Child Health Implications of Water Sector Policies in Africa

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Abstract

Each year, diarrheal diseases claim the lives of nearly 2 million people—ninety percent of them children under the age of five. The problem is especially critical in Africa, a continent that contains ten percent of the world's population, but accounts for forty percent of the deaths of children under age five. Can politically-controversial private sector participation (PSP) in the urban piped water industry improve child health? This paper uses panel data on the sub-national regions of 26 African countries over 1985-2006 to shed light on this question. This is the period during which nearly all African countries that today have PSP in water introduced those arrangements. A fixed effects analysis suggests that the introduction of PSP is associated with a decrease in diarrhea among under-five children of about five percentage points, and an instrumental variables analysis suggests that the effects may be even larger. PSP in water also appears to be associated with significantly higher rates of reliance on piped water as the primary water source, suggesting that increased access may be driving child health improvements.

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1 Introduction

In the past ten years, diarrheal diseases—often caused by unclean water—have killed more children than every armed conflict in the world over the last 60 years, combined (Nelson 2004). Among the most vulnerable are young children, especially those under age five. Young children have both the least knowledge of how to avoid exposure to disease and the least resistance to disease when it does strike.[1] The World Health Organization has brought attention to this critical issue, pointing out that unclean water causes diarrhea, which kills an estimated 1.8 million people worldwide each year, 1.6 million of whom are children under five.[2] Not surprisingly, this is an alarming issue that has drawn the attention of governments, international aid organizations, development banks, and even private firms. Solutions have come in many forms including grants, lending, and—particularly in urban areas—plans to reform the piped water sector by introducing private sector participation (PSP) of some form. In urban Africa, the majority of people obtain their water from pipes, which are located in their homes or in fixed public locations to which they travel (known as a public standpipes). An important and largely unanswered research question is whether PSP can lower the diarrheal disease rate among under-five children in low income, developing countries.

Public, monopolistic provision of infrastructure services is becoming increasingly less common—and less advocated—in the developing world.[3] Since the 1980s, there has been an explosion of PSP arrangements in infrastructure industries including telecommunications, electricity, transportation, and piped water. The various forms of PSP are often blanketly referred to as privatization.[4] The stated motivations for PSP are varied, and include theoretical efficiency gains, fiscal crises, conditionality requirements of lending organizations, and even the greater feasibility of PSP owing to the recent development of more effective

[1]See Gasana *et al.* (2001) and Burstrom *et al.* (2005).

[2]Gordon, *et al.* (2004).

[3]Recent studies on the effects of competition and privatization in network industries include Winston (1993), Petrazzini (1996), Ros (1999), La Porta and Lopez de Silanes (1999), Frydman *et al.*(1999), Chisari *et al.* (1999), Noll *et al.* (2000), Estache *et al.* (2001), Megginson and Netter (2001), Wallsten (2001), Li and Xu (2002), Nellis (2005), and Kikeri and Kolo (2005). Sector improvements include increased service availability, greater productivity, and lower retail prices, among other positive findings.

[4]PSP refers to a variety of different arrangements involving the private sector including divestiture, concessions, leases, affermage contacts, and management and service contracts.

regulatory institutions. PSP is least prevalent in industries in which the service provided is critical to human health and wellbeing, in which the government profits heavily from state control (such as when investments can be easily delayed at low cost), and in which direct competition between providers is not feasible (the case of natural monopoly). Piped water is a prime example of such an industry. Despite the associated difficulties and low initial levels of private involvement, however, the fraction of the world population obtaining its piped water from a private provider increased five-fold between 1990 and 2003.[5]

PSP in the water industry is highly controversial, and can face the risk of reversal because life itself depends on adequate water consumption. Nonprofits and citizens from the developing world often protest the "commodification" of water, asserting that PSP will harm the poor, and that access to a clean, improved water source is a basic human right. Nonprofit Public Citizen (2004) has stated: "Perhaps the greatest theft of common resources facing humanity and the planet is the corporate takeover of the world's water." These sentiments are not uncommon. An AfroBarometer survey of 12 African countries undertaking economic reforms between 1999 and 2001 revealed that only 35 percent of the population preferred private ownership to state ownership. Furthermore, in May 2007, Friends of the Earth International presented a letter—signed by 138 groups from 48 countries—asking donor countries to withdraw support from the World Bank's Public Private Infrastructure Advisory Facility, an agency that funds consultants to advise governments on how to privatize key sectors of their economies, including water.

Government officials may refrain from PSP because it is profitable to keep firm control in government hands (see Shleifer and Vishny, 1994), and private firms may be hesitant to enter knowing that governments have these incentives. For example, government firms often operate at a loss or engage in heavy cross-subsidization in an effort to achieve particular policy goals, whereas private firms are driven by the profit motive. In a world of incomplete contracting, privatization may necessarily imply a completely new distribution of the pie which is not desirable from a political perspective. Other features of the water and waste

[5]See Organization for Economic Cooperation and Development (2003) and Marsden (2003). Note, however, that only 5% of the world's population received their water from the formal private sector in 2003.

water treatment infrastructure itself create incentives for governments and firms to delay investment. A large portion of sector assets, such as pipes, are literally sunk, have no alternative uses, and are extremely long-lived. Because the fixed costs make up such a large share of total costs and because the system can operate for a long period of time without much investment, a self-financing utility will earn quasi-rents (Noll 2002). The existence of these quasi-rents creates pressures to use them for short-term priorities rather than investment in the water system. Consumers may demand lower tariffs, a call politicians are likely to answer. Governments that own and operate their water systems may face pressure to use revenues for other immediate needs. Long-lived fixed assets mean that private operators, meanwhile, are especially prone to expropriation by the government and may therefore wish to refrain from reinvesting the quasi-rents—a quintessential example of the hold-up problem.

In the theory literature, the potential for efficiency gains from PSP in the water industry is not clear cut due to a lack of direct competition between providers. To the extent that piped water is a natural monopoly industry, it is not desirable to duplicate the water provision network or limit economies of scale by fragmentation. However, the lack of competition alone can limit how much PSP is undertaken and makes the consumer impacts of PSP uncertain. Demsetz (1968) proposes a solution to the lack of direct competition: competition for the market, through a bidding process. However, Goldberg (1976) and Williamson (1976) identify problems with this approach: collusion, asymmetric information, problems in the pricing of assets, and other incumbent advantages may result in an anti-competitive bidding process. These problems likely plague the water sector, where the number of bidders for large contracts has historically been quite small. Moreover, any resulting contracts are incomplete in practice (Williamson, 1976). As a result, competition for the market in the water sector cannot fully substitute direct competition. Without a fully competitive market, the theory remains unclear about efficiency gains of water privatization.

Empirical papers confirm the theory's ambiguity about the effect of ownership in monopolistic markets. Despite glowing reports about the potential of PSP in other industries, evidence on the consumer impacts of PSP in the water sector is mixed. While some studies find that PSP bodes well for efficiency and consumer welfare,[6] others are less optimistic or find null results.[7] Overall, however, there is a paucity of econometric studies in this area, with the case study methodology predominating. Among empirical analyses, I know of only two studies (Estache and Kouassi, 2002 and Kirkpatrick *et al.*, 2004) which focus on Africa specifically; both examine PSP's impact on utility efficiency rather than consumer impacts directly, and they come to opposite conclusions.[8] There are some econometric studies of other regions of the world (see Ménard and Saussier (2000), Saal and Parker (2001), Estache and Rossi (2002), Galiani *et al.* (2005), Wallsten and Kosec (2008), and Clarke *et al.* (2008)), but most are confined to single countries that differ from African countries in important ways: by their level of development, their level of dependence on donor aid and lending, and their motivations for privatizing. Furthermore, with the exception of Galiani *et al.* (2005), all of these studies focus either on utility efficiency instead of consumer outcomes specifically,[9] or on consumer access to piped water rather than the broader health impacts of PSP.

Galiani *et al.* (2005) find that the child mortality rate from water-related diseases in Argentina fell following water privatization, with poor municipalities benefiting more than richer municipalities. This is encouraging news for those considering PSP. However, an important point must be made: Argentina is an upper-middle income country with a high Human Development Index score, and its provinces underwent privatization for appreciably different reasons than the typical motivations in Africa. Jerome (2004) notes that, "Africa's atypical experience and unique socioeconomic characteristics are such that the policy preconditions that are indispensable for effective liberalization and privatization are rarely met." In short, findings from Argentina may be inapplicable to poorer, less-developed countries generally, or Africa specifically. Galiani *et al.* (2005) also do little to shed light on the relative importance of international development loans and other aid versus PSP itself on consumer health—particularly because such lending does not play the vital role in Argentina that it

[6] See Galiani and Petrecolla (1996), Noll *et al.* (2000), Kirkpatrick *et al.* (2004), Galiani *et al.* (2005), and Nellis (2005).

[7] See, e.g., Byrnes *et al.* (1986), Fox and Hofler (1986), Tynan (2000), Estache and Rossi (2002), Clarke *et al.* (2004), and Kirkpatrick and Parker (2004).

[8] Estache and Kouassi (2002) use a stochastic production frontier method and find that private operators are more cost-efficient. Kirkpatrick *et al.* (2004) use a stochastic production frontier and a data envelopment analysis and find that there are no differences in cost efficiency.

[9] In particular, Saal and Parker (2001) and Estache and Rossi (2002).

does in Africa. This is a grave omission in the literature given the high incidence of international development loan-accompanied PSP projects in the developing world. For example, between 1990 and 1995, there were 21 World Bank water sector loans which imposed privatization as a condition for lending; between 1996 and 2002, there were 61.[10] With a weak African Development Bank and pervasive poverty across much of the continent, the World Bank plays a key development lending role. In response to the difficult water situation faced in Africa, the director of the World Bank's Energy, Transport, and Water division, Jamal Saghir, declared that World Bank involvement in Africa's water infrastructure has to include PSP.[11] It is important not to attribute the effects of water and sewerage sector loans—or of development aid more broadly—to PSP. And it is even more important that we understand the individual, partial effects of each.

In Africa, PSP is often the remedy pursued by government officials to treat the problems of a severely distressed water sector in which they have under-invested for years. As shown in Kosec (2008), even in the United States—where government accountability is generally higher—privatization is more likely when a government-owned firm has been cited by the Environmental Protection Agency for health-endangering water contamination. PSP is a quick solution when a government-owned and operated water firm has become a liability. Additionally, as mentioned above, PSP arrangements are often accompanied by water and sewerage sector loans and aid. Both of these factors present unique problems for exploring the consumer effects of PSP in low income, developing countries. Estimation that ignores the fact that PSP is an endogenously-determined policy choice that targets potentially unobservable sector problems would tend to underestimate any consumers benefits of PSP. Indeed, this paper finds evidence of precisely this type of underestimation of PSP's benefits due to the endogeneity of PSP. Additionally, it is important to partial out the effects of aid and PSP itself to avoid overestimating the benefits of PSP whenever aid tracks the initiation of a PSP arrangement. Owing to these empirical complications, existing empirical research on the effects of PSP in the water sector has often ignored low income, developing countries.

[10] See, for example, The Center for Public Integrity (2003) and World Bank (2006).
[11] Alexander (2002).

However, it is vital—especially during periods of budgetary strain—for low income countries to understand how reforms in this critical industry will affect the development process.

A few other notable studies have also examined the health benefits of various water sector policies. Even though they did not examine private sector participation in the piped water sector specifically, their results are highly informative for the present analysis. First, Bennett (2008) finds that when the government expanded access to piped water in the Philippines, this benefited households by exposing them to fewer pathogens, but the technology also desensitized them to unsanitary conditions which led to a net increase in diarrhea. Second, Kremer *et al.* (2007) find that one particular method of improving the water supply in rural Kenya–protecting springs by encasing them in concrete–is associated with significantly lower child diarrhea incidence. While Kenyan laws and customs prevent those with springs on their land from charging water usage rates, the authors explore whether privatizing the springs and allowing their owners to charge rates would encourage those owners to invest in protecting those spring with concrete in welfare-improving ways. However, the results of their simulations show that people are worse off–not better–following privatization. Among other findings, the present paper concludes that PSP in the water sector is associated with higher reliance on piped water as a primary water source. This means that while Galiani *et al.* (2005) would predict that child health would improve following PSP, Bennett (2008) would predict that child health would be harmed by PSP. Furthermore, if the findings of Kremer *et al.* (2007) in rural areas and with springs are robust in urban areas and with piped water supplies, then they would also suggest that PSP will harm child health. I put these opposing findings to the test shortly.

I use an original, unbalanced panel dataset at the sub-national region level to empirically explore the effects of PSP in the water sector on child health outcomes in 26 African countries. I take an instrumental variables approach and incorporate sector-specific lending and grant controls in order to avoid the potential pitfalls identified above. Both the fraction of the world water market controlled by the country that originally colonized an African country, and the fraction of the population in the former colonizer country that currently obtains water from a private provider (whether local or foreign) are used as instruments for PSP in the associated African country. Several econometric tests reveal that these instruments are strongly correlated with PSP in the African country of interest and that they do not suffer weak instrument problems. Furthermore, tests of overidentifying restrictions support my contention that these instruments are uncorrelated with the error term. The paper finds evidence that the introduction of PSP is associated with a decrease in diarrheal disease among under-five children of between 19.9 and 24.2 percentage points. This finding holds after controlling for World Bank water and sewerage sector lending, United Nations multilateral aid flows, a country's Human Development Index (HDI) score, population density, and other controls including sub-national region fixed effects and year fixed effects. Additionally, World Bank lending is associated with lower diarrheal disease rates; a $1 increase in average annual per capita World Bank sewerage sector loans over the previous 5 years is associated with a drop in diarrheal disease prevalence of between 12 and 13 percentage points. PSP in the water sector also appears to be associated with higher rates of access to piped water, measured by the fraction of the population relying primarily on piped water as their water source.

The paper is organized as follows: Section 2 offers background information on water and human health, as well as their importance to the piped water PSP debate. Section 3 describes the dataset. Section 4 presents a fixed effects analysis. Section 5 addresses the likely endogeneity of the PSP dummy variable and presents the results of estimation using two instrumental variables. Section 6 discusses potential causal channels for the effects of PSP on diarrheal disease by exploring the determinants of access to an improved water source. Finally, section 7 concludes.

2 Background on Water and Human Health

Whether viral, bacterial, or parasitic in origin, diarrhea threatens children's health, causing both debilitation (morbidity) and death. According to the Institute for OneWorld Health

(2008):

> Diarrheal episodes can be either acute or persistent (lasting two weeks or more). Of all childhood infectious diseases, diarrheal diseases are thought to have the greatest effect on growth, by reducing appetite, altering feeding patterns, and decreasing absorption of nutrients. The number of diarrheal episodes in the first two years of life has been shown not only to affect growth but also fitness, cognitive function, and school performance.

Unfortunately, nearly 20 percent of the world's population does not have access to improved water—typically defined as water from a piped source—and more than one-third does not have access to improved sanitation.[12] The problem is even more critical in Africa, a continent that has ten percent of the world's population, but forty percent of the deaths of children under the age of five.[13] Poverty rates have been falling in every region of the world except Sub-Saharan Africa. While Sub-Saharan Africa accounted for nineteen percent of the world's poor in 1990, it is expected to account for half by 2015.[14] These statistics have led international organizations and other leaders in development to seek solutions to Africa and the rest of the world's water shortcomings. In September of 2000, the United Nations General Assembly finalized a list of international development goals to be achieved by 2015, known as the "Millennium Development Goals." Among the goals are: a) to reduce by half the proportion of people without sustainable access to safe drinking water, b) to reduce by two-thirds the mortality rate among children under five, and c) to reverse the incidence of malaria and other major diseases. These are goals that organizations like the World Bank and the UN continually seek to achieve, and they are threatened by poorly-run water sectors. Two common responses to water concerns have been international development loans and grants intended for the water and sewerage sector, and privatization.

It may be misleading to examine any single performance measure in assessing the effects of water privatization. Higher connection rates to piped water or lower prices are of little benefit if the water supply is contaminated or if it suffers from frequent supply interruptions. Likewise, high-quality piped water will not benefit consumers if they are forced to rely on water from streams or wells due to high prices, recurrent supply interruptions, or the

[12] Kessides (2003).
[13] See Batholomew and Oot (2005).
[14] World Bank (2005).

simple unavailability of piped water connections. And, as Bennett (2008) notes, individuals may respond to increased access to a cleaner water source—such as a piped source—by engaging in fewer other health-improving measures, which could actually result in a reduction in health along some measures. Given that African time-series data on water prices or the incidence of water contamination of various types are sparse and of questionable reliability, statistics on connection rates to piped water supplies or utility efficiency are difficult to interpret from a consumer welfare standpoint.[15] However, for the average household in a developing country, utility efficiency, greater access to piped water, less frequent supply interruptions, higher water quality, and lower prices are primarily seen as means to the end of human health and subsistence. Health has a profound impact on an individual's level of productivity, and thus poor health can pose significant costs for families and economies. When the health of children is at stake, some would even argue that there is a moral obligation to work to improve it. A critically important consumer welfare indicator is thus the health impact of water privatization.

The prevalence of diarrhea in under-five children is the indicator of consumer health status examined in this paper. Worldwide, about a fifth of all infant and child deaths are the direct result of diarrhea.[16] Even children who do not die from diarrheal disease may experience adverse development and growth effects as a result. Table 11 presents a rough exploration of the correlation between the prevalence of diarrhea and child mortality in the 26-country dataset I compiled; a 10% decrease in the prevalence of diarrhea is associated with an approximate 1% decrease in the child mortality rate. Table 1 presents statistics on the morbidity and mortality rates associated with various water-related diseases. In most countries, diarrheal diseases are responsible for the majority of the economic losses associated with water-related disease.[17] According to the United Nations (1993), as much as one tenth of every person's productive time in the developing world is sacrificed as a result of water-related diseases.[18] This adverse health effect comes from a variety of diarrheal diseases including

[15] See Kirkpatrick *et al.* (2004).

[16] See http://bmj.bmjjournals.com/cgi/content/extract/330/7494/748-g (last accessed September 2008).

[17] Gasana *et al.*(2001).

[18] Attacks usually last 3 to 7 days, but may last 10-14 days (Gasana *et al.* 2001).

cholera, colitis, gastritis, gastroenteritis, enteritis, intestinal inflammation, and typhoid fever, originating from pathogens such as rotavirus, adenovirus, and Norwalk Virus.[19] Unsafe water is widely considered to be the major cause of diarrhea, which has motivated governments to implement policies aimed at expanding access to piped water and ensuring that it is of high quality.[20] The reason for the focus on piped water[21] is that alternative, non-improved water sources—wells, springs, rivers, streams, and lakes—are frequently contaminated by human and animal fecal matter and other contaminants. This has obvious implications for the prevalence of diarrheal diseases in the population consuming water from these sources.[22] Second, to the extent that piped water is a more readily accessible, reliable water source, this can contribute to the use of larger quantities of water. Research has shown that the use of larger quantities of water may reduce the prevalence of diarrhea. *Ceteris paribus*, households that use more water are able to clean their homes and bodies more frequently, and maintain an environment that is less hospitable for infectious diseases.[23] If a tap is available in the house, water storage may even become obsolete; this would reduce diarrhea in theory, because storage of water in containers contributes significantly to illness given that containers are often contaminated.

An unclean water source is by no means the only factor affecting the incidence of diarrheal diseases. First, increased awareness of personal hygiene and proper food and water handling by parents may positively impact children's health. In urban areas where refrigerators can conceivably be kept, these can serve an important function in improving health. There also is a large body of evidence that a mother's level of education is a good proxy for her level of knowledge about how to assure that water is safe to drink and how to protect her children from diarrheal diseases.[24] Second, cleanliness of public areas and regulated health standards (including rules about the handling of excreta) can reduce the incidence

[19]See Gasana *et al.* (2001) and Burstrom *et al.* (2005).

[20]Diarrheal disease is usually attributed to the ingestion of water or foods that are contaminated with fecal coliforms or other pathogens; even piped water contain such contaminants (Alberini, Eskeland, Krupnick, and McGranahan 1996).

[21]Jalan and Ravallion (2003) find that the impact of piped water on the prevalence of diarrhea is largely unaffected by whether households obtain piped water from an in-home tap versus a public standpipe. The present analysis therefore does not differentiate between the location of the piped water source used by the household.

[22]See Merick (1985), Esrey *et al.* (1991), Lavy *et al.* (1996), Gasana *et al.* (2001), and Leipziger *et al.* (2003).

[23]See Merrick (1985), Esrey *et al.* (1991), Alberini *et al.* (1996), and Gasana *et al.* (2001).

[24]See Merrick (1985), Alberini *et al.* (1996), Gasana *et al.* (2001), Jalan and Ravallion (2003), and Burstrom *et al.* (2005).

of diarrhea.[25] Improvements will likely be seen in both of these areas as national income and general socioeconomic development increase.[26] As a result, we would expect diarrheal disease rates to drop as the Human Development Index (HDI) of a country increases. The HDI is a United Nations Development Program-constructed index designed by a group of economists in 1990 that combines normalized measures of life expectancy, educational attainment, literacy, and GDP PPP; higher values on the index are meant to indicate higher social development and social opportunities. A final factor potentially affecting the incidence of diarrhea is development lending and grants—especially water and sewerage-specific aid. There is some literature suggesting that loans and other aid may not reduce poverty, but the evidence is mixed.[27] The effect of loans and aid—in particular, assistance which is targeted at the water and sewerage sectors—on diarrheal disease is less known. All of these variables are important control variables when analyzing the effects of PSP in water on child health.

Piped water is admittedly a more viable option in urban areas than in rural areas, and therefore all analysis that follows examines only the urban portion of each African subnational region considered.[28] As Table 2 shows, of the 74 Demographic and Health Surveys (DHS) conducted in African countries since 1992, an average of 75% of urban households report using piped water as their primary water source, while this figure is only 19% for rural households. In rural Africa, access and affordability may mean that piped water plays little role in villagers' lives—whether it is organized under a PSP arrangement or not.[29] Nonetheless, between 20 and 40% of the population of many African countries lives in urban areas, and the prevalence of diarrheal diseases is sometimes even higher in urban areas than in rural.[30] Because of the high dependence on piped water in these areas, rural water policies such as those considered by Kremer *et al.* (2007, 2008) may be inapplicable. Additionally, urbanization is on the rise in Africa. This highlights the need for a better understanding of

[25] See Burstrom *et al.* (2005).

[26] See Merrick (1985), Pritchett and Summers (1996), Alberini *et al.* (1996), Wang (2002), and Jalan and Ravallion (2003).

[27] See Gavin and Rodrik (1985), Gilbert *et al.* (1999), Stiglitz (1999), and Kilby (2000).

[28] Urbanization is defined by household survey administrators.

[29] An emerging literature examines how diarrheal diseases might be reduced through rural water policies in areas where piped water systems are often not viable; see, for example, Kremer *et al.* (2007) and Kremer *et al.* (2008).

[30] Based on Demographic and Health Survey (DHS) descriptive statistics. There could be many reasons for this, but the most likely source is the extra pollution and exposure to pathogens that occurs when populations are more densely concentrated.

the factors affecting diarrheal disease among urban-dwelling children.

3 Data

Pre-assembled data on child welfare in Africa are hard to come by, especially if one wishes to follow the same cross-sectional units over time. I was able to construct a novel dataset by individually analyzing and aggregating the data available in household surveys from numerous African countries. These surveys are most often conducted by governments, non-profits, and international organizations. The same individuals and households are typically not tracked over time, but surveys record the sub-national region[31] in which a household is located and visit the same sub-national regions each time data are collected, making efforts to ensure that the data are regionally-representative. It is therefore possible to aggregate household data to the level of the sub-national region in order to compare changes in regional averages over time. These surveys contain data on child health indicators, where the family obtains water (from a piped water source or from elsewhere), whether the family has a flush toilet (connection to sewerage), household member education data, households assets, and various other household characteristics. For each survey, I identified relevant geographic variables that could be matched up across surveys, and then constructed region-level weighted means from the existing data series. I repeated the procedure for each household survey.

The statistics on child health come from Demographic and Health Surveys (DHS). DHS surveys are one of the leading sources of data on maternal and child health, child survival, infectious diseases, reproductive health, and nutrition in Africa.[32] The surveys also vary little across countries and over time (at least for a base set of questions), ensuring that they are comparable within and across countries. Each DHS survey has household-level data on whether each child under age five in the household experienced diarrhea at some point during the previous two weeks. I was able to aggregate this up to the household level (the fraction of children in the household experiencing diarrhea at some point during the last two

[31] Sub-national region is the general term I apply to provinces, states, or regions within each country; the exact terminology varies by country.

[32] Demographic and Health Surveys (2008).

weeks),[33] and then aggregated these data up to the sub-national region level, giving a fraction of the urban, under-five population in that sub-national region that suffered from diarrhea at some point during the last two weeks. I similarly extracted data on the fraction of the urban population reporting that they receive water primarily from a piped source (either an in-house tap, a yard tap, a neighbor's tap, or a public standpipe). As a measure of general wealth, I additionally recorded the fraction of households reporting owning a refrigerator. In urban areas, this asset is associated with safe food storage practices and a greater ability to guard against bacteria and parasites; its means in the sample is 0.29.

In order to determine whether or not the results are the same among the poor as they are on average, I wanted to compute all regional aggregates not only for all households, as described above, but also by the household's status or class. Because DHS surveys do not include data on income, I used education level as a proxy for income in determining poverty status. I broke households into three groups when computing sub-national region aggregates: those for which the household head had no education, those for which the household head had primary education but no more, and those for which the household head had secondary education or more. For ease of exposition, I term the three groups the lower, middle, and upper classes. It should be kept in mind that a household's class refers to the education level of its head, rather than its income.[34] Given that the diarrheal disease prevalence data could be computed by class, I was able to estimate the same equations several times, but with varying dependent variables: first diarrheal disease prevalence among all households in the sub-national region, then diarrheal disease prevalence among households in the sub-national region with an uneducated head, then with a head with primary education, and finally with a head having secondary or more education.

While many other large-scale household surveys in Africa do not include child health data series, they do contain other valuable information on such factors as whether households use piped water. In order to run some ancillary regressions to study the factors

[33] The reason for not including each child individually in computing sub-national region averages was to avoid oversampling of children from large households.

[34] As a result of how this variable is used and what it proxies for, I only examine households that have a male head. Households with female heads may not be typical, and furthermore, women may be uneducated for reasons other than a household's income level or ability to afford education and leisure. Thus, results based on a female head's level of education may be misleading.

associated with higher access to piped water, I augmented the DHS data with 14 non-DHS surveys. These surveys included Priority Surveys (PS), Living Standards Measurement Surveys (LSMS), Multiple Indicators Clusters Surveys (MICS), and Income, Expenditure, and Household Surveys (IES). The non-DHS surveys were selected at random from a very large pool of potential surveys; attention was only restricted to surveys for which the same survey type was available for two different years in the same country, and to surveys from 1985 and later[35] For each of these survey types, as for the DHS surveys, I aggregated the household-level data to the level of the sub-national region. While this involved mixing data from different types of surveys in the final analysis, this is unlikely to be problematic given that data are aggregated to the sub-national region level, the appropriate weights are used to ensure that the surveyed households are representative of that sub-national region regardless of the survey type, and all surveys ask the same, very straightforward question of whether or not the household relies primarily on a piped source for its water needs. Furthermore, the same survey instrument was always used over time in a given country (and sub-national region fixed effects always used); all of the variation in survey types used (PS, LSMS, MICS, etc) is across countries and not within them. Furthermore, it should be underscored that the mixing of data from different survey types only affected the regressions exploring access to piped water and not the regressions exploring diarrhea (all diarrhea data come from DHS surveys).

In total, I collected data from 79 different surveys (65 DHS, 14 non-DHS). The result was an unbalanced panel dataset at the sub-national region-level covering 26 African countries: Benin, Burkina Faso, Central African Republic, Cameroon, Chad, Djibouti, Egypt, Ethiopia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Tanzania, Uganda, and Zambia. There are an average of three years of data (surveys) for each country (between two and five). For the child health regressions, I relied only on the 65 DHS surveys. This

[35]Because PSP is a relatively new phenomenon in many African nations, I targeted surveys from 1985 and later when choosing non-DHS surveys. Note that there are no pre-1985 DHS survey for Africa.

represents the universe of all DHS surveys conducted in Africa which were useable.[36] I used all 79 surveys in a series of regressions examining the factors affecting access to piped water. Table 3 shows all countries and sub-national regions in the dataset, and the survey years for which I collected data on each.

Unfortunately, a comprehensive database of private sector participation in the water industry in Africa does not exist. As of the early 1980s, only the Ivory Coast had PSP in water. However, during the years covered by the surveys (1985-2006), PSP in water was introduced for the first time to various parts of Africa. In order to study the effects of PSP, I first had to assemble a dataset cataloguing what had been done in the water sectors of all 26 African countries. Table 4 summarizes these findings. In some cases, PSP was never introduced, and thus the water sector is listed as remaining publicly-owned and operated throughout the country. Among areas that introduced PSP, PSP was often the solution to menacing sector problems that had rendered water systems a liability rather than a potentially profitable state enterprise. In a large number of cases, the introduction of PSP into the urban piped water sector has occurred at the national level, affecting all or most of the urban water networks in the sub-national regions of the country. In other cases, PSP was only introduced into select cities or provinces. Every effort was made to obtain accurate information and thus code a dummy variable for PSP at the sub-national region level for each survey year. African countries have undertaken a number of different types of PSP arrangements, and a detailed exploration of the differential effects of each contractual form (e.g., concessions, leases, affermage contracts, private management contracts, etc) is outside of the scope of this analysis. Because of sample size issues and given that a concession contract in one country may not truly be comparable to a concession contract in another country anyhow, I found it most tractable to lump together the various types of PSP. Thus, the PSP variable is a dummy for a PSP arrangement of any kind being in place in a given sub-national region - year.

[36]DHS surveys were excluded in only a limited number of cases. Primary reasons for exclusion are: There was only one survey available for a given country (11), data access was restricted and thus the data were not publicly available (5), the survey did not cover the necessary variables (3), and the data were raw resulting in complications in their use (11).

The principal health outcome used—the fraction of children under age five that experienced diarrhea sometime during the previous two weeks—is the same one used by Alberini *et al.* (1996). An arguable better measure of child health is death by cause (in particular, deaths caused by water-borne disease). Unfortunately, such death statistics are not available for most African countries. Furthermore, because of the lack of access to medical care, a large percentage of deaths in Africa are of unknown cause. While data on the fraction of a mother's children that survived past age five were available for each DHS survey year, this is not an ideal measure of current mortality rates since it reflects an unknown combination of lagged and current child mortality data. Additionally, the myriad potential causes of death make specifying an appropriate econometric model explaining child mortality difficult or impossible. Numerous factors that we cannot hope to measure and that likely vary randomly over time and space contribute to child mortality. The causes of diarrhea, however, are more well-specified and primarily linked to sanitation and water conditions. For these reasons, and given the debilitating and potentially deadly effects of diarrhea, I chose diarrheal disease prevalence as the central indicator of child health.

In addition to the household survey data and information on which sub-national regions had PSP in water, I also collected data on several important controls: the country's Human Development Index score (1-100, where 100 is most developed), the population density (people per square mile), the average annual per capita amount of World Bank water and sewerage sector loans and grants over the previous five years (and two years, and for a country's entire history, for the purpose of sensitivity analysis), and net multilateral flows per capita from all United Nations programs (in constant 2000 USD). To construct the instrumental variables, I had to obtain data on the market shares of former colonizers of Africa in the world (excluding Africa) water market for each year between 1985 and 2006,[37] and I also had to obtain data on the fraction of these countries' own populations that were served by private water providers for each year between 1985 and 2006. All of these data were obtained from international institutions and non-profits including the World Bank, the

[37] Africa is excluded from "the world" in order to avoid the endogeneity of the instruments.

United Nations, the Public Services International Research Unit (PSIRU), and Envisager Limited (creator of the annual World Water Yearbook).

Table 5A summarizes the means and standard deviations of key variables in the dataset, and table 5B presents a matrix of pairwise correlation coefficients. The basic summary statistics reveal that an average of 17.3% of under-five children in urban areas reported having experienced diarrhea at some point during the last two weeks. They also reveal that of the regions and years covered in the surveys, about 18.9% of them were marked by a PSP arrangement being in place in that region-year. Simple correlations reveal very little linear relationship between PSP in the water sector and the prevalence of diarrheal diseases. Indeed, the correlation coefficient between the PSP dummy and the fraction of the under-five population experiencing diarrhea at some point during the last two weeks is -0.01. While of the expected negative sign, this correlation is remarkably weak. World Bank water sector and sewerage sector aid is also very weakly related to diarrheal disease, with correlation coefficients of only 0.039 and 0.029, respectively. The sign is the opposite of what is expected, but makes sense given these are simple correlations that do not control for such factors as a country's Human Development Index. As expected, World Bank water sector aid is positively correlated with PSP; the correlation coefficient is 0.25. This highlights the need to control for both PSP and World Bank funding in order to partial out the effects of each. World Bank water and sewerage sector loans, as well as United Nations aid, are both negatively correlated with a country's Human Development Index and with the fraction of the population owning a refrigerator. This is in keeping with the expectation that development assistance is targeted at countries with low incomes and low educational attainment.

In order to more rigorously explore these correlations, and to control for unobserved heterogeneity, we turn to a multivariate, fixed effects analysis.

4 Standard Fixed Effects Model

I began with a simple fixed effects model of the factors affecting diarrheal disease prevalence among children five and under. I was particularly interested in the coefficient on private sector participation in the water sector. Equation (1) is the baseline fixed effects model.

$$\begin{aligned} ddp_{iht} = \beta_0 + \beta_1 psp_{it} + \beta_2 wbwater_{it} + \beta_3 wbsewer_{it} + \beta_4 hdi_{it} + \\ \beta_5 fridge_{it} + \beta_6 popdens_{it} + \beta_7 un_{it} + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \tag{1}$$

ddp is diarrheal disease prevalence in urban areas of sub-national region i, among educational attainment group h, in year t. Diarrheal disease prevalence refers to the fraction of the under-five sub-national region population experiencing diarrhea at some point during the past two weeks. The subscript h takes on four values, representing the four different ways in which I take the average of diarrheal disease prevalence over the sub-national region: all households in the region, all households in the region whose household head has no education, all households in the region whose head has primary schooling only, and all households in the region whose head has secondary or more education. *psp* is a dummy variable for region i having PSP in its urban water sector in year t. *hdi* is the Human Development Index score of the country in which region i is located, in year t.[38] *wbwater* (*wbsewer*) is average annual dollars per capita loaned or granted by the World Bank for water (sewerage) specific projects during the previous five years to the country in which region i is located, as of year t.[39] *fridge* is the fraction of the urban population in region i that owns a refrigerator in year t. *popdens* is the number of persons per square mile in the country in which region i is located, in year t. *un* is net multilateral flows per capita from all United Nations programs (in constant 2000 USD) received by the country in which region i is located, in year t. α_i are sub-national region fixed effects, and γ_t are year fixed effects.

[38] The HDI is a United Nations Development Program-constructed index designed by a group of economists in 1990 that combines normalized measures of life expectancy, educational attainment, literacy, and GDP PPP; higher values on the index are meant to indicate higher social development and social opportunities.

[39] Lending and grants over the past five years is admittedly an arbitrary measure of World Bank support. However, a smaller lending window was deemed insufficient for the projects undertaken to take full effect, particularly in the case of large-scale construction projects or programs that are slow to launch. Further, the results do not appear to be very sensitive to the length of the window used. I tried alternative specifications for the previous two years and for total lending and grants per capita to date; the results are substantially similar.

All specifications of the model include sub-national region fixed effects. The necessity of including fixed effects stems from unobserved heterogeneity among regions of Africa. Geographic heterogeneity is most obvious, with some regions having desert conditions while others have lush forests; this has obvious implications for how complicated it is to provide and receive piped water, for child hydration needs, and for general susceptibility to disease. Also important is heterogeneity of a nation's colonial history and resultant institutions. Not only the identity of the colonial power, but also the power's relationship with each country and each of its sub-regions in particular affects modern day institutions (see Acemoglu and Robinson, 2006). The region fixed effects control for the aspects of this within - sub-national region heterogeneity that do not change over the sample period. Ethnic, religious, social, cultural, institutional, and gastronomic factors that are essentially constant over time are also captured by the sub-national region fixed effects. Year fixed effects are also included to control for factors that are constant across countries but which vary over time; such factors include the vaccines, medicines, and medical procedures in existence, the state of global capital markets, and the general level of health in the world.

The literature presented in section 2 offers a number of priors regarding the signs of each regressor. Since more education and higher incomes equip a family with the knowledge of how to avoid illness and the resources to buy more food, safer water, flush toilets, soap, more medical care, and more electricity (for boiling water and refrigerating food), one would expect a higher HDI score to be associated with a lower diarrheal disease prevalence. The amounts loaned or granted by the World Bank for water and sewerage sector projects control for external assistance in the water sector. One would also expect diarrheal disease prevalence to decrease as water and sewerage-related grants and loans increase; the goal of such assistance is to improve the quality of life in developing countries via these critical sectors. Because higher population per square mile puts more strain on existing water resources and because congestion and interaction with sick people breeds disease, it is likely that higher population density would be associated with higher diarrheal disease rates. The sign of the coefficient on PSP is not absolutely certain. As noted earlier, some research shows that PSP improves sector performance even when competition is not possible, whereas other research indicates that competition is necessary. Given that the water market does not allow for direct competition by its very nature, the theory thus remains unclear about the benefits of PSP in water. Nonetheless, I suspect that the water sector in African countries is generally in such poor shape (from a lack of investment) that PSP is likely to increase efficiency and quality in noticeable ways. First, a company driven by a profit motive is not likely to abuse the utility for personal gain as might a politician; political officials have been known to offer service subsidies to key allies and to offer jobs in the utility to political supporters. Second, a private company—which is typically a foreign firm in the African case—is concerned about its reputation throughout the world. This gives them incentives to offer high quality water wherever possible (nothing spreads quicker than news of a water supply that made people sick). The result should be fewer redundant employees, fewer leaks, more water, and higher service reliability and water quality. According to theory, this would imply lower diarrheal disease rates after PSP.

Table 6 presents the regression results from estimating equation (1) with a simple fixed effects model in which h is set to be the average diarrheal disease prevalence over *all* urban households in region i. All model specifications include region fixed effects, although only the last four columns include year fixed effects. Regressors were added sequentially; the coefficient on *psp* is negative and significant at at least the 5% level in all model specifications. Column 8, the baseline model, reveals that the presence of PSP in a region's urban water systems is associated with an approximate 5 percentage point drop in diarrheal disease prevalence. *wbsewer* has the expected negative sign; it is significant at the 1% level, and an extra $1 per capita annually (over each of the last 5 years) is associated with a 7.5 percentage point drop in the diarrheal disease rate. The sign on *wbwater* is actually positive—either due to measurement error, because sector reorganization has temporary health costs during an adjustment period, or because it is still mildly correlated with something unobservable in the error term. However, it is not significant at conventional significance levels. None of the other regressors approach significance.

5 Instrumental Variables Fixed Effects Model

While the dataset and empirical approach allow me to control for a wide variety of country and sub-national region characteristics, the possibility remains that there are latent factors correlated with both PSP and diarrheal disease prevalence which drive the diarrheal disease rate. That is, the PSP variable may be endogenous. Public utilities are potentially profitable sources of revenue for politicians, and water utilities in particular can go years without new investments, even if quality and service reliability suffer somewhat. Furthermore, because water is such a sensitive industry, and water so necessary for human health, introducing PSP is politically unpopular and potentially infeasible. Given these features, it is not surprising that, as shown in Kosec (2008), PSP is more likely following a bout of low water quality. When people are already used to bad water quality, they are relatively less sensitive to equally bad water quality in the future, whereas customers beginning at a higher quality level might be quite sensitive to the drop. As a result, there is likely less political pressure against the introduction of PSP after people are accustomed to low quality and the government has revealed some level of incompetence. Furthermore, an ailing utility is almost undoubtedly worth less to a political official than a well-functioning utility. At the same time, these factors likely affect the diarrheal disease rate; contamination and low infrastructure investment levels cannot bode well for health. However, the condition of water utilities and the reasons for introducing PSP are typically unobservable. I know of no source that would help me ascertain and measure droughts, contamination episodes, and the degree of under-investment in water infrastructure in a satisfactory way for even a small subset of the 26 countries in the dataset. As a result, the PSP dummy is likely correlated with those utility characteristics that remain in the error term, making it an endogenous regressor. This motivates an instrumental variables approach in order to consistently estimate the effect of PSP on diarrheal disease rates.

Finding an appropriate instrumental variable was no easy task; the exclusion restriction is difficult to satisfy when the dependent variable is so sensitive to physical geography, small changes in the distribution of resources, or even changes in how people think (such as knowledge of the value of washing hands or appropriately disposing of waste). In order to find a variable highly correlated with PSP in the water sector in various regions of Africa, but not correlated with the error term, I stepped outside of Africa entirely, going back to the colonial era. Africa was originally colonized by five main European powers: France, the United Kingdom, Portugal, Germany, and Italy. Table 7 lists the original colonizers of each of the 26 countries in the dataset.[40] By the mid-1870s, Europe had done little to intervene in Africa beyond establishing a few coastal trading posts and the key colonies of Algeria and South Africa. However, as described by Pakenham (1991),

> Suddenly, in half a generation, the Scramble gave Europeans virtually the whole continent: including thirty new colonies and protectorates, 10 million square miles of new territory, and 110 million dazed new subjects, acquired by one method or another. Africa was sliced up like a cake, the pieces swallowed by five rival nations—Germany, Italy, Portugal, France, and Britain.

Today, all five countries are active in the world market for private piped water provision. As of 2006, France controlled about 37% of the world water market, the UK controlled 9%, Italy controlled 7%, Germany controlled 5%, and Portugal controlled 4% (data from Envisager Limited, 2008). These shares do not appear to track a country's GDP (Germany led in this regard throughout the 1985-2006 sample period, followed by the UK), nor GDP growth (Germany, Portugal, or the UK led during all of 1985-2006). Indeed, all are high income, OECD countries engaged in the international business community. However, piped water PSP arrangements in Africa typically involve large international firms, and frequently involve a company from the former colonizing country (see, e.g., Hall, 2007 and Table 4). This is no coincidence; we can think of it as a story of political and cultural influence. Intimate knowledge, on the part of a private water provision firm, of local language, customs, corporate culture, politics, and history—while unlikely to lead African public officials to extend a PSP agreement to one company over a more-qualified company—*are* likely to matter on the margins. That is, when an Africa country's public officials are deciding between two companies' (one from the former colonizer and one from some other country) nearly equally

[40] Some African countries had multiple colonizers—particularly those originally colonized by Germany but lost following World War I. I focus on the initial colonizer.

attractive PSP contract offers, these political and cultural influence channels are likely to act decisively in favor of the firm from the country's colonizer. Likewise, if an African country is indifferent between privatizing its water sector and keeping it public, these political and cultural influence channels may tip the indifference in favor of privatizing. However, this political influence cannot operate at all if a country's former colonizer is not sufficiently involved in the world water market. If the African country's former colonizer *is* active in the world water market—with the level of its activity measured by its market share of the world market—then there is likely to be at least one if not more than one firm from that former colonizer providing implicit or explicit offers of PSP. An increase in the number of such offers would drive upward the probability of privatization in the country in question, and would show up in the data as a large share of privatization contracts being contracts with a company from the country's former colonizer. It turns out that this is precisely what we find in the data. Indeed, the world water market share of a country's former colonizer is positively correlated with water privatization in a given African country, and there is a clear bias toward privatizing with a company from a former colonizer country.

I call this world water market share variable *colonmkt*, and use it as an instrument for PSP. Its mean is 0.155. The fact that this instrument is correlated with PSP, conditional on the other covariates, can of course be tested in the data; the correlation is found to be robust. Annual data for 1985-2006 on the market shares of each of the original colonizing powers of the African countries in the DHS dataset were provided to me by the managing director of Envisager Limited, an independent water and waste water market analysis firm.[41]

The crux of the exclusion restriction rests on the argument that changes in the fraction of the world water market controlled by the colonial power that originally colonized the African country do not affect diarrhea except by making PSP in the water sector of that African country more likely. That is, we must show that *colonmkt* is uncorrelated with the error term of equation (1). Since *colonmkt* does not appear to track a country's GDP or GDP growth, it does not seem plausible to think that an increase in a European country's

[41]Data were compiled for me personally by managing director David Lloyd Owen, author of the annual Water Yearbooks put out by the firm Pinsent Masons.

fraction of the water market would be associated with an increase in development assistance coming from that European power and bound for its former colony—a possible argument for failure of the exclusion restriction. Nor does it seem likely that the water experts in Europe would become increasingly likely, as their share of the water market grew, to offer the African country they colonized technical assistance to improve public water systems. Those most knowledgable about how to help—European experts working for the large private water firms—would have the least incentive to encourage forms of water sector improvement other than bringing in a private operator. Thus, I argue that the exclusion restriction holds.

To test the robustness of the results to the use of a different instrument, and, more importantly, to allow for estimation of an over-identified model (which permits a test of overidentifying restrictions), I also used a second instrument. This instrument is the fraction of the population in the country that originally colonized an African country that obtains their water from a private provider. I call this variable *colonpriv*; its mean is 0.368. The story for inclusion here is simple; given that the former colonial powers are well-functioning democracies, expansions in the amount of PSP in their water sectors generally reflects a popular will for more PSP, and good outcomes from previous PSP experiences. Due to cultural and linguistic ties between African countries and their colonizers, however, expansion of PSP in water in the former colonizer is simply good advertising for the policy of PSP in water. It offers a model of how PSP can be effectively carried out, and can encourage African countries to do the same in their own water sectors. The exclusion restriction seems to hold here as well; PSP in Europe seems to be driven by local politics more than anything else. In Europe, controlling a greater share of the world's water market does not appear to be associated with higher PSP at home. GDP does not seem to explain PSP in Europe either. Thus, it does not seem likely that an increase in the fraction of people in the UK receiving water from a piped source would affect diarrheal disease rates in Ghana through any other means than by increasing the probability of PSP in Ghana's water sector.

Table 8 presents the results of estimating equation (1) while instrumenting for the PSP dummy with three instrument sets: First using only instrument A, which is *colonpriv*, then using only instrument B, which is *colonmkt*, and finally using both of these instruments. In each case, regressors were progressively added; columns 4, 8, and 12 reflect the baseline regression model of equation (1) using each of the three instrument sets. In the first stage regression of each of these three columns of Table 8, the t-statistics for each instrument exceed 2.0, suggesting that the instrument(s) are highly correlated with *psp*. When we use *colonmkt* alone or when we use both instruments, the t-statistics are even higher. In all three cases, the value of the Anderson likelihood-ratio test statistic results in a rejection (at the 1% level) of the null hypothesis that the smallest canonical correlations of *psp* and the instruments are zero, offering strong evidence that the proposed instrument sets are positively correlated with the endogenous regressor (Hall *et al.* 1996). When we use only *colonmkt* and when we use both instruments, the Cragg-Donald F-statistics exceed 33 in the baseline model. These F-statistics far exceed the critical values recommended by Stock and Yogo (2002) when testing for the weakness of instruments, and thus we can strongly reject that the model suffers from problems associated with weak instruments. These instrument sets are exceptionally strongly positively correlated with *psp*, as expected. When we use only *colonpriv*, however, the Cragg-Donald F-statistic is only 7.836. This indicates that the instrument *colonpriv* alone is weak. For example, Card's refutability test suggests that this statistic should exceed 10.0 or else instrumental variable estimation is not reliable as the estimator will not only be badly biased but will also have a nonnormal sampling distribution, even in large samples (making statistical inference meaningless).[42] Thus, we focus further analysis on the instrument *colonmkt* and on the combination of the two instruments.

While an exclusion restriction cannot be directly tested, we can perform a test of overidentifying restrictions (in order to indirectly test it) by estimating equation (1) while using both *colonpriv* and *colonmkt* as instruments for *psp*. As shown in column 12, the value of the Hansen J Statistic is sufficiently small that we fail to reject the null hypothesis that the matrix of instruments is exogenous. This evidence in favor of the instrument being uncorrelated with the residuals supports the arguments made earlier regarding why the

[42]This statistic also fails to exceed Stock and Yogo's critical value for 10% maximal IV size, which is 16.38, or even the critical value for 15% maximal IV size, which is 8.96.

exclusion restriction holds.

The instrumental variables results are similar to the OLS results, but the magnitude of some of the coefficients is larger, and significance is generally higher. This can be explained by attenuation bias associated with measurement error, but also—in the case of *psp*—by the fact that endogeneity likely led to a downward bias of this coefficient. This is consistent with a story of PSP being brought to the most poorly-performing areas, which is plausible given that many governments consider such firms to be cash cows requiring little investment and allowing for large profits. If this is the mentality of African governments, than they are unlikely to wish to part with such firms—through PSP arrangements—unless circumstances are sufficiently bad to force this type of divestiture.

The results show that private sector participation in the water sector has a negative and statistically significant effect on diarrheal disease prevalence. Using only *colonmkt* as an instrument, among all urban households, the introduction of PSP in the water sector is associated with a diarrheal disease rate that is 19.9 percentage points lower than it is in the case of no PSP. This result is statistically significant at the 1% level. Using both instruments yields a higher estimate of 24.2 percentage points, which is also significant at the 1% level. This supports the hypothesis that PSP improves child health in Africa by lowering the diarrheal disease rate after controlling for factors like PSP, aid flows, and region and year fixed effects.

World Bank funding to the water and sewerage sectors is also associated with relatively lower diarrheal disease prevalence, although the results are somewhat unexpected. Using only *colonmkt* as an instrument, a \$1 increase in per capita World Bank sewerage sector aid over each of the previous 5 years is associated with a diarrheal disease rate that is 12 percentage points lower than in the case of no World Bank aid (13 percentage points lower when both instruments are used). At the same time, however, an increase of \$1 in World Bank water sector aid over the previous 5 years is associated with a diarrheal disease rate that is 6.4 percentage points higher than in the case of no such aid (7.9 percentage points higher when both instruments are used). The results on both water and sewerage sector aid are significant at the 1% level. This perverse result could indicate several things. First, it could simply be the result of measurement error. Since World Bank funding at the country level does not precisely control for the amount of World Bank funding to each sub-national region, and because the annual amount of funding per capita over the previous five years is clearly an arbitrary window of time, it may be that the World Bank variables are not revealing the true effects of this development assistance. Additionally, by discussing this result with a civil engineer, I learned that water sector projects are technologically a lot more complicated and risky than sewerage sector projects. In short, removal of waste is a more straightforward and less sensitive task than treating water and generating a product intended for human consumption. This might explain why the immediate benefits of sewerage sector loans are observable while those in the water sector are not. The fact that there is a negative rather than a null result for World Bank water sector funding, however, might indicate that World Bank aid is being targeted at ailing countries and water systems in a way that does not track the country's Human Development Index score, *hdi*, nor a region's access rate to refrigerators, *fridge*. That is, while it was hoped that any targeting behind World Bank lending would be captured by rates of education, income, and access to refrigeration (control variables already in the model), the World Bank variables may be correlated with additional factors that affect diarrhea and are in the error term. This would prove problematic for the analysis and would require additional instrumental variables even though none are available at the moment. However, measurement error seems to be a very likely culprit behind this result. Importantly, it seems that, on the whole, World Bank funding is associated with a lower diarrheal disease rate. The benefits of sewerage aid are almost double the apparent negative effects of water sector aid.

The other control variables in the model are not significant, although they generally have the expected signs. *popdens* has a positive coefficient in all models, and it approaches significance when both instrumental variables are used, suggesting that an increase in the number of people living in each square mile is associated with higher diarrheal disease rates. The coefficient on United Nations net multilateral flows per capita, *un*, is negative as expected, but insignificant. The coefficients on the Human Development Index and the fraction of the population with a refrigerator, *hdi* and *fridge* are completely insignificant. This is surprising, suggesting that GDP and education levels alone are not great predictors of the diarrheal disease rate.

Table 9 further explores the baseline regressions of Table 8 (columns 8 and 12). Columns 8 and 12 from Table 8 are repeated as columns 1 and 5 in Table 9. Added are regressions for each of the three different educational attainment groups. Columns 1-4 use both *colonmkt* and *colonpriv* to instrument for *psp*, whereas columns 5-8 use only *colonmkt* as an instrument. Interestingly, the effect of PSP is greatest in magnitude among the lower and middle classes, for whom PSP is associated with a diarrheal disease prevalence that is between 26.7 and 32.4 percentage points lower than in the case of no PSP. Once again, these results are statistically significant at the 1% level. On the other hand, World Bank grants and lending appear to benefit the middle and upper classes most, for whom an increase in World Bank sewerage sector aid of one dollar per capita per year over the previous five years is associated with a diarrheal disease prevalence that is between 13.7 and 19.5 percentage points lower than in the case of no World Bank aid.

The findings suggest that lower-class children may benefit from PSP more than do upper class children. This is consistent with a number of stories, including one in which poor families' access to improved water sources increases following the introduction of PSP, allowing them to "catch up" to wealthier families with regard to access. Furthermore, the results may actually understate the effect of PSP on diarrheal disease. For example, Esrey *et al.* (1991) find that access to an improved water source decreases the *severity* of diarrheal disease even more than it decreases its incidence. Thus, the effect of PSP on the prevalence of diarrheal disease is only part of the story of how PSP can improve child health. Once again, the other regressors are insignificant. Only *hdi* approaches significance; for all three classes of households, the coefficient has the expected negative sign.

6 Potential Causal Channels

The instrumental variables analysis indicates that PSP in the piped water sector, World Bank sewerage sector loans, and possibly decreases in population density and increases in a country's Human Development Index are associated with lower diarrheal disease rates among children under age five. However, the causal channels are unclear. Examining the levers a private operator stands to move after entering the water sector helps clarify matters. In particular, the operator may:

1. Raise, lower, or maintain water prices. Note that if connections that were previously not being paid are "regularized," and recipients thus charged for the first time, then this is an effective increase in the price of water for some segment of the population.

2. Raise, lower, or maintain water quality. There are many aspects of quality that are relevant, including contaminant levels, outages, and typical hours per day of service availability.

3. Raise, lower, or maintain the barriers to getting connected to the water distribution network. This refers to administrative stumbling blocks or waiting periods faced by those desiring (i.e. willing and able to pay for) connections.

The question is: which levers might a private water firm operator move in order to contribute to a lower prevalence of diarrheal disease following the introduction of PSP? It should be clear that, *ceteris paribus*, access rates to a piped water source can only increase if either prices are lowered, water quality increases, barriers to connection are lowered, or some combination of the three occurs. Thus, increased access would appear to be an indicator of consumer welfare-improving changes in the water industry.

An important indicator of consumer access to water is the fraction of urban households reporting using an improved (piped) source as their primary source of water. As described in section 3, I have sub-national region-level data on this indicator for the entire sample period. In order to explore how PSP affects access, I estimate several versions of equation (2):

$$\begin{aligned} pipedwater_{it} = \beta_0 + \beta_1 psp_{it} + \beta_2 wbwater_{it} + \\ \beta_3 hdi_{it} + \beta_4 popdens_{it} + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \tag{2}$$

All variables are as described earlier. World Bank sewerage sector spending is now excluded since spending in this sector should not have a direct impact on access rates in the water sector. The results are presented in Table 10. In the baseline specification of column 8, we see that PSP in the water sector is associated with a 6.1 percentage point increase in rates of access to piped water. The result is significant at the 5% level, and supports a story in which PSP lowers the diarrheal disease rate by increasing rates of access to piped water. Whether access rates increase due to a reduction in prices, an increase in quality, or lower barriers to getting connected is not resolved, but one or more of these three channels would appear to be at work. According to Clarke *et al.* (2008), a review of 23 case studies on the introduction of PSP into the water sector yielded 7 instances of a decrease in water prices following PSP and 9 instances of an increase in prices following PSP. Among the six case studies of African countries, two resulted in price increases and two resulted in price decreases. If water prices do not change with PSP, then increased access would suggest that there were instead improvements in service availability and/or water and service quality following PSP. Wallsten and Kosec (2008) showed that PSP did not appear to affect the level of contaminants in the drinking water supply in the United States. If this finding holds in Africa (an unresolved question for future research), then PSP may be associated with higher access to piped water and lower diarrheal disease rates purely due to improvements in service quality and the elimination of administrative stumbling blocks and waiting periods faced by those desiring a piped water connection (and able and willing to pay for it).

When both sub-national region and year fixed effects are included (columns 5-8), an additional dollar per capita per year of World Bank water sector spending over the last five years initially appears to have a significant positive impact on access rates to water. However, while the coefficient remains positive, the significance goes away once we add additional control variables (arriving at the baseline specification of column 8). Among the other control variables, a country's Human Development Index (HDI) seems to matter for access rates; a 10 point increase in a country's HDI is associated with an 8 percentage point increase in the urban access rate to piped water. This finding is significant at the 1%

level and suggests that access to water infrastructure closely tracks incomes and educational levels. Additionally, an increase in population density of 10 more people per square mile is associated with a 4 percentage point decrease in the urban access rate to piped water. This finding is significant at the 5% level, and is consistent with a story of increasing density of the population straining infrastructure resources and thus reducing consumer access to a piped water source.

While the analysis of this section is by no means comprehensive, it does support the theory that PSP in water is associated with lower diarrheal disease prevalence because consumer access to piped water is expanding under PSP. The question of the mechanism by which access increases (whether by a reduction in prices, an increase in water quality, or increased service availability and quality) remains an open question for future research. One thing that is clear is that, to the extent that PSP does lower the diarrheal disease rate in young children—even if it has few other positive impacts, or a host of negative impacts on consumers—it represents a clear redistribution of "health resources" to children. While one could argue that the redistribution could be achieved by more efficient means, it is valuable to know of one means by which child health might be improved, in case more efficient means are not possible. That is, PSP may be a solution to underinvestment in child health.

7 Conclusion

The findings of this paper suggest that policymakers have reason to be optimistic about the potential of PSP in the piped water sector to improve child health in Africa. This paper uses a novel panel dataset of the sub-national regions of 26 African countries over 1985-2006 to shed light on the health effects of PSP in Africa. An initial fixed effects analysis reveals that both PSP and World Bank sewerage sector lending are associated with lower diarrheal disease rates in young children. An instrumental variables analysis that uses two novel instruments produces results that are similar, but larger in magnitude. The paper finds evidence that the introduction of PSP is associated with a decrease in diarrheal disease among under-five children of between 19.9 and 24.2 percentage points. This finding holds after controlling for World Bank water and sewerage sector lending, United Nations multilateral aid flows, a country's Human Development Index (HDI) score, population density, and other controls including sub-national region fixed effects and year fixed effects. Additionally, World Bank lending is associated with lower diarrheal disease rates; a $1 increase in average annual per capita World Bank sewerage sector loans over the previous 5 years is associated with a drop in diarrheal disease prevalence of between 12 and 13 percentage points. PSP in the water sector also appears to be associated with higher rates of access to piped water, measured by the fraction of the population relying primarily on piped water as their water source. Interestingly, while PSP appears to benefit lower and middle class children the most, World Bank sewerage sector lending appears to benefit middle and upper class children the most. This suggests that critics of PSP may be ignoring an important factor when launching attacks against PSP: the health of young children.

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Table 1: Selected Water Related Morbidity and Mortality

Diseases	Estimated Morbidity (episodes per year or people infected)	Estimated Mortality (deaths per year)	Relationship of Disease to Water and Sanitation Conditions
Diarrheal diseases	1,000,000,000	2,200,000 to 5,000,000	Strongly related to unsanitary excreta disposal, poor personal and domestic hygiene, unsafe drinking water
Intestinal helminths	1,500,000,000 (people infected)	100,000	Strongly related to unsanitary excreta disposal, poor personal and domestic hygiene
Schistosomiasis	200,000,000 (people infected)	200,000	Strongly related to unsanitary excreta disposal and absence of nearby sources of safe water
Dracunculiasis	150,000 (in 1996)	---	Strongly related to unsafe drinking water
Trachoma	150,000,000 (active cases)	---	Strongly related to lack of face washing, often due to absence of nearby sources of safe water
Poliomyelitis	114,000	---	Related to unsanitary excreta disposal, poor personal and domestic hygiene, unsafe drinking water
Trypanosomiasis	275,000	130,000	Related to the absence of nearby sources of safe water

Source: Pacific Institute Research Report (2002), Peter Gleick, "Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020."
Notes: This Table excludes mortality and morbidity associated with water-related insect vectors, such as malaria, onchocerciasis, and dengue fever.

Table 2: Prevalence of Piped Water in Urban vs. Rural Households

Country and Survey Year	Urban Households	Rural Households
Benin 1996	58.7	15.1
Benin 2001	67.5	30.1
Burkina Faso 1992/93	66.3	4.8
Burkina Faso 1998/99	72.7	2.0
Burkina Faso 2003	88.5	4.0
Cameroon 1991	68.7	12.6
Cameroon 1998	74.6	18.2
Cameroon 2004	69.3	12.6
CAR 1994/95	43.1	1.5
Chad 1996/97	23.3	4.3
Chad 2004	41.9	2.6
Comoros 1996	73.7	40.9
Congo (Brazzaville) 2005	86.8	8.0
Cote d'Ivoire 1994	78.2	24.7
Cote d'Ivoire 1998/99	79.1	30.4
Eritrea 1995	59.7	8.1
Eritrea 2002	67.0	18.2
Ethiopia 2000	80.8	5.3
Ethiopia 2005	90.1	12.5
Gabon 2000	93.1	19.1
Ghana 1993	75.8	12.8
Ghana 1998	84.0	15.7
Ghana 2003	72.4	10.8
Guinea 1999	63.7	4.1
Guinea 2005	68.0	3.3
Kenya 1993	87.3	19.6
Kenya 1998	84.1	18.6
Kenya 2003	71.2	18.5
Lesotho 2004	90.4	53.1
Madagascar 1992	76.9	5.2
Madagascar 1997	56.0	4.6
Madagascar 2003/2004	64.5	13.9
Malawi 1992	82.1	18.0
Malawi 2000	83.5	13.8
Malawi 2004	74.4	9.1
Mali 1995/96	49.3	2.7
Mali 2001	58.9	17.1

Mauritania 2000/01	77.9	22.5
Mozambique 1997	70.5	8.6
Mozambique 2003	59.1	5.0
Namibia 1992	96.4	34.7
Namibia 2000	97.9	40.3
Niger 1992	61.3	6.5
Niger 1998	63.9	7.9
Niger 2006	90.8	8.3
Nigeria 1999 (1)	49.8	13.2
Nigeria 2003	33.0	8.5
Rwanda 1992	69.4	19.7
Rwanda 2000	76.0	27.9
Rwanda 2005	55.4	22.6
Senegal 1992/93	84.1	19.7
Senegal 1997	84.4	24.4
Senegal 2005	89.2	40.3
South Africa 1998	97.9	57.7
Tanzania 1992	77.8	19.2
Tanzania 1996	77.8	25.1
Tanzania 1999	80.1	22.3
Tanzania 2004	67.7	23.6
Togo 1998	74.9	20.2
Uganda 1995	44.6	1.1
Uganda 2000/01	63.3	1.6
Uganda 2006	59.4	7.2
Zambia 1992	89.2	10.5
Zambia 1996	80.6	7.0
Zambia 2001/02 (2)	81.7	6.5
Zimbabwe 1994	97.4	17.6
Zimbabwe 1999	98.4	17.4
Zimbabwe 2005/06	97.2	11.8
Egypt 1992	97.2	64.2
Egypt 1995	96.6	69.4
Egypt 2000	99.0	75.9
Egypt 2005	98.8	88.3
Morocco 1992	94.1	17.5
Morocco 2003-2004 (3)	96.0	30.8
AVERAGE:	75.1	19.2

Source: Measure DHS Stat Compiler (2008).

Table 3: List of Surveys

Country	Sub-National Regions Included	Survey Years Included
Benin	Atacora, Atlantique, Borgou, Mono, Queme, Zou	1996, 2001, 2006
Burkina Faso	Ouagadougou, North, East, West, Central-South	1993, 1999, 2003
Cameroon	Yaounde, Douala, Adamaoua, Centre excluding Yaounde, Est, Extreme-Nord, Littoral excluding Douala, Nord, Nord-Quest, Quest, Sud, Sud-Quest	*1996, 2001* (PS)
Cameroon	North/Extreme North/Adamaoua, Central/South/East, West and Littoral, Northwest and Southwest	1991, 1998, 2004
Central Africa Republic	Bangui, Ombelia M'poko, Lobaye, Mambere Kadei, Sangha Mbaere, Nana Mambere, Ouham Pende, Ouham, Kemo, Nana Gribizi, Bamingui Banoran, Ouaka, Basse Kotto, Mbomou, Haute Kotto, Haut Mbomou, Vakaga	*1992, 2000* (MICS)
Chad	Borkou-Ennedi-Tibesti, Chari-Baguirmi, Lagone Occidental, Mayo Kebi, Moyen Chari, Ouaddai, Ndjamna	1997, 2004
Djibouti	Djibouti city, Ali Sabih, Dikhil, Obock, Tadjoura	*1996, 2002* (PS)
Egypt	Cairo, Alexandria, Port Said, Suez, Damietta, Dakhalia, Sharkia, Kalyubia, Kafr El-sheikh, Gharbia, Menoufia, Behera, Ismailia, Giza, Beni Suef, Fayoum, Menya, Assuit, Souhag, Qena, Aswan	1992, 1995, 2000, 2003, 2005
Ethiopia	Tigray, Afar, Amhara, Oromiya, Somali, Ben-Gumz, Snnp, Gambela, Harari, Addisa Beba, Dire Dawa	2000, 2005
Ghana	Western, Central, Greater Accra, Eastern, Volta, Ashanti, Brong Ahafo, Northern, Upper East, Upper West	*1992, 1998* (LSMS)
Ghana	Western, Central, Greater Accra, Eastern, Volta, Ashanti, Brong Ahafo, Northern, Upper East, Upper West	1993, 1998 2003
Guinea	Conakry	1999, 2005
Guinea Bissau	Bissau, Bafata, Gabu, Biombo, Cacheu, Oio, Bolama, Quinara, Tombali	*1993, 2000* (IES)
Ivory Coast	Abidjan, all other cities, Eastern Forest - rural, Western Forest - rural, Savanna – rural, Center, Center North, North East, Center East, South, South West, Center West, West, North West, North	*1985* and *1988* (LSMS), *1992* and *1998* (PS)
Ivory Coast	Center, Center North, North East, Center East, South, South West, Center West, West, North West, North	1994, 1999
Kenya	Nairobi, Central, Coast, Eastern, Nyanza, Rift Valley, Western	1993, 1998, 2003
Madagascar	Antananarivo, Fianarantsoa, Toamasina, Mahajanga, Toliary, Antsiranana	1992, 1997, 2004
Malawi	Northern, Central, Southern	1992, 2000,

		2004
Mali	Bamako, Kayes and Koulikoro, Sikasso and Segou, Mopti-Gao-Tombboucto	1987, 1996, 2001, 2006
Morocco	Casablanca and Rabat	1992, 2004
Mozambique	Niassa, Cabo Delgado, Nampula, Zambezia, Tete, Manica, Sofala, Inhambane, Gaza, Maputo province, Maputo city	1997, 2003
Namibia	Northwest, Northeast, Central, South	1992, 2000
Niger	Niamey, Dosso, Maradi, Agadez-Tahousa, Tillaberi, Diffa-Zinda	1992, 1998, 2006
Nigeria	Akwaibom, Anambra, Bauchi, Benue, Borno, Crossriver, Imo, Kaduna, Kano, Katsina, Kwara, Lagos, Niger, Ogun, Ondo, Oyo, Plateau, Rivers, Sokoto, Abuja	1990, 1999, 2003
Rwanda	Ville de Kigali, Kigali Rurale, Gitarama, Butare, Gikongoro, Cyangugu, Kibuye, Gisenyi, Ruhengeri, Byumba, Umutara, Kibungo	2000, 2005
Senegal	Dakar, Ziguinchor, Diourbel, Saint-Louis, Tambacounda, Kaolack, Thies, Louga, Fatick, Kolda	1993, 1997, 1999
Tanzania	Dodoma, Arusha, Kilimanjaro, Tanga, Morogoro, Pwani, Dar es Salam, Lindi, Mtwara, Ruvuma, Iringa, Mbeya, Singida, Tabora, Rukwa, Kigoma, Shinyanga, Kagera, Mwanza, Zanzibar, Pemba	1992, 1996, 1999, 2004
Uganda	Central, Eastern, Northern, Western, Kampala	1995, 2001, 2006
Zambia	Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, Northern-Western, Southern, Western	1992, 1996, 2002

Note: Italics indicate that a survey is not included in the diarrheal disease regressions, and only in the access and expenditure regressions (the survey type is indicated in parentheses). All region-years included in the diarrheal disease regressions come from DHS surveys and were also included in the water access regressions. Some sub-national regions commonly analyzed separately have been combined into a single region for ease of comparing surveys from different years, since some surveys analyze all sub-national regions separately while others aggregate some of them together. Above, a "/" indicates where two or more regions have been combined in order to make regions comparable across survey years. In general, I have used the smallest sub-national regions possible.

Table 4: Description of Private Sector Participation Arrangements in the Water Sector Among Countries in the Dataset

Country	Description of PSP Arrangement, if One Exists
Benin	Publicly owned and operated.
Burkina Faso	A national operator, ONEA, provides water and sanitation services to 41 urban centers in Burkina Faso. In 2001, ONEA signed a 5-year management contract with private firms Veolia and Mazars & Guerard in order to improve its commercial and financial management of the urban water systems of Burkina Faso.
Cameroon	Nation-wide PSP began in 1997. In 2000, Suez Lyonnaise was awarded a 51% stake and a 20-year concession.
Central African Republic	The government of the Central Africa Republic entered into a 15-year lease contract with Saur in 1991.
Chad	The government of Chad entered into a nation-wide, 30 year concession contract in 2000 with Vivendi (Veolia).
Djibouti	In 1996, the government of Djibouti signed a lease contract. In 1999, the urban water system in Djiboutiville was sold to a controlling operator. The privatization was undertaken under the guidance of World Bank staff.
Egypt	Publicly owned and operated.
Ethiopia	Publicly owned and operated.
Ghana	In 2005, the national water firm, Ghana Water Company Limited (GWCL), signed a 5-year management contract with Aqua Vitens Rand Ltd. (AVRL) covering urban Ghana. AVRL is a joint venture of the public Dutch company Vitens Rand water services BV and Aqua Vitra Ltd. The aim of the contract is to improve sector performance and rehabilitate and extend the infrastructure.
Guinea	In 1989, the government introduced PSP into the water system in Conakry via a 10-year lease to Saur. The government retained ownership of the assets, but a private firm began paying a leasing fee in return for "rental" of the intrastructure assets and was responsible for operating the system and billing and collecting revenue. According to Bayliss (2002), between 1989 and 1996, the connection rate to piped water rose from 38% to 47%, the number of employees per 1,000 connections was more than halved, metering of consumers' water usage increased from 5% to 98% of customers, and water and service quality reportedly increased.
Guinea Bissau	In 1995, the government of Guinea Bissau entered into a management contract with a private firm.
Ivory Coast	The government entered into a management contract in 1960 with the French firm Saur. In 1987, the contract was renegotiated for 20 years. Many speculate that a performance contract will soon be added in an attempt to emulate the successful Senegalese system.
Kenya	In 1999, the government signed a 10-year management contract with Vivendi to offer water billing and revenue management services to the water system serving Nairobi.
Madagascar	Publicly owned and operated.
Malawi	Publicly owned and operated.
Mali	In 1994, national operator EDM was in critical shape, with poor service, low coverage rates, and a troubled financial position. The government entered into a management contract in 1995, but it was terminated early (in 1998). Saur won a 20-year national concession contract in January 2001 to distribute water in Mali.

Morocco	In 1997, the government signed a 30 year concession contract with LYDEC (Suez) covering Casablanca. In 1999, the government signed a 30-year concession contract with Redal (Veolia) covering Rabat.
Mozambique	Between 2000 and 2004, the World Bank gave a 115 million dollar loan to Mozambique. The loan required that privatization occurr in all major cities. Consequently, all areas except Niassa, Tete, Manica, Inhambane, and Gaza came under a private management contract in 1999 with the company Saur. These excluded systems have yet to introduce PSP. Following the withdrawal of Saur, Aguas de Portugal was left with a 73% stake in the water system.
Namibia	Publicly owned and operated.
Niger	In 2001, the government granted a 10-year lease contract to the French Multinational Veolia. Despite PSP, the government continued to make investments in extension of the network, with the use of development bank loans. Several consumer organizations have claimed water was cheaper and more readily available before privatization.
Nigeria	Publicly owned and operated.
Rwanda	In 2003, the government of Rwanda awarded a 5-year contract to Lahmeyer International, the German management consultants, to take over management of Electrogaz, the national electricity and water utility.
Senegal	In 1996, the government undertook a nation-wide PSP arrangement that involved a 10 year affermage contract with limited investment obligations. The companies involved were the international firm Saur and local private investors. The objective of the privatization was to improve overall management, with a particular focus on reducing unaccounted-for-water (leakage) and collection rates from customers. The PSP affected only urban areas of the country.
Tanzania	In 2003, the government signed a 10 year lease contract with the firms Biwater and Gauff to take control of the water sector in Dar es Salam. The government terminated the contract in May 2005, and the operator took the decision to court.
Uganda	The government had a limited management contract for the operations of Kampala's water supply for 1997-2001. The government entered into a more extensive management contract covering other urban centers of Uganda (51 towns) in 2002.
Zambia	In January 2001, the government entered into a 4-year management contract in Copperbelt Province with Saur. Proposals to switch to a deeper PSP arrangement (via a 10-year lease contract for this province) by World Bank consultants were turned down. There is talk of a future lease contract for Lusaka, but the future of PSP in Zambia is uncertain.

Sources: Hall, David and Emanuele Lobina (2006); Bayliss, Kate (2002); German Development Cooperation (2005); newspaper article and literature review.

Table 5A
Variable Descriptions and Descriptive Statistics

Variable	Description	Mean	S.D.	Min.	Max.	Obs.
Panel A: Variables from Dataset Used in Child Health Regressions						
ddp	Diarrheal disease prevalence in urban areas among children 5 and under	0.173	0.090	0	0.518	549
ddp, no education	Diarrheal disease prevalence in urban areas among children 5 and under, households where head has no education	0.189	0.128	0	0.744	375
ddp, primary education	Diarrheal disease prevalence in urban areas among children 5 and under, households where head has primary education and no more	0.179	0.120	0	0.790	471
ddep, secondary+ education	Diarrheal disease prevalence in urban areas among children 5 and under, households where head has secondary or more education	0.160	0.109	0	0.677	465
psp	Dummy for private sector participation in the water sector	0.189	0.392	0	1	549
wbwater	Average annual World Bank water sector loans and grants per capita during previous 5 years, US$	0.400	0.671	0	3.431	549
wbsewer	Average annual World Bank sewerage and solid waste management sector loans and grants per capita during previous 5 years, US$	0.101	0.259	0	1.443	549
hdi	Human Development Index (UNDP)	48.376	10.366	27.200	70.800	549
fridge	Fraction of households that own a refrigerator	0.286	0.296	0	0.997	549
popdens	Population density in the country (people per square mile)	69.707	68.854	2.301	366.343	549
un	UN net multilateral flows per capita (all UN programs, constant 2000 USD)	1.701	1.480	0.203	7.737	549
colonpriv	Fraction of population currently served by a water utility with private sector participation, in the country that originally colonized this country	0.368	0.329	0	0.710	549
colonmkt	Fraction of the world's private water market controlled by the country that originally colonized this country	0.155	0.115	0	0.402	549

Panel B: Variables from Dataset Used in Water Access Regressions						
pipedwater	Fraction of the population that primarily obtains water form a piped water source	0.634	0.307	0	1	711
psp	Dummy for private sector participation in the water sector	0.293	0.455	0	1	711
wbwater	Average annual World Bank water sector loans and grants per capita during previous 5 years, US$	0.342	0.619	0	3.431	711
hdi	Human Development Index (UNDP)	47.468	9.727	27.200	70.800	711
popdens	Population density in the country (people per square mile)	65.363	64.559	2.301	366.343	711

Panel C: Variables from Dataset Used in Diarrheal Disease—Child Mortality Rate Correlation Regressions						
lncmr	Log of under 5 child mortality rate in urban areas (0-100% of live births)	2.311	0.516	0.501	3.316	530
lnddp	Log of diarrheal disease prevalence in urban areas among children 5 and under (0-100% of children)	2.707	0.587	-0.148	3.946	530
hdi	Human Development Index (UNDP)	48.517	10.496	27.200	70.800	530
fridge	Fraction of households that own a refrigerator	0.290	0.299	0	1	530
popdens	Population density in the country (people per square mile)	68.510	68.327	2.301	366.343	530

Table 5B
Correlation Matrix of Key Variables in Diarrheal Disease Dataset

	ddp	ddp - no education	ddp - primary education	ddp - secondary education	psp	wbwater	wbsewer	hdi	fridge	popdens	un	colonpriv	colonmkt
ddp	1.00												
ddp - no education	0.53	1.00											
ddp - primary education	0.61	0.24	1.00										
ddp - secondary education	0.61	0.16	0.26	1.00									
psp	-0.01	-0.02	-0.01	0.02	1.00								
wbwater	0.04	0.04	0.01	0.07	0.31	1.00							
wbsewer	0.03	0.08	0.02	-0.02	-0.18	0.25	1.00						
hdi	-0.15	-0.07	-0.06	-0.14	-0.24	-0.18	-0.04	1.00					
fridge	-0.13	-0.07	-0.05	-0.09	-0.18	-0.26	-0.22	0.80	1.00				
popdens	-0.14	-0.04	-0.08	-0.14	-0.11	-0.04	-0.04	0.10	0.02	1.00			
un	0.15	0.09	0.12	0.04	0.15	-0.02	0.08	-0.28	-0.34	-0.10	1.00		
colonpriv	-0.01	0.02	0.03	-0.07	-0.45	-0.05	0.17	0.50	0.53	0.28	-0.23	1.00	
colonmkt	0.04	0.00	0.01	0.08	0.39	0.20	0.02	-0.12	-0.02	-0.19	0.07	-0.17	1.00

Table 6: OLS, Fixed Effects - Diarrheal Disease Prevalence

Dependent Variable: Diarrheal disease prevalence in urban areas among children 5 and under (% experiencing diarrhea during last 2 weeks)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Dummy for private sector participation in the water sector	-0.052	-0.072	-0.066	-0.070	-0.035	-0.054	-0.053	-0.049
	(3.43)**	(3.45)**	(3.41)**	(2.97)**	(2.10)*	(2.71)**	(2.56)*	(2.17)*
Average annual World Bank water sector loans and grants per capita during previous 5 years, US$		0.011	0.014	0.015		0.014	0.014	0.013
		(1.24)	(1.54)	(1.50)		(1.58)	(1.56)	(1.33)
Average annual World Bank sewerage and solid waste management sector loans and grants per capita during previous 5 years, US$		-0.057	-0.062	-0.059		-0.070	-0.072	-0.075
		(3.60)**	(3.85)**	(3.81)**		(3.53)**	(3.77)**	(3.79)**
Human Development Index (1-100)			-0.003	-0.003			0.001	0.001
			(1.73)+	(1.68)+			(0.59)	(0.43)
Fraction of urban households that own a refrigerator (0-1)			0.019	0.024			-0.014	-0.022
			(0.31)	(0.37)			(0.22)	(0.32)
Population density (people per square mile)				0.0003				-0.00005
				(0.34)				(0.51)
UN net multilateral flows per capita (all UN programs, constant 2000 USD)				-0.001				0.002
				(0.19)				(0.28)
Constant	0.182	0.187	0.321	0.323	0.183	0.194	0.136	0.173
	(63.77)**	(54.73)**	(4.53)**	(4.26)**	(23.67)**	(23.60)**	(1.32)	(1.56)
Observations	549	549	549	549	549	549	549	549
Number of Sub-national Regions	208	208	208	208	208	208	208	208
Sub-national Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
R-squared	0.04	0.07	0.08	0.08	0.21	0.24	0.24	0.24

Robust t statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%.

Table 7: Original Colonizers of African Countries in the Sample

African Country	Original European Colonizer
Benin	France
Burkina Faso	France
Cameroon	Germany
Central African Republic	France
Chad	France
Cote d'Ivoire	France
Djibouti	France
Egypt	UK
Ethiopia	Italy
Ghana	UK
Guinea	France
Guinea Bissau	Portugal
Kenya	UK
Madagascar	France
Malawi	UK
Mali	France
Morocco	France
Mozambique	Portugal
Namibia	Germany
Niger	UK
Nigeria	UK
Rwanda	Germany
Senegal	France
Tanzania	Germany
Uganda	UK
Zambia	UK

Source: African Echo, 2006 (http://http//www.africanecho.co.uk/index.html)

Table 8: IV with Fixed Effects – Diarrheal Disease Prevalence

Dependent Variable: Diarrheal disease prevalence in urban areas among children 5 and under (% experiencing diarrhea during last 2 weeks)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Instrument A: Fraction of colonizer country population that receives water from a private firm (local or foreign)				**Instrument B:** Fraction of world's private water market controlled by the country that originally colonized this country				**Instruments A and B**			
Dummy for private sector participation in the water sector	-1.028	-0.411	-0.436	-0.440	-0.119	-0.199	-0.199	-0.199	-0.151	-0.241	-0.242	-0.242
	(0.83)	(2.04)*	(1.96)+	(1.93)+	(2.94)**	(3.60)**	(3.53)**	(3.52)**	(3.76)**	(4.56)**	(4.48)**	(4.46)**
Average annual World Bank water sector loans and grants per capita during previous 5 years, US$		0.134	0.142	0.146		0.063	0.063	0.064		0.077	0.077	0.079
		(1.93)+	(1.87)+	(1.83)+		(3.21)**	(3.17)**	(3.13)**		(3.87)**	(3.84)**	(3.78)**
Average annual World Bank sewerage and solid waste management sector loans and grants per capita during previous 5 years, US$		-0.221	-0.227	-0.193		-0.131	-0.131	-0.120		-0.149	-0.149	-0.133
		(2.37)*	(2.29)*	(2.44)*		(4.05)**	(4.10)**	(4.31)**		(4.36)**	(4.34)**	(4.42)**
Human Development Index (1-100)			-0.003	-0.001			-0.0002	0.0004			-0.001	0.0002
			(0.71)	(0.15)			(0.09)	(0.15)			(0.26)	(0.08)
Fraction of urban households that own a refrigerator (0-1)			-0.061	0.004			-0.032	-0.012			-0.037	-0.009
			(0.66)	(0.04)			(0.50)	(0.18)			(0.55)	(0.13)
Population density (people per square mile)				0.004				0.001				0.002
				(1.40)				(1.17)				(1.59)
UN net multilateral flows per capita (all UN programs, constant 2000 USD)				-0.014				-0.004				-0.006
				(0.86)				(0.51)				(0.67)
Observations	516	516	516	516	516	516	516	516	516	516	516	516
Number of Sub-national Regions	175	175	175	175	175	175	175	175	175	175	175	175
Sub-national Region Fixed Effects and Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cragg-Donald F Statistic (test for weak instruments)	1.027	8.523	7.350	7.836	72.144	45.800	44.592	49.211	39.639	31.765	30.535	33.252
Anderson Canonical Correlations LR Statistic	1.069	8.827	7.673	8.224	67.983	44.956	45.125	48.637	74.227	61.056	59.221	64.388
t-statistic, first stage regression, instrument A	0.82	2.30	2.17	2.08					1.88	2.91	2.81	2.75
t-statistic, first stage regression, instrument B					7.33	6.16	5.78	5.99	7.85	6.64	6.28	6.52
Hanson J Statistic									6.850	1.591	1.735	1.788
Hanson J Statistic Chi-squared p-value									0.0089	0.2072	0.1878	0.1812

Robust z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%

Table 9: IV with Fixed Effects – Diarrheal Disease Prevalence by Class

Dependent Variable: Diarrheal disease prevalence in urban areas among children 5 and under (% experiencing diarrhea during last 2 weeks)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Instruments A and B				Instrument B			
	All households	No education	Primary education	Secondary or more education	All households	No education	Primary education	Secondary or more education
Dummy for private sector participation in the water sector	-0.242	-0.267	-0.288	-0.202	-0.199	-0.270	-0.324	-0.194
	(4.46)**	(2.62)**	(3.45)**	(3.32)**	(3.52)**	(2.75)**	(3.56)**	(2.61)**
Average annual World Bank water sector loans and grants per capita during previous 5 years, US$	0.079	0.092	0.095	0.078	0.064	0.093	0.107	0.075
	(3.78)**	(2.80)**	(3.22)**	(3.71)**	(3.13)**	(3.24)**	(3.34)**	(3.10)**
Average annual World Bank sewerage and solid waste management sector loans and grants per capita during previous 5 years, US$	-0.133	-0.059	-0.182	-0.138	-0.120	-0.060	-0.195	-0.137
	(4.42)**	(1.11)	(3.97)**	(3.85)**	(4.31)**	(1.11)	(4.05)**	(3.84)**
Human Development Index (1-100)	0.0002	-0.002	-0.007	-0.004	0.0004	-0.002	-0.007	-0.004
	(0.08)	(0.40)	(1.41)	(1.26)	(0.15)	(0.39)	(1.41)	(1.25)
Fraction of urban households that own a refrigerator (0-1)	-0.009	-0.010	0.021	0.039	-0.012	-0.009	0.022	0.037
	(0.13)	(0.06)	(0.20)	(0.50)	(0.18)	(0.05)	(0.20)	(0.47)
Population density (people per square mile)	0.002	0.0002	0.002	0.001	0.001	0.0002	0.003	0.001
	(1.59)	(0.06)	(1.32)	(0.79)	(1.17)	(0.08)	(1.50)	(0.63)
UN net multilateral flows per capita (all UN programs, constant 2000 US$)	-0.006	-0.028	0.009	0.012	-0.004	-0.028	0.008	0.013
	(0.67)	(1.31)	(0.64)	(1.10)	(0.51)	(1.32)	(0.55)	(1.13)
Observations	516	327	420	414	516	327	420	414
Number of Sub-national Regions	175	114	137	142	175	114	137	142
Sub-national Region Fixed Effects and Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cragg-Donald F Statistic (for test of weak instruments)	33.252	37.978	24.166	31.074	49.211	41.786	37.649	43.150
Anderson Canonical Correlations LR Statistic	64.388	70.998	47.911	60.173	48.637	41.744	37.862	42.990
t-statistic, first stage regression, instrument A	2.75	3.17	2.32	2.54				
t-statistic, first stage regression, instrument B	6.52	7.26	5.56	6.39	5.99	5.98	5.06	5.82
Hanson J Statistic	1.788	0.002	0.695	0.038				
Hanson J Statistic Chi-squared p-value	0.1812	0.9683	0.4044	0.8455				

Robust z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%.

Table 10: OLS, Fixed Effects – Usage of a Piped Water Source

Dependent Variable: Fraction of urban population that primarily obtains water from a piped water source	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Dummy for private sector participation in the water sector	0.071	0.068	0.063	0.108	0.047	0.029	0.035	0.061
	(3.42)**	(2.71)**	(2.49)*	(3.84)**	(1.60)	(0.92)	(1.08)	(1.99)*
Average annual World Bank water sector loans and grants per capita during previous 5 years, US$		0.003	0.001	-0.009		0.021	0.016	0.003
		(0.20)	(0.07)	(0.62)		(1.66)+	(1.23)	(0.25)
Human Development Index (1-100)			0.002	0.009			0.008	0.008
			(1.53)	(4.39)**			(2.99)**	(2.93)**
Population density (people per square mile)				-0.005				-0.004
				(3.22)**				(2.12)*
Constant	0.616	0.616	0.508	0.499	0.613	0.602	0.234	0.483
	(117.80)**	(112.96)**	(7.01)**	(7.07)**	(20.60)**	(18.03)**	(1.87)+	(3.20)**
Observations	711	711	711	711	711	711	711	711
Number of Sub-national Regions	258	258	258	258	258	258	258	258
Sub-national Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
R-squared	0.02	0.02	0.03	0.06	0.11	0.12	0.13	0.14

Robust t statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%

Table 11: OLS, Fixed Effects – Correlation Between Urban Child Mortality and Diarrheal Disease Prevalence

Dependent Variable: Log of child mortality rate in urban areas	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Natural log of diarrheal disease prevalence in urban areas	0.082	0.056	0.057	0.080	0.091	0.101
	(1.98)*	(1.36)	(1.37)	(1.54)	(1.83)+	(2.00)*
Human Development Index (1-100)		-0.020	-0.022		-0.023	-0.021
		(2.96)**	(3.08)**		(2.36)*	(2.15)*
Fraction of urban households that own a refrigerator (0-1)		-1.011	-1.005		-1.092	-1.038
		(2.97)**	(2.96)**		(3.36)**	(3.27)**
Population density (people per square mile)			0.001			0.008
			(0.64)			(3.04)**
Constant	-2.140	-0.903	-0.901	-2.010	-0.681	-1.243
	(27.12)**	(3.52)**	(3.51)**	(20.48)**	(1.57)	(2.66)**
Observations	520	520	520	520	520	520
Number of Sub-national Regions	202	202	202	202	202	202
Sub-national Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	No	No	No	Yes	Yes	Yes
R-squared	0.02	0.23	0.23	0.22	0.32	0.33

Robust t statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%.
Clustered standard errors used.