Sanitation and Property Tax Compliance: Analyzing the Social Contract in Brazil*

Evan Plous Kresch　Mark Walker　Michael Carlos Best
François Gerard　Joana Naritomi

Abstract

This paper investigates the role that sanitation plays in upholding the social contract, whereby citizens pay taxes in exchange for governments providing goods and services. We study the case of Manaus, Brazil, where sewer connections vary considerably across the city and property taxes are calculated in a presumptive manner that does not account for a household's access to sanitation. We find that households with access to the city sewer system are significantly more likely to pay their property tax, relative to households that only have access to latrines or lack access to improved sanitation entirely. Our evidence is consistent with a role for the social contract in this decision, as households with sewer systems are more likely to have positive attitudes towards the municipal government.

Keywords: Sanitation; Property Tax; Social Contract; Tax Compliance; Brazil

JEL Classification Numbers: H26, O18, Q53

*Kresch: ekresch@oberlin.edu, Oberlin College & CDEP (Corresponding Author); Walker: mwalker2@oberlin.edu, Oberlin College; Best: michael.best@columbia.edu, Columbia University, BREAD, CEPR, & NBER; Gerard: f.gerard@qmul.ac.uk, Queen Mary University of London & CEPR; Naritomi: J.Naritomi@lse.ac.uk, London School of Economics & CEPR. We are grateful to Luigi Caloi, Malavika Mani, Samira Noronha, Maggie Shi, and Thaissa Sousa for excellent research assistance. This paper is in partnership with the *Secretaria Municipal de Finanças e Tecnologia da Informação* (SEMEF), who provided access to the administrative tax data. This project was supported by the World Bank's Development Impact Evaluation Department (DIME) and the J-PAL Governance Initiative. We are grateful to Britta Augsburg, Molly Lipscomb, Shaun McRae, and participants of the ADBI-IFS Conference on Sanitation and Development for comments on an earlier draft. Any remaining errors are ours alone.

"We look admiringly upon the public baths, a boon swiftly bestowed... Rome is restored to herself and under your rule, Caesar, the joys of the people are these..."

—Marcus Valerius Martialis (on Emperor Domitian), 80 CE

Taxation represents the citizen's side of the "social contract"–the price people pay for the goods and services their government provides. Government failure to support basic services, therefore, undermines the social contract and encourages citizens to disinvest via nonpayment of taxes. This can create a vicious cycle, where declining revenue limits the government's ability to provide services, further lowering citizen's incentives to fund the state (Besley and Persson, 2013; Haq et al., 2020). This equilibrium of high tax delinquency and low service provision is particularly prevalent in developing countries, which lag behind in providing basic services and where some countries collect less than half of billed tax revenue (Castro and Scartascini, 2015). This chronic underfunding and underprovision of basic services has far-reaching consequences for health, welfare, and economic growth.

Among services provided by a government, improved sanitation is arguably among the most salient, able to impact individuals on a daily basis. Sanitation generates a large return to public spending by improving health and welfare: lack of improved sanitation is one of the leading causes of diarrheal outbreaks in developing countries, accounting for approximately 1,656,000 deaths globally each year (Troeger et al., 2018). In addition to the significant effects on individual health, improved sanitation produces positive externalities that improve quality of life (Coffey, Geruso and Spears, 2018; Deutschmann et al., 2021; Duflo et al., 2015; Geruso and Spears, 2018; Kresch, Lipscomb and Schechter, 2020). Moreover, sanitation's high salience has been used by governments as evidence of responsiveness to citizen welfare (Duflo, Galiani and Mobarak, 2012). Given sanitation's central role and broad reach in everyday lives–in addition to the significant direct benefits–increasing access to improved sanitation has the potential to play a significant role in upholding the government's side of the social contract.

This paper studies the relationship between urban sanitation and property tax compliance. We focus on the case of Manaus, the seventh largest city in Brazil and the capital of the northern state of Amazonas. Property tax is a key source of municipal revenue, but nonpayment is the highest among all large Brazilian cities; less than half of taxpayers paid their property tax bills in 2017. Manaus also lags behind the rest of Brazil in access to sewer systems (Silveira, 2016): less than a quarter of households have a sewer connection, with ten percent lacking access to any type of improved sanitation.

Several features of the property tax and sanitation system in Manaus make it possible to study their relationship. First, Manaus employs a presumptive approach to determining a household's tax bill, using a set of easily observable housing characteristics to determine the property value. Crucially, access to sanitation does not factor into the tax calculation, leading to households with identical tax bills that face significantly different sanitation options. Second, access to the sewer network varies throughout the city with very fine granularity: homes and businesses directly adjacent to each other routinely differ on whether they have a sewer connection. While this paper focuses on Manaus, the nature of presumptive taxes (Best et al., 2015; Brockmeyer et al., 2021) and non-universal urban sewer provision (Duflo, Galiani and Mobarak, 2012) is not unique to this setting and is often observed in developing countries.

Exploiting variation in access to improved sanitation over nearly 200,000 households in the city, we find that households with access to the municipal sewer system are significantly more likely to be compliant with property tax payments. Controlling for tax liability and a variety of household and neighborhood characteristics, we find an estimated 15 percentage point increase in compliance for sewered households relative to households that lack access to sanitation. Households with a sewer connection are also significantly more likely to pay the property tax relative to households using latrines as their primary sanitation method. These results are robust to alternative specifications: an instrumental variables approach that instruments for a household's access to sanitation, as well as a matching approach that non-parametrically compares compliance rates between households with access to the sewer system, access to improved latrines, and lacking improved sanitation altogether.

To further investigate the role the social contract plays in this observed relationship, we use a household survey conducted by Best et al. (2019) that elicits views on local government and the current tax system. Controlling for their property tax liability and other socioeconomic characteristics, households with sewer access were significantly more likely to have favorable views of the government. This effect is driven entirely by compliant households, as households that are delinquent in their property tax payments do not significantly differ in the level of government approval as households that lack access to sanitation. These correlations are consistent with a role for the social contract in our setting, and suggests policy implications for simultaneously improving services and raising the necessary revenue to fund these improvements.

It is important to note that water and sewage services in Manaus are provided by a private company - Águas de Manaus - under a concessionaire contract with the city. Thus an individual's property tax payment is not directly linked to the level of service provided by the utility. In this, the social contract we investigate differs from previous studies that focus on the direct effect of an individual's bill payment behavior on service provision (Dzansi et al., 2018; McRae, 2015). However, the municipal government plays a very active role in ensuring that Águas de Manaus provides service in line with the concessionaire contract; for example, in September 2021 David Almeida (the Mayor of Manaus) initiated an audit of the company in the wake of a court ruling brought by the city against Águas de Manaus for its pricing policy.[1] In light of the active and public-facing role the municipal government takes in regulating the service provider, in addition to our findings on government approval, we take the social contract in this setting to be a form of citizen protest, whereby households refuse to fund the government as a way to pressure the city to hold the concessionaire accountable for increased service quality and access.

Our paper contributes to the literature on the social contract between government provision of services and tax compliance. This link has been recently highlighted as a promising method for addressing tax compliance in developing countries (Haq et al., 2020; Slemrod, 2019; Stantcheva, 2020). Other recent research underscores the fact that the social contract may also go the other way: Weigel (2020) finds that increased tax enforcement leads to greater citizen interaction and demands for political engagement. Previous studies highlighting this relationship to citizens has shown little impact (Castro and Scartascini, 2015), implying that simply ensuring citizen awareness of the links between taxes and benefits may be insufficient; if reforms go unnoticed by citizens, disinvestment behavior will not change (Acemoglu et al., 2020; Blumenthal, Christian and Slemrod, 2001).

Another branch of the literature finds positive effects on tax compliance with the distribution of direct rewards and benefits. Significant increases in compliance rates have resulted after the roll-out of street paving in Mexico (Gonzalez-Navarro and Quintana-Domeque, 2013) and from randomly rewarding compliant households with new sidewalks in Argentina (Carrillo, Castro and Scartascini, 2021).[2] Krause (2020) finds a 27 percent increase in tax compliance from a program that randomized municipal garbage collection in Haiti, with Bowers et al. (2020) finding similar positive effects on tax compliance from trash collection in Malawi. Our paper differs from this work in that sewer service to households is not directly funded by the municipal government. Rather households with sewers are billed monthly by the private utility company for this service. However, as the municipal government retains regularity authority over the sector, the relationship we find is an indirect effect of sanitation provision through its effect on the positive perceptions of government. In this sense, the effect we observe is similar to the spillover effect found in Carrillo, Castro and Scartascini

[1] In a press release concerning the audit, Mayor Almeida stated that "... we are going to do exactly that: search point by point, item by item, this contract so that it is truly fulfilled and that what was agreed, signed, agreed upon is fulfilled for the population of the city of Manaus." Source: link to article.

[2] The significant complexity and cost of properly installing an urban sewer system makes paving new roads and sidewalks the more cost effective option for increasing tax compliance. However, this does not take into account sanitation's significant value to public health.

(2021), where neighbors of lottery winners also increase tax compliance after the completion of the new sidewalk.

This paper also relates to the broad literature studying the socioeconomic impacts of improved sanitation. Recent research has documented several spillovers associated with increased access to sanitation, including effects on infant mortality (Geruso and Spears, 2018; Watson, 2006), school enrollment (Adukia, 2017), and health and human capital (Hammer and Spears, 2016; Mara et al., 2010). The economic and productivity costs of poor sanitation have also been extensively studied (Bartram et al., 2005; Fuente et al., 2020; Van Minh and Hung, 2011). Our paper provides evidence on an additional consequence of urban sanitation – a positive fiscal externality on tax compliance – for policymakers to consider when valuing investment in this vital utility.

This paper is organized as follows. Section I provides background on the legislation concerning basic sanitation plans. Section II describes the data and section III discusses the empirical identification strategy. Estimation results are presented in section IV, and section V provides concluding remarks.

I Background

A Sanitation in Manaus

Manaus is the largest city and capital of Amazonas state, with approximately 2.2 million residents. Despite its remote location in the north of the country, Manaus is one of the wealthier cities in Brazil, with GDP per capita of $10,095 (IBGE, 2018). Like many areas in the north and northeast of the country, Manaus lags behind in providing high quality sanitation service and reducing open defecation (IBGE, 2011; Silveira, 2016).

Prior to 1999, sanitation services in Manaus were provided by the state utility company in Amazonas (COSAMA; *Companhia de Saneamento do Amazonas*); since then responsibility for providing water, sanitation, and solid waste (WS) services lies with the municipal government. This arrangement of municipal supervision of the WS sector is unusual in Brazil, where the vast majority of municipalities have these service provided by state companies (Kresch, 2020). In Manaus, these services are largely provided through a concessionary agreement between the municipal government and the company Águas de Manaus.[3] The municipal government retains significant regulatory authority, as is common in relations with water

[3] Águas de Manaus is a subsidiary of Aegea Saneamento, one of the largest private sanitation companies in the country. Águas de Manaus took over operations from Manaus Ambiental S.A., a private utility company which had provided service since 1999.

utility companies in Brazil (Heller, 2007); Águas de Manaus is closely and actively supervised by local government agencies such as the municipal public service agency (AGEMAN) and the state consumer protection agency (Procon-AM).

While household access to piped water is nearly universal (over 95 percent), access to the sewer system is much lower, with only 23 percent of household connected (Olivier et al., 2006). The vast majority of households (65 percent) use some form of improved latrine for sanitation. These latrines can either be individual or shared communally across households. The remaining households have no access to improved sanitation, disposing of waste in either open pits, drainage ditches, or in public spaces (Silveira, 2016).

Access to the sewer system varies widely across the city, and the presence of a sewer system in an area is itself no guarantee of sewer connectivity. As figure 1 shows, homes and businesses directly adjacent to each other routinely differ on whether they have a sewer connection. This leads to households in the same neighborhood and block–presumably with similar socioeconomic conditions–varying markedly in their sanitation experience; a point we discuss in more detail in section III.

The lack of sanitation take-up is largely due to the state of the city sewer network. Increased urbanization, an emphasis on achieving universal water connectivity, and institutional neglect led to a sewer network in Manaus that is disjointed and with sporadic coverage (GFA, 2018). When the system expanded, sewer lines were installed up to the sidewalk, with no plans to provide universal connections to households on the sewer line. Connecting to the sewer system was the expected responsibility of the homeowner, and although the large majority of households had the means to cover the connection costs, many households declined to pay in the hopes of getting the service for free (IADB, 2013). This has resulted in an environment where the majority of residents dumping waste into small tributary streams (*Igarapés*) that flow into the Amazon River (de Melo et al., 2019), with even newly-built condominiums and high-income houses draining sewage directly into waterways.[4]

The state of sanitation in Manaus is representative of the situation in most cities in Brazil, both large and small. There are several reasons why improved sewers have not reached the same degree of near universalization as other utilities in Brazil, such as water and electricity. First, unlike water systems that are pressurized, sewer systems require gravity differentials which are more difficult to design and construct, especially in the dense and challenging topography of Brazil's hilly coastal metropolises. Second, the perceived political gain from building sewer infrastructure is much lower than for piped water systems, leading to little incentive for policymakers to push for expansion (Stepping, 2016; Tesh and Paes-Machado, 2004).

[4]For more details, see https://earthjournalism.net/node/5323

The lack of political will to enforce sewer planning and regulation is partly due a "flush and forget" mentality described by many wastewater officials, where residents do not value wastewater treatment *per se*, and rather that it is removed from the living space. Interviewing a sanitation policymaker in Manaus, Stepping (2016) notes the attitude toward the Rio Negro that *"the city looks to the river that seems to be an ocean and thinks to itself 'why should my wastewater be treated?"'* This attitude in conjunction with increased urbanization since the 1980s resulted in the majority of urban households constructing private latrine systems, and made it difficult for sanitation companies to convince households to connect to the sewer lines once they arrived in the street.[5] Even in cities with existing laws that required households to connect to sewer lines, much of the time these regulations were not enforced by the utility or lawmakers (Stepping, 2016). Wealthy areas in São Paulo and Rio de Janeiro (Stepping, 2016) and Brasilia and Salvador (Melo, 2005), in addition to Manaus, often lack individual connections to the improved sewer network.

B Calculation of Property Tax

Property tax (IPTU; *Imposto Predial e Territorial Urbano*) in Manaus is assessed and collected by the municipal tax authority (SEMEF; *Secretaria Municipal de Finanças e Tecnologia da Informação*). Each year, SEMEF calculates the tax liability for all properties in the city and provides owners a property tax bill in January. The first payment is due in March, with residents having the option of making a single payment or paying their tax bill in ten monthly installments. Late or delinquent payments of the IPTU bill results in penalties such as legal actions, fines, and accrued interest.

IPTU is a presumptive tax and is calculated using a small set easily observable attributes of a property to estimate the building value (V^E; *valor da edificação*) and land value (V^T; *valor do terreno*). For a given property h in year t, the property tax is calculated as:

$$\begin{aligned} IPTU_{h,t} &= (V^E_{h,t} + V^T_{h,t}) \times A_{h,t} \\ where \quad V^E_{h,t} &= g(\mathbf{E}_{h,t}\boldsymbol{\beta}^E) \\ and \quad V^T_{h,t} &= f(\mathbf{T}_{h,t}\boldsymbol{\beta}^T) \end{aligned} \tag{1}$$

A given property's house and land characteristics are given by $\mathbf{E}_{h,t}$ and $\mathbf{T}_{h,t}$, respectively. Housing characteristics include information on the building materials (e.g. roof, exterior walls, framing), alignment, position, and size of the building. Land characteristics includes

[5] This lack of motivation by individual households to connect to the sewer system has led some cities to attempt *condominial* sewerage policies, where a single wastewater line directly connects (and runs through) several households in a city block, with limited success (Melo, 2005).

the location, area, topography, and flood vulnerability of the property. These characteristics are multiplied by building and land coefficients ($\boldsymbol{\beta}^E$ and $\boldsymbol{\beta}^T$), which are determined by SEMEF estimates of how much these features contribute to the property value.[6]

The estimated value of the property ($V_{h,t}^E + V_{h,t}^T$) is multiplied by a yearly *alíquota* ($A_{h,t}$). This property-year schedule factors in inflation and primary use of the property.[7] Appendix table A.1 provides the precise formula and building/land characteristics used to calculate IPTU.

Crucially for our analysis, the type of sanitation system is not a characteristic used by SEMEF in the IPTU calculation. This is due in part to the presumptive nature of the tax, as sanitation systems are often inside a building or in the back of the property, and are not easily viewed by property assessors from the public street frontage. Moreover, that property taxes are based on fixed characteristics and not on property values, the type of sanitation system used by a household is not factored in to its yearly tax bill. This implies that households with the same tax liability may face very different sanitation options, and attitudes towards the public sanitation system; this point is explored further in section III.

II Data

Property tax data comes from the municipal tax authority, SEMEF. Administrative data provided by SEMEF includes a cadaster of all registered properties in the city, listing the land and housing characteristics used to calculate IPTU. This data is geo-referenced to a lot-level map of Manaus. The cadaster also contains information on other characteristics of the property not used in the IPTU calculation, including the type of sanitation system. Sanitation use rates for properties in the cadaster are 22.9 percent, 65.7 percent, and 11.5 percent for the sewer system, latrines, and open/no improved sanitation, respectively.[8]

We also have data on tax liabilities and payments at the property level. The payment history allows us to calculate tax compliance for a given household as an indicator for whether a household made any payment on their IPTU in a given year.

The cadaster presents a recent snapshot of property registration collected by SEMEF, as housing characteristics may be updated in the system (although this is done infrequently). Since the data was provided to us in early 2018, we restrict our analysis to 2017–the last

[6] These coefficients were originally set in 1983 and were updated in 2011.

[7] The *alíquota* also converts Reals to an internal currency used in SEMEF systems, known as UFM (*Unidade Financeira Municipal*). The 2017 aliquota to convert UFM to Reals is the rate R\$111.11=1UFM.

[8] We were unable to receive detailed usage and sewerage network data from Águas de Manaus, and rely on the sanitation data recorded and updated by SEMEF.

full year for which we have tax and payments data.[9] Restricting our sample to residential households in 2017 yields a dataset of 199,621 unique observations.[10]

Views on government and the tax system come from a household survey conducted by Best et al. (2019) in Manaus in February 2019. Of the universe of properties in Manaus, we restricted the survey to residential units in similar neighborhoods throughout the city; post-implementation yielded a sample of 5,341 households. In the survey we collected–among other details–information on the respondent's views on the municipal government, the current property tax system, and whether nonpayment is justified. Using lot-level identifiers, the survey can be linked to the administrative data on tax liabilities, payments, and other property characteristics.

We use two questions from the survey as our main variables of interest. Information on views of the municipal government reflects the respondent's answer to the question: *"How much do you agree with the following statement: Generally, the municipal government is doing a good job providing services for citizens."* Similarly, information on a respondent's views of the current property tax system come from the question, *"How much do you agree with the following statement: "In some situations, it could be justifiable for households like mine to not pay their IPTU this year."* Responses to both questions were recorded on a five-level Likert scale from "strongly agree" to "strongly disagree". We construct an indicator variable equal to one if the respondent either agrees or strongly agrees with the statement, allowing us to run a linear probability model in section IV.

III Empirical Strategy

Our empirical strategy relies on two characteristics of Manaus to explore the relationship between sanitation and tax compliance. First, SEMEF employs a presumptive tax on property, where liabilities are calculated using a small set of observables that does not include a household's access to sanitation. This implies that households receiving the same-sized tax bill can face very different experiences in regards to publicly provided sewer services. Figure 2, panel A shows the distribution of sanitation type across quintiles of the tax distribution. Although the majority of households in the city use a latrine system, there is notable variation in sanitation across property values. While–as expected–a larger share

[9] As any change to the cadaster in regards to sanitation is likely to be a movement towards an improved service, in the rare event that the cadaster was not updated at the time of our analysis is likely to *downwardly bias* any estimates of the relationship between sanitation and tax compliance.

[10] We also restrict attention to 2017 since a large reform to the property tax system was introduced in 2012 and phased in through 2016. As the information from the cadaster is a static snapshot, we would be unable to disentangle the effect of the sanitation system on this reform in a panel setting. See Best et al. (2019) for more details of the reform.

of households with the lowest property values have no access to improved sanitation, the presumptive nature of IPTU results in some of the highest valued households lacking access to sewers as well. As households with the same tax bill face different sanitation options, we can plausibly use the variation in sanitation across households–after controlling for the size of the tax liability and other household characteristics–to analyze its relationship to a household's attitude towards property tax compliance.

The second important characteristic of our setting is that access to sewer lines varies widely across the city, and is not concentrated in spatial clusters. Panel B of figure 2 shows the distribution of sanitation coverage across the administrative zones Manaus. As in panel A, we see that most households use latrine systems, although there is a sizable fraction of households in each part of the city that have access to the sewer system or lack access to sanitation entirely. The map in figure 1 provides a snapshot of the city at the lot level and highlights the fact that access to the sewer system can vary widely, even for households on the same block. The wide and varied distribution of sewer access across the city makes it much less likely that the differences in compliance rates across sanitation type is being driven by other spatially correlated characteristics in the city.

OLS and IV Estimator

To explore the relationship between a household's access to sanitation and its property tax compliance (c_h), we run the following empirical specification:

$$c_h = \alpha + \beta_{sewer} \times Sewer_h + \beta_{latrine} \times Latrine_h + \gamma \log(\tilde{T}_h) + \delta_1 \mathbf{X_h} + \delta_{bairro} + \varepsilon_h \quad (2)$$

where $Sewer_h$ is an indicator for whether household h has access to the sewer system, and $Latrine_h$ is an indicator for whether household h uses an improved latrine. Estimates of β_{sewer} and $\beta_{latrine}$ are relative to the omitted category of households that dispose of waste in the open and do not have access to improved sanitation. We restrict our attention to compliance rates in 2017–the last year for which we have the full payments data.

We control for a household's tax liability, defining $\log(\tilde{T}_h)$ as the demeaned log IPTU, so that α is the compliance rate of a household with the average tax bill and no access to sanitation. Given the size of our dataset, we can estimate alternative specifications that more flexibly control for the tax liability. Appendix table A.2 presents estimations using a binned percentile approach and a higher order polynomial fit to control for a household's tax liability; estimates using these alternative controls are similar in magnitude and significance to our main specification.

Since we are using a cross-section (albeit of the entire city) instead of a repeated panel of household payments, some caution must be exercised in interpreting the causality of the relationship between sanitation and tax compliance. While changes in a household's liability has been shown to have a significant effect on compliance (Best et al., 2019; Brockmeyer et al., 2021), the slow implementation of urban sanitation in developing countries makes a similar within-household study difficult, barring a large-scale government intervention. However, the various methods to control for omitted variable bias discussed in the next paragraphs make us more confident that the variation in sanitation is in part driving the observed attitudes towards nonpayment.[11]

The biggest threat to our interpretation of the coefficient estimates is the presence of unobservable differences across households that are correlated with – and misattributed to – sanitation access. Controlling for the size of the tax liability addresses the most direct effect on a household's compliance decision. Additionally, insofar as the IPTU captures the value of the house, controlling for it is useful in proxying for budgetary and liquidity constraints faced by households. In addition to the tax liability, we control for a range of other household-level characteristics ($\mathbf{X}_h$) observed in the cadaster that are not directly included in the IPTU calculation, such as whether a household has a basement or balcony. We also include neighborhood fixed effect (δ_{bairro}) in equation 2, as the neighborhood (*bairro*) is the primary division of the city, and the one that is most salient to households.

There may exist other differences across households driving tax compliance not captured by housing or neighborhood characteristics, such as household income and the degree to which households are liquidity constrained (Brockmeyer et al., 2021). To investigate this, we study the relationship between sanitation and household income at the census tract level – the most granular level for which we have income data across the entire city.[12] Panel A of figure 3 shows the relationship between mean monthly household income per capita in a census tract and the share of sanitation and latrine ownership.[13] There appears to be slight to no relationship between income across sewer and latrines, respectively. This documented relationship is consistent with the situation in most large urban centers in Brazil, where even wealthy areas can lack access to sewer networks in cities from São Paulo to Rio de Janeiro (Stepping, 2016) to Brasilia and Salvador (Melo, 2005).

[11] Another possibility is reverse causality, where households gain access to the sewer system *because* they are compliant with their property taxes. We find this explanation to be unlikely for a few reasons. First, there is no strong spatial correlation between a household's sewer access and areas of the city that are less delinquent on IPTU. Additionally, there is no formal partnership between SEMEF and Águas de Manaus that condition service between the two organizations.

[12] Virtually all of the census tracts divide the city along neighborhood lines, making it impossible to include both census controls and neighborhood fixed effects. Estimates using census controls and fixed effects are nearly identical in both significance and magnitude to the preferred specification.

[13] Data on household income comes from the 2010 Brazilian Census, which is provided by the Brazilian Institute of Geography and Statistics (IBGE).

One may be concerned that the lack of a pronounced relationship between income and sewer access is due to household incomes being measured with considerable error in the census. Figure 3 panel B plots the relationship between the household income and the IPTU liability averaged over census tracts. There is a much more pronounced positive correlation between household income and property tax liabilities, suggesting that measurement error in the census is not a major concern and that the presumptive tax calculation implemented by SEMEF does a reasonable job of achieving progressivity. Taken together, both panels of figure 3 provide reassuring evidence that the likelihood of other household characteristics driving the results of the paper is small.

While figure 3 shows a weak relationship between income and sanitation at the census-tract level, there could potentially be a positive relationship between income and sewer connections *within* a census tract. To fully address the independence assumption, we would ideally control for income at the household level, however the administrative data provided by SEMEF does not include individual-level identifiers to link with payroll data (RAIS; *Relacao Anual de Informacoes Socials*).[14] Nevertheless, as the household survey we conducted (see section II) asked respondents about their monthly income bracket, we are able to determine - only for the survey sample - whether sewer connections, after controlling for observables, are as-if randomly assigned. Figure 4 presents point estimates and confidence intervals for the probability that a household in a given income bracket has access to a sewer, controlling for income, neighborhood, and household characteristics.[15] Although point estimates for the higher income brackets are larger than the lower income brackets, none of the coefficients are statistically different from zero and we find that household income does not predict whether a household has a sewer connection. While this does not confirm the independence assumption for our entire dataset, it does provide supporting evidence for the validity of our empirical specification.

Even with the inclusion of household and neighborhood controls in equation 2, there may still be concerns of unobservable factors driving both a household's sewer connection and tax payment behavior. Since our estimation strategy relies on variation in sanitation usage across households, measurement error in the SEMEF data - where a household's sanitation is incorrectly recorded in the cadaster - might be mischaracterizing variation in sanitation across the city. This would be especially concerning in situations where a small set of

[14] An alternative approach to test the independence assumption is to use income and sanitation data from a different survey, such as the Brazilian Consumer Expenditure Survey. However, these national surveys do not have sufficient coverage of respondents in Manaus, and lack sufficiently detailed location information to take into account income differences within a neighborhood or census tract.

[15] Predicted estimates of whether household h has sewer access are shown in appendix table A.3. The results are similar across various specifications modelling the income bracket of households in the sample survey.

households differ in sanitation systems from their neighbors.

To address this issue, we run an alternative specification that instruments for the probability of a household having a sewer connection. Specifically, we predict the probability that household h has a sewer (latrine) connection on the share of households on the same block with sewer (latrine) connections. This predicted sanitation variable is positively correlated with the probability that household h has a sewer connection, but is plausibly uncorrelated with its property tax compliance in a given year. Estimates from the IV approach are shown in table 1 to be similar in magnitude and significance to the OLS estimation.

Matching Estimator

Given that our setting does not allow for a quasiexperimental research design, the standard alternative approach to using an OLS estimator is to explicitly implement a matching estimation scheme (Imbens and Wooldridge, 2009). The conventional matching approach compares the outcomes of individuals with similar propensity scores of receiving treatment conditional on observables. The propensity score matching approach requires a binary treatment to define the treatment and control populations, and is not perfectly suited to our setting. This necessitates a modified version of the matching estimator, allowing more than one type of treatment that a household could potentially receive.

Each household h in Manuas can have one of three sanitation options: *sewer*, *latrine*, or *open*/no access to improved sanitation. For all households in our study, we observe the tax compliance c_h, type of sanitation system t_h, and vector of household characteristics ($\mathbf{X}_h$), including the IPTU liability. Letting $d_h(sewer) = \mathbb{1}(t_h = sewer)$ be an indicator for whether household h has a sewer system (with analogous definitions for the other sanitation types), the observed compliance outcome is a function of the potential outcomes:

$$c_h = d_h(sewer)c_h(sewer) + d_h(latrine)c_h(latrine) + d_h(open)c_h(open) \tag{3}$$

For each household, we only observe one of the possible sanitation outcomes, and generate the triplet of propensity scores $\{p(t_h = sewer|\mathbf{X}_h), p(t_h = latrine|\mathbf{X}_h), p(t_h = open|\mathbf{X}_h)\}$ conditional on the vector of observable characteristics. For this analysis, we match households on their calculated IPTU liability, although matching on a richer set of additional non-IPTU household characteristics yields similar estimates for the effects on compliance rates.

With three potential outcomes, there are three pairwise average treatment effects (ATEs). Given an appropriate weighting function (w), the ATE of households with sewer systems compared to those with no improved sanitation is:

$$ATE_{sewer,open} = \frac{\sum_{h=1}^{N} c_h d_h(sewer) w_h}{\sum_{h=1}^{N} d_h(sewer) w_h} - \frac{\sum_{h=1}^{N} c_h d_h(open) w_h}{\sum_{h=1}^{N} d_h(open) w_h} \quad (4)$$

with analogous ATEs comparing latrines versus no sanitation, and sewers versus latrines.

We calculate the weighting function using the vector-base kernel weighting (VBKW) approach outlined in Garrido, Lum and Pizer (2021). With multiple treatments, the VBKW approach assigns weights to observations that have similar *vectors* of propensity scores. In our setting, VBKW assigns non-zero weights to households in the *open* group if their value of $p(t_h = sewer|\mathbf{X}_h)$ is within the bandwidth of a sewered household, with the additional conditions imposed that their value of $p(t_h = open|\mathbf{X}_h)$ is within a bandwidth of the sewered household's propensity score of having *open* sanitation, as well as their value of $p(t_h = latrine|\mathbf{X}_h)$ being within the kernel bandwidth of a sewered household's analogous propensity score. The kernel function applies more weight to households with smaller differences in their vector of propensity scores.

Estimates of the ATE for households with sewers versus those lacking sanitation and the ATE for households with latrines versus those lacking improved sanitation are presented separately in table 1 and discussed in the next section. The construction of the kernel, bandwidth, and weights used in estimating equation 4 are presented in greater detail in Garrido, Lum and Pizer (2021). One benefit of following this approach compared to other weighting schemes is that by creating kernel weights over a single subpopulation, the VBKW estimator is more robust to extreme values than other weighting approaches, such as inverse probability treatment weighting (IPTW) or entropy weighting (DiNardo and Tobias, 2001). Point estimates from the matching estimator are presented alongside the OLS and IV estimates in table 1 and discussed in the next section.

IV Results

A Tax Compliance

We start this section by examining the relationship between a household's access to sanitation and its likelihood to pay property tax. Table 1 reports estimation results of tax compliance across a range of specifications. Households with access to the piped sewer system are significantly more likely to be compliant with IPTU payments than households with no sanitation system, even controlling for a household's tax liability and set of observable housing and neighborhood characteristics. OLS estimates of the effect of sewer access on compliance range from 13.5 to 16.2 percentage points (columns 1 and 2), representing a 22 and 35 percent increase in compliance over the baseline compliance for households with no improved sanitation facilities.

Households with improved latrine facilities are also more likely to pay their property taxes compared to household without access to an improved sanitation system. Estimates in columns 1 and 2 of table 1 are statistically significant at the 99 percent confidence level, with the more conservative estimate controlling for household and neighborhood characteristics of 11.6 percentage points. Taking point estimates of β_{sewer} and $\beta_{latrine}$ from column 2 translate to an increased compliance rate of approximately 22 percent and 19 percent, respectively, compared to households with open defecation practices.

The difference in compliance rates between households with sewer access and latrine systems is also statistically significant. F-statistics testing the difference between OLS estimates of β_{sewer} and $\beta_{latrine}$ are provided in columns 1 and 2 of table 1; across the specifications, the difference between the coefficient estimates is statistically significant at a greater than 99 percent confidence level. The more conservative specification (column 2) shows an estimated difference of 2 percentage points between the groups, with sewer-accessible households more likely to pay property tax than those household using latrines.

IV estimates instrumenting a household's access to a sewer (or latrine) by the share of households on the block with the same sanitation type are presented in columns 3 and 4 alongside the OLS estimates in table 1. Estimated coefficients from the IV estimation are larger than the OLS estimates, but are similar in magnitude and significance to the relationship predicted in the main empirical specification.

We also present estimates using the matching estimator in table 1. As the VBKW procedure outlined in Garrido, Lum and Pizer (2021) produces pair-wise ATEs, we present the effect of comparing sewered households to those without sanitation in column 5 and the effect of latrine households versus households without improved sanitation in column 6. Point estimates from the matching approach are nearly identical to those produced using the OLS and IV regressions. The similarity in estimated effect sizes between the parametric and non-parametric approach gives us confidence that it appears variation in sanitation is in part driving the observed attitudes towards nonpayment.

As the property tax is calculated using a presumptive formula that does not factor in a household's sanitation level, calculating the revenue loss from delinquency is relatively straightforward. Total liabilities for households in 2017 was R$12.3 billion, with cumulative arrears for delinquent households lacking improved sanitation totalling R$475.5 million. Assuming all households in the city were connected to sewers and displayed similar attitudes towards property taxes as table 1, back-of-the-envelope calculations project increased municipal revenues of around R$62 million. This represents a sizable increase in municipal funds, and does not factor in the additional social and health benefits of improved sanitation in urban environments (see Kresch, Lipscomb and Schechter (2020)).

B Views on Government and Tax System

In this section, we shed light on a potential mechanism to rationalize the increased compliance rate of households with sewer access. Using results from the city-wide survey, we provide evidence that households with piped sewer systems have significantly more positive views on local government. We interpret these results as consistent with the "social contact"– where households with greater access to municipal services are more likely to see the benefit of providing the government with funds necessary to maintain and deliver these services.

Table 2 presents estimation results using the specification outlined in equation 2, with attitudes toward the municipal government and nonpayment of property taxes as the dependent variables. In column 1 we measure the compliance rate for the survey sample; estimates are similar to those in column 2 of table 1, providing supportive evidence that the survey sample is fairly representative of Manaus.

Three key findings emerge from the remaining columns of table 2. First, households that have access to the city sewer system are significantly more likely to agree that the overall performance of the municipal government is good (column 2). This effect is entirely driven by the subset of sewered households that are compliant with IPTU payments (column 3), as delinquent households with sewers are not significantly more likely to approve of the government (column 4).

We do not find that the full sample of households using latrines have similar views towards the local government. However, averaging over both compliant and non-compliant households obscures significant heterogeneity in the views of each group. Compliant households with latrines are significantly more likely to agree with the quality of government services, whereas delinquent latrine households are significantly less likely to approve of the government. As the cost of building a private latrine is borne entirely by the household, the fact that delinquent latrine households hold views that are more negative than those delinquent individuals who simply don't have access to sewerage is consistent with the (failure of the) social contract. Additionally, compliant households with sewer service are nearly twice as likely (with a statistically significant difference) to hold a favorable view of government, suggesting that access to sanitation is partly driving these views.

That the overall sample of households with latrines have higher compliance rates than no-sanitation households yet are not significantly more favorable to the municipal government suggests additional mechanisms driving their tax decisions. Columns 5 through 7 of table 2 show that these latrine households are significantly less likely to view non-payment of IPTU as justifiable, with compliant households more likely to hold this view. Point estimates for sewered households in columns 5 and 6 are also negative, albeit not statistically significant. This non-significance may in part be due to the smaller sample size of the survey, as F-tests on the difference in estimates for sewer and latrine household does not reject the hypothesis that they are similar. We take this result as evidence that other aspects of the tax system may be driving part of a household's decision to pay their property tax, although the difference between sewer and latrine households–both in terms of their compliance rates and views on government–suggest that households benefiting from the social contract are more likely to support the public finance systems necessary to deliver basic services.

V Conclusion

This paper studies the relationship between urban sanitation and property tax compliance. As sanitation is a highly visible utility with municipal authority over service provision, access to the sewer system may make households more likely to pay their municipal property tax (Slemrod, 2019). Exploiting the granular variation in sewer access across the city, we find that sewered households are significantly more likely (approximately 15 percentage points) to pay their property tax bill. We also find evidence consistent with the social contract partly driving this result; estimates from a survey of households find those with access to city sewers have more favorable views of government, with the result entirely driven by households that are compliant with tax payments.

Our paper sheds light on an understudied fiscal externality of providing sanitation for policymakers to consider when justifying the large fixed costs needed to construct and maintain urban sewer systems. To contextualize this, table 3 shows the costs and benefits associated with other programs specifically targeted at increasing tax compliance, namely increasing public services (panel A) and increase messaging by the tax authority (panel B). Our findings on tax compliance rates in Manaus are similar in magnitude to other interventions, although sanitation interventions can be much more expensive per capita (panel C). However, this cost-benefit analysis does not take into account the health benefits of improved sanitation in urban environments (Kresch, Lipscomb and Schechter, 2020) that are not present in messaging interventions, for example.

This analysis is particularly relevant in the rapidly urbanizing areas of the developing world, where property tax compliance is low (Cogneau et al., 2020) and costs of connecting the "last mile" of sewers hinders household adoption (Ashraf, Glaeser and Ponzetto, 2016). Our results suggest that the costs of subsidizing sewer connections throughout a city could be partially offset by the increase in property values and compliance with property taxes. While our paper documents a real-world relationship between sanitation and tax compliance, future research that randomizes the roll-out of sanitation access would be insightful in further identifying the causal mechanism and sanitation's role in the social contract.

References

Abramovsky, Laura, Britta Augsburg, and Francisco Oteiza. 2019. "Sustainable total sanitation-Nigeria: Final research report."

Acemoglu, Daron, Ali Cheema, Asim I Khwaja, and James A Robinson. 2020. "Trust in state and nonstate actors: Evidence from dispute resolution in Pakistan." *Journal of Political Economy*, 128(8): 3090–3147.

Adukia, Anjali. 2017. "Sanitation and education." *American Economic Journal: Applied Economics*, 9(2): 23–59.

Ashraf, Nava, Edward L Glaeser, and Giacomo AM Ponzetto. 2016. "Infrastructure, incentives, and institutions." *American Economic Review*, 106(5): 77–82.

Augsburg, Britta, and Paul Andres Rodriguez-Lesmes. 2018. "Sanitation and child health in India." *World Development*, 107: 22–39.

Bartram, Jamie, Kristen Lewis, Roberto Lenton, and Albert Wright. 2005. "Focusing on improved water and sanitation for health." *The Lancet*, 365(9461): 810–812.

Besley, Timothy, and Torsten Persson. 2013. "Taxation and development." In *Handbook of public economics*. Vol. 5, 51–110. Elsevier.

Best, Michael Carlos, Anne Brockmeyer, Henrik Jacobsen Kleven, Johannes Spinnewijn, and Mazhar Waseem. 2015. "Production versus revenue efficiency with limited tax capacity: theory and evidence from Pakistan." *Journal of Political Economy*, 123(6): 1311–1355.

Best, Michael, Francois Gerard, Evan Kresch, Joana Naritomi, and Laura Zoratto. 2019. "Greener on the Other Side: Inequity and Tax Collection." NTA.

Blumenthal, Marsha, Charles Christian, and Joel Slemrod. 2001. "Do normative appeals affect tax compliance? Evidence from a controlled experiment in Minnesota." *National Tax Journal*, 54(1): 125–138.

Bowers, Jake, Nuole Chen, Christopher Grady, and Matthew Winters. 2020. "Can information about taxation and improved public services increase tax compliance? Lessons from Malawi." Evidence in Governance and Politics (EGAP).

Brockmeyer, Anne, Alejandro Estefan, Karina Ramírez Arras, and Juan Carlos Suárez Serrato. 2021. "Taxing property in developing countries: Theory and evidence from Mexico." National Bureau of Economic Research.

Carrillo, Paul E, Edgar Castro, and Carlos Scartascini. 2021. “Public good provision and property tax compliance: Evidence from a natural experiment.” *Journal of Public Economics*, 198: 104422.

Castro, Lucio, and Carlos Scartascini. 2015. “Tax compliance and enforcement in the pampas evidence from a field experiment.” *Journal of Economic Behavior & Organization*, 116: 65–82.

Coffey, Diane, Michael Geruso, and Dean Spears. 2018. “Sanitation, disease externalities and anaemia: evidence from Nepal.” *The Economic Journal*, 128(611): 1395–1432.

Cogneau, Denis, Marc Gurgand, Justine Knebelmann, Victor Pouliquen, and Bassirou Sarr. 2020. “Bringing property owners into the tax net: avenues of fiscal capacity and local accountability. Evidence from Dakar, Senegal.” Working Paper.

Cohen, Isabelle M. 2021. *Essays on Public Finance and Development.* University of California, Berkeley.

Coville, Aidan, Sebastian Galiani, Paul Gertler, and Susumu Yoshida. 2020. “Enforcing payment for water and sanitation services in Nairobi’s slums.” National Bureau of Economic Research.

de Melo, Moacir Guimarães, Brina Aguiar da Silva, Gilcllys de Souza Costa, João Cândido André da Silva Neto, Patrícia Kaori Soares, Adalberto Luis Val, Jamal da Silva Chaar, Hector Henrique Ferreira Koolen, and Giovana Anceski Bataglion. 2019. “Sewage contamination of Amazon streams crossing Manaus (Brazil) by sterol biomarkers.” *Environmental Pollution*, 244: 818–826.

Deutschmann, Joshua W, Molly Lipscomb, Laura Schechter, and S Jessica Zhu. 2021. “Spillovers without social interactions in urban sanitation.” *Working Paper.*

Devoto, Florencia, Esther Duflo, Pascaline Dupas, William Parienté, and Vincent Pons. 2012. “Happiness on tap: Piped water adoption in urban Morocco.” *American Economic Journal: Economic Policy*, 4(4): 68–99.

DiNardo, John, and Justin L Tobias. 2001. “Nonparametric density and regression estimation.” *Journal of Economic Perspectives*, 15(4): 11–28.

Duflo, Esther, Michael Greenstone, Raymond Guiteras, and Thomas Clasen. 2015. “Toilets can work: Short and medium run health impacts of addressing complementarities and externalities in water and sanitation.” National Bureau of Economic Research.

Duflo, Esther, Sebastian Galiani, and Mushfiq Mobarak. 2012. “Improving access to urban services for the poor.” *Abdul Latif Jameel Poverty Action Lab Report.*

Dzansi, James, Steven L Puller, Brittany Street, and Belinda Yebuah-Dwamena. 2018. “The Vicious Circle of Blackouts and Revenue Collection in Developing Economies: Evidence from Ghana.” Mimeo.

Fuente, David, Maura Allaire, Marc Jeuland, and Dale Whittington. 2020. "Forecasts of mortality and economic losses from poor water and sanitation in sub-Saharan Africa." *PloS one*, 15(3): e0227611.

Garrido, Melissa M, Jessica Lum, and Steven D Pizer. 2021. "Vector-based kernel weighting: A simple estimator for improving precision and bias of average treatment effects in multiple treatment settings." *Statistics in Medicine*, 40(5): 1204–1223.

Geruso, Michael, and Dean Spears. 2018. "Neighborhood sanitation and infant mortality." *American Economic Journal: Applied Economics*, 10(2): 125–62.

GFA, Consulting Group GmbH. 2018. "SFD Lite Report - Manaus, Brazil." Sustainable Action Alliance.

Gonzalez-Navarro, Marco, and Climent Quintana-Domeque. 2013. "Local Public Goods and Property Tax Compliance: Evidence from Residential Street Pavement." Lincoln Institute of Land Policy.

Hammer, Jeffrey, and Dean Spears. 2016. "Village sanitation and child health: effects and external validity in a randomized field experiment in rural India." *Journal of Health Economics*, 48: 135–148.

Haq, Osman, Adnan Qadir Khan, Benjamin Olken, and Mahvish Shaukat. 2020. "Rebuilding the social compact."

Heller, Léo. 2007. "Basic sanitation in Brazil: lessons from the past, opportunities from the present, challenges for the future." *Journal of Comparative Social Welfare*, 23(2): 141–153.

IADB. 2013. "Programa Social y Ambiental de los Igarapés de Manaus - Suplementario." *https://www.iadb.org/projects/document/EZSHARE-1555264205-1986?project=BR-L1005;BR-L1217*, [Online; accessed 21-November-2021].

IBGE. 2011. *Atlas de saneamento : 2011.* Rio de Janeiro:IBGE, Diretoria de Geociências.

IBGE. 2018. "Cidades e Estados." *https://www.ibge.gov.br/cidades-e-estados/am/manaus.html*, [Online; accessed 20-April-2021].

Imbens, Guido W, and Jeffrey M Wooldridge. 2009. "Recent developments in the econometrics of program evaluation." *Journal of economic literature*, 47(1): 5–86.

Krause, Benjamin. 2020. "Balancing Purse and Peace: Tax Collection, Public Goods, and Protests."

Kresch, Evan Plous. 2020. "The Buck Stops Where? Federalism, Uncertainty, and Investment in the Brazilian Water and Sanitation Sector." *American Economic Journal: Economic Policy*, 12(3): 374–401.

Kresch, Evan Plous, Molly Lipscomb, and Laura Schechter. 2020. "Externalities and spillovers from sanitation and waste management in urban and rural neighborhoods." *Applied Economic Perspectives and Policy*, 42(3): 395–420.

Mara, Duncan, Jon Lane, Beth Scott, and David Trouba. 2010. "Sanitation and health." *PLoS Med*, 7(11).

Mascagni, Giulia, and Christopher Nell. 2022. "Tax compliance in Rwanda: Evidence from a message field experiment." *Economic Development and Cultural Change*, 70(2): 000–000.

McRae, Shaun. 2015. "Infrastructure quality and the subsidy trap." *American Economic Review*, 105(1): 35–66.

Melo, Jose Carlos. 2005. "The experience of condominial water and sewerage systems in Brazil." *Case studies from Brasılia, Salvador and Parauapebas. Lima: Water and Sanitation Program Latin America.*

Olivier, Anne, et al. 2006. "Water tariff increase in Manaus (Brazil): an evaluation of the impact on households."

Pereira, U, and N Aleixo. 2018. "Os Resíduos Sólidos Urbanos como Condicionante de Doenças na Cidade de Manaus/AM." *Revista Geonorte*, 9(31): 32–53.

Pomeranz, Dina. 2015. "No taxation without information: Deterrence and self-enforcement in the value added tax." *American Economic Review*, 105(8): 2539–69.

Shimeles, Abebe, Daniel Zerfu Gurara, and Firew Woldeyes. 2017. "Taxman's dilemma: Coercion or persuasion? Evidence from a randomized field experiment in Ethiopia." *American Economic Review*, 107(5): 420–24.

Silveira, André Braga Galvão. 2016. "SAÚDE SEM BANHEIROS?: evolução da defecação a céu aberto e do acesso a banheiros no Brasil." *Revista de Políticas Públicas*, 20(1): 185–200.

Slemrod, Joel. 2019. "Tax compliance and enforcement." *Journal of Economic Literature*, 57(4): 904–54.

Stantcheva, Stefanie. 2020. "Understanding tax policy: How do people reason?" National Bureau of Economic Research.

Stepping, Katharina. 2016. "Urban sewage in Brazil: drivers of and obstacles to wastewater treatment and reuse. Governing the Water-Energy-Food Nexus Series." German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE).

Tesh, Sylvia N, and Eduardo Paes-Machado. 2004. "Sewers, garbage, and environmentalism in Brazil." *The Journal of Environment & Development*, 13(1): 42–72.

Troeger, Christopher, Brigette F Blacker, Ibrahim A Khalil, Puja C Rao, Shujin Cao, Stephanie RM Zimsen, Samuel B Albertson, Jeffery D Stanaway, Aniruddha Deshpande, Zegeye Abebe, et al. 2018. "Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis for the Global Burden of Disease Study 2016." *The Lancet Infectious Diseases*, 18(11): 1211–1228.

Van Minh, Hoang, and Nguyen Viet Hung. 2011. "Economic aspects of sanitation in developing countries." *Environmental health insights*, 5: EHI–S8199.

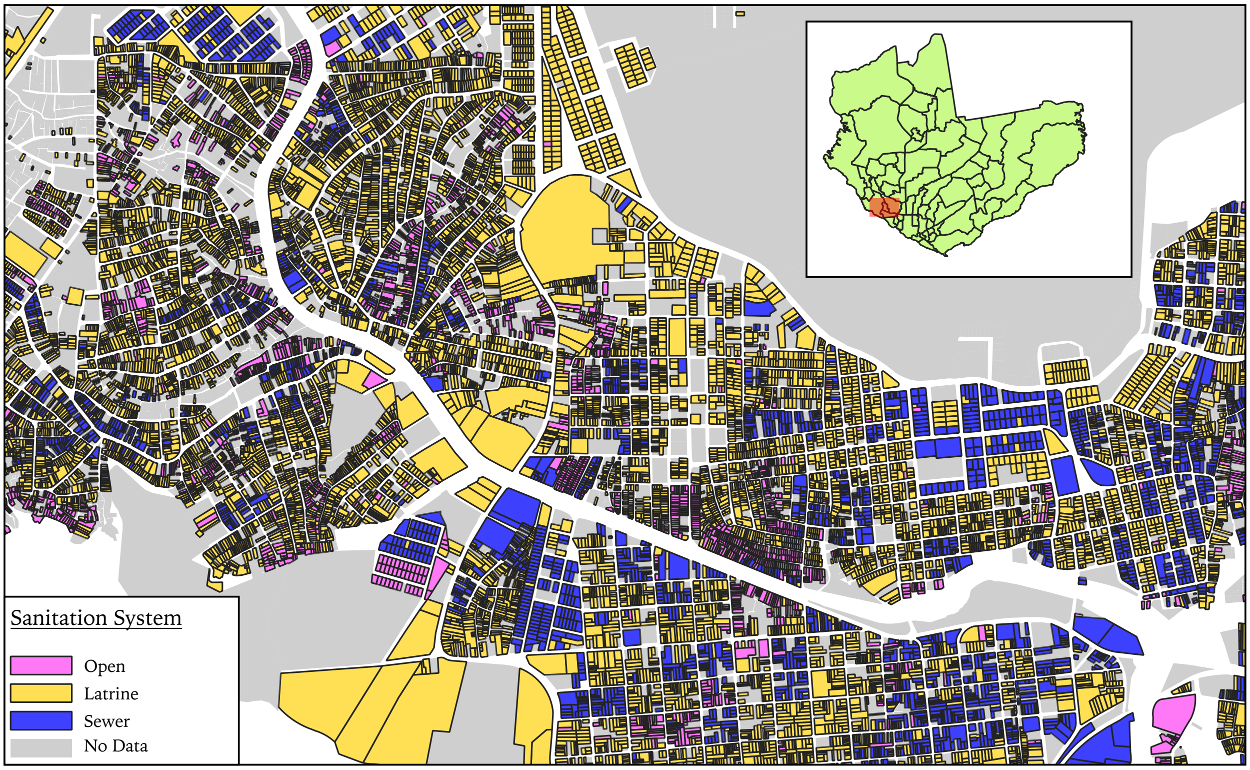
Watson, Tara. 2006. "Public health investments and the infant mortality gap: Evidence from federal sanitation interventions on US Indian reservations." *Journal of Public Economics*, 90(8-9): 1537–1560.

Weigel, Jonathan L. 2020. "The participation dividend of taxation: How citizens in Congo engage more with the state when it tries to tax them." *The Quarterly Journal of Economics*, 135(4): 1849–1903.

Yishay, Ariel Ben, Andrew Fraker, Raymond Guiteras, Giordano Palloni, Neil Buddy Shah, Stuart Shirrell, and Paul Wang. 2017. "Microcredit and willingness to pay for environmental quality: Evidence from a randomized-controlled trial of finance for sanitation in rural Cambodia." *Journal of Environmental Economics and Management*, 86: 121–140.

Figures

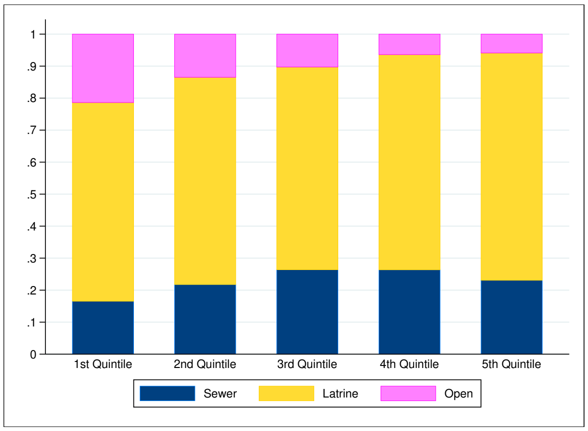
Figure 1: Sanitation Systems Across Manaus



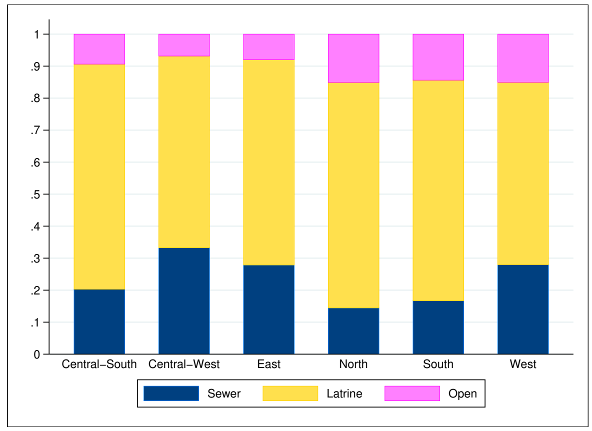
Notes: This figure shows the sanitation system at the lot-level for a highlighted section of Manaus. Data on a property's sanitation system comes from SEMEF.

Figure 2: Distribution of Sanitation Coverage

Panel A: Across Tax Liabilities



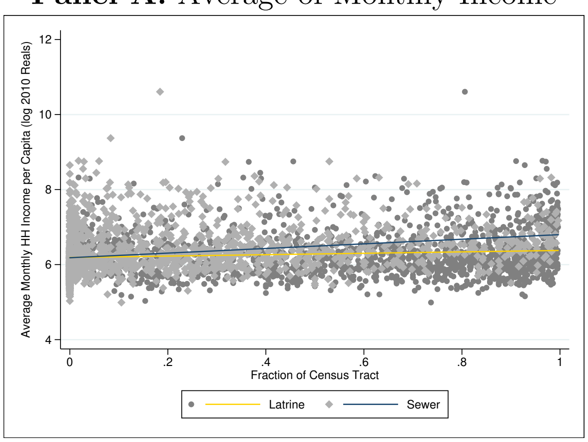
Panel B: Across Administrative Zones



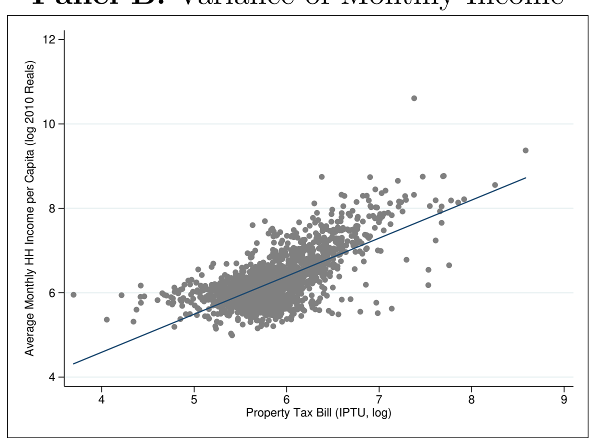
Notes: Panels depict the share of households with a given sanitation system. Households with open systems lack access to any improved sanitation and dispose of waste in either rivers, drainage canals, or public spaces.

Figure 3: Income and Sanitation Coverage by Census Tract

Panel A: Average of Monthly Income

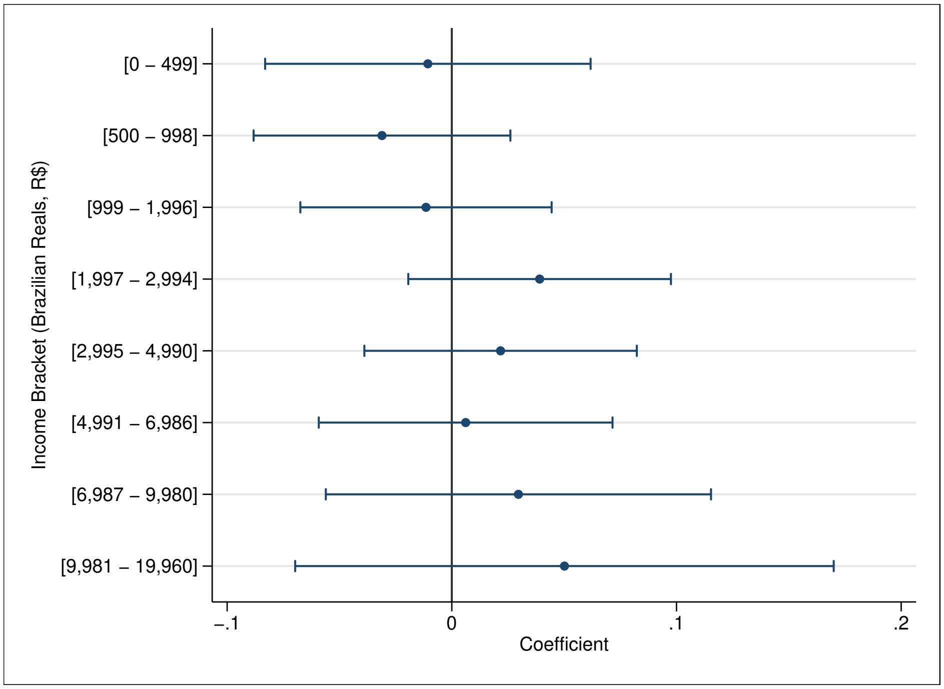


Panel B: Variance of Monthly Income



Notes: Panel A plots monthly household income per capita, averaged over the 2,213 census tracts with sewer and latrine usage. Each dot corresponds to the share of households with sewers and latrines averaged over the census tract. Lines of best fit plotting the relationship between household income and latrine and sewer usage are depicted in yellow and blue, respectively. Panel B plots census tract-average monthly household income per capita against the average annual 2017 IPTU bill for households in a given census tract. Household income variables come from the 2010 Brazilian Census, and data on property tax and sewer and latrine usage are provided by SEMEF.

Figure 4: Income and Sewer Access (Survey Sample)



Notes: This figure plots coefficient estimates and 95 percent confidence intervals from a linear probability models. The outcome variable is an indicator for whether household h has sewer access, and is regressed on indicators for the eight bins of monthly household income, controlling for household tax liability and neighborhood fixed effects. Households above the top income bracket (0.3% of observations) are dropped from the LPM analysis.

Tables

Table 1: Property Tax Compliance

	OLS		IV		VBKW (matching)	
	(1)	(2)	(3)	(4)	(5)	(6)
Has Sewer Access	0.162***	0.135***	0.217***	0.187***	0.152***	
	(0.00388)	(0.00414)	(0.00482)	(0.00538)	(0.00437)	
Has Latrine Facility	0.125***	0.116***	0.163***	0.149***		0.116***
	(0.00314)	(0.00768)	(0.00396)	(0.00817)		(0.00399)
Constant (α)	0.456***	0.606***	0.416***	0.569***	0.451***	0.460***
	(0.00314)	(0.00768)	(0.00396)	(0.00817)	(0.00369)	(0.00375)
Observations	199,621	199,621	199,621	199,621	68,377	153,865
IPTU Liability	Yes	Yes	Yes	Yes	-	-
Non-IPTU HH Controls	No	Yes	Yes	Yes	-	-
Neighborhood FE	No	Yes	No	Yes	-	-
$\beta_{sewer} - \beta_{latrine}$	0.0365	0.0196	-	-	0.036	
F-statistic	202.3	50.20	74425	62699	-	-
$Prob > F$	< 0.001	< 0.001	-	-	-	-

Notes: Coefficients represent estimates from linear probability models. Robust standard errors are in parentheses, controlling for tax liability and various household-level and neighborhood controls. The IV estimates shown in columns (3) and (4) include these controls, as well as the share of household $h's$ block that has sewer access and latrines, respectively. F-statistics for the IV estimates in columns (3) and (4) are the Kleibergen-Paap rk Wald F-statistic. Matching estimates presented in columns (5) and (6) use the vector-based kernel weighting (vbkw) command, which is outlined in greater detail in Garrido, Lum and Pizer (2021). Matching is performed based on IPTU liability. Significantly different than zero at 99 (***), 95 (**), 90 (*) percent confidence.

Table 2: Views on Government and Nonpayment

		"Quality of government services is good"			"Nonpayment of IPTU is justifiable"		
	Property Tax Compliance (1)	All Households (2)	Compliant Households (3)	Delinquent Households (4)	All Households (5)	Compliant Households (6)	Delinquent Households (7)
Has Sewer Access	0.129***	0.044**	0.098***	0.003	-0.026	-0.050	0.010
	(0.0217)	(0.0210)	(0.0269)	(0.0333)	(0.0226)	(0.0305)	(0.0347)
Has Latrine Facility	0.094***	-0.011	0.055**	-0.071***	-0.039**	-0.056**	-0.019
	(0.0187)	(0.0174)	(0.0229)	(0.0263)	(0.0193)	(0.0268)	(0.0282)
Constant (α)	0.527***	0.294***	0.232***	0.340***	0.534***	0.540***	0.540***
	(0.0165)	(0.0156)	(0.0205)	(0.0234)	(0.0171)	(0.0243)	(0.0248)
Observations	5,341	5,341	3,269	2,072	5,341	3,269	2,072
$\beta_{sewer} - \beta_{latrine}$	0.035	0.055	0.043	0.075	0.013	0.006	0.029
F-test	4.586	11.40	4.613	7.362	0.544	0.093	0.998
$Prob > F$	0.032	< 0.001	0.032	0.007	0.461	0.761	0.318

Notes: Coefficients represent estimates from linear probability models. Robust standard errors are in parentheses, controlling for tax liability and various non-IPTU household controls. Significantly different than zero at 99 (***), 95 (**), 90 (*) percent confidence.

Table 3: Tax Compliance: Service-Provision and Other Interventions

A. Public Services Provision Interventions

Authors	Cost	Benefits
(Carrillo, Castro and Scartascini, 2021) Sidewalk extension (Argentina)	1550 USD (2009)	3 to 4 pp increase in on-time payment
(Krause, 2020) Garbage collection (Haiti)	3000 USD (2019)	27-40% increase over mean tax payment amount
(Bowers et al., 2020) Garbage disposal (Malawi)	Not disclosed	18 pp increase in tax compliance

B. Messaging Interventions (Promise of Services or Enforcement)

Authors	Cost	Benefits
(Cohen, 2021) SMS messaging (Uganda)	.035 cents/text for 63,700 texts	8.7-13.7% increase in payment likelihood
(Mascagni and Nell, 2022) Letter/email/SMS (Rwanda)	< 4000 USD	6 million USD total across varied treatments
(Shimeles, Gurara and Woldeyes, 2017) Hand delivered Letters to businesses (Ethiopia)	Not disclosed	32-38% increase in profit tax payable
(Pomeranz, 2015) Letters & audits (Chile)	Mass mail costs (not specified)	1,326/firm/mo peso median increase in VAT payment

C. Water and Sanitation: Costs Across Countries

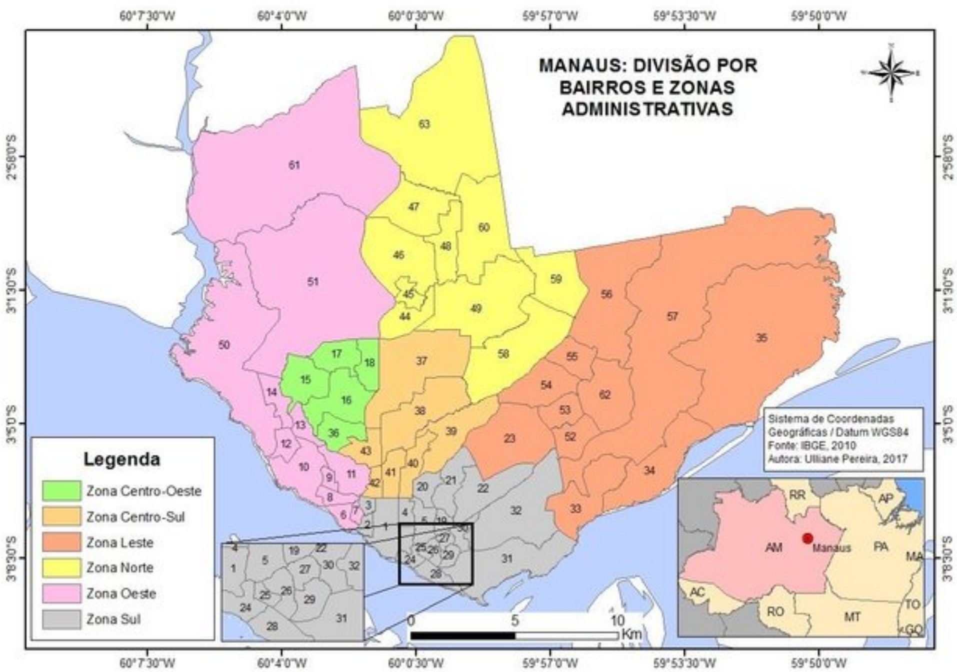
Authors	Cost (per connection)	Sanitation Type
Yishay et al. (2017) (Cambodia)	40 USD	latrine access
Augsburg and Rodriguez-Lesmes (2018) (India)	178 USD (2010)	toilet construction
Abramovsky, Augsburg and Oteiza (2019) (Nigeria)	400 USD	toilet construction (VC)
Ashraf, Glaeser and Ponzetto (2016) (Zambia)	960 USD	water & sewer connection
Coville et al. (2020) (Kenya)	1100 USD	water & sewer connection
Devoto et al. (2012) (Morocco)	540-1340 USD	water connection

Notes: This table summarizes the results and costs of sanitation-related and informational interventions on tax compliance, providing comparative context for the estimates in this study.

A Appendix

A.I Appendix Tables and Figures

Figure A.1: Administrative Zones of Manaus



Notes: This map shows the administrative zones of Manaus regularly used in local policies. Source: Pereira and Aleixo (2018).

Table A.1: IPTU Calculation Factors

$IPTU = (VE + VT) \times aliquot$					
$VE = Value(m^2) \times Area \times (CAT/100) \times Alignment \times Construction \times Position$			$VT = Value(m^2) \times Area \times Situation \times Typography \times Pedology$		
Alignment • Aligned • Backtracked	Construction • Isolated • Combined • Detached	Position • Front • Back • Superimposed Front • Superimposed Back • Mezzanine • Gallery • Village	Situation • Corner • Middle of Block • Village • Enclave • Horizontal Condo • Favela/Stilit	Topography • Flat • Uphill • Downhill • Irregular	Pedology • Floodable + 50% • Floodable - 50% • Firm

Notes: This table shows the equation used by SEMEF to calculate a household's property tax bill. CAT is defined as the sum of building components points, and factors in the construction material used in a household's roof, exterior walls, structure, and building height.

Table A.2: Alternative Specifications Controlling for Tax Liability

	IPTU Liability Control: Percentiles		IPTU Liability Control: Higher Order Polynomial	
	Compliance (1)	Compliance (2)	Compliance (3)	Compliance (4)
Has Sewer Access	0.157***	0.130***	0.159***	0.130***
	(0.00391)	(0.00419)	(0.00389)	(0.00416)
Has Latrine Facility	0.125***	0.114***	0.125***	0.113***
	(0.00345)	(0.00358)	(0.00345)	(0.00358)
Constant (α)	0.537***	0.721***	0.529***	0.594***
	(0.0118)	(0.0122)	(0.0460)	(0.0459)
Observations	199,621	199,621	199,621	199,621
Non-IPTU HH Controls	Yes	Yes	Yes	Yes
Neighborhood FE	No	Yes	No	Yes

Notes: Coefficients represent estimates from linear probability models. Robust standard errors are in parentheses, controlling for tax liability and various household controls and neighborhood fixed effects. Significantly different than zero at 99 (***), 95 (**), 90 (*) percent confidence.

Table A.3: Sewer Access and Household Income (Survey Sample)

	LPM of Household Having Sewer Access			
	(1)	(2)	(3)	(4)
Income Bracket:				
$[R\$0 - 499]$	-0.0107	-0.0201		
	(0.0370)	(0.0367)		
$[R\$500 - 998]$	-0.0311	-0.0355		
	(0.0292)	(0.0289)		
$[R\$999 - 1,996]$	-0.0115	-0.0164		
	(0.0285)	(0.0283)		
$[R\$1,997 - 2,994]$	0.0391	0.0330		
	(0.0298)	(0.0296)		
$[R\$2,995 - 4,990]$	0.0217	0.0197		
	(0.0309)	(0.0308)		
$[R\$4,991 - 6,986]$	0.00616	0.00642		
	(0.0333)	(0.0333)		
$[R\$6,987 - 9,980]$	0.0296	0.0293		
	(0.0437)	(0.0436)		
$[R\$9,981 - 19,960]$	0.0501	0.0521		
	(0.0611)	(0.0610)		
Middle of Income Bracket			0.0000**	0.0000**
			(0.000)	(0.00)
Middle of Income Bracket^2				-0.0000*
				(0.000)
Observations	5,328	5,328	5,151	5,151
IPTU Liability	Yes	No	Yes	Yes
IPTU Characteristics	No	Yes	No	No
Neighborhood FE	Yes	Yes	Yes	Yes

Notes: Coefficients represent estimates from linear probability models. The outcome variable is an indicator for whether household h has sewer access. Robust standard errors are in parentheses, controlling for neighborhood fixed effects and either log tax liability (column 1) or the vector of characteristics that determines household $h's$ tax liability (column 2). Households above the top income bracket (0.3% of observations) are dropped from the LPM analysis. Columns 3 and 4 present regression estimates assigning the middle value for each household in a given income bracket. Point estimates of "0.000" are smaller than 0.0001. Significantly different than zero at 99 (***), 95 (**), 90 (*) percent confidence.