Privatization of public goods: Evidence from the sanitation sector in Senegal

Joshua W. Deutschmann
University of Chicago

Jared Gars
Bocconi University

Jean-François Houde
University of Wisconsin

Molly Lipscomb *
University of Virginia

Laura Schechter
University of Wisconsin

October 20, 2021

Abstract

Privatization of a public good (the management of sewage treatment centers in Dakar, Senegal) leads to an increase in the productivity of downstream sewage dumping companies and a decrease in downstream prices of the services they provide to households. We use the universe of legal dumps of sanitation waste from May 2009 to November 2018 to show that legal dumping increased substantially following privatization–on average an increase of 61.7%, or an increase of about 14,000 cubic meters each month. This is due to increased productivity of all trucks, not just those associated with the company managing the treatment centers. Household-level survey data shows that prices of legal sanitary dumping decreased by ten percent following privatization, and DHS data show that diarrhea rates among children under five decreased in Dakar relative to secondary cities in Senegal following privatization with no similar effect on respiratory illness as a placebo.

JEL Classification Codes:O120, O170
Keywords:Sanitation, Privatization, Urban Development

*Corresponding author: molly.lipscomb@virginia.edu, Garrett Hall, 235 McCormick Ave, Charlottesville VA 22903

1 Introduction

Public utilities in developing countries are often poorly managed and fall into disrepair due to low state managerial capacity and poorly designed incentive systems. Since public utilities provide key services, the impact of poor management can be substantial. Upstream inefficiencies can raise prices and reduce supply downstream. One response to the difficulty of government management of utility services has been to privatize the services or operate through public-private partnerships, potentially increasing efficiency and reducing costs.

There are two possible conflicting impacts of privatization. On one hand, privatization can improve the efficiency of the utility and lead to quality improvements if the government lacks the capacity to adequately manage it. On the other hand, private companies may raise prices taking advantage of the natural monopoly and ignoring the health externalities (Chong and de Silanes, 2004; Megginson and Netter, 2001).

When the acquiring firm is already operating in the industry, privatization also allows that firm to gain direct access to a key input. Vertical integration in this context can lead to efficiency gains, for example by increasing the incentive of the operator to invest in higher service quality or reduce prices. However, to the extent that firms have market-power, a vertically integrated operator can also fully or partially prevent or "foreclose" access to the utility for competing firms; for example by raising the access price or reducing quality. The empirical evidence on the net effect of vertical integration is mixed. While some papers have confirmed the presence of foreclosure or "raising rivals' costs" effects (Chipty, 2001; Luco and Marshall, 2020), the general view of antitrust authorities is that efficiency effects tend to dominate (Hortaçsu and Syverson, 2007).

We measure the overall effect of privatization of sewage treatment centers in Dakar, Senegal in November 2013, focusing on the effect on productivity. Outcomes include the intensity of capital use, the propensity to invest in new capital, the territory in which companies get business, and the number of days they operate in a week. Before privatization, the treatment centers were managed by ONAS, a government agency charged with managing Senegal's sanitation sector. These sewage treatment centers collect waste from trucks which pump out latrine pits and septic tanks and dump the waste at the center for a fee. The centers then process the waste in holding ponds with some filtration. This is the only legal (and hygienic) form of disposal of sewage waste in Dakar for households without a direct connection to a sewerage system. In 2012, following complaints by the truckers about long wait times and frequent closures at the treatment centers, the Senegalese government decided to privatize their management.[1] They ran a call for bids and selected the company Delvic, formed from a partnership of two of the largest companies in the sanitation truck sector (Delta and Vicas), to take over management of the centers in 2013 via a public-private partnership.

There are several unique aspects to this context that make it a particularly interesting environment in which to study the impact of privatization. First, most studies measuring the impact of privatization look at industries such as water, electricity, and telecommunications which interact directly with consumers (McKenzie and Mookherjee, 2003) and focus on the poor incentives that utilities may have in terms of achieving the "last mile" (Ashraf et al., 2016) or investing in maintenance of the network (McRae, 2015). In our study, the treatment centers do not directly serve consumers but instead are an upstream input

[1] The sewage treatment centers are operating far above their designed maximum daily capacity, and maintaining that operation requires active management of various infrastructure at the centers (Sene, 2017).

into the production of sanitation services. Sewage treatment center management affects the efficiency of downstream companies (the trucks), which in turn supply sanitation services to consumers. Second, it is rare to have data from before and after privatization on downstream businesses. In this case, the treatment centers always collected the license plate of each truck that dumped waste at the center, no matter the ownership. We collected and digitized the handwritten records from 2006 through 2018.[2] From this data we can observe how privatization affected individual truckers. Finally, most of the literature measuring the impacts of privatization have focused first on Eastern Europe (Barberis et al., 1996; Megginson and Netter, 2001) and later on Latin America (Chong and de Silanes, 2004; Granados and Sánchez, 2014; McKenzie and Mookherjee, 2003; Saiani and de Azevedo, 2018). We study privatization in Africa where there is much less evidence (Kirkpatrick et al., 2006; Kosec, 2014). To our knowledge, this case represents the first privatization of sewage treatment centers in Sub-Saharan Africa.

Identification is difficult because the privatization occurred at all three treatment centers at the same time. As a result, the primary identification strategy in this paper is an event study. However, we are able to combine several large data sources and evaluate differential impacts of the privatization on various market players using difference-in-differences analysis. We have a large sample measuring the universe of legal dumping in Dakar over a period of nine years, with the privatization occurring towards the middle of that period, so we are able to see the extent to which the privatization led to temporary versus permanent changes in Dakar's sanitation market. Our data allows us to observe dumping at the truck level as center managers track the plate number of each truck that dumps at the treatment center together with an attribution for the company to which the truck belongs (on average companies own 2 trucks).

Sanitation companies rely on the treatment centers as part of their supply chain: they need to dump at the centers between each job, so any blockages at the center level can have substantial impacts on their productivity. Volume at the centers increased substantially following privatization. We see an average increase of 1,806 trips per month (or about 14,000 cubic meters of sewage) from an initial average prior to privatization of 3,138 trips per month (26,000 cubic meters). Prior to privatization, the treatment centers were managed by ONAS, the government agency responsible for sanitation in Senegal, but privatization meant that the treatment centers were delegated to a group of two sanitation companies for management. Privatization led to large increases in the productivity of truckers downstream. The average company did 54% more jobs following privatization. The productivity increases were not limited to the companies managing the privatized centers. After accounting for the larger size of these companies, there was no statistically significant difference in the increase in traffic from the companies responsible for the management of the centers relative to the other companies. The increased productivity per truck is therefore not driven by these two vertically integrated downstream companies.

We show that the large productivity changes at the company level are due to increased truck-level productivity, increased investment in capital stock, improved management of capital, and changed hours of operations. The highly disaggregated nature of our data (at the truck-dumping level) allows us to estimate the change in activity at the truck level and the extent to which trucks work on weekends. We find that most companies do not invest in additional trucks following privatization, but they do maintain 19% more trucks active in their fleet. This is an important source of gain in productivity: at baseline, the average company had only 61% of their fleet actively dumping in any given week.[3] Maintenance issues

[2]Because of inconsistencies in the data prior to May 2009, we begin our sample in May, 2009.

[3]Part of the low baseline activity may be due to measurement error and trucks doing non-desludging related work such

are often expensive, and parts can take some time to source, so this is likely due to better continued management of their fleet). Trucks do approximately 67% more trips per week following privatization. We break this down into the intensive and extensive margin. Trucks work 0.71 additional days per week. Conditional on working on a given day, the number of trips increases by 12.9%.

Improving the efficiency of the sanitation sector is especially important due to its direct connection with diarrheal diseases, which have important welfare impacts on communities and lasting impacts on children (Hammer and Spears, 2016). Diarrheal diseases remain a major public health problem in African cities (WHO, 2017), due in part to rapid urbanization without sufficient investment in sanitation infrastructure. In Senegal, a country where both large and secondary cities struggle to provide basic services, diarrhoea is the leading cause of death among children under the age of 5 years, responsible for 14% of total disability-adjusted life years (Wang et al., 2016). Notably, Senegal's urban population has doubled in the past 60 years and is projected to reach 60% by 2030 (World Bank, 2017), placing more pressure on the sanitation infrastructure.

A household whose latrine or septic tank has filled with waste has two choices to desludge it (i.e., to remove the waste). They can hire a person to manually shovel the waste out of the pit and leave it on the street or in an open field nearby (a manual desludging),[4] or they can hire a trucker to pump the waste and take it away in a truck (a mechanized desludging). In the case of a mechanized desludging, the trucker can dump the sewage illegally in nearby canals, vacant lots, or in the ocean, or the trucker can dump the sewage legally at a treatment center. Lower productivity in the sector therefore results in higher prices of mechanical desludgings and more substitution toward less sanitary manual desludgings, which leads to substantial and enduring health impacts.

Increasing the amount of waste disposed in treatment centers has important impacts on health.[5] Such a large increase in sewage removal from neighborhoods would have had a substantial impact on quality of life. We use DHS data to compare the incidence of diarrhea in children under five in Dakar with the incidence in secondary Senegalese cities of similar population density prior to and post privatization. Following privatization, diarrhea rates among children under five decreased in Dakar relative to other Senegalese cities which did not have similar sanitation reforms at the time, suggesting that the increased use of the privatized treatment centers improved health. A similar effect is not seen for respiratory illness which would not be expected to be affected by improvements in sanitation.[6]

Most previous studies of the privatization of sanitation services involve the privatization of water and sewerage systems. Almost all such studies find privatization leads to increases in water and sewerage connections (Chong and de Silanes, 2004; McKenzie and Mookherjee, 2003), although Kirkpatrick et al. (2006) find no effect of water privatization in Africa. Some studies go one step further to look at effects on health and again most find improvements in health outcomes, especially in the poorest areas or among

as flood control, but we find large gains in the number of active trucks at the company-week level following privatization, demonstrating that prior to privatization there was substantial excess capacity that was only harnessed once treatment centers were privatized.

[4]Given the heavy and difficult to transport nature of the sludge, manual desludgers rarely transport the sludge more than a block from the home, and they most commonly dispose of the sludge in the street in front of the home

[5]Manual waste disposal is illegal in many countries, including Senegal, and has strong negative effects on the households engaging in it as well as on their neighbors (Deutschmann et al., 2021a; Gertler et al., 2015; Johnson and Lipscomb, 2021).

[6]Higher incidence of diarrhea may lead to higher incidence of respiratory disease, but the primary impact of poor sanitation is through diarrhea (D et al., 2010). Any impact of sanitation on respiratory disease would make the difference in effects between diarrhea and respiratory disease a lower bound on the total impact.

the poorest individuals (Galiani et al., 2005; Kosec, 2014; Saiani and de Azevedo, 2018), with one negative effect found by Granados and Sánchez (2014). We contribute new evidence on the productivity and welfare benefits of privatization of sanitation services.

The existing literature shows the positive impacts of privatization of sanitation utilities that provide piped service directly to consumers. This is the only paper we know of looking at the privatization of sanitation in the form of an upstream input: sewage treatment centers. Despite the lack of evidence, these centers are extremely important. According to the World Bank Africa WSS Utility Survey (World Bank, 2005), among low income (non-fragile) countries in Africa only 26.7 percent of the population had a wastewater connection, 85 percent of wastewater treatment plants were non-functioning, and only 8.5 percent of the wastewater collected in the existing service area was subject to any form of treatment as of 2005. A substantial majority of sewage waste in Africa is collected outside of the sewer network, and must therefore use the types of trucking providers we study in this paper. Improving the productivity of these trucks through increasing the managerial capacity and functionality of treatment centers could therefore create significant welfare benefits.

2 Background

Dakar has treatment centers in the Rufisque, Niayes, and Camberene neighborhoods. These treatment centers collect and process waste produced by households without a connection to the sewage network, which included more than 75% of the city's population in 2013 (Sene, 2017). Prior to privatization, vacuum truck operators complained about the state of the three treatment centers. There were typically long lines of trucks waiting to dump as the dumping process was slow; treatment centers were closed on weekends and often closed early in the afternoon; and one of the centers closed multiple times, sometimes for months at a time, because it was either overwhelmed with sludge or its equipment had broken down.[7] These disruptions restricted the number of jobs that truckers were able to do during a day, especially the number of jobs for which they dumped the sludge legally. Truckers rely on being able to dump their sludge in a timely fashion and continue on to other jobs.

In 2012, the government launched a call for proposals for a private enterprise to take over the management of the treatment centers. The winning bid was submitted by a new partnership named Delvic, formed as a partnership between two of the largest waste removal companies in the city (Delta and Vicas).[8] The Delvic partnership officially began managing the treatment centers in November 2013. This "delegation" of the treatment centers did not give Delvic ownership of the treatment centers, and major investments in facilities and equipment remained the responsibility of ONAS. However, it gave Delvic full authority to manage the centers as well as 50% of the net revenue collected from the centers after they had paid ONAS an annual licensing fee. In return, Delvic was required to make small investments necessary for the operation of the facilities and to ensure that all users had access to the facilities. The operating profits of the centers increased from $7,100 prior to privatization to $33,300 in 2016 (Diop and Mbeguere, 2017).

According to truckers surveyed at the time, following privatization there were fewer disruptions to

[7] The centers, designed to process about 240 m^3 of sludge per day, were collecting more than four times that amount in 2012 (Sene, 2017).

[8] Of eight initially interested firms, only the Delvic partnership managed to submit a complete bid for the contract: https://www.onasbv.sn/app/uploads/2014/07/Rapport-Avancement-Num-2.pdf

service at the centers and centers were better maintained. Desludging trucks were able to get in and out of the centers faster as they added dumping capacity, reducing wait times (which had commonly been over an hour before privatization). In addition, some centers were open longer hours and on weekends. Finally, truckers appreciated that the centers made restrooms available as they had few other choices of places to stop during work hours. Table A1 provides an overview of self-reported changes that truck operators noted at the treatment centers and how they adjusted their behavior following privatization. More than three quarters of the truckers think the post-privatization changes have been positive, with longer opening hours and more days at the top of the list for reasons why. For the quarter who think privatization led to negative changes, the most common complaint is increased dumping costs. While the official dumping cost was not increased following privatization, it is possible that treatment center operators use discretion in terms of when and how to collect payments. Four-fifths of the truckers state that they work more days and/or longer hours after privatization.[9]

The overall impact of privatization on the amount of dumping done at the three treatment centers is shown in Figures 1 and 2. The first panel of Figure 1 shows that the number of dumping trips made in total was quite flat from 2009 through 2013 before privatization. Immediately following privatization there is a sharp increase in the number of trips made with a continued increase thereafter until it plateaus in 2017. The second panel shows that there was an upward trend in the number of trucks active in the market over the entire period, with a discontinuity when privatization took place. The first panel of Figure 2 shows a small change in the total number of active trucks after privatization, which may be attributable in part to the loan guarantee program described below in Section 2.1 which resulted in 29 new trucks entering service in Dakar from 2013-2015. The second panel of Figure 2 shows a large increase in the intensity of truck usage. The number of trips per truck per month had been declining prior to privatization,[10] but this trend was reversed after privatization.

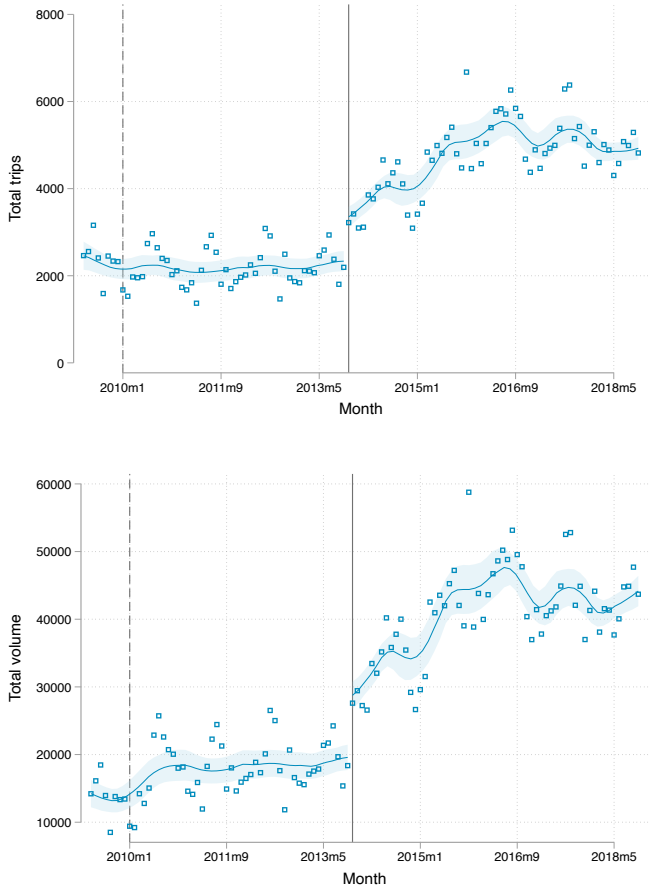
This increase in dumping at the treatment centers may be due to an increase in households' use of mechanized desludging and a decrease in their use of manual desludging. Almost all (98.9%) of the sludge dumped at the treatment centers is categorized as coming from a residence, while only 1% is categorized as coming from industry and 0.1% is categorized as coming from government offices.

The increase in dumping at treatment centers could also be due to a decrease in illegal dumping by trucks. Trucks may dump sewage in nearby sewage drains and canals of which there are a network around Dakar, directly into the ocean, at Yarakh (an informally designated spot), or in vacant lots. Dumping at any place other than a treatment center is illegal and caries a substantial fine. According to discussions with the truckers, the threat of being caught is large. The fine for illegal dumping varies between $400 and $1,200 (the cost of approximately 16 to 48 household desludgings performed by a truck), though an offending trucker would typically offer a bribe to the police officer rather than paying the full fine. The welfare impacts of substitution from illegal dumping to dumping at the treatment centers may be similar to the welfare impacts of substitution between manual and mechanized desludging as illegally dumped

[9]Prior to privatization, the mean truck completed just 3.5 jobs per week, suggesting many trucks were operating substantially below full capacity.

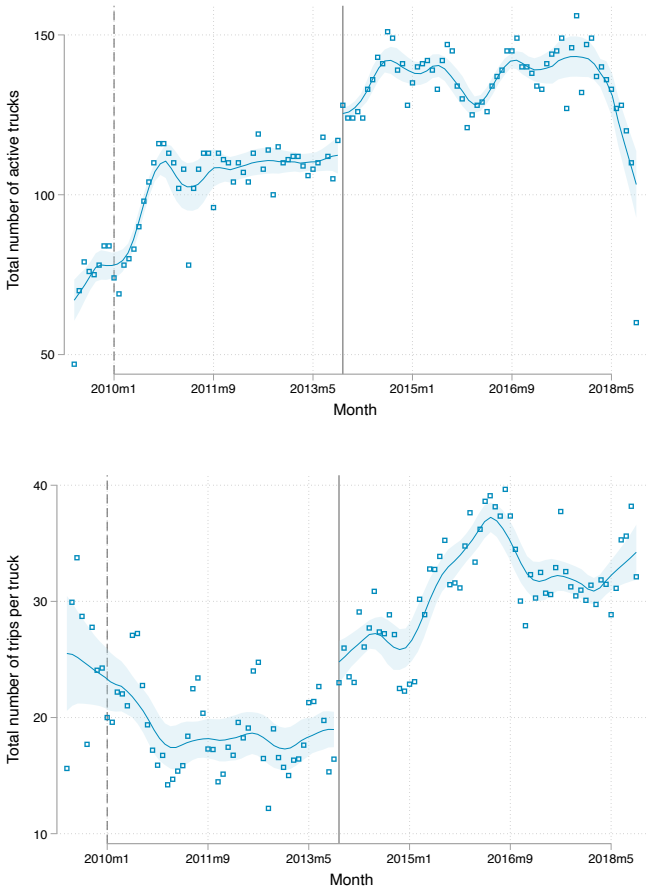
[10]This decline may have been expected from either inelastic demand for mechanized desludging services with increased numbers of active trucks or if the existing fleet of trucks had been near capacity and additional trucks were added–however, trucks did on average 3.5 jobs per week, suggesting that they were not near capacity and in other work we show that the elasticity of demand for mechanical desludging services in Dakar is -2.208 (Deutschmann et al., 2021a), which suggests that demand is quite elastic

Figure 1: Total trips and volume in the market per month



These figures show locally weighted polynomial regressions of the total number of trips and total volume dumped over time at the month level using a panel of all recorded trips to treatment centers between May 2009 and November 2018. The y-axis in panel A shows the total number of monthly trips made to any treatment center. The y-axis in panel B shows the total volume of waste (m^3) deposited to any treatment center. The solid vertical line indicates the month of privatization (November 2013) and the dashed vertical line indicates the month of the dumping price change (January 2010). The shaded area indicates 95% confidence bands.

Figure 2: Monthly activity at the truck level



These figures shows locally weighted polynomial regressions of productivity measures over time at the month level using a panel of all recorded trips to treatment centers between May 2009 and November 2018. The y-axis in panel A shows the total number of trucks that made at least one trip to any treatment center. The y-axis in panel B shows the number of trips per active truck that made at least one trip to any treatment center. The solid vertical line indicates the month of privatization (November 2013) and the dashed vertical line indicates the month of the dumping price change (January 2010). The shaded area indicates 95% confidence bands.

sewage may be transported out of the immediate neighborhood of the household, but may still end up dumped close to communities. The increase in the overall amount of waste dumped at treatment centers is therefore a fair estimate of the welfare effects from the privatization policy.

2.1 Other interventions in the sanitation sector

Privatization of the treatment centers was one component of a larger program, the "Faecal Sludge Market Structuring Programme" (PSMBV) which ONAS, the agency responsible for sanitation in Senegal, started in late 2011 (Diop and Mbeguere, 2017). One may be concerned that the impacts of privatization that we measure are confounded with the impacts of other activities in the sector related to this larger program over the period. Most of the projects associated with this program were completed by August 2016. The primary projects which could have increased the volume of sludge at treatment centers only covered a limited area of Dakar, and because we were actively involved in a number of these projects for other research studies, we are able to estimate the maximum impact that each could have had on dumping at the treatment centers. We next discuss the key components of the larger ONAS program in detail in order to quantify how much of the effect we identify could have come from the other projects.

Desludging Call center In February 2014, ONAS launched a call center service to connect households to mechanized desludging operators using auctions (Deutschmann et al., 2021b). Even during the period when the call center was most highly advertised, volume at the call center never exceeded 200 auctions per month. The call center can therefore explain no more than 11% of the increase in volume at the treatment center (under the most conservative assumption that all households purchasing a mechanized desludging through the call center would have otherwise used a manual desludgings).

Subsidies and mobile money saving program As part of a companion research project, we offered subsidies to 4100 households starting in late March 2014 to encourage them to sign up to purchase a mechanized desludging, and offered a mobile money savings program to some of the households who accepted our subsidy offer (Deutschmann et al., 2021a; Lipscomb and Schechter, 2018). 1496 households enrolled in the program. The program increased mechanized desludging among the treatment group by 3.1 percentage points–from 31.5% to 34.6%. This would be an additional 127 mechanized desludgings between March 2014 and May 2015. This could account for at most 0.0035 percent of the total increase in desludgings following privatization.[11]

Loan guarantee program As part of the PSMBV program, ONAS established a loan guarantee fund in partnership with the National Bank of Economic Development and the Association of Sanitation Actors of Senegal. This provided a financing mechanism for sanitation companies to invest in new or used trucks to be imported from Europe. The program resulted in about 29 trucks entering service in Dakar, with the first trucks arriving in September 2014 (Sene, 2017). While this could explain an increase in the number of trucks, our regressions show a small but insignificant impact of the privatization on number

[11] In 2017, ONAS launched a city-wide subsidy program which offered households discounts on mechanized desludgings. This program ran from May to November in 2017 and subsidized 5350 desludgings over that period (Deutschmann, 2021), which represents about 14% of all recorded trips to the treatment centers during that time period. The effects of privatization we observe are not concentrated in these months.

of trucks in the market. We do see the companies most connected to Delvic (namely Delta and Vicas) adding approximately four trucks. This capital investment can not necessarily then be attributed to the privatization policy.

Other potential biases An alternative is the possibility that with privatization came an increase in enforcement against illegal dumping and/or manual desludging. We are unable to evaluate enforcement–most truckers would pay a bribe if caught dumping illegally rather than risk having to pay the full fine. However, dumping outside of the treatment centers was illegal long before privatization, and while an increase in enforcement could explain part of the overall increase in volume at the treatment centers, it would be hard for it to fully explain the increase in weeks in which trucks were active, the increase in work on weekends, and the change in concentration of activity of truckers. The results must, therefore, be interpreted with the caveat that to the extent that privatization involved an increase in enforcement or that households reacted to the improvement in local sanitation by also making further improvements in their own households (better latrines, separated animals, etc), the full volume and health impact of the privatization policy is the combination of the pure privatization of management of the centers as well as any additional enforcement or household level changes that came as a reaction to it.

3 Data

Treatment center data There are three treatment centers in Dakar–Rufisque, Camberene, and Niayes. Trucks pay 300 CFA per cubic meter to dump the sludge at any of the three treatment centers.[12] They are typically charged based on the size of their truck under the assumption that the truck is full. The treatment center manager writes a receipt for the dumping fee, and at the same time records basic data on each truck that enters including the date, the license plate, and the amount of sludge in a notebook. After privatization, the centers maintained the same record-keeping processes, only adopting computerized data entry systems several years after privatization. We collected all available records from the treatment centers from November 2006 through October 2018, resulting in over 434,000 dumping observations.[13]

The records were mostly handwritten, which we then digitized, and this poses some problems. The 'name' field may show the owner's name, the company's formally registered name, the company's informally used name, or the driver's name. License plates are sometimes only partially recorded and numbers may be transposed. In addition, license plates are periodically changed, so the same truck may have multiple plates over the years of our data. To the extent possible, we correct license plates and assign the correct company name to each truck. Due to difficulties in cleaning the names and plates, the data contains more license plates and more companies than actually exist. This issue should not be affected by privatization.[14]

One might be concerned that Delvic, the company selected to manage the privatized treatment centers, would have an incentive to overstate volumes in order to appear particularly efficient and well-run. To

[12] This dumping price is fixed and standard across all three treatment centers. The price was 200 CFA before January 7, 2010. We control for this price change in all regressions. It is the only price change that has occurred in the Dakar treatment centers since they began operating.

[13] Because of some data inconsistencies in the early data, we focus our sample period on May 2009-November 2018. We also collapse the data to the company-weekly, truck-weekly, or truck-daily level depending on the specification resulting in a smaller sample size.

[14] All regressions include either company or license plate fixed effects.

explore this concern, we sent two enumerators to each treatment center for three days each in 2014 to keep their own logs of the trucks that entered the treatment centers. The enumerator logs and the Delvic logs included the same number of dumps. A second concern may be that the managers behaved differently when the enumerators were there, but the volume reported on the days that the enumerators were there were very similar to the volume reported on other days in the same month without enumerator presence.

There was also a change in recording of trips at the centers in 2015. In early 2015 the data began to be digitized directly at the centers,[15] which may have affected the overlap between the combination of plate and company names in the old and new data. This leads to some additional changes in companies that trucks are associated with at that point, potentially overstating the number of companies and number of fixed effects in the company regressions, but would not have led to additional jobs. We can evaluate the potential impact that this change in record keeping had on trips at the centers using Figure 3. First, Camberene switched to digital record keeping in 2012. Figure 3 shows a very flat trajectory of trips for Camberene from late 2011 through mid 2013, suggesting that it is unlikely that digital record keeping impacted recorded volume. In addition, if digital record keeping made it easier for centers to record more trips following privatization, we would see a larger increase in trips following privatization for the Niayes and Rufisque centers than for Camberene. In fact, the opposite is true. Because there were changes in the recording of some plates and companies, however, 2015 has substantial measurement error associated with company names. We therefore do not report results on company entrance and exit.[16]

In addition to understanding the impacts of privatization on capital, capital use, productivity, and working hours of trucks, we are also interested in measuring whether privatization affects the territory in which each trucker works as this may impact the competitiveness of the market. To do so, we consider the number of treatment centers a truck visits in a given week. If privatization improves the reliable availability of treatment centers, truckers may be more willing and able to compete for business in a larger area.

Household survey data We evaluate the downstream impact using household survey data[17] measuring the date of their last desludging, the price they paid for the desludging, and whether it was manual or mechanized. This is recall data, so it is subject to some concerns over accuracy, particularly in cases in which the desludging took place farther from the time the household was surveyed. In order to control for local differences in wealth, soil type, etc, we include subzone, or neighborhood, fixed effects.[18] The sample is representative of the population in the peri-urban areas of Dakar that are not connected to the sewer network. In total, there are 27 subzones and we survey an average of 127 households per subzone. The surveys took place in November 2012 and July 2014 (note that the timing of the second survey in mid-2014 constrains the sample of desludgings that we are able to observe post-privatization). In each survey, households reported the details of their last desludging prior to the survey, including the date, price, number of trips it took to complete, and whether it was mechanized or manual. From these reports, we construct a

[15] In 2015, all three centers transitioned to a new digital platform for recording truck information each time they visited a center. Previously, from 2012 to 2015 the Camberene center used an Excel file for recording visits. The other centers recorded all records on paper before 2015, as did Camberene until 2012.

[16] The changes appear to be in naming conventions, not in total numbers or typos, so number of trucks per company does not appear to have been affected by this change in record keeping.

[17] The survey is a partial panel–many households were surveyed twice, but in order to increase coverage of different geographic areas, some households were replaced with households in different areas in the second survey. We do not take advantage of the panel nature of the data in our regressions.

[18] We constructed subzones by dividing each of the 10 arrondissements in Dakar into five roughly equally sized blocks. The resulting subzones were intended to capture relatively discrete geographic areas which could be referred to as near a well-known landmark for ease of reference for study participants.

panel at the subzone-month level of all desludgings between April 2011 and July 2014 (up to eight months after privatization). Our dependent variables of interest in these regressions are the probability that a household gets a mechanical desludging given that they are getting a desludging and the price that they report paying for a desludging if they get a mechanical desludging. On average, 55% of desludgings are mechanized and the average price of a mechanized desludging is 25,000 CFA, or approximately $50.

Household health data We estimate the impacts of privatization of waste treatment centers on health externalities using eight rounds of Demographic Health Surveys (DHS) collected between 2005 and 2019 (Agence Nationale de la Statistique et de la Demographie-ANSD/Senegal, 2019).[19] We consider two measures of child illness - diarrhea and cough incidence. All women (15-49 years old) in the household report incidence of illnesses, including diarrhea and cough, in the two weeks prior to the survey for children born in the last five years. Based on these responses, we construct a measure of disease incidence based on whether any child in the household experienced an episode of illness in the two weeks prior to the survey.

The DHS is a nationally representative repeated cross-section household survey. The sample is drawn in two stages. First, a total of 200 clusters (census districts) were drawn with probability proportional to the population of the cluster. In total, this included 79 urban and 121 rural clusters. Then, 22 households were drawn from each cluster with equal probability. The DHS sample does not include information on the specific urban areas that households are drawn from, though the pool of potential clusters belong to 165 urban communes (defined by the National Statistical Office) across 14 regions. This results in 28 survey strata - 14 urban and 14 rural. In our estimation, we compare disease incidence in Dakar to other urban areas in Senegal based on two definitions of urban. The first definition is the official classification, which includes all communes with at least 10,000 inhabitants. To construct a control group that is more similar to Dakar, our second definition includes urban clusters that have a population density at least as large as our lowest population density sampled point in Dakar. In 2012, for example, this results in 16 clusters in Dakar (153 households) and 63 urban clusters outside of Dakar (799 households), of which 39 clusters are as dense as Dakar (503 households).

Summary statistics Table 1 provides summary statistics prior to privatization. We observe 97 companies in the data (the regressions are limited to the sample of companies present prior to privatization), owning an average of 2 trucks with 1.2 trucks active in an average week. Most (66%) companies are independent owner-operators (which have a single truck), while 28% are mid-sized (2-5 trucks), and only 6% of companies own more than 5 trucks. Companies do an average of 7 dumps per week, with 10 dumps in weeks in which they do at least one dump.

Trucks arrive at the center an average of 3.5 jobs per week, but this varies from a minimum of 0 jobs in a week to a maximum of 50, suggesting that many of the trucks are not close to their capacity constraints. Only 61% of trucks belonging to an average company are "active" (i.e. show up as having dumped at at least one treatment center during the week) in an average week. In weeks in which trucks make at least one trip, they average 6.0 trips, but they only work an average of 1.7 days per week. However, some trucks work 7 days per week during the few weekends prior to privatization when the centers were open. This suggests that the average truck may have had substantial excess capacity. Trucks worked approximately 20% of Saturdays and 2% of Sundays prior to privatization in weeks in which they dumped at least once.

Truckers commonly favor a specific territory. The average trucker visits the same center for 92% of their

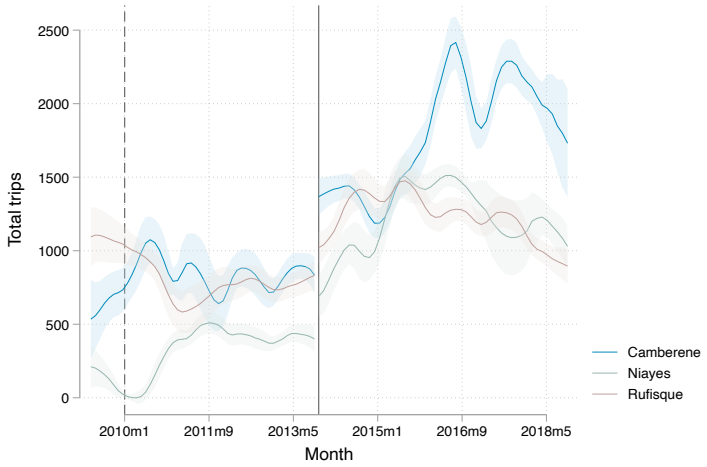
[19]The years with data are 2005, 2010, 2012, 2014, 2015, 2016, 2017, 2018, and 2019. This yields information on children from 6,828 households.

Table 1: Summary statistics (pre-privatization)

Variable	(1) Obs	(2) Mean	(3) Std. Dev.	(4) Min	(5) Max
Panel A: Company characteristics					
Trucks owned	97	1.99	1.98	1	12
Share trucks active	97	0.61	0.24	0	1
Own 1 truck	97	0.66	0.48	0	1
Own 2-5 trucks	97	0.28	0.45	0	1
Own 5+ trucks	97	0.06	0.24	0	1
Panel B: Company level data (weekly)					
Trips	14877	7.05	13.28	0	205
Trips (active)	10394	10.09	14.89	1	205
Trucks owned	14877	2.02	1.95	1	12
Trucks active	14877	1.17	1.45	0	11
DeltaVicas	14877	0.03	0.17	0	1
Panel C: Truck level data (weekly)					
Trips	30000	3.50	4.89	0	50
Trips (active)	17475	6.00	5.11	1	50
Days worked	30000	1.68	1.82	0	7
Work Saturday	17475	0.20	0.40	0	1
Work Sunday	17475	0.02	0.14	0	1
Trips share at preferred center	12369	0.92	0.15	0	1
N centers	12369	1.30	0.52	1	3
Panel D: Household Data (Desludgings)					
Mechanized=1	2978	0.55	0.50	0	1
Price (CFA)	1580	25001.14	9202.45	10000	60000
Panel E: Household DHS Data (2012)					
Diarrhea (Dakar)	153	0.27	0.45	0	1
Diarrhea (Other urban)	799	0.19	0.39	0	1
Diarrhea (Other urban dense)	503	0.16	0.37	0	1
Cough (Dakar)	153	0.22	0.42	0	1
Cough (Other urban)	799	0.20	0.40	0	1
Cough (Other urban dense)	503	0.22	0.42	0	1

Company and truck level variables are based on transaction data from all reported desludgings at treatment centers in Dakar between May 2009 and November 2013 (pre-privatization). Data on household desludgings is based on two household surveys that took place on November 2012 and June 2014. The sample includes all reported desludgings that took place prior to privatization, beginning in April 2011. Summary statistics for the household health data are calculated using the Demographic and Health Survey for year 2012. The price of mechanized desludging is winsorized at the bottom 1% and top 1%. Trips active includes the sample of trips in which the company or truck makes at least one trip in a week.

Figure 3: Trips per month by center



This figure shows locally weighted polynomial regressions of trips at each center at the month level using a panel of all recorded trips to each treatment center between May 2009 and November 2018. The y-axis shows the total number of monthly trips made to a treatment center. The solid vertical line indicates the month of privatization (November 2013) and the dashed vertical line indicates the month of the dumping price change (January 2010). The shaded area indicates 95% confidence bands.

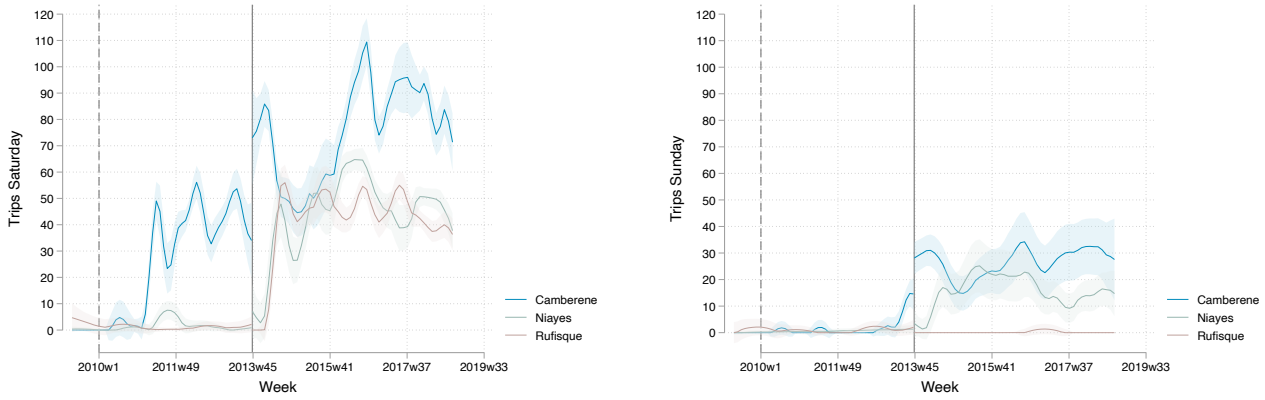
weekly trips and goes to 1.3 treatment centers in a week, suggesting that they are in general remaining relatively close to their garage. The treatment center that received the most dumps prior to privatization was Camberene (45%), followed by Rufisque (32%) and Niayes (23%). Figure 3 shows the total number of monthly trips to each treatment center. The share of truckers that favored each center is roughly equivalent to the total share of trips that each center receives. This may reduce travel costs, but may also mean that some areas are less competitive than others.

Panel D of Table 1 shows the averages of the outcomes that we measure using our surveyed household data. Households use mechanized desludging 55% of the time prior to privatization, and pay an average of 25,000 CFA (or approximately $50) per desludging. Panel E reports the average outcomes of the health data from the 2012 DHS survey that was conducted in the year prior to privatization. We compare illness incidence in Dakar to other urban areas in Senegal, as well as other urban areas that are at least as dense as Dakar.[20] Amongst households with at least one child under the age of 5 years, 27% in Dakar had at least one incidence of diarrhea in the two weeks prior to the survey, compared to 19% in other urban areas and 16% in other dense urban areas. In contrast, rates of cough are similar across the three groups (20-22%).

Timeline of center opening days/hours Figure 4 shows the total number of trips that occur at each center on Saturdays (Panel a) and Sundays (Panel b) over the length of the study period. Prior to privatization, Camberene began opening for limited hours on Saturdays in May 2011 and then expanded their opening hours on Saturdays in the weeks following privatization. Niayes and Rufisque remained closed on Saturdays prior to privatization, with the exception of a period of two months in 2011 in which Niayes was open with limited hours. Camberene and Niayes also opened with limited hours on Sundays in July 2013 and April 2014, respectively. However, Rufisque remained closed on Sundays following privatization.

[20]The official definition of urban is agglomerations of 10,000 or more inhabitants.

Figure 4: Total trips by treatment center on Saturday and Sunday



These figures show locally weighted polynomial regressions of the total number of trips on weekend days at the week level using a panel of all recorded trips to treatment centers between May 2009 and November 2018. The y-axis in panel A shows the total number of trips made to each treatment center on Saturday. The y-axis in panel B shows the total number of trips made to each treatment center on Sunday. The solid vertical line indicates the month of privatization (November 2013) and the dashed vertical line indicates the month of the dumping price change (January 2010). The shaded area indicates 95% confidence bands.

4 Empirical strategy

Our empirical evidence measuring the effect of privatization on the sanitation sector in Dakar involves four steps. We first present the results at the company-week level for companies in the industry before privatization. We then estimate the several different ways in which company dumping volumes may have changed in response to the privatization–the extensive margin: capital investment and the intensity of use of capital, and the intensive margin: productivity of the trucks.

The intensive margin truck-level results are the most direct way to observe the impact of privatization on truckers' ability to complete more jobs, so we next consider several ways in which privatization may have impacted the way that the truckers were able to perform their work: the number of trips per day that the truck works, the number of days worked per week and the number of Saturdays (and Sundays) that trucks work (which tends to be more convenient for clients), and the regional concentration of their jobs as measured by the number of treatment centers they visit and the share of trips to their primary treatment center.

Third, for both of the previous steps we consider whether these results vary by the companies directly involved in privatization (Delta and Vicas) versus the rest of the market. Since Delta and Vicas became vertically integrated post-privatization, we investigate the extent to which these two companies had differential reactions to privatization. One might worry that the increases in productivity are entirely driven by gains for these two companies, offset by losses among the other companies. We do not find evidence that productivity changes were driven by these companies.

Finally, we estimate the welfare impacts of the privatization on households by using household survey data from our surveys of peri-urban neighborhoods in Dakar. This allows us to estimate changes in propensity to use mechanical desludging and prices of mechanical desludgings prior to and after privatization. We also use DHS data to compare child health outcomes in Dakar to other secondary cities in Senegal prior

to and after privatization.

4.1 Company-level regressions

We begin by estimating the impact of the privatization on companies' productivity and available capital. Outcomes Y_{cmw} are measured for company c in month m (for example January) in year-by-week w (for example the first week of January 2013). We limit the sample to all companies that were present in the market prior to the date of privatization. We estimate the following specification for all weeks between May 2009 and November 2018:

$$\begin{aligned} Y_{cmw} = \alpha + \beta_1 PostPrivatization_w + \beta_2 PriceChange_w + \beta_3 \log(Rainfall_w) + \beta_4 \log(Rainfall_{w-1}) \\ [+\beta_5 DeltaVicas_c * PostPrivatization_w] + \tau_w + \mu_c + \nu_m + \epsilon_{cmw}. \end{aligned} \tag{1}$$

Outcomes at the company level include productivity (total weekly trips and volume by company), capital (number of trucks owned by company), and intensity of use of capital (active trucks by company). At the week level, the number of trucks owned by company c includes the total number of trucks that belong to the company that are between the first week and last week that they appear in the data. The number of active trucks only includes the subset of these trucks that make at least one trip in week w. The control variable of interest is $PostPrivatization_w$ which equals 1 in the week of privatization and all weeks thereafter, and equals 0 prior to privatization. In addition, we control for an indicator for after the treatment center's dumping price changed ($PriceChange_w$). We also include a linear weekly time trend τ_w. Finally, we control for the log of rainfall in that week and the previous week ($log(Rainfall)$) since pits are more likely to fill up when rains are heavy.

We include company fixed effects μ_c to control for differences in average productivity across companies, and month fixed effects ν_m to control for differences in the weather and other seasonal influences. Standard errors use two-way clustering at the company and week levels. The sample includes all companies that were present in the data prior to privatization and each company has an observation for every week between their first and final appearance at a treatment center. Weeks in which trucks are not observed at any treatment station are given a 0 for that week.

In order to observe whether there are differential impacts of privatization on companies associated with Delta and Vicas, we estimate heterogeneous impacts by including the bracketed part of equation (1). This adds the interaction between the post-privatization indicator and whether the company's owners also manage the treatment centers ($DeltaVicas_c$).

4.2 Truck-level regressions

We then turn to the behavior of individual trucks. We limit the sample to all trucks i that belong to companies present pre-privatization and all weeks between May 2009 and November 2018. We estimate the following specification:

$$\begin{aligned} Y_{icmw} = \alpha + \beta_1 PostPrivatization_w + \beta_2 PriceChange_w + \beta_3 log(Rainfall_w) + \beta_4 log(Rainfall_{w-1}) \\ [+\beta_5 DeltaVicas_c * PostPrivatization_w] + \tau_w + \eta_{ic} + \nu_m + \epsilon_{icmw} \end{aligned} \tag{2}$$

Outcome variable Y_{icsw} include the number of jobs that the truck does in a week and the number of jobs that the truck does in a week in which it was active (did at least one job). We further consider the effect on the share of jobs that the truck does at its preferred center, if the truck works on Saturday or Sunday that week, and the number of days the truck works in that week. We include the same control variables as in the company-level regressions, in addition to truck fixed effects (η_{ic}). Standard errors use two-way clustering at the truck and week levels. As in the company-level regressions, we test for differential impacts of privatization based on whether Delta or Vicas owns the truck (β_5).

5 Results

5.1 Company-level productivity

We find that privatization had a substantial impact on the productivity of desludging companies. In Table 2, we estimate that following privatization, desludging companies did on average 5 more jobs per week, a 70% increase in jobs relative to their work prior to privatization. We can compare this to the effect of the 2010 increase in the price of dumping, which decreased trips by 32% on average.[21] The dumping price increase would have increased the cost of a job for the average 8 cubic meter truck by 800 CFA. Since the coefficient on the privatization of the treatment centers is approximately 2.2 times as large as the coefficient on the price change, the size of the volume increase for privatization corresponds to a decrease in costs of approximately 1700 CFA per job, or 7% of the average price of a mechanized desludging.[22]

Privatization does have a larger impact on Delta and Vicas than it does on the other companies. Delta and Vicas complete 15.4 more jobs per week following privatization, while other companies only complete 4.5-5 extra jobs. It is important to note that Delta and Vicas are among the largest sanitation companies, so this overall increase in number of jobs is spread over more trucks, and when we take into account the size of the companies using an inverse hyperbolic sine specification, Delta and Vicas increase their trips and volume less in relative terms than smaller firms.

Table 3 suggests that most companies do not invest in new trucks following privatization. However, Delta and Vicas are significantly more likely than other companies to get new trucks, investing in 2.7 trucks after privatization. While the loan guarantee program encouraged truck acquisition, smaller companies that entered after privatization may have been more likely to take advantage of the program. In contrast, the impact of privatization on the number of trucks that companies have working in a given week is positive and statistically significant, as shown in Table 3. On average, companies have an additional 0.39 trucks active in a given week, an average increase in their fleet size of 18%. This suggests that they are maintaining trucks and keeping them on the streets more following privatization. While privatization may not convince the average company to purchase new trucks, companies do appear to keep their fleet active more of the time.

[21] The results on price changes should be interpreted with caution as there was a gas price increase close in time to the treatment center price increase, which may be partially taken up in this effect.

[22] Before privatization, the average price for a mechanized desludging in our household survey data was 25,001 CFA (see Table 1).

Table 2: Total weekly trips and volume by company

	(1) Trips	(2) Trips	(3) IHS(Trips)	(4) IHS(Trips)	(5) Volume	(6) Volume	(7) IHS(Volume)	(8) IHS(Volume)
Post privatization	5.002***	4.549**	0.537***	0.545***	43.46***	38.89**	0.775***	0.793***
	(1.771)	(1.792)	(0.127)	(0.128)	(15.33)	(15.66)	(0.193)	(0.195)
Price change	-2.309**	-2.337**	-0.366***	-0.365***	6.905	6.615	-0.371**	-0.370*
	(1.010)	(1.006)	(0.126)	(0.126)	(14.23)	(14.21)	(0.186)	(0.186)
(Post privatization) x (DeltaVicas)		15.38***		-0.269**		155.2***		-0.613***
		(3.240)		(0.135)		(32.67)		(0.199)
Constant	7.165***	7.326***	1.851***	1.848***	33.58***	35.20***	3.264***	3.258***
	(1.653)	(1.610)	(0.126)	(0.126)	(10.28)	(9.591)	(0.171)	(0.172)
Observations	28152	28152	28152	28152	28152	28152	28152	28152
R^2	0.606	0.613	0.516	0.516	0.609	0.618	0.436	0.436
Mean dep. var.	7.05	7.05	1.72	1.72	58.04	58.04	3.16	3.16
Share positive	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Rainfall	X	X	X	X	X	X	X	X
Linear timetrend	X	X	X	X	X	X	X	X
Month of year FE	X	X	X	X	X	X	X	X
Company FE	X	X	X	X	X	X	X	X

Notes: The table reports OLS estimates of our weekly company level specification (based on equation (1)), using the sample of observed companies between May 2009 and November 2018. The dependent variable is the total number of trips made and total volume dumped (meters cubed) by company c to a treatment center in week w. The observations are at the company-week level. *Post privatization* equals one for all observations after November 2013. *Price change* equals one for all observations following the price increase by 100 CFA at all treatment centers (Jan 7, 2010). *DeltaVicas* equals one if the company is Delta or Vicas (the two largest companies that manage the privatized centers). All specifications include fixed effects for the company (c) and month of year (s), and control for rainfall, lagged rainfall (mm), and a linear time trend. IHS indicates that the variable has been transformed using the inverse hyperbolic sine transformation. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Table 3: Number of active trucks by company

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Trucks owned				**Trucks active**			
	Trucks	Trucks	IHS(Trucks)	IHS(Trucks)	Trucks	Trucks	IHS(Trucks)	IHS(Truck)
Post privatization	0.135	0.0562	0.0261	0.0192	0.390***	0.381***	0.188***	0.192***
	(0.120)	(0.117)	(0.0355)	(0.0355)	(0.128)	(0.129)	(0.0456)	(0.0463)
Price change	0.698***	0.693***	0.195***	0.194***	0.0892	0.0886	-0.0345	-0.0343
	(0.209)	(0.208)	(0.0496)	(0.0494)	(0.124)	(0.124)	(0.0499)	(0.0499)
(Post privatization) x (DeltaVicas)		2.659***		0.233***		0.299		-0.130
		(0.542)		(0.0775)		(0.285)		(0.0809)
Constant	1.378***	1.406***	1.078***	1.080***	1.021***	1.025***	0.785***	0.784***
	(0.221)	(0.203)	(0.0529)	(0.0526)	(0.136)	(0.136)	(0.0565)	(0.0571)
Observations	28152	28152	28152	28152	28152	28152	28152	28152
R^2	0.842	0.853	0.860	0.861	0.676	0.676	0.614	0.615
Mean dep. var.	2.02	2.02	1.25	1.25	1.17	1.17	0.80	0.80
Share positive	1.00	1.00	1.00	1.00	0.77	0.77	0.77	0.77
Rainfall	X	X	X	X	X	X	X	X
Linear timetrend	X	X	X	X	X	X	X	X
Month of year FE	X	X	X	X	X	X	X	X
Company FE	X	X	X	X	X	X	X	X

Notes: The table reports OLS estimates of our weekly company level specification (based on equation (1)), using the sample of observed companies between May 2009 and November 2018. The dependent variable is the total trucks owned by company i that made any trip to a treatment center in week w. The observations are at the company-week level. *Post privatization* equals one for all observations after November 2013. *Price change* equals one for all observations following the price increase by 100 CFA at all treatment centers (Jan 7, 2010). *DeltaVicas* equals one if the company is Delta or Vicas (the two largest companies that manage the privatized centers). All specifications include fixed effects for the company (c) and month of year (s), and control for rainfall, lagged rainfall (mm), and a linear time trend. IHS indicates that the variable has been transformed using the inverse hyperbolic sine transformation. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Table 4: Total weekly trips and volume by truck

	(1) Trips	(2) Trips	(3) IHS(Trips)	(4) IHS(Trips)	(5) Volume	(6) Volume	(7) IHS(Volume)	(8) IHS(Volume)
Post privatization	2.375***	2.406***	0.550***	0.597***	21.17***	21.24***	0.883***	0.982***
	(0.417)	(0.441)	(0.0790)	(0.0821)	(3.648)	(3.903)	(0.129)	(0.134)
Price change	-2.005***	-2.006***	-0.415***	-0.417***	-0.851	-0.854	-0.488***	-0.491***
	(0.528)	(0.528)	(0.0995)	(0.0994)	(3.728)	(3.728)	(0.159)	(0.159)
(Post privatization) x (DeltaVicas)		-0.301		-0.457**		-0.668		-0.949***
		(1.090)		(0.179)		(10.49)		(0.295)
Constant	5.667***	5.665***	1.817***	1.815***	32.30***	32.29***	3.221***	3.215***
	(0.528)	(0.528)	(0.101)	(0.101)	(3.546)	(3.543)	(0.159)	(0.158)
Observations	67381	67381	67381	67381	67381	67381	67381	67381
R^2	0.362	0.362	0.326	0.328	0.340	0.340	0.290	0.293
Mean dep. var.	3.50	3.50	1.27	1.27	28.78	28.78	2.47	2.47
Share positive	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Rainfall	X	X	X	X	X	X	X	X
Linear timetrend	X	X	X	X	X	X	X	X
Month of year FE	X	X	X	X	X	X	X	X
Truck FE	X	X	X	X	X	X	X	X

Notes: The table reports OLS estimates of our weekly level specification (based on equation (2)), using the sample of observed trucks between May 2009 and November 2018. The dependent variable is total number of trips made and total volume dumped (meters cubed) by truck i to a treatment center in week w. The observations are at the truck-week level. The sample is limited to trucks that belonged to companies that were established prior to privatization. *Post privatization* equals one for all observations after November 2013. *Price change* equals one for all observations following the price increase by 100 CFA at all treatment centers (Jan 7, 2010). *DeltaVicas* equals one if the company is Delta or Vicas (the two largest companies that manage the privatized centers). All specifications include fixed effects for the truck (i) and month of year (s), and control for rainfall, lagged rainfall (mm), and a linear time trend. IHS indicates that the variable has been transformed using the inverse hyperbolic sine transformation. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

5.2 Truck-level productivity

We investigate the impact of privatization on the number of trips done per truck in a week and total volume dumped in Table 4 to provide us with an estimate of the overall increase in business companies are able to do with a unit of capital. On average, privatization results in each truck doing 2.3 more trips per week. This is a huge effect–a 68% increase relative to the mean prior to privatization. For comparison, the increase in treatment center prices in 2010 (an increase in cost of 800 CFA per trip on average) decreased trips by 2.0 trips per week on average, or 57%. Similarly, average weekly volume increased by 74%.

Table 5 shows that at least part of this increase in volume is caused by an increase in the number of trips that trucks are able to do per day. Here the sample is restricted to days on which the truck logged at least one dump at any of the treatment centers. This increase in volume of dumping may be because of decreased wait times at the treatment centers, improved maintenance of the center, or faster management of trucks. On average, trucks are able to do 13% more trips per day following privatization than they did prior to privatization.

Delta and Vicas do not see larger increases in trips per truck than the average company. The differential impact in number of trips that Delta and Vicas showed relative to other companies following privatization came from three channels: first, they each have more trucks than the average company, so a similar per-truck productivity improvement means a larger total improvement in productivity. This impact is no longer seen when we use the IHS specification which implicitly corrects for company size. Second, they purchased more trucks following privatization while most companies did not see an impact of privatization on their capital investment, and finally, on days on which the Delta and Vicas trucks were active, they increased volume of trips by more than other trucks in the market. This may indicate some favoritism at

Table 5: Trips per day that truck is active

	(1) Trips	(2) Trips	(3) IHS(Trips)	(4) IHS(Trips)	(5) Trips	(6) Trips	(7) IHS(Trips)	(8) IHS(Trips)
Post privatization	0.262***	0.219***	0.0977***	0.0831***	0.236***	0.224***	0.0881***	0.0862***
	(0.0787)	(0.0824)	(0.0275)	(0.0287)	(0.0750)	(0.0782)	(0.0270)	(0.0280)
Price change	-0.392***	-0.387***	-0.137***	-0.135***	-0.428***	-0.427***	-0.154***	-0.154***
	(0.117)	(0.117)	(0.0392)	(0.0391)	(0.113)	(0.113)	(0.0380)	(0.0380)
(Post privatization) x (DeltaVicas)		0.401**		0.134**		0.106		0.0162
		(0.159)		(0.0567)		(0.132)		(0.0484)
Constant	2.261***	2.269***	1.456***	1.458***	2.164***	2.167***	1.417***	1.417***
	(0.110)	(0.108)	(0.0357)	(0.0352)	(0.0997)	(0.0999)	(0.0335)	(0.0336)
Observations	44165	44165	44165	44165	44166	44166	44166	44166
R^2	0.340	0.342	0.322	0.324	0.215	0.215	0.205	0.205
Mean dep. var.	2.017	2.017	1.368	1.368	2.017	2.017	1.368	1.368
Rainfall	X	X	X	X	X	X	X	X
Linear timetrend	X	X	X	X	X	X	X	X
Month of year FE	X	X	X	X	X	X	X	X
Truck FE	X	X	X	X				
Company FE					X	X	X	X

Notes: The table reports OLS estimates of our weekly level specification (based on equation (2)), using the sample of observed trucks between May 2009 and November 2018. The dependent variable is total number of trips made by truck i to a treatment center over the total number of days that the truck made at least one trip in week w. The observations are at the truck-week level. The sample is limited to trucks that belonged to companies that were established prior to privatization. *Post privatization* equals one for all observations after November 2013. *Price change* equals one for all observations following the price increase by 100 CFA at all treatment centers (Jan 7, 2010). *DeltaVicas* equals one if the company is Delta or Vicas (the two largest companies that manage the privatized centers). All specifications include fixed effects for the truck (i) and month of year (s), and control for rainfall, lagged rainfall (mm), and a linear time trend. IHS indicates that the variable has been transformed using the inverse hyperbolic sine transformation. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

the treatment center toward "company member" trucks as part of this volume may be a result of reduced wait times.

6 Mechanisms

We now investigate the mechanisms through which privatization of the treatment centers led to increased productivity. Privatization could increase efficiency due to improved maintenance of the public good. Efficiency could also improve due to vertical integration itself. A non-integrated utility earns profits only from the operation of the treatment center, and therefore does not internalize the effect of raising prices or reducing service quality on the retail operation of downstream firms. A vertically integrated operator in contrast directly benefits from improvements in the productivity of the treatment center, since it has a direct impact the profitability of its own retail operation, and indirectly affects the profitability of its upstream operation by increasing the supply from other retail operators. In other words, since Delta and Vicas earn profits from both their downstream and upstream operations, they have a private incentive to increase the volume of sludge dumped at the treatment center. For instance, they can monitor their drivers to dump less sludge illegally, or invest in technologies that reduce bottlenecks and down-times at the treatment centers. They can also indirectly lower dumping prices, by adjusting the compensation of their drivers to tie it with the number of legal dumps, or by offering credit to rival companies.

On the other hand, we may be concerned about Delta and Vicas engaging in "input foreclosure." A vertically integrated supplier has an incentive to favor their own trucks, and exclude their rivals' trucks. Under partial foreclosure, the upstream supplier (the treatment center) raises the cost to access the treatment center to non-integrated downstream firms relative to integrated downstream firms. Although we

Table 6: Worked Saturdays and number of days worked by truck

	(1) Work Saturday	(2) Work Saturday	(3) Work Sunday	(4) Work Sunday	(5) Days worked	(6) Days worked	(7) N centers	(8) N centers
Post privatization	0.136***	0.139***	0.134***	0.133***	0.698***	0.703***	0.114***	0.0951**
	(0.0274)	(0.0286)	(0.0235)	(0.0242)	(0.110)	(0.116)	(0.0380)	(0.0405)
Price change	0.0973***	0.0968***	0.0101	0.0101	-0.165	-0.166	0.0177	0.0208
	(0.0247)	(0.0248)	(0.0149)	(0.0149)	(0.107)	(0.107)	(0.0462)	(0.0461)
(Post privatization) x (DeltaVicas)		-0.0307		0.00422		-0.0458		0.149
		(0.0525)		(0.0439)		(0.213)		(0.0916)
Constant	0.0661***	0.0654***	0.0172	0.0173	3.106***	3.105***	1.354***	1.359***
	(0.0231)	(0.0231)	(0.0185)	(0.0187)	(0.109)	(0.109)	(0.0460)	(0.0457)
Observations	44165	44165	44165	44165	44165	44165	33997	33997
R^2	0.249	0.249	0.211	0.211	0.280	0.280	0.330	0.331
Mean dep. var.	0.20	0.20	0.02	0.02	2.89	2.89	1.30	1.30
Rainfall	X	X	X	X	X	X	X	X
Linear timetrend	X	X	X	X	X	X	X	X
Month of year FE	X	X	X	X	X	X	X	X
Truck FE	X	X	X	X	X	X	X	X

Notes: The table reports OLS estimates of our weekly level specification (based on equation (2)), using the sample of observed trucks between May 2009 and November 2018. The dependent variable is equal to 1 if truck i made a trip to any treatment center on Saturday in week w (columns 1-2), is equal to 1 if truck i made a trip to any treatment center on Sunday in week w (columns 3-4), the total number of days that truck i made at least one trip to a treatment center in week w (columns 5-6), and the total number of treatment centers that truck i visited in week w (the sample is limited to trucks that made at least three trips in the week. (columns 7-8). The observations are at the truck-week level. The sample is limited to trucks that belonged to companies that were established prior to privatization. *Post privatization* equals one for all observations after November 2013. *Price change* equals one for all observations following the price increase by 100 CFA at all treatment centers (Jan 7, 2010). *DeltaVicas* equals one if the company is Delta or Vicas (the two largest companies that manage the privatized centers). All specifications include fixed effects for the truck (i) and month of year (s), and control for rainfall, lagged rainfall (mm), and a linear time trend. IHS indicates that the variable has been transformed using the inverse hyperbolic sine transformation. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

find some evidence that Delta and Vicas benefited from privatization (e.g. new trucks and more trips per day), we do not find that the company expanded its supply more than other suppliers. Instead, other companies on average increased their weekly output at a higher proportion to Delvic. This is consistent with important efficiency gains from vertical integration, and limited or zero foreclosure.

In addition to being in better repair and less likely to close down under privatization, desludgers report that after privatization treatment centers are open an additional hour per day and are more often open on Saturdays and Sundays.[23] We test the impact of privatization on the number of Saturdays and Sunday worked per week by truck in Table 6 and find that truckers were 14 percentage points more likely to work on a Saturday post-privatization than prior to privatization, and 13 percentage points more likely to work on Sunday. There is no differential impact on the probability of working Saturdays for Delta and Vicas. On average, trucks worked an additional 0.7 of a day more during the week following privatization than they had prior to privatization, which is an increase of 25%. The increase in the number of days worked is likely due both to the increases in weekend opening hours, as well as fewer days that trucks are left idle due to lack of work or maintenance.

Prior to the privatization, desludgers often cited concerns about treatment centers going offline due to repairs, so they were less willing to serve regions of the city that were farther from their main treatment center. As trucks are parked at a garage that is shared with other truckers who typically use the same treatment center, the drivers receive information quickly on closures at their preferred treatment center, but may be surprised by closures at treatment centers that are farther away. With gas as a major input cost, the risk of arriving at a closed center might make them less likely to expand their territory to neighborhoods served by further treatment centers. We test whether desludgers expand their territory

[23]There were some weekend day openings prior to privatization, but it was infrequent and inconsistent. The trips on Saturdays and Sundays are shown in figure 4.

following privatization by estimating the effect of privatization on the number of treatment centers that trucks visit in a week.

Table 6 provides suggestive evidence that following privatization truckers may less consistently work in their own territories. After privatization, trucks increase the number of centers that the visit in a week by .11, which represents a 9% increase. This suggests a decrease in the distance cost associated with the supply of desludging services, and a potential increase in the competitiveness of the market through a reduction in spatial differentiation. The increase in competitiveness is born out through substantial price decreases, as shown in the household regressions below in Table 7. The impact is larger for Delta and Vicas–suggesting that they also expand their territory, though the coefficient is insignificant.

7 Welfare impacts

We evaluate the extent to which the increased quantity of sludge dumped at treatment centers following privatization was also reflected in a larger reported market share for mechanized desludging and whether the potential increase in supply and cost savings were reflected in lower prices for households. Finally, the main welfare benefit of an increase in dumping at treatment centers, whether due to an increase in mechanized desludgings or a decrease in illegal unsanitary dumping, is in terms of a more sanitary environment. To the extent that sanitation improves, diarrhea rates may also go down. We compare changes in children's diarrhea prevalence reported in Dakar and in secondary cities in Senegal.[24]

7.1 Household utilization and prices

As the ultimate goal of the privatization policy was to improve sanitation in Dakar, we investigate its impacts on the prices that consumers pay for mechanized desludging and the share of mechanized versus manual desludgings that they purchase. We use household surveys collected before and after privatization to evaluate the impact of privatization on these outcomes. We have retrospective data from surveys with 4331 households that purchased a desludging during the period April 2011 to July 2014 in 445 neighborhoods. We estimate the following specification:

$$y_{hm} = \alpha + \beta_1 PostPrivatization_m + \upsilon_n + \phi_m + \epsilon_{nm} \tag{3}$$

where y_{hm} is the household's probability of purchasing a mechanized desludging given that they purchased a desludging or the price that they paid for the desludging. We include month of year and subzone control variables (υ_n and ϕ_m) and cluster standard errors at the neighborhood and month level using twoway clustering in all regressions.

We test the impact of privatization on the share of desludgings done that were mechanized in Table 7. It is important to note that this is a short-run effect as the survey took place 8-9 months after privatization. Privatization does not have a statistically or economically significant impact on the share of mechanized desludgings in the neighborhoods we surveyed. This regression may suffer from attenuation bias due to

[24]Other papers looking at the health effects of privatization of water and sewerage find that the poor benefit the most (Galiani et al., 2005; Kosec, 2014), seemingly due to an increase in connections among these populations. Our setting does not involve connections, but rather truckers dumping in treatment centers rather than in neighborhoods, so we do not expect to find heterogeneous impacts.

the fact that we are relying on retrospective reports of how many months ago a household's most recent desludging was performed. In addition, our surveys took place in June and July 2014 which tend to be the two months in which households most frequently get desludgings,[25] so we could have missed much of the impact in terms of switching from manual to mechanical based on timing issues. Even so, this is suggestive evidence that the large increase in sludge dumped at the treatment centers was primarily caused by a decrease in illegal dumping by the trucks, rather than a decrease in manual desludgings by households.

Table 7: Share mechanized and mechanized prices reported by households

	(1) Pr(Mechanized)	(2) Price
Post privatization	0.00848	-2557.8***
	(0.0295)	(585.7)
Constant	0.531***	22916.0***
	(0.0108)	(342.8)
Observations	4331	2376
R^2	0.151	0.265
Mean dep. var.	0.560	24421.4
Rainfall controls	X	X
Linear timetrend	X	X
Month of year FE	X	X
Subzone FE	X	X

Notes: The table reports OLS estimates of the impacts of privatization on the share of mechanized desludgings and the mechanized desludging price (based on equation (3)) using a panel of reported desludgings in the household survey data between April 2011 and July 2014. The observations are at the household-month level. The dependent variables are whether the household chose mechanized desludging over manual desludging (column 1) and the price of the mechanized desludging (column 2) for household h in subzone n in month m. The price is winsorized at the 1st and 99th percentile. *Post privatization* equals one for all observations starting in November 2013. All specifications include fixed effects for the subzone and month of year, and control for rainfall, lagged rainfall (mm), and a linear time trend. Standard errors are clustered by subzone and month. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

To the extent that the market is fully competitive, we should expect full pass-through of changes in input costs to the consumer.[26] Truckers have lower costs if they experience shorter lines at treatment centers, pay fewer bribes due to dumping illegally less often, and drive less far to do illegal dumping. If there is market power, changes in input costs will not be fully passed through. Therefore, our estimate of the impact of privatization on mechanized price provides a lower bound for the impact of the privatization on desludger input costs. Table 7 shows that the average reported price of a mechanized desludging went down by 2557 CFA following privatization. This effect is approximately 10% of the mean price.

7.2 Health outcomes

Improved sanitation, either due to an increase in mechanized desludgings or a decrease in illegal unsanitary dumping, may reduce negative health externalities. We analyze the impact of privatization on the incidence of diarrhea and use the incidence of cough as a placebo test. Improved health can lead to increases in human capital and on to sustained economic growth.

[25] Dumping is about 20% higher on average during these months according to the treatment center data.

[26] In other work, we find that the market is not fully competitive (Houde et al., 2021). To the extent that the market is less than fully competitive, price changes for consumers represent a lower bound on cost changes to suppliers.

To estimate the extent to which privatization improved children's health, we estimate panel regressions comparing diarrhea rates in Dakar to those in secondary cities in Senegal. The outcome variable is an indicator variable for any under 5 child in household i experiencing an episode of diarrhea in the two weeks prior to the survey in month m and year t in urban region r. Our regressions take the form:

$$Illness_{irmt} = \sum_{t=2010}^{2019} \beta_t \cdot Dakar_i + \Gamma X_{irmt} + \gamma_t + \lambda_m + \nu_r + \epsilon_{irmt} \tag{4}$$

The main control of interest, $Dakar_i$, is an indicator variable that equals 1 if the household lives in Dakar, and 0 otherwise. We further control for time-varying household characteristics including the number of children under 5, the household's water source, toilet type, if the toilet is shared with other families, the age and education of the household head, and an index of household wealth. Region fixed effects control for underlying differences in the incidence of illness in each region.[27] The year fixed effects absorb changes in illness incidence that affect all regions, and month fixed effects account for seasonal variation in diarrhea risk. The main coefficients of interest are β_t, which measure the differential change in illness incidence in Dakar (where privatization occurred) in year t relative to households in other urban regions in Senegal. In addition, we identify urban clusters that have a population density at least as large as our lowest population density sampled point in Dakar and estimate equation (4) on this subsample. As a falsification test, we also estimate this regression for an alternative outcome (cough incidence), which should be less affected by improved sanitation.

Figure 5 plots the estimated coefficients of equation (4) for both diarrhea (Panel A) and cough (Panel B).[28] The figure reveals that diarrhea incidence declines in Dakar following privatization relative to other urban areas in Senegal, and remains persistently lower thereafter. Privatization is associated with an 18 percentage point decline in diarrhea incidence relative to other urban areas in Senegal. In contrast, we find little effect of privatization on the incidence of cough.

8 Conclusion

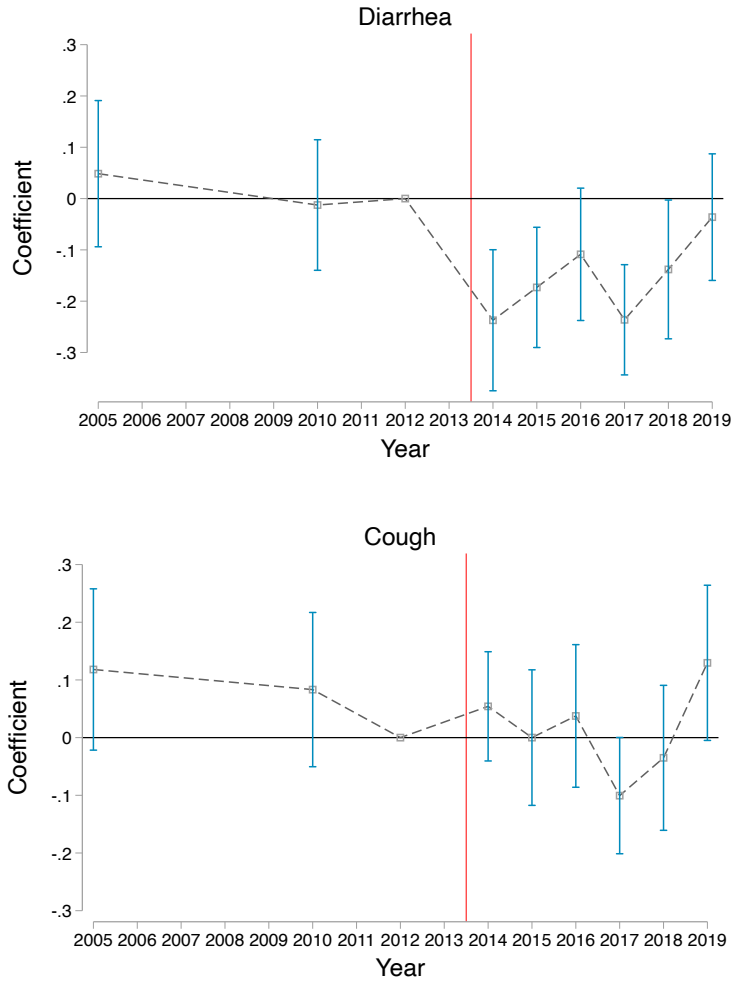
Effective oversight of public goods is difficult, and poor government management can lead to negative impacts on downstream sectors. Maintenance issues, wait times, and unpredictability can impact productivity, leading to higher input costs and higher downstream prices. In sectors such as sanitation in which there are substantial health externalities from lack of access, the welfare effects of poor management can be significant.

We show that Senegal's privatization of the management of its sewage treatment plants led to a substantial increase in the amount of legal sewage treatment at treatment centers. Our data does not allow us to clearly decompose this effect between the increase in the use of mechanized desludging and the decrease

[27] We use region fixed effects instead of strata fixed effects because our sample is limited to urban regions. The DHS data in Senegal followed a stratified sampling method based on the classification of households as urban vs rural as well as by region. Our data includes the city of Dakar (as treatment) and the following cities as controls: Diourbel, Fatick, Kaffrine, Kaolack, Kedougou, Kolda, Louga, Matam, Saint-Louis, Sedhiou, Tambacounda, Thies, and Ziguinchor. These cities have limited sewerage infrastructure and most have no functioning treatment center for sanitary sludge disposal during the period we study.

[28] Table A4 reports the corresponding estimates, with and without controls, for both the full urban sample and the subsample that includes urban areas with a sufficiently high population density.

Figure 5: Illness incidence amongst children under 5 in Dakar vs other urban areas in Senegal



This figure plots the coefficients from running an event study regression as in Equation (4). The dependent variable is the incidence of diarrhea (Panel A) and the incidence of cough (Panel B). The omitted category is 2012, the year leading up to the 2013 privatization (indicated with a red line). The bars indicate 95% confidence intervals based on standard errors clustered by survey cluster.

in illegal dumping. However, both practices result in similar poor disposal of sanitation and result in negative health impacts in urban communities.

We show suggestive evidence of an impact from privatization on water borne diseases. While there are other policies and unobservable factors that may have simultaneously reduced diarrhea in Dakar relative to other regions, the immediate and persistent effect in the years directly following privatization suggest that the large increase in sanitary waste disposal likely contributed to improved health outcomes in the city. The impact of privatization on welfare is therefore quite large.

Downstream small businesses benefit from improved efficiency of key input factors. We show that the average downstream trucking company did more jobs per week. This effect is both from the ability to do more jobs per day, and because companies use their capital more intensively–trucks are actively engaged in the market a larger proportion of weeks in the year and and trucks work more of the week.

References

Agence Nationale de la Statistique et de la Demographie-ANSD/Senegal, e. I. D. (2019). Senegal: Enquete demographique et de sante continue-eds-continue 2005, 2010, 2012, 2014, 2015, 2016, 2017, 2018, 2019.

Ashraf, N., Glaeser, E. L., and Ponzetto, G. A. (2016). Infrastructure, incentives, and institutions. *American Economic Review*, 106(5):77–82.

Barberis, N., Boycko, M., Shleifer, A., and Tsukanova, N. (1996). How does privatization work? Evidence from the Russian shops. *Journal of Political Economy*, 104(4):764–790.

Chipty, T. (2001). Vertical integration, market foreclosure, and consumer welfare in the cable television industry. *American Economic Review*, 91(3):428–453.

Chong, A. and de Silanes, F. L. (2004). Privatization in Latin America: What does the evidence say? *Economia*, 4(2):37–111.

D, M., J, L., B, S., and D, T. (2010). Sanitation and health. *PLOS Med*, 7(11).

Deutschmann, J., Lipscomb, M., Schechter, L., and Zhu, J. (2021a). Spillovers without social interactions in urban sanitation. Working paper.

Deutschmann, J. W. (2021). Subsidies and the sustainability of technology adoption: Evidence from the sanitation services market in Dakar. Working Paper.

Deutschmann, J. W., Gars, J., Jean-François, H., Johnson, T., Lipscomb, M., Mbeguere, M., Nehrling, S., Schechter, L., and Zhu, S. J. (2021b). Using market mechanisms to increase the take-up of improved sanitation. Working paper.

Diop, B. S. and Mbeguere, M. (2017). Fsm innovation. dakar: Organising the faecal sludge market. *Report for the Bill and Melinda Gates Foundation.*

Galiani, S., Gertler, P., and Schargrodsky, E. (2005). Water for life: The impact of the privatization of water services on child mortality. *Journal of Political Economy*, 113(1):83–120.

Gertler, P., Shah, M., Alzua, M. L., Cameron, L., Martinez, S., and Patil, S. (2015). How does health promotion work? Evidence from the dirty business of eliminating open defecation. Working paper.

Granados, C. and Sánchez, F. (2014). Water reforms, decentralization and child mortality in Colombia, 1990-2005. *World Development*, 53:68–79.

Hammer, J. and Spears, D. (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.

Hortaçsu, A. and Syverson, C. (2007). Cementing relationships: Vertical integration, foreclosure, productivity, and prices. *Journal of Political Economy*, 115(2):250–301.

Houde, J.-F., Johnson, T., Lipscomb, M., and Schechter, L. (2021). Imperfect competition and sanitation: Evidence from randomized auctions in senegal. *Working Paper*.

Johnson, T. and Lipscomb, M. (2021). Pricing people into the market: Targeting through mechanism design. Working paper.

Kirkpatrick, C., Parker, D., and Zhang, Y.-F. (2006). An empirical analysis of state and private-sector provision of water services in Africa. *World Bank Economic Review*, 20(1):143–63.

Kosec, K. (2014). The child health implications of privatizing Africa's urban water supply. *Journal of Health Economics*, 35:1–19.

Lipscomb, M. and Schechter, L. (2018). Subsidies versus mental accounting nudges: Harnessing mobile payment systems to improve sanitation. *Journal of Development Economics*, 135:235–254.

Luco, F. and Marshall, G. (2020). The competitive impact of vertical integration by multiproduct firms. *American Economic Review*, 110(7):2041–2064.

McKenzie, D. and Mookherjee, D. (2003). The distributive impact of privatization in Latin America: Evidence from four countries. *Economia*, 3(2):161–233.

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

Megginson, W. and Netter, J. M. (2001). From state to market: A survey of empirical studies of privatization. *Journal of Economic Literature*, 39(2):321–389.

Saiani, C. and de Azevedo, P. F. (2018). Is privatization of sanitation services good for health? *Utilities Policy*, 52:27–36.

Sene, M. (2017). Increasing Financial Flows for Urban Sanitation: Case Study in Dakar, Senegal. Technical Report, World Water Council.

Wang, H., Bhutta, Z. A., Coates, M. M., Coggeshall, M., Dandona, L., Diallo, K., Franca, E. B., Fraser, M., Fullman, N., Gething, P. W., et al. (2016). Global, regional, national, and selected subnational levels of stillbirths, neonatal, infant, and under-5 mortality, 1980–2015: a systematic analysis for the global burden of disease study 2015. *The Lancet*, 388(10053):1725–1774.

WHO (2017). The top 10 causes of death.

World Bank (2005). Wss utilities in africa survey [dataset].

World Bank (2017). Perspectives urbaines. *Villes émergentes pour un Sénégal émergent, Washington.*

Appendix Tables

Table A1: Trucker reports of changes after privatization

Variable	(1) Obs	(2) Mean
Panel A: Positive changes at center		
Positive changes=1	203	0.77
Longer hours	157	0.79
Fewer days closed	157	0.71
Shorter wait line for dumping	157	0.19
Improvements to center	157	0.12
Quicker payment	157	0.06
Panel B: Negative changes at center		
Negative changes=1	203	0.24
Increased dumping costs	48	0.31
Longer wait line for dumping	48	0.27
Stricter rules about contents dumped	48	0.21
More days closed	48	0.15
Favoritism	48	0.06
Longer payment	48	0.02
Panel C: Adjustments to operating hours		
Change way work=1	204	0.80
Finish days later	163	0.81
Give more weekend appointments	163	0.75
Give more afternoon appointments	163	0.45
Accept clients from the call center	163	0.01

The table presents summary statistics from the survey with truck owners and operators that took place in January and February 2015. Summary statistics are presented based on whether they noted changes at the treatment centers after November 2013 that were positive (Panel A) or negative (Panel B), and how they adjusted their behavior as a result of longer operating hours (Panel C).

Table A2: Aggregate trips per month

	(1) Trips	(2) Ln(Trips)
Post privatization	1806.8***	0.639***
	(202.2)	(0.0641)
Price change	-106.1	0.0307
	(229.9)	(0.131)
Constant	1899.0***	7.452***
	(269.8)	(0.166)
Observations	114	114
R^2	0.855	0.845
Mean dep. var.	3138.6	7.959
Price change	X	X
Rainfall	X	X
Linear timetrend	X	X
Month of year FE	X	X

Notes: The table reports OLS estimates of monthly aggregate trips to any treatment center. The sample includes all observed companies and trucks between May 2009 and November 2018. The dependent variable is the total number of trips made by any truck to a treatment center in month m. *Post privatization* equals one for all observations after November 2013. *Price change* equals one for all observations following the price increase by 100 CFA at all treatment centers (Jan 7, 2010). All specifications include fixed effects for month of year, and control for rainfall, lagged rainfall (mm), and a linear time trend. We report robust standard errors in parentheses. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Table A3: Diarrhea incidence amongst children under 5 in Dakar

	(1) Diarrhea	(2) Diarrhea
Post privatization	-0.126*	-0.149**
	(0.0673)	(0.0656)
Constant	0.383***	0.0994
	(0.0542)	(0.0666)
Observations	2003	2003
R^2	0.046	0.144
Mean dep. var.	0.35	0.35
Strata FE	X	X
Month FE	X	X
Controls		X

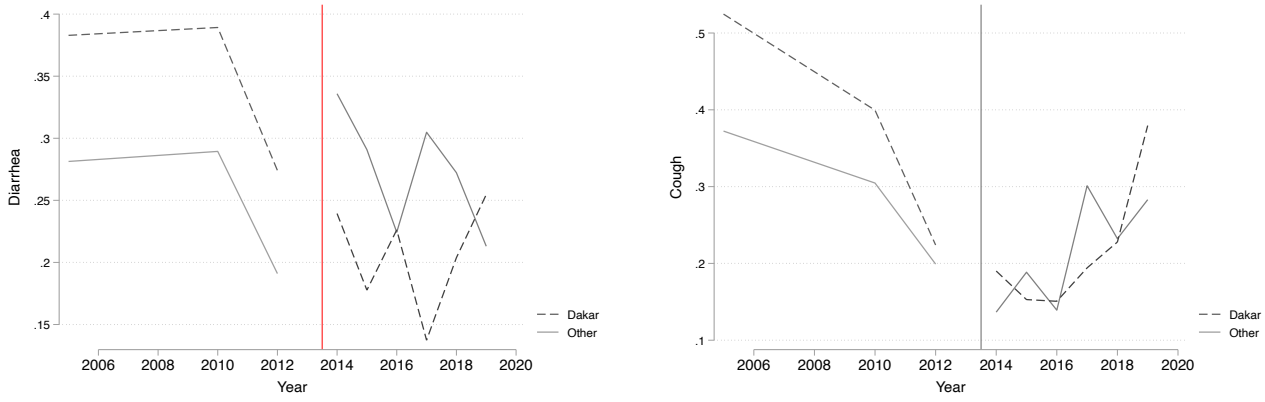
Notes: The table reports OLS estimates of diarrhea incidence amongst households with children under 5 years of age. The sample includes all households with at least on under 5 child, that is classified as urban in the region of Dakar. The data includes 9 waves of the DHS data from Senegal (2005, 2010, 2012, 2014, 2015, 2016, 2017, 2018, and 2019). *Post privatization* equals one for all observations after the 2012 wave. All specifications include fixed effects for strata (region) and month of year, and control for including the number of children under 5, the household's water source, toilet type, if the toilet is shared with other families, the age and education of the household head, an index of household wealth, and a linear time trend. We report robust standard errors in parentheses at the cluster level. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Table A4: Illness incidence amongst children under 5 in Dakar vs other urban areas in Senegal

	(1) Diarrhea	(2) Diarrhea	(3) Diarrhea	(4) Diarrhea	(5) Cough	(6) Cough	(7) Cough	(8) Cough
Dakar x 2005	0.00547	0.0176	0.0146	0.0485	0.0990	0.0993	0.105	0.118*
	(0.0692)	(0.0660)	(0.0735)	(0.0724)	(0.0625)	(0.0625)	(0.0725)	(0.0711)
Dakar x 2010	0.0493	0.0295	-0.00491	-0.0126	0.0700	0.0561	0.0849	0.0832
	(0.0671)	(0.0639)	(0.0677)	(0.0647)	(0.0600)	(0.0625)	(0.0659)	(0.0679)
Dakar x 2014	-0.158**	-0.216***	-0.177***	-0.237***	0.0575	0.0207	0.0799*	0.0542
	(0.0695)	(0.0716)	(0.0676)	(0.0698)	(0.0445)	(0.0455)	(0.0478)	(0.0481)
Dakar x 2015	-0.175***	-0.186***	-0.163***	-0.173***	-0.0374	-0.0290	-0.0124	0.0000368
	(0.0594)	(0.0589)	(0.0596)	(0.0595)	(0.0558)	(0.0571)	(0.0579)	(0.0597)
Dakar x 2016	-0.0680	-0.0981	-0.0735	-0.109*	-0.00234	-0.0178	0.0449	0.0376
	(0.0614)	(0.0611)	(0.0668)	(0.0656)	(0.0538)	(0.0603)	(0.0572)	(0.0628)
Dakar x 2017	-0.218***	-0.249***	-0.201***	-0.236***	-0.136***	-0.143***	-0.0995*	-0.101*
	(0.0579)	(0.0549)	(0.0572)	(0.0546)	(0.0494)	(0.0505)	(0.0511)	(0.0512)
Dakar x 2018	-0.111	-0.125*	-0.129*	-0.138**	-0.0234	-0.0321	-0.0339	-0.0350
	(0.0716)	(0.0676)	(0.0725)	(0.0687)	(0.0598)	(0.0594)	(0.0652)	(0.0639)
Dakar x 2019	-0.00103	-0.0215	-0.00294	-0.0362	0.0889	0.0751	0.137**	0.130*
	(0.0657)	(0.0622)	(0.0650)	(0.0627)	(0.0593)	(0.0597)	(0.0672)	(0.0684)
Constant	0.304***	0.119***	0.307***	0.225***	0.267***	0.0441	0.264***	0.00459
	(0.0248)	(0.0440)	(0.0254)	(0.0555)	(0.0212)	(0.0423)	(0.0229)	(0.0537)
Observations	11476	11476	8731	8731	11476	11476	8731	8731
R^2	0.031	0.102	0.033	0.102	0.070	0.104	0.066	0.102
Mean dep. var.	0.268	0.268	0.266	0.266	0.271	0.271	0.278	0.278
Strata FE	X	X	X	X	X	X	X	X
Year FE	X	X	X	X	X	X	X	X
Month FE	X	X	X	X	X	X	X	X
Controls		X		X		X		X
High density			X	X			X	X

Notes: The table reports OLS estimates of illness incidence amongst households with children under 5 years of age. The sample includes all households with at least on under 5 child, that is classified as urban. The data includes 9 waves of the DHS data from Senegal (2005, 2010, 2012, 2014, 2015, 2016, 2017, 2018, and 2019). *Post privatization* equals one for all observations after the 2012 wave. All specifications include fixed effects for strata (region) and month of year. Where indicated, we control for the number of children under 5, the household's water source, toilet type, if the toilet is shared with other families, the age and education of the household head, an index of household wealth. We report robust standard errors in parentheses at the cluster level. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Figure A1: Illness incidence amongst children under 5 in Dakar vs other urban areas in Senegal



This figure plots the weighted average values for disease incidence across years for Dakar and other urban areas in Senegal between 2010-2019. The dependent variable is the incidence of diarrhea (Panel A) and the incidence of cough (Panel B).