49.16%
Has a Voter's ID card?	13.79%	34.48%	0.08%	2.81%	13.80%	34.50%
Electricity connection	94.38%	23.04%	96.44%	18.53%	93.51%	24.63%
Monthly Per Capita Expenditure (Rs.)	6575.34	4588.9	9141.44	9541	6669.76	5537.29
Household size	1.4	0.6	1.33	0.6	1.41	0.59
Disruptor of Disease Pathways						
Has piped drinking water?	21.52%	41.10%	17.92%	38.35%	24.29%	42.89%
Has Private toilet?	34.39%	47.50%	66.27%	47.28%	35.69%	47.91%
Is the house structurally good?	29.51%	45.62%	54.95%	49.76%	32.14%	46.70%
Is there underground drainage? System	21.56%	41.13%	33.42%	47.17%	22.58%	41.82%
Is garbage collected by municipality?	46.88%	49.91%	45.48%	49.80%	45.75%	49.82%
Is it an independent house?	60.18%	48.96%	58.38%	49.29%	59.98%	49.00%
Is there proper ventilation?	18.19%	38.58%	44.95%	49.75%	19.27%	39.45%
Is there separate kitchen with tap?	31.62%	46.50%	30.84%	46.18%	29.43%	45.58%

For each household, we observe the incidence of two infectious diseases within the last 30 days - diarrhoea and malaria. Disease onset preceding before the manifestation of symptoms, the actual onset of the illness may be within or before the 30 days. In 2012, 16.68% of all slum households report stomach disorders in the household as against 15.79% non-slum, urban households. The occurrence of stomach disorders in 2018 is around 10%. But the occurrence of malaria is far lower (4.78% for slum households and 3.31% of non-slum urban households) as captured in Table 1. But in 2018, incidence of malaria and other diseases spread by mosquitoes like dengue, chikungunya, encephalitis, etc. is around 10%. Public investments in vector control reflect efforts made by the city municipality in tackling the problem of flies and mosquitos in the last 365 days; these include measures such as spraying chemicals, fogging, and cleaning garbage among others. We find 44.69% of urban households in 2012 and (46.04% in 2018) report receiving public vector control programs in their settlements. With only 14.45% of rural sample reporting the same in 2012, these public efforts are largely urban in nature. This rises to 35.42% rural households in 2018. We can also see that among this urban population more than half of the slum households (49.70% in 2012) receive public vector-control efforts while 38.99% in 2012 of the urban households living outside slums have such an exposure. These numbers seemed to have improved in 2018. 57.70% of slum households and 45.31% of the non-slum urban households received public vector-control efforts in 2018. Such improvements in the statistics between 2012 and 2018 could be attributed to the success of sanitation and drinking water schemes and programmes of the Government such as Swachh Bharat Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Smart Cities Mission, National Rural Drinking Water Programme (NRDWP) which was initiated by the new government with their considerable emphasis on *Swacch Bharat* or Clean India after they came to power in 2014.

We also observe private health inputs made by households to avert exposure to disease through controlling exposure to flies, mosquitoes and by improving hygiene within their residential unit. For example, we observe if households attempt to disrupt the spread of disease by treating water using physical or chemical methods before drinking, storing drinking water in a proper container or taking water out of the main container properly – all related to the water channel. Similarly, we observe if households invest in private inputs to address the hygiene channel; they can limit exposure to the problem of flies/mosquitoes by fixing nets in the windows, preventing water from accumulating in the surrounding or using smoke, use of mosquito repellents, etc. Disposal of household wastewater would also be an important way to avert diseases transmitting along the hygiene channel. We measure whether households safely re-use the wastewater after treatment or dispose the wastewater with or without treatment responsibly to a covered drainage system.

Table 1 presents descriptive statistics for our key outcome variables, as well as for the household and its investments to disrupt disease progression pathways for the 2012 data. The descriptive statistics for 2018 data are collected in Appendix Table 1. The raw sample has data on 5,316 slum resident households and 36,813 non-slum urban households in 2012 and 2378 slum households and 40,724 non-slum urban households in 2018. For the first part of the analysis we restrict the analysis to the slum sample and investigate the relative importance of public verses household investments in averting

diseases. Thus, we model the incidence of stomach disorders (malaria) in the last 30 days using a logistic regression function of both public investments as well as a range of disease specific strategies that the household may adopt to prevent being affected. Our variables of interest are public investment in settlement level efforts of controlling flies, mosquitos, and improving hygiene, and the household disease specific strategies to disrupt disease channels for the spread of infectious diseases.

We repeat the analysis above in a sample of households that live in slum-like urban settlements outside of designated as slums. Swaminathan and Mukherji (2012) document the joint existence of designated slums and slum-like conditions in settlements outside the slum where health indicators may be worse than in slums. Since the public investments are managed for all areas by the municipality independent of the settlement's slum status, we look at the impact that such activities have in settlements that have emerged but are not yet entrenched within the urban area to be declared a slum.

To identify such slum-like conditions outside the slum we use a propensity score model to identify a group of urban households that are like slum resident households on a wide range of attributes. In our propensity score model, we specifically match households on their access to infrastructure within the household to capture details of the micro-environment in the settlement. Further it captures nature of homeownership, possession of a voter's card, electricity connection, a separate kitchen with tap, proper ventilation, piped drinking water, private latrine, underground drainage and socio-economic status of the household captured by caste and consumption quintiles are few of such attributes. The construction of the matched sample is based on nearest neighbour matching (1:1) match so that for each of the 5316 slum resident households, we found an equivalent non-slum resident household. This matched sample of non-slum households who are like slum households but live outside, to explore the importance of public and private investments in emerging settlements.

Table 1 show that the non-slum sample after matching is much closer on all household variables as well as household investments in preventing the spread of diseases. 81.78% of all slum households invest in their own vector-control measures and 10.83% experience some water stagnation around the source of their drinking water. However, only 29.11% dispose their household waste water responsibly. Importantly, 45.75% of them avails garbage disposal services from their municipal bodies, 35.80% of these households avail them daily.

Our regression models adjust for important indicators of the settlement conditions (the drainage system in the settlement, the principal source of water for drinking purposes and the type of toilet used) and household attributes (nature of homeownership, possession of a voter's ID card, electricity connection, a separate kitchen with tap, proper ventilation, piped drinking water, and socio-economic status of the household captured by caste and consumption quintiles). Further, hygiene specific infrastructure measures in combination with a rich set of household and neighbourhood control variables allows us to usefully account for key determinants of stomach disorders and malaria.

Results

Table 1 confirm that stomach disorders are more frequent than malaria in 2012. Interestingly, matched non-slum households report higher stomach disorders than slum households. Households with access to public investments in controlling the micro-environment have lower incidence of both stomach disorders and malaria among slum households and non-slum households. The unconditional impact of public investments on stomach disorders is much larger than the impact on malaria.

Table 2
Odds Ratio from a Logistic Model Investigating a Drinking Water Channel for Incidence of Stomach disorders and Malaria among Slum Households and Matched Urban Non-slum Households in India : 2012 National Sample Survey on Drinking Water, Sanitation, Hygiene and Housing (69th Round)

Variable	**Stomach-disorder, OR (95% CI)**		**Malaria, OR (95% CI)**	
	Slum Sample	**Non-Slum Sample**	**Slum Sample**	**Non-Slum Sample**
Access to public vector control? (Y/N)	0.66 (0.53–0.81)	0.69 (0.45–1.08)	0.67 (0.48–0.92)	1 (0.56–1.81)
Whether the households				
treats water by physical or chemical means	0.95 (0.78–1.16)	0.58 (0.40–0.83)	1.86 (1.32–2.60)	0.73 (0.44–1.24)
stores drinking water in proper container	0.74 (0.36–1.53)	0.8 (0.48–1.32)	0.61 (0.19–1.96)	1.4 (0.51–3.86)
handles drinking water properly	0.68(0.55–0.83)	0.94(0.68–1.30)	0.71(0.51–0.98)	1.63(0.92–2.86)
finds drinking water to be of bad quality or smell	1.62(1.23–2.14)	1.93(1.17–3.21)	0.94(0.59–1.50)	2.15(0.76–6.07)
Stagnant water near source	0.98(0.74–1.29)	0.67(0.25–1.79)	1.37(0.87–2.15)	2.74(1.09–6.86)
Water sufficiency round the year	0.66(0.52–0.83)	0.64*(0.40–1.02)	0.8(0.55–1.14)	1.06(0.55–2.01)
Observations	5,316	5,316	5,316	5,316
Log Likelihood	-2344	-2683	-999	-916
df_m	7	7	7	7
chi2	55.8	21.7	30.4	20.6

Regression results in Table 2 indicate that treating drinking water by physical or chemical methods is not associated with benefits for slum households and in fact is associated with increased stomach disorders for equivalent households living outside the slum (Columns 2 and 3). Drinking water from a tap or using a vessel with a handle (both household level actions) reduces stomach disorders but has no

impact for equivalent non-slum households. Finally, in instances where the principal source of drinking water is of bad taste or smells we find both slum residents and non-slum residents report greater stomach problems. Thus, the way in which water reaches the home appears to be an important determinant of intestinal health.

Table 2 suggests that government efforts are associated with a reduction in stomach problems in slum households. Equivalent non-slum households do not see any gains from government investments in improving hygiene and through vector control programs. We find broadly similar patterns with the drinking water channel for the incidence of malaria with government efforts playing a key role in reducing malaria in slums in last two columns of Table 2. Physical or chemical methods of treating water are associated with an increase rather than decrease in malaria and this finding is robust to many specifications, while using water from the tap or a vessel with a handle is associated with a reduction in the incidence of malaria in slums.

Table 3

Odds Ratio from a Logistic Model Investigating a Hygiene Channel for Incidence of Stomach disorders and Malaria among Slum Households and Matched Urban Non-slum Households in India : 2012 National Sample Survey on Drinking Water, Sanitation, Hygiene and Housing (69th Round)

Variable	**Stomach-disorder, OR (95% CI)**		**Malaria, OR (95% CI)**	
	Slum Sample	**Non-Slum Sample**	**Slum Sample**	**Non-Slum Sample**
Access to public vector control? (Y/N)	0.69***	0.7	1.03	0.73*
	(0.55–0.87)	(0.44–1.11)	(0.57–1.84)	(0.53–1.02)
Whether the households				
undertake efforts vector control themselves	1.18	1.31	2.24**	0.93
	(0.91–1.53)	(0.89–1.91)	(1.09–4.64)	(0.63–1.36)
drains wastewater properly	0.75**	0.93	0.83	1.23
	(0.59–0.95)	(0.58–1.49)	(0.48–1.43)	(0.85–1.78)
has garbage disposal done by Municipal Body	0.85	0.64*	0.77	0.78
	(0.67–1.07)	(0.41–1.00)	(0.48–1.23)	(0.52–1.17)
has garbage disposed daily	0.84	0.85	0.81	0.85
	(0.67–1.06)	(0.68–1.05)	(0.56–1.17)	(0.62–1.17)
has garbage disposed daily by Municipal Body	1.06	1.16	1.37	1.14
	(0.78–1.44)	(0.82–1.64)	(0.81–2.31)	(0.73–1.78)
Stagnant water near source	0.91	0.58	2.51	1.24
	(0.68–1.21)	(0.19–1.78)	(0.79–7.94)	(0.78–1.96)
Observations	5,318	5,316	5,316	5,318
Log Likelihood	-2364	-2712	-924	-1013
df_m	7	7	7	7

Variable	Stomach-disorder, OR (95% CI)		Malaria, OR (95% CI)	
	Slum Sample	Non-Slum Sample	Slum Sample	Non-Slum Sample
chi2	32.3	16.1	13.6	9

Tables 4 and 5 collects the results of the logistic regressions via the drinking water channel and hygiene channel respectively for the 2018 household data. Results in both tables reiterates the findings from the earlier round. Table 4 which investigate the drinking water channel for 2018 data shows that there are significant drops in morbidity due to stomach orders and malaria associated with access to public vector control programs but this seems to be not the case with private avoidance behaviours. On the other hand, Table 5 shows similar significant results for hygiene channel for 2018 data, but fails to find any association for incidence of malaria.

Table 4
Odds Ratio from a Logistic Model Investigating a Drinking Water Channel for Incidence of Stomach disorders and Malaria among Slum Households and Matched Urban Non-Slum Households in India: 2018 National Sample Survey on Drinking Water, Sanitation, Hygiene and Housing (76th Round)

Variable	**Stomach-disorder, OR (95% CI)**		**Malaria, OR (95% CI)**	
	Slum Sample	**Non-Slum Sample**	**Slum Sample**	**Non-Slum Sample**
Access to public vector control? (Y/N)	0.60**	0.81	0.52***	1.45
	(0.38–0.94)	(0.51–1.28)	(0.32–0.83)	(0.91–2.32)
Whether the households				
treats water by physical or chemical means	2.39***	1.41*	1.31	0.76
	(1.56–3.65)	(0.95–2.11)	(0.84–2.05)	(0.48–1.21)
	0.59**	0.74	0.77	1.35
stores drinking water in proper container	(0.38–0.91)	(0.48–1.14)	(0.48–1.23)	(0.83–2.19)
	0.86	1.07	1.09	0.96
	(0.59–1.25)	(0.96–1.19)	(0.75–1.57)	(0.87–1.06)
handles drinking water properly	0.86	0.96	1.09	1.35
	(0.59–1.25)	(0.63–1.47)	(0.75–1.57)	(0.81–2.25)
Stagnant water near source	1.55*	0.79	1.47	0.64
	(0.93–2.57)	(0.39–1.62)	(0.92–2.35)	(0.27–1.49)
Water sufficiency round the year	0.48**	0.68	0.79	0.51*
	(0.27–0.84)	(0.36–1.30)	(0.45–1.40)	(0.26–1.01)
Observations	2,378	2,128	2,378	2,128
Log Likelihood	-730	-626	-656	-586
df_m	6	6	6	6
chi2	40.4	6.12	15.0	6.94

Table 5

Odds Ratio from a Logistic Model Investigating a Hygiene Channel for Incidence of Stomach disorders and Malaria among Slum Households and Matched Urban Non-Slum Households in India: 2018 National Sample Survey on Drinking Water, Sanitation, Hygiene and Housing (76th Round)

Variable	**Stomach-disorder, OR (95% CI)**		**Malaria, OR (95% CI)**	
	Slum Sample	**Non-Slum Sample**	**Slum Sample**	**Non-Slum Sample**
Access to public vector control? (Y/N)	0.58**	0.79	1.42	0.58**
	(0.37–0.94)	(0.51–1.23)	(0.89–2.28)	(0.35–0.95)
Whether the households				
undertake efforts vector control themselves	0.99	1.06	1.95**	1.64*
	(0.61–1.62)	(0.55–2.07)	(1.03–3.71)	(0.95–2.85)
drains wastewater properly	0.94	1.08	0.84	1.00
	(0.80–1.10)	(0.94–1.23)	(0.67–1.04)	(0.91–1.10)
has garbage disposal done by Municipal Body	0.91	1.08	1.19	1.05
	(0.74–1.11)	(0.86–1.36)	(0.96–1.46)	(0.86–1.28)
has garbage disposed daily	0.85	1.28	1.30	0.58*
	(0.51–1.42)	(0.89–1.83)	(0.84–1.99)	(0.30–1.10)
has garbage disposed daily by Municipal Body	1.02	0.93	0.98	1.18*
	(0.87–1.20)	(0.81–1.07)	(0.87–1.12)	(0.99–1.41)
Stagnant water near source	1.82**	0.72	0.69	1.26
	(1.08–3.09)	(0.33–1.58)	(0.32–1.48)	(0.77–2.05)
Observations	2,378	2,128	2,128	2,378
Log Likelihood	-756	-628	-580	-649
df_m	7	7	7	7

Variable	Stomach-disorder, OR (95% CI)		Malaria, OR (95% CI)	
	Slum Sample	Non-Slum Sample	Slum Sample	Non-Slum Sample
chi2	12.2	4.46	30.2	26.2

Discussion

In the case of slums, we find that public investments substantially reduce the incidence of malaria and stomach disorders. These are important gains particularly because stomach disorders are symptomatic of possible diarrhoea, typhoid or cholera and malaria and occurs quite frequently. Public efforts that try to control the problem of files and mosquitoes seem to be effective in averting morbidity due to such diseases within these households when compared to household-level efforts, given the sanitation conditions of the slum settlements. For both diseases, public programs on their own are effective and are almost always protective of slum households.

Our findings also surface several patterns that warrant closer examination. First, across both survey rounds, private household efforts to treat drinking water — whether by physical filtration or chemical treatment — show no protective association against stomach disorders in slum households and are, in some specifications, positively associated with malaria risk. This counterintuitive result is broadly consistent with Clasen et al. (2007), who found that the efficacy of household-level water treatment is sensitive to compliance, and that compliance is highly variable even in controlled intervention settings; in the uncontrolled conditions of Indian slums, such variability is likely to be greater still. A selection effect may also be at play: households that invest in water treatment may do so precisely because their baseline water quality is worse, which would attenuate or reverse the apparent protective association. Second, the near absence of any benefit from public vector control among matched non-slum urban households is striking. One interpretation, consistent with Swaminathan and Mukherji (2012), is that slum-like conditions outside designated boundaries represent transitional settlements with heterogeneous infrastructure deficits, where a single programmatic input cannot disrupt disease transmission without broader environmental improvements. A third noteworthy result is the persistent protective association between proper wastewater drainage and stomach disorders in slum households. This aligns with Watson (2006)'s argument that the returns to sanitation investment are highest in dense communities with low baseline sanitation coverage, where the externalities of any given household's drainage behaviour — and, by extension, of public drainage infrastructure — are largest; private vector-control measures, targeted only at one's own dwelling, cannot replicate these settlement-level spillovers. Taken together, these patterns reinforce the argument that the collective action problems inherent to disease control in high-density environments limit the reach of private avoidance behaviour and strengthen the case for coordinated public investment — a theme developed in the community sanitation literature through field evidence on latrine adoption and neighbourhood health outcomes (Pattanayak, 2007; Armand et al., 2017).These results support the idea that social policy initiatives in trying to

alleviate the stresses from urbanization should specifically consider vector control programs and programs to improve hygiene. Not only do these have a direct impact on health but, it has an important equity aspect in that it provides coverage to households who are unable to invest in private efforts to disrupt disease transmission channels.

Several limitations of this study should be acknowledged. First, the cross-sectional design of the data implies that our inferences are associational and should be read as conditional correlations rather than treatment effects. The direction of potential endogeneity is important to consider: for example, municipalities with greater exposure to vector borne diseases may receive greater vector control interventions, both public and private; in such scenarios we'd overestimate the true impacts. Similarly, more motivated communities may not only ensure that their neighbourhoods have better hygiene and sanitation, but are also likely to be able to command access to vector borne interventions; taken together, causal inference is problematic, even as we see clearly that when slums receive vector borne interventions we also see lower incidence of vector borne diseases in the communities.. Second, the disease outcome variables — incidence of stomach disorders and malaria in the preceding 30 days — are self-reported and subject to recall bias, and the broad category of "stomach disorders" conflates conditions with distinct aetiologies and transmission pathways. Third, while propensity score matching produces a non-slum comparison group that is substantially more comparable to the slum sample on observed household characteristics, matching cannot account for unobserved confounders such as residential sorting or neighbourhood-level fixed effects. Finally, the NSS data capture only whether households report having received public vector control efforts, not the frequency, coverage, or quality of those efforts. Variation in municipal programme delivery is a source of heterogeneity that a binary exposure variable cannot capture, and future research using administrative programme records would be valuable for disentangling these effects.

Notwithstanding these limitations, the consistency of the main findings across two nationally representative survey rounds separated by six years, and across two distinct disease transmission channels, substantially strengthens confidence in the core result. The analytical leverage afforded by the 69th and 76th Round of the NSSO surveys is particularly valuable in this respect: because the 76th Round schedule was designed to retain direct comparability with the 69th, and because both rounds are among the only nationally representative surveys in India to simultaneously record public vector control exposure, private avoidance behaviour, and disease incidence at the household level, they provide a rare evidentiary basis for drawing inferences about the relative efficacy of public and private health inputs across time. The period between the two surveys also coincides with the launch of major government sanitation and urban infrastructure programmes in India — including the Swachh Bharat Mission and the Smart Cities Mission — and the improvements in public vector control coverage documented in our descriptive statistics between 2012 and 2018 are consistent with the scale-up of these initiatives. Whether this increase in coverage translates into improved health outcomes at the city or district level remains an important question for future research. More broadly, the results contribute to a growing body of evidence suggesting that in the context of rapid urbanisation in low- and middle-income countries, targeted public health investment in informal settlements represents not merely a

redistributive transfer but a cost-effective strategy for reducing the aggregate disease burden across the urban population (Shafique et al., 2024; Wolf et al., 2023).

Declarations

Funding Declaration

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Author Contribution

Althaf Shajahan wrote the manuscript, did the data work and ran the statistical analysisArnab Mukherji supervised and reviewed the manuscript

Data Availability

The datasets generated during and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS].• The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.• All data generated or analysed during this study are included in this published article (and its Supplementary Information files).• The datasets generated during and/or analysed during the current study are not publicly available due to [REASON(S) WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.• No datasets were generated or analysed during the current study.• The data that support the findings of this study are available from [THIRD PARTY NAME] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [THIRD PARTY NAME].

References

1. Armand, A., Carneiro, P., Locatelli, A., Mihreteab, S., & Keating, J. (2017). Do public health interventions crowd out private health investments? Malaria control policies in Eritrea. *Labour Economics*, *45*, 107–115.
2. Belmaker, I., Dukhan, L., Elgrici, M., Yosef, Y., & Shahar-Rotberg, L. (2006). Reduction of vaccine-preventable communicable diseases in a Bedouin population: Summary of a community-based intervention programme. *The Lancet*, *367*(9515), 987–991.
3. Chin, James, ed. 2000. *Control of Communicable Diseases Manual*. Washington, DC: American Public Health Association.

4. Clasen TF, Schmidt WP, Rabie T, Roberts I, Cairncross S. 2007. Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. *British Medical Journal*; 334(7597):782.
5. Cohen, J. M., Woolsey, A. M., Sabot, O. J., Gething, P. W., Tatem, A. J., & Moonen, B. (2012). Optimizing investments in malaria treatment and diagnosis. *Science*, *338*(6107), 612–614.
6. Cutler, David, and Grant Miller. 2005. "The role of public health improvements in health advances: the twentieth-century United States." *Demography* 42 (1).
7. Deuchert, E., and C. Wunsch. 2014. "Evaluating nationwide health interventions: Malawi's s insecticide treated net distribution programme." *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 177(2):523-552.
8. Eisenstein, M. 2016. "Disease: Poverty and pathogens." *Nature* (531) 7564: S61-S63.
9. Ezeh, A., O. Oyebode, D. Satterthwaite, Y. Chen, R. Ndugwa, J. Sartori, B. Mberu, G. J. Melendez-Torres, T. Haregu, S. I. Watson, W. Caiaffa, A. Capon, R. J. Lilford. 2017. "The history, geography, and sociology of slums and the health problems of people who live in slums." *The Lancet* 389, no. 10068 (2017): 547-558.
10. Frumkin, Howard, and Andy Haines. "Global Environmental Change and Non-communicable Disease Risks." *Annual Review of Public Health* 40 (2019): 261-282.
11. Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. Water for life: The impact of the privatization of water services on child mortality. *Journal of Political Economy* 113(1): 83-120.
12. Krishna, A., M. S. Sriram, and P. Prakash. 2014. "Slum Types and adaptation strategies: identifying policy-relevant differences in Bangalore." *Environment and Urbanization* 26 (2): 568-585.
13. Larson, B. A., and E. Gnedenko. 1998. Avoiding health risks from drinking water: Theory and Moscow study results" Harvard University, Harvard Institute for International Development.
14. Lengeler, C. (2004). Insecticide-treated nets for malaria control: Real gains. In *Bulletin of the World Health Organization* (Vol. 82, pp. 84–84). SciELO Public Health.
15. Mayo, A. W. (2007). Prioritization of intervention methods for prevention of communicable diseases in Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C*, *32*(15–18), 1204–1211.
16. Nabarro, D. N. and. Taylor, E. M. 1998. "The Roll Back Malaria campaign" *Science*. 208: 2067-208.
17. Pattanayak, Subhrendu K., Katherine L. Dickinson, Jui-Chen Yang, Sumeet R. Patil, Purujit Praharaj, and Christine Poulos. 2007. Promoting latrine use: midline findings from a randomized evaluation of a community mobilization campaign in Bhadrak, Orissa. *Working Paper 07-02. Durham NC: Research Triangle Institute*
18. Packard, R. M. (2009). "Roll back malaria, roll in development"? Reassessing the economic burden of malaria. *Population and Development Review*, *35*(1), 53–87.
19. Rego, R. F., Moraes, L. R. S., & Dourado, I. (2005). Diarrhoea and garbage disposal in Salvador, Brazil. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *99*(1), 48–54.

20. Riley, Lee W., Albert I. Ko, Alon Unger, and Mitermayer G. Reis. 2007. "Slum health: Diseases of neglected populations." *BMC International Health and Human Rights* 7(2).
21. Schwarz, P., and E. Pruyt. "Modelling and simulation the Zika Outbreak under Deep Uncertainty: A Multi-Method Multi-Resolution Approach." In 34rd International System Dynamics Conference. 2016.
22. Skudarnov, S. E., & Kurkatov, S. V. (2011). Incidence of non-communicable diseases and health risks due to potable water quality. *Gigiena i Sanitariia*, *6*, 30–32.
23. Swaminathan, Hema, and Arnab Mukherji. 2012. "Slums and Malnourishment: Evidence from women in India." *American Journal of Public Health* 102(7): 1329 – 1335.
24. Tozan, Y., and S. Derya Uysal. Micro-econometric evaluation of malaria control programs in sub-Saharan Africa. In EALE Conference, 2014
25. Unger, A., and L. W. Riley. 2007. Slum health: from understanding to action. *PLoS Med* 4.10: e295.
26. United Nations. 2014. *World Urbanization Prospects: The 2018 Revision*. Press Release, New York: UN.
27. Wagner EG, Lanoix JN. 1958. Excreta Disposal for Rural Areas and Small Communities. Geneva. World Health Organization Monograph Series No 39 WHO 1958.
28. Watson, Tara. 2006. "Public health investments and the infant mortality gap: Evidence from federal sanitation interventions on US Indian reservations." *Journal of Public Economics* 90 (8): 1537-1560.
29. Yelling, J. A. 2012. *Slums and Slum Clearance in Victorian London*. London and New York: Routledge.
30. Kanungo, S., Chatterjee, P., Saha, J., Dutta, S., Bhattacharya, M. K., & Sur, D. (2021). Water, Sanitation, and Hygiene Practices in Urban Slums of Eastern India. *The Journal of Infectious Diseases*, 224(Supplement_5), S573–S583. https://doi.org/10.1093/infdis/jiab354
31. Lachyan, A., Zaki, R. A., Banerjee, B., & Aghamohammadi, N. (2023). The effect of community-based intervention on dengue awareness and prevention among poor urban communities in Delhi, India. *Journal of Research in Health Sciences*, 23(4), e00596. https://doi.org/10.34172/jrhs.2023.131
32. Palit, A., Batabyal, P., Kanungo, S., & Sur, D. (2012). In-house contamination of potable water in urban slum of Kolkata, India: a possible transmission route of diarrhea. *Water Science & Technology*, 66(2), 299–303. https://doi.org/10.2166/wst.2012.177
33. Shafique, S., Bhattacharyya, D. S., Nowrin, I., Sultana, F., Islam, M. R., Dutta, G. K., Otmani del Barrio, M., & Reidpath, D. D. (2024). Effective community-based interventions to prevent and control infectious diseases in urban informal settlements in low- and middle-income countries: a systematic review. *Systematic Reviews*, 13, 253. https://doi.org/10.1186/s13643-024-02651-9
34. UNFPA. (n.d.). Urbanization. United Nations Population Fund. https://www.unfpa.org/urbanization
35. Wolf, J., Johnston, R. B., Ambelu, A., Arnold, B. F., Bain, R., Bhatt, S., Brown, J., Carlton, E. J., Clasen, T., Colford, J. M., Jr, Cumming, O., Dangour, A. D., Ensink, J., Freeman, M. C., Gordon, B., Guess, K., Hammer, C. C., Hunter, P. R., Knee, J., … Pruss-Ustun, A. M. (2023). Burden of disease attributable to unsafe drinking water, sanitation, and hygiene in domestic settings: a global analysis for selected

adverse health outcomes. *The Lancet*, 401(10393), 2060–2071. https://doi.org/10.1016/S0140-6736(23)00458-0

Figures

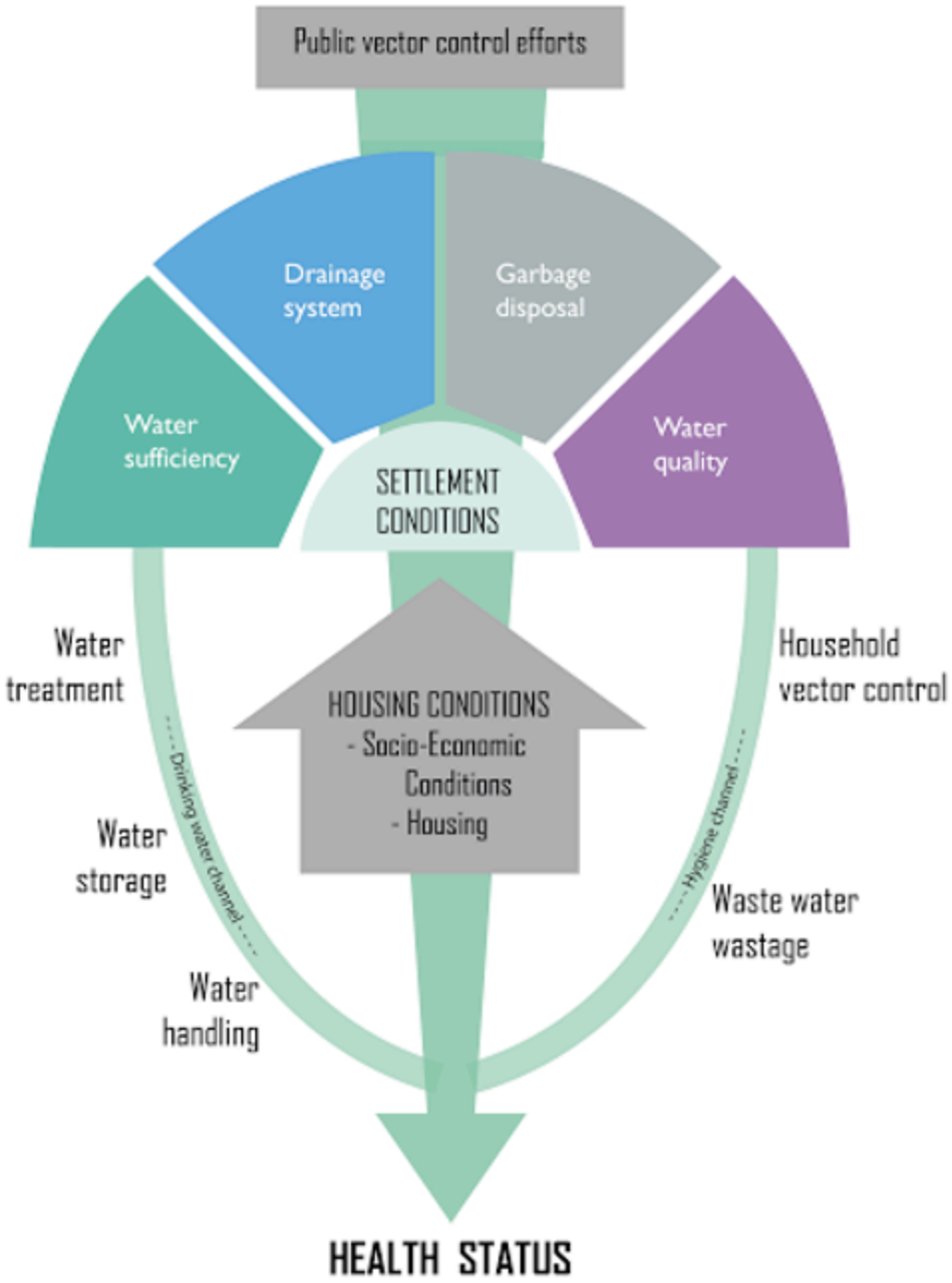


Figure 1

Pathways in Micro-Environment

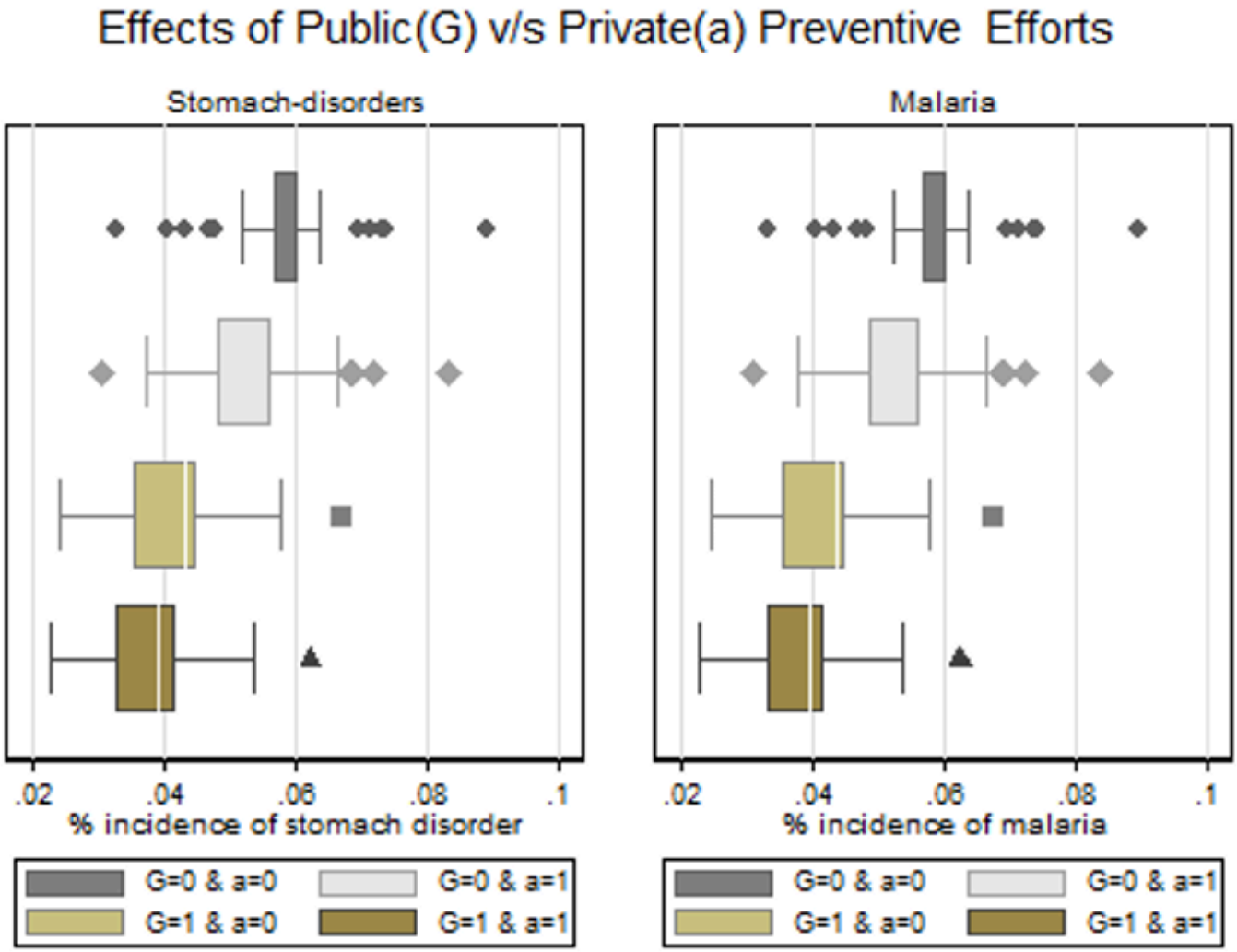


Figure 2

Effects of Public and Private Preventive efforts

Supplementary Files

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- AppendixTable1SummaryStatisticsforSlumandNon.docx