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Privatization of Public Goods: Evidence from the Sanitation Sector in Senegal
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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.

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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 generating productivity gains or eliminating double marginalization. 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 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. The sewage treatment centers collect waste from the sewer network and from individual 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. In 2013, following complaints by the truckers of ineffective management of the centers, the Senegalese government decided to privatize their management. 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 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). In our study, the treatment centers do not directly serve consumers but instead are an upstream input 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.[1] From this data we can observe how privatization affected individual truckers. Third 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).

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.

The impacts of privatization were large. Volume at the centers increased substantially. We see an average increase of 1,748 trips per month (or about 14,000 cubic meters of sewage) from an initial average prior to privatization of 3,256 trips per month (26,000 cubic meters). Privatization led to large increases in the productivity of truckers downstream. The average company did 50% more jobs following privatization. These 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.

The highly disaggregated nature of our data (at the truck-dumping level) allows us to estimate the extent to which 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. We find that most companies do not invest in additional trucks following privatization, but they do maintain 18% more trucks active in their fleet (maintenance issues 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 49% 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 9.8%.

The privatization of the sanitation sector is especially important due to its direct connection with diarrheal diseases. These diseases have important welfare impacts on communities and lasting impacts on children (Hammer and Spears, 2016). 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), 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.

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

Increasing the amount of waste disposed in treatment centers has important impacts on health.[2] 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 prior to and post privatization. Following privatization, diarrhea rates among children under five decreased in Dakar relative to other Senegalese cities, 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.

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) (though 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 the poorest individuals (Galiani et al., 2005; Kosec, 2014; Saiani and de Azevedo, 2018) (with one negative effect found by Granados and Sánchez (2014)).

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 the 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. Prior to privatization, truckers 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. 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).[3] The

[2] Manual waste disposal 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).

[3] Of eight initially interested firms, only the Delvic partnership managed to submit a complete bid for the contract:

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 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 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 being open longer 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, which was mentioned by 15 people. 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.

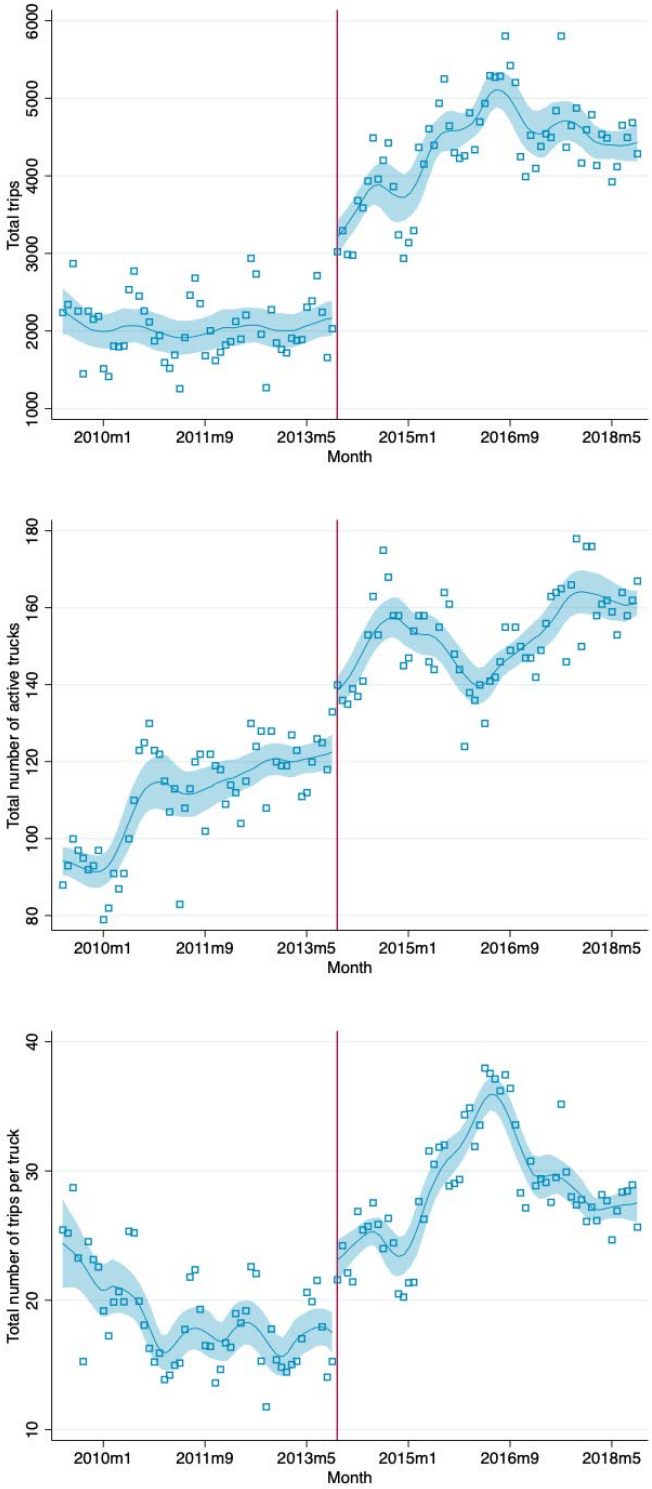
The overall impact of privatization on the amount of dumping done at the three treatment centers is shown in Figure 1. The first panel of the figure shows that the number of dumping trips made in total was quite flat from 2009 through 2013 before privatization. Immediately following privatization there 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 third panel shows a large increase in the intensity of truck usage. The number of trips per truck per month had been declining prior to privatization, 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 are similar to the

https://www.onasbv.sn/app/uploads/2014/07/Rapport-Avancement-Num-2.pdf

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



These figures show 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 monthly trips made to any treatment center. The y-axis in panel B shows the number of active trucks that made at least one trip to any treatment center. The y-axis in panel C shows the number of trips to any treatment center per active truck. The vertical line indicates the month of privatization (November 2013). The shaded area indicates 95% confidence bands.

welfare impacts of substitution between manual and mechanized desludging,[4] so the increase in the overall amount of waste dumped at treatment centers is a fair estimate of the welfare effects from the privatization policy.

2.1 Other interventions in the sanitation sector

One may be concerned that the impacts of privatization that we measure are confounded with the impacts of other activities in the sector over the period. The Gates Foundation funded several projects across Dakar, but these were in large part 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, we are able to estimate the maximum impact that each could have had on dumping at the treatment centers.

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 We offered subsidies to 4100 households 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). Only 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 September 2013 and May 2015. This could account for at most 0.0035 percent of the total increase in desludgings following privatization.

Loan guarantee program With support from the Gates Foundation, ONAS and Delvic purchased 11 trucks in September 2014 and provided loan guarantees for companies to finance them. While this could explain an increase in the number of trucks, our regressions show no significant impact of the privatization on number 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.

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 the treatment center.[5] They are typically charged based on the size of their truck under the assumption that the truck is full. The treatment

[4] Illegally dumped sewage may be transported out of the immediate neighborhood of the household, but is typically dumped nearby.

[5] The price was 200 CFA before January 7, 2010. We control for this price change in all regressions.

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 notebooks. 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.[6]

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 properly 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.[7]

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 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. One may be concerned 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,[8] and there is not always good 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. For this reason, we do not report results on company entrance and exit.

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 define each trucker's preferred treatment center as the station they used the most in 2012, since truckers usually dump at the treatment center closest to the residence they have desludged. Starting in 2013, we calculate the share of dumping that truckers do each week at their preferred treatment center relative to the other stations in order to evaluate the extent to which privatization leads truckers to expand their territory.

Household survey data We evaluate the downstream impact using household survey data 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

[6]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.

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

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

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. [9] 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 June 2014. 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 consider desludgings in the 18 months prior to the survey, and construct a panel at the subzone-month level all desludgings between April 2011 and November 2014 (one year 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 all eight rounds of Demographic Health Surveys (DHS) collected between 2005 and 2019 (Agence Nationale de la Statistique et de la Demographie-ANSD/Senegal, 2019).[10] We employ 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.

The DHS is a nationally representative repeated cross-section household survey. The sample is drawn in two stages. First, a total of 200 census districts (79 urban and 121 rural) were drawn with probability proportional to the population of the census district. Then, 22 households were drawn from each census district 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 census districts belong to 165 urban communes (defined by the National Statistical Office) across 14 regions.

Summary statistics Table 1 provides summary statistics prior to privatization. Trucks do 2.87 jobs per week, but this varies from a minimum of 0 jobs in a week to a maximum of 51. In weeks in which trucks make at least one trip, they average 6.3 trips. This suggests that the average truck may have substantial excess capacity. In addition, many trucks are idle for most of the week and work on average 1.3 days–in weeks in which the trucks work at least one day, trucks work an average of 2.9 days per week, yet some trucks work 7 days per week during the few weekends prior to privatization when the stations were open.

Truckers commonly favor a specific territory. The average trucker uses the same station 77% of the time. The treatment center that received the most dumps prior to privatization was Camberene (45%), followed by Rufisque (32%) and Niayes (23%). Figure 2 shows the total number of monthly trips to each treatment center. The share of truckers that favored each station is roughly equivalent to the total share of trips that each station receives. This may reduce travel costs, but may also mean that some areas are less competitive than others. Delta and Vicas, whose management merged to form Delvic which manages the privatized treatment centers, account for 8% of the sample of trucks. Companies report an average of

[9] 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.

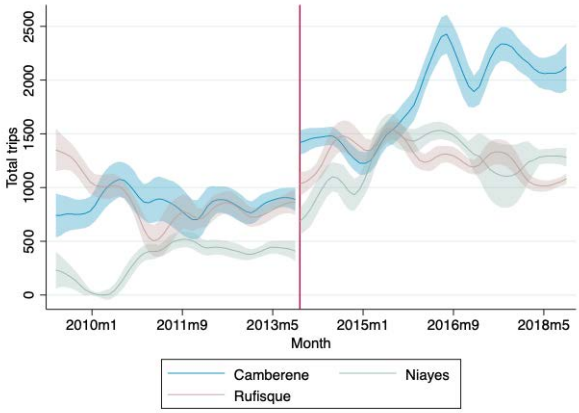
[10] The years with data are 2005, 2010, 2012, 2014, 2015, 2016, 2017, 2018, and 2019. This yields information on children from 6,828 households.

Table 1: Summary statistics (pre-privatization)

Variable	(1) Obs	(2) Mean	(3) Std. Dev.	(4) Min	(5) Max
Panel A: Aggregate level data (monthly)					
Trips	54	2039.6	404.8	1259	2941
Panel B: Company level data (weekly)					
Trips	19237	5.71	12.24	0	205
Trips (active)	11141	9.87	14.76	1	205
Trucks owned	19237	2.11	2.23	1	16
Trucks active	19237	0.97	1.39	0	11
DeltaVicas	127	0.02	0.12	0	1
Panel C: Truck level data (weekly)					
Trips	40534	2.71	4.53	0	50
Trips (active)	18732	5.87	5.09	1	50
Days worked	40534	1.31	1.74	0	7
Work Saturday	18732	0.19	0.39	0	1
Trips share at favorite center (2012)	17319	0.77	0.37	0	1
DeltaVicas	272	0.08	0.27	0	1
Panel D: Household Data (Desludgings)					
Mechanized=1	2978	0.55	0.50	0	1
Price (CFA)	1580	25001	9202	10000	60000
Panel E: Household Data (Health)					
Diarrhea incidence (Dakar)	196	0.26	0.44	0	1
Diarrhea incidence (Other urban)	799	0.22	0.42	0	1
Cough incidence (Dakar)	196	0.18	0.39	0	1
Cough incidence (Other urban)	799	0.21	0.41	0	1

Aggregate, company level, 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%. The trips share at favorite center in 2012 includes only the sample of trucks that were present in the data in 2012. Trips active includes the sample of trips in which the company or truck makes at least one trip in a week.

Figure 2: 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 vertical line indicates the month of privatization (November 2013). The shaded area indicates 95% confidence bands.

5.7 trips per week and 2.1 trucks per company.

Timeline of station opening days/hours Figure 3 shows the total number of trips that occur at each station 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.

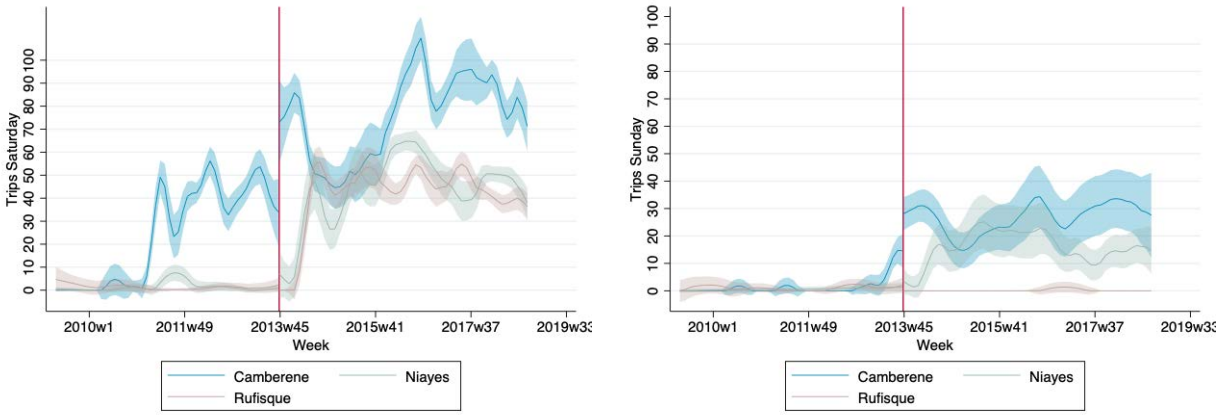
4 Empirical strategy

Our empirical evidence measuring the effect of privatization on trucking companies involves four steps. We first present the results at the company-week levels 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 that they are able to do, the number of days worked per week and the number of Saturdays that trucks work (which tends to be more convenient for clients), and the regional concentration of their jobs.

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 differ-

Figure 3: 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 vertical line indicates the month of privatization (November 2013). The shaded area indicates 95% confidence bands.

ential 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 (season) s (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:

$$\begin{aligned} Y_{csw} = \alpha + \beta_1 PostPrivatization_w + \beta_2 PriceChange_w + \beta_3 \log(Rainfall_w) + \beta_4 \log(Rainfall_{w-1}) \\ + \beta_5 LinearTimeTrend_w [+ \beta_6 DeltaVicas_c * PostPrivatization_w] + \mu_c + \nu_s + \epsilon_{csw}. \end{aligned} \tag{1}$$

Outcomes at the company level include productivity (total weekly trips by company), capital (number of trucks owned by company), and intensity of use of capital (active trucks by company). 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 time trend. 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_s to control for differences in the weather and other seasonal influences. Standard errors use two-way clustering at the company and week levels. Unless otherwise noted, 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.

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:

$$\begin{aligned} Y_{icsw} = \alpha + \beta_1 PostPrivatization_w + \beta_2 PriceChange_w + \beta_3 log(Rainfall_w) + \beta_4 log(Rainfall_{w-1}) \\ + \beta_5 LinearPredictedTimeTrend_w [+\beta_6 DeltaVicas_c * PostPrivatization_w] + \eta_{ic} + \nu_s + \epsilon_{icsw} \end{aligned} \tag{2}$$

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 station, if the truck works on Saturday 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 ($\eta_i c$). 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.

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 4 more jobs per week, a 50% 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 34% on average.[11] The dumping price increase would have increased the cost of a job for the average 8 cubic meter truck by 800 CFA on average. Since the coefficient on the privatization of the treatment centers is approximately 1.5 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 1200 CFA per job, or 5% of the price of the average job.

[11] 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.

Table 2: Total weekly trips by company

	(1) Trips	(2) Trips	(3) IHS(Trips)	(4) IHS(Trips)
Post privatization	4.061***	3.688**	0.495***	0.498***
	(1.425)	(1.443)	(0.116)	(0.117)
Price change	-2.201**	-2.229**	-0.340***	-0.340***
	(0.878)	(0.875)	(0.130)	(0.130)
(Post privatization) x (DeltaVicas)		17.75***		-0.137
		(3.449)		(0.137)
Constant	5.814***	5.969***	1.547***	1.546***
	(1.417)	(1.377)	(0.119)	(0.119)
Observations	36938	36938	36938	36938
R^2	0.608	0.616	0.548	0.548
Mean dep. var.	9.484	9.484	1.814	1.814
Rainfall	X	X	X	X
Linear timetrend	X	X	X	X
Month of year FE	X	X	X	X
Company FE	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 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. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Privatization does have a larger impact on Delta and Vicas than it does on the other companies. Delta and Vicas complete 17.75 more jobs per week following privatization, while other companies only complete 3.7-4 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, there is no differential impact on Delta and Vicas.

Table 3 shows 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 4 trucks after privatization. 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 0.32 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 them on the streets more of the time.

5.2 Truck-level productivity

We investigate the impact of privatization on the number of trips done per truck in a week 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 more trips per week (statistically significant at the 1% level). This is a huge effect–a 49-53% increase. For comparison, the increase in treatment center

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	0.0173	-0.0655	0.00797	0.00153	0.326***	0.313***	0.175***	0.176***
	(0.118)	(0.143)	(0.0304)	(0.0311)	(0.107)	(0.108)	(0.0431)	(0.0436)
Price change	0.515***	0.509***	0.140***	0.139***	0.00679	0.00578	-0.0527	-0.0527
	(0.162)	(0.161)	(0.0395)	(0.0394)	(0.103)	(0.103)	(0.0507)	(0.0507)
(Post privatization) x (DeltaVicas)		3.935**		0.306*		0.645*		-0.0474
		(1.716)		(0.166)		(0.362)		(0.0864)
Constant	1.483***	1.518***	1.123***	1.126***	0.867***	0.873***	0.667***	0.667***
	(0.231)	(0.201)	(0.0443)	(0.0433)	(0.122)	(0.120)	(0.0524)	(0.0527)
Observations	36938	36938	36938	36938	36938	36938	36938	36938
R^2	0.869	0.882	0.882	0.883	0.691	0.692	0.635	0.635
Mean dep. var.	2.455	2.455	1.363	1.363	1.286	1.286	0.820	0.820
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 c that made any trip to a treatment center in week w (columns 1-4) and the total number of trucks owned by company c that made at least one 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). *Delta or Vicas* 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 and month of year, and control for rainfall, lagged rainfall (mm), and a linear time trend. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

prices in 2010 (an increase in cost of 800 CFA per trip on average) decreased trips by 1.4 trips per week on average, or 27%(significant at the 1% level).

Table 5 shows that much 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 8.3-9.7% 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 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 (and vertical integration) could increase efficiency due to improved maintenance

Table 4: Total weekly trips by truck

	(1) Trips	(2) Trips	(3) IHS(Trips)	(4) IHS(Trips)
Post privatization	1.951***	1.980***	0.491***	0.525***
	(0.346)	(0.365)	(0.0727)	(0.0758)
Price change	-1.358***	-1.361***	-0.266***	-0.270***
	(0.403)	(0.402)	(0.0881)	(0.0880)
(Post privatization) x (DeltaVicas)		-0.282		-0.331
		(0.932)		(0.213)
Constant	4.408***	4.410***	1.448***	1.450***
	(0.475)	(0.474)	(0.0995)	(0.0990)
Observations	91295	91295	91295	91295
R^2	0.361	0.361	0.352	0.353
Mean dep. var.	3.888	3.888	1.223	1.223
Rainfall	X	X	X	X
Linear timetrend	X	X	X	X
Month of year FE	X	X	X	X
Truck 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 the 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. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Table 5: Trips per day that truck is active

	(1) Trips	(2) Trips	(3) IHS(Trips)	(4) IHS(Trips)
Post privatization	0.258***	0.217***	0.0979***	0.0841***
	(0.0757)	(0.0791)	(0.0267)	(0.0279)
Price change	-0.367***	-0.360***	-0.125***	-0.123***
	(0.109)	(0.109)	(0.0362)	(0.0361)
(Post privatization) x (DeltaVicas)		0.387**		0.130**
		(0.156)		(0.0559)
Constant	2.233***	2.238***	1.443***	1.445***
	(0.102)	(0.101)	(0.0333)	(0.0329)
Observations	47894	47894	47894	47894
R^2	0.329	0.331	0.314	0.315
Mean dep. var.	1.993	1.993	1.357	1.357
Rainfall	X	X	X	X
Linear timetrend	X	X	X	X
Month of year FE	X	X	X	X
Truck 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. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

of the public good. Efficiency could also improve due to vertical integration itself, through the elimination of double marginalization for instance. 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. 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. They can also adjust the compensation of their drivers to tie it with the number of legal dumps.

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 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 in the same proportion as Delvic. This is consistent 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.[12] We test the impact of privatization on the number of Saturdays 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. There is no differential impact on the probability of working Saturdays for Delta and Vicas, members of AAAS, small companies, or new companies. The additional Saturdays worked were not the only additional hours worked for trucks: on average trucks worked an additional 0.7 of a day more during the week following privatization than they had prior to privatization.

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 the main treatment center. We test whether desludgers expand their territory following privatization by estimating the effect of privatization on the percent of dumps that trucks do at the treatment center that they used most often in 2012, before privatization.

Table 7 provides suggestive evidence that following privatization truckers may less consistently work in their own territories. After privatization, companies do a smaller share of their dumping at their most frequented station. Trucks reduce their use of their preferred treatment center by 10 percentage points (from a baseline of 72%). 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 8. The impact is the opposite on Delta and Vicas–in fact, if anything they consolidate their territory.

[12]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 3.

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

	(1) Work Saturday	(2) Work Saturday	(3) Days worked	(4) Days worked
Post privatization	0.151***	0.153***	0.712***	0.716***
	(0.0271)	(0.0281)	(0.110)	(0.115)
Price change	0.114***	0.114***	-0.100	-0.101
	(0.0239)	(0.0239)	(0.104)	(0.105)
(Post privatization) x (DeltaVicas)		-0.0229		-0.0379
		(0.0515)		(0.212)
Constant	0.0606***	0.0602***	3.038***	3.037***
	(0.0214)	(0.0214)	(0.107)	(0.107)
Observations	47894	47894	47894	47894
R^2	0.248	0.248	0.287	0.287
Mean dep. var.	0.414	0.414	3.334	3.334
Rainfall	X	X	X	X
Linear timetrend	X	X	X	X
Month of year FE	X	X	X	X
Truck 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 equal to 1 if truck i made a trip to any treatment center on Saturday in week w (columns 1-2) and the total number of days that truck i made at least one trip to a treatment center in week w (columns 3-4). 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. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

Table 7: Share of trips to most frequented center

	(1) Share	(2) Share
Post privatization	-0.101***	-0.116***
	(0.0266)	(0.0296)
Price change	0.0959***	0.0993***
	(0.0290)	(0.0292)
(Post privatization) x (DeltaVicas)		0.149*
		(0.0779)
Constant	0.677***	0.679***
	(0.0374)	(0.0369)
Observations	32744	32744
R^2	0.395	0.399
Mean dep. var.	0.706	0.706
Rainfall	X	X
Linear timetrend	X	X
Month of year FE	X	X
Truck FE	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 share of trips made by truck i to their favored treatment center in week w. Favored treatment center of truck i is defined as the treatment center truck i visited most often in 2012. As a result, the sample only includes trucks that were present in 2012. 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. Standard errors are clustered by company and week. * Significant at 10 percent level; ** Significant at 5 percent level; *** Significant at 1 percent level.

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.[13]

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 201 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 8. 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 the fact that we are relying on retrospective reports of how many months ago a household's most recent desludging was performed. 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.

To the extent that the market is fully competitive, we should expect full pass-through of changes in input costs to the consumer. 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 8 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.

[13] 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.

Table 8: 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.

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 using incidence of cough as a placebo test. Improved health can lead to increases in human capital and on to sustained economic growth.

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 year t in urban region r. Our regressions take the form:

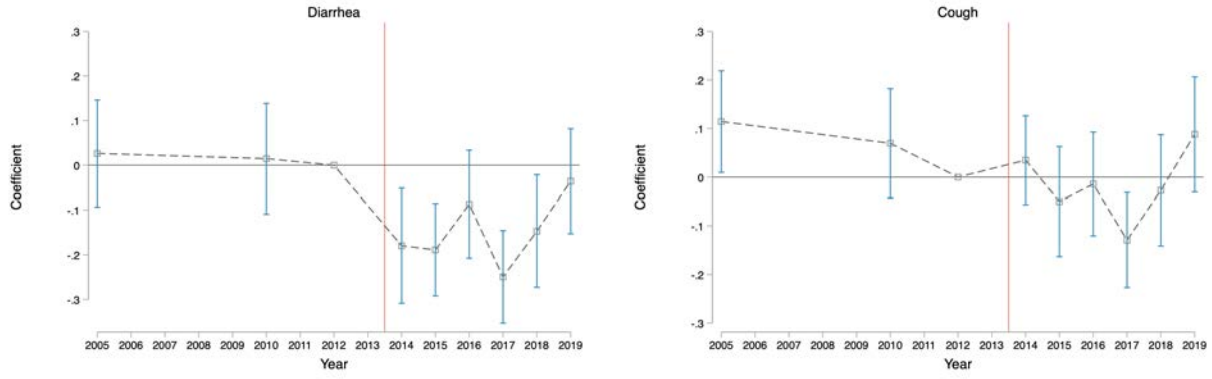
$$Illness_{irt} = \sum_{t=2010}^{2019} \beta_t \cdot Dakar_i + \gamma_t + \nu_r + \epsilon_{irt} \tag{4}$$

The main control of interest, $Dakar_i$, is an indicator variable that equals 1 if the household lives in Dakar, and 0 otherwise. Region fixed effects control for underlying differences in the incidence of illness in each region.[14] The year fixed effects absorb changes in illness incidence that affect all regions. 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. As a falsification test, we also estimate this regression for an alternative outcome (cough incidence), which should be less affected by improved sanitation.

Figure 4 plots the estimated coefficients of equation (4) for both diarrhea (Panel A) and cough (Panel B). 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

[14] 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.

Figure 4: 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.

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 into an increase in the use of mechanized desludging, and a decrease in illegal dumping. However, both practices result in similar poor disposal of sanitation, and result in negative health impacts in urban communities.

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 and trucks work more of the week.

The evidence suggests a potential connection between sanitation privatization and water borne diseases. While privatization is one of numerous 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.

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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	1748.1***	0.617***
	(172.1)	(0.0492)
Price change	-436.5***	-0.156**
	(159.6)	(0.0634)
Constant	2201.9***	7.674***
	(155.2)	(0.0613)
Observations	114	114
R^2	0.901	0.910
Mean dep. var.	3256.1	8.003
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.