An Empirical Analysis of State and Private-Sector Provision of Water Services in Africa

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Under pressure from donor agencies and international financial institutions such as the World Bank, some developing countries have experimented with the privatization of water services. This article reviews the econometric evidence on the effects of water privatization in developing economies and presents new results using statistical data envelopment analysis and stochastic cost frontier techniques and data from Africa. The analysis fails to show evidence of better performance by private utilities than by state-owned utilities. Among the reasons why water privatization could prove problematic in lower-income economies are the technology of water provision and the nature of the product, transaction costs, and regulatory weaknesses.

The provision of safe and affordable water services is a priority for most developing economies. According to the World Bank (2003, p. 1), more than 1 billion people in the developing world lack access to clean water and nearly 1.2 billion lack access to adequate sanitation services. An estimated 12.2 million people die each year of diseases directly related to drinking contaminated water. The inclusion of a water access target in the Millennium Development Goals—to halve the proportion of people without access to safe drinking water by 2015—is a recognition of the importance of safe water supply in reducing poverty in the developing world (Calderon and Serven 2004).

A major cause of poor access to water services in developing countries is the inefficiencies of water utilities, which serve mainly urban areas. In many systems, as much as a third of production is lost, revenues are insufficient to cover operating costs, and the quality of the water is poor (World Bank 2004b, p. 220). Faced with the deterioration in water sector performance, and with

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most water utilities under public ownership, donor agencies have advocated privatization to promote more efficient operation, increase investment and service coverage, and reduce the financial burden on government budgets (World Bank 1995).

A range of services including water supply have now been opened up to private capital (Harris 2003; World Bank 2003). Private participation has been less common in water systems, however, than in other infrastructure sectors, and the pace of reform has been slower and harder to sustain politically (World Bank 2004b, p. 220). Although privatization appears to have the potential to improve water services and meet the needs of the poor, these goals may be difficult to achieve. The technology of water provision (high fixed costs and location specificity) severely restricts prospects for competition, the transaction costs of organizing long-term concession agreements are considerable, and regulatory weaknesses suggest the need for caution. There is also the difficulty of balancing adequate returns to investors and ensuring that water services remain affordable to the poor.

The challenge for public policy is to meet both efficiency and social welfare objectives and to determine whether or to what extent privatization is critical to achieving the Millennium Development Goal for safe, accessible, and affordable water services. This article explores these issues by examining the impact of privatization of water services in Africa. It reviews the econometric evidence on the impact of water privatization and then, for a data set for African water utilities, uses statistical data envelope analysis and stochastic cost frontier measures to triangulate the evidence and assess consistency across results.[1] While data availability restricted the number of dimensions of performance that could be estimated, the results for cost efficiency and service quality fail to show that privatized water utilities perform better than state-run utilities. The data deficiency may explain the failure to identify better performance under private operation. However, special difficulties that face privatization and regulation in water services, also examined, likely play a role.

I. Evidence to Date

Private water suppliers have long been active as water vendors at the street level in all developing countries, but there was little privatization of piped water services before 1990 (Snell 1998; Collignon and Vézina 2000). Privatized services could be found in only a few countries, generally French-speaking former colonies such as Côte d'Ivoire that had inherited a reliance on private firms for water services, as is the practice in France. Between 1984 and 1990, only eight contracts for water and sewerage projects were awarded to the private sector

1. As Bauer *et al.* (1998) emphasize, there can be greater confidence in comparative analysis if different measurements produce reasonably consistent conclusions.

worldwide, and cumulative new capital expenditure in private water services totaled less than $1 billion.

During the 1990s, however, there was a significant increase in water privatization, stimulated by donor agency pressures, and in 1997 private investment had risen to $25 billion (World Bank 2003). By the end of 2000, at least 93 countries had privatized some of their piped water services, including Argentina, Chile, China, Colombia, the Philippines, South Africa, the transition economies of Central Europe, and, among industrial countries, Australia and the UK (Brubaker 2001). Based on the World Bank Private Participation in Infrastructure (PPI) Database for the period 1990–2002, there were 106 such projects in Latin America and the Caribbean and 73 in East Asia and Pacific, but only seven projects in the Middle East and North Africa, and 14 in Sub-Saharan Africa. Latin America and the Caribbean and East Asia and Pacific together accounted for more than 95 percent of total investment. During 1990–2002, a small number of countries accounted for most of the privatization of water services, and within these countries, the totals were dominated by a few large contracts (table 1). In Argentina, one project accounted for $4.9 billion, or 20 percent, of all private investment in water services in Latin America, and in the Philippines five contracts accounted for 38 percent of the investments in East Asia.

Studies of privatization have found that competition is generally more important than ownership itself in explaining improvements in performance in developing countries (Zhang, Kirkpatrick, and Parker 2003; Parker and Kirkpatrick 2005). But whereas competition is feasible in telecommunications and parts of energy supply, such as generation, it is usually cost inefficient in the market for water services. While there is scope for introducing some competition into billing and metering and construction, replacement, and repair work within water services, competition in the provision of water supplies is normally ruled out by the scale of the investment in network assets that is needed to deliver the

TABLE 1. Largest Investments in Water Services in Developing Countries, 1990–2002

Country	Value (US$ Billions)	Number of Projects
Argentina	7.23	10
Philippines	5.87	5
Chile	3.95	13
Brazil	3.17	33
Malaysia	2.75	6
China	1.93	44
Romania	1.04	3
Turkey	0.94	2
Indonesia	0.92	8

Source: Authors' analysis using data from the World Bank PPI Database (http://rru.worldbank.org/PPI).

product. Moreover, even where competition for consumers might seem feasible, for example, at the boundaries between different water utilities, the costs of moving water down pipes is far higher than the costs of transmitting telephone calls and distributing electricity, placing a serious limitation on competition. Also, mixing water from different sources can affect water quality, an important consideration for domestic consumers and especially for water-using industries, such as brewing and food processing. In other words, the technology of water supply and the nature of the product severely restrict prospects for competition in the market and therefore the efficiency gains that can result from encouraging competition following privatization. This leaves rivalry under privatization taking the form mainly of competition for the market or competition to win the contract or concession agreement.

Evidence suggests that privatization in noncompetitive markets produces ambiguous results in terms of improving economic performance (Megginson and Netter 2001), highlighting the need for effective regulation of privatized utilities. The institutional requirements to ensure that privatized monopolies perform well—an effective system of state regulation and supporting governance structures—are likely to be missing in many developing countries (Parker and Kirkpatrick 2005). This represents a further difficulty to significantly improving performance in the short term through water privatization.

Privatized water services contracts can be set up as service contracts for specialized services (such as billing), management contracts and leases for existing facilities (operating existing facilities without new private-sector investment), concessions (requiring private-sector investment in facilities), divestitures (sale by the state of some or all of the equity in state enterprises), and greenfield investments (including build-operate-transfer schemes) (Johnstone and Wood 2001; World Bank 2004b). The most common are contracts under which private firms provide the services, but the government remains the ultimate owner of the water system and may remain responsible for some investment (OECD 2003). Of 233 water and sewerage contracts with the private sector during 1990–2002 included in the World Bank's PPI Database, 40 percent involved concession contracts, accounting for 64 percent of total investment. Greenfield projects, less common, have often involved the building and operation of new water treatment plants, as in China, and build-operate-transfer schemes for water supplies have been used in Latin America and the Caribbean. Sales of state-owned water businesses to the private sector have been rare, accounting for only 15.6 percent of water projects and 8 percent of the total funds invested.

Although privatization of water services has occurred, it is important not to exaggerate its importance. Little more than 5 percent of the world's population receives drinking water through private operators (OECD 2003), and since the Asian economic crisis of 1997/98, there has been a marked slowdown in infrastructure privatization in lower-income economies (Harris 2003). Moreover, the main forms that water privatization take raise concerns about the transfer of risk from the public to the private sector, an issue discussed later in this article.

The case study evidence on water privatization presents a mixed picture, with some cases showing improvements in labor productivity, operating costs, reliability and quality of services, and share of the population served (Crampes and Estache 1996; Estache, Gomez-Lobo, and Leipziger 2001; Galiani, Gertlier, and Schargrodsky 2002; Shirley and Menard 2002; World Bank 2004b, pp. 252–57). Balanced against these positive findings is some evidence of higher water charges and public opposition leading to canceled schemes. The evidence is reviewed in Kirkpatrick and Parker (2005) and by Shirley (2002). The few published econometric analyses of the effects of water privatization in lower-income economies present little evidence that privatization has resulted in marked improvement in performance. Estache and Rossi (2002) compared private and public water companies in 29 Asia and Pacific region countries using 1995 survey data on 50 water enterprises (22 with some form of private-sector participation) from the Asian Development Bank. Adopting stochastic cost frontier modeling and applying error components and technical efficiency effects models, they conclude that efficiency was not significantly different in the private and state water sectors.

A study by Estache and Kouassi (2002), using a sample of 21 African water utilities during 1995–97, estimated a production function from an unbalanced panel data set and used Tobit modeling to relate resulting inefficiency scores to governance and ownership variables. The study found that private ownership was associated with a lower inefficiency score. However, only three firms in the sample had any private capital, and levels of corruption and governance were far more important in explaining efficiency differences between firms than was the ownership variable.

A study of water supply in Africa in the mid- to late-1990s by Clarke and Wallsten (2002) reported greater service coverage under private ownership. On average, they found smaller supplies for lower-income households (proxied by educational attainment) where there was a state-sector operator. While Clarke and Wallsten conclude that private participation leads to more supplies to poorer households, there may be offsetting service difficulties and higher charges when supplies are privatized. Drawing strong conclusions on the desirability of water privatization based on a single measure, such as service coverage, may be misleading. The analysis below uses a range of performance measures in an attempt to address this problem.

II. Assessing Performance in Privatized African Water Utilities

To advance understanding of the results of privatization in water services, data were taken from the Water Utility Partnership for Capacity Building in Africa's Service Providers' Performance Indicators and Benchmarking Network Project (SPBNET) database, which includes 110 water utilities in Africa. The data collected, usually by questionnaire survey, relate mainly to 2000.[2] The data set used for this study covers 13 countries and 14 utilities that reported private-sector involvement.[3] However, not all of these firms could be included in each stage of the analysis because of incomplete data entries. The descriptive statistics for the sample are given in appendix table A.1.

Suppliers are categorized as either state owned or privately owned, a designation that captures the various institutional options for private-sector involvement in the water sector, including management and leasing contracts. Ideally, the form that private-sector involvement takes would be used to judge the degree of privatization, but the data source permits ownership to be modeled only as a binary variable. This limitation is shared by the earlier econometric studies mentioned above. More generally, the data set is characterized by heterogeneity, small sample size, and a small number of privatized firms. The data limitations mean that the results must be treated as tentative.

Conclusions on the impact of water privatization may be sensitive to the performance measure used. Therefore, to assess the impact of private capital on performance in water services, a range of performance measures were calculated. First, several statistical measures were computed from the data set:

- Labor productivity—ratio of labor costs to total costs, ratio of number of staff to number of water connections, and staff per million cubic meters of water distributed—to reflect the efficiency of labor use.
- Proportion of operating costs spent on fuel and chemicals—to reflect economies in nonlabor operating costs.
- Rate of capital utilization—to reflect capital stock efficiency.
- Average tariffs—to reflect the costs of services to consumers.
- Share of the population served, unaccounted-for water (water losses), and hours of availability of piped water per day—to reflect the quality of service to consumers.

Average figures were computed for both state-owned and privately owned water suppliers for between 61 and 84 utilities depending on the performance measure (table 2). On average, the private sector seems superior in production efficiency. Private-sector water utilities have higher labor productivity (lower ratio of staff to number of connections and amount of water distributed) and a lower share of labor costs in operating costs than do state-owned firms. The

2. The database (http://www.wupafrica.org) was developed with financial and technical support from the UK Department for International Development. Data for a few utilities relate to 1999 or 2001. Given the closeness of the years, all data are treated as applying to 2000 to adopt a cross-sectional analysis of performance.

3. Concession and management and lease contracts, together with privately owned assets, are categorized as private utilities. The utilities classified as private were cross-checked with the World Bank's PPI Database. The countries in the database with private water utilities are Cameroon, Cape Verde, Côte d'Ivoire, Gabon, Ghana, Kenya, Morocco, Nigeria, Republic of Guinea, Senegal, South Africa, Tunisia, and Zambia.

Table 2. Performance Ratios in African Water Utilities, 2000

Performance Indicator	Average for State-Sector Operations (SD)	Average for Private-Sector Operations (SD)	*F*-test for Between-Group Difference in means (Probability Statistics)
Labor productivity			
Labor costs in total costs (percent)	29 (17)	21 (27)	1.45 (0.23)
Number of staff per 1,000 water connections	20.1 (19.9)	13.1 (14.4)	0.22 (0.65)
Number of staff per million cubic meters of water distributed	123 (519.7)	78 (151.8)	0.18 (0.68)
Operating costs (percent)			
Share spent on fuel	20 (16)	11 (12)	0.44 (0.51)
Share spent on chemicals	17 (16)	4 (5)	2.37 (0.13)
Capital			
Capital utilization (percent)	60 (21.6)	67 (21.8)	0.076 (0.79)
Consumer charges			
Average tariff (US$ per cubic meter)	168 (473)	305 (440)	1.9 (0.17)
Share of customers metered (percent)	60 (41.5)	79 (38.4)	1.45 (0.23)
Quality of service			
Share of population served (percent)	63 (29.8)	64 (30.2)	0.22 (0.64)
Unaccounted-for water (percent of total)	34.8 (13.5)	29.0 (13.1)	0.63 (0.43)
Availability of piped water (hours per day)	17 (6.7)	16 (9.3)	0.25 (0.62)

Source: Authors' analysis using data from the Water Utility Partnership for Capacity Building in Africa's Service Providers' Performance Indicators and Benchmarking Network Project database (http://www.wupafrica.org).

private sector is also more economic in its use of other inputs (fuel and chemicals) and achieves a slightly higher capital utilization rate of 67 percent as against 60 percent in the public sector firms.

Charges are on average 82 percent higher in the private sector, and more customers have their water consumption metered under privatized services.[4] Metering water can increase revenues derived from consumers by linking payments to the volume of water used. The private sector also has lower water losses (probably assisted by greater use of metering), averaging 29 percent as against 35 percent for state-owned firms. Other measures of customer service suggest smaller differences between the private and state sectors, however. On average, state-owned firms supply piped water for 17 hours a day, while the private-sector records a slightly lower figure of 16 hours. The state and private sectors serve about the same share of the population in their areas, at 63 and 64 percent, respectively.

The standard deviations show a high degree of variance in performance within both the state and the private-sector categories for each of the measures, implying the need for care in interpreting conclusions based on average performance. Similarly, the *F*-test results for the difference in means for the public and private utilities' performance ratios show that none are statistically significant (table 2). Also, data from the SPBNET database suggest that privately owned water utilities in Africa are on average more than twice as large as state-owned utilities in terms of the total volume of water distributed (92 million cubic meters a day as against 36.4 million cubic meters a day) and have more connections in their systems (averaging 159,600 for private utilities and 94,500 for state-owned firms). This may partially account for the private utilities' somewhat higher labor productivity.

To provide a fuller appraisal of relative performance, two further sets of performance measures were calculated, drawing on the same database, one using stochastic frontier analysis and one using data envelopment analysis.

Stochastic Cost Function Analysis

Because most water utility firms are required to meet demand and so are not free to choose the level of output, the analysis is based on a cost frontier instead of a production frontier. With output set exogenously, the firm is expected to minimize the costs of producing a given level of output. The coefficients of the cost function can be estimated by ordinary least squares (OLS) regression analysis, or a stochastic cost frontier model can be estimated by the maximum likelihood method. The stochastic cost frontier model decomposes the error term into stochastic noise (v_i) and cost inefficiency (μ_i).

Various distributions have been suggested for the inefficiency term in the stochastic cost function. Two of the most commonly used are the half-normal

4. Tariff figures have to be viewed with care since tariff levels are affected by public policy toward subsidies.

distribution (Aigner, Lovell, and Schmidt 1977) and the truncated normal distribution (Stevenson 1980). The truncated normal distribution is a generalization of the half-normal distribution, obtained by truncating the normal distribution at 0, with mean μ and variance σ_{μ}^2. Preassigning μ to be 0 reduces the truncated distribution to half normal. The appropriate model for estimation can be determined by testing the null hypothesis, H_0: $\mu = 0$. If the hypothesis $\mu = 0$ is rejected, the assumption of the truncated distribution is correct. If μ is not significantly different from 0, a model assuming a half-normal distribution should be estimated instead.

As in the parameterization proposed in Battese and Correa (1977), σ_{μ}^2 and σ_{v}^2 are replaced by $\sigma^2 = \sigma_{\mu}^2 + \sigma_{v}^2, \gamma = \sigma_{\mu}^2/(\sigma_{\mu}^2 + \sigma_{v}^2)$, to allow application of maximum likelihood estimates. The parameter γ lies between 0 and 1, with 0 indicating that the deviation from the frontier is due entirely to noise and 1 indicating that the deviation is due entirely to inefficiency. The superiority of a stochastic frontier can be tested by the null hypothesis, H_0: $\gamma = 0$. If the null hypothesis cannot be rejected, this indicates that the inefficiency term should be removed from the model, leaving a specification with parameters that can be consistently estimated using OLS.

The stochastic cost function has been widely specified as a Cobb–Douglas function or as a translog cost function. A generalized likelihood ratio test is used to determine whether a Cobb–Douglas function is appropriate. The result shows that the null hypothesis of the Cobb–Douglas specification cannot be rejected. In addition, Leamer's extreme bound analysis shows that the range of the coefficients of the key variables for the Cobb–Douglas function is much smaller than that of the translog mode, confirming that use of the Cobb–Douglas specification is appropriate.[5] To account for variable returns to scale, the quadratic term of the output variable is included. The coefficient is statistically insignificant, however.[6] A likelihood ratio test also points to the standard Cobb–Douglas specification.

As in the literature, the cost function is estimated using data on the cost level, the output level, and input prices. Operating and maintenance costs (*COST*) are used as the dependent variable in the cost frontier because adequate capital cost data are not available to compute total costs. An arbitrary cost function is therefore formulated that excludes the price of the capital input.[7] Average

5. Leamer's extreme bound analysis was applied to the Cobb–Douglas and the translog specifications. Accordingly, the output and input variables were treated as focus variables and the control variables as doubtful variables. The bounds from the Cobb–Douglas model were much narrower than those from the translog model. In addition, in the translog model, the bound for the material input variable spanned zero. The results suggested that the coefficients for the Cobb–Douglas model were more robust than those for the translog specification.

6. The full results of these tests are available from the authors.

7. Estache and Rossi (2002) follow a similar procedure. In response to a referee's comment that the exclusion of a fixed-capital measure might result in a misspecification of the cost function, an alternative specification of the cost function was tested that used the number of water treatment plants as a proxy variable for capital costs. The results for the ownership variable were unaffected.

personnel cost per employee (*MP*) is used to reflect the cost of labor, and material cost per unit of water distributed (*MAT*) is included as an additional determinant of noncapital costs. The amount of water distributed per year (*WD*) is included in the cost function as the output variable. Also included is a quality variable, measured by the hours of piped water available per day (*QUALI*).[8]

A number of control or environmental variables are also included to capture cross-country heterogeneity in the political, legal, and economic environment.[9] Good governance, in the form of sound finance and regulatory systems and protection of property rights, has been found to be an important explanation for differences in economic performance (North 1990; Jalilian, Kirkpatrick, and Parker 2002; Kaufmann, Kray, and Zoido-Lobatón 2002), including in water services (Estache and Kouassi 2002). The freedom variable (*FRD*) developed by the Fraser Institute (http://www.freetheworld.com) is therefore included to capture wider governance or regulatory effects on performance in water utilities that might otherwise be attributed to ownership. An index of property rights (*PROPERTY*) is used as a measure of the quality of the investment environment (http://www.freetheworld.com). The fiscal balance variable (*BALANCE*) proxies the quality of macroeconomic management (http://www.freetheworld.com). A density variable, measured by population served per connection (*DEN*), drawn from the SPBNET database, is included because it plays an important role in defining the network infrastructure.[10] Annual water resources per capita (*WRS*) is used as another control (WRI 2003). GDP per capita (*GDP*) is included to capture the extent of economic development (World Bank 2002). Finally, a dummy variable (*ONS*) is included to account for the effects of ownership on performance, taking a value of 1 if the utility had private capital.

All variables except the ownership variable and those in index or percentage terms are logged. In total, the estimations include 76 observations, including 10 private-sector operations. The program FRONTIER 4.1 is used to obtain the maximum likelihood estimates of the parameters and efficiency measures. The procedure for estimation is as follows. An error-component model is first estimated with the assumption of a half-normal distribution for the inefficiency term.[11] To

8. Alternative quality indicators (unaccounted-for water and share of samples that fail to meet quality standards) were also tested, with similar results.

9. See Rodrik, Subramanian, and Trebbi (2004) and Glaeser and others (2004) for a discussion of the use of institutional quality variables in quantitative analysis.

10. As pointed out by a referee, this density measure does not fully capture the dispersion of connections since it does not allow for the number of connections per building. Data on more common measures of dispersion, such as connections per kilometer of main lines or connections per square kilometer, were not available.

11. The error component model is the standard form of stochastic frontier model used in the literature. It decomposes the error term into stochastic noise and cost inefficiency. The truncated-distribution assumption yields $\mu = 0.47$, with a standard error of 2.56. A likelihood ratio test shows that the hypothesis $\mu = 0$ could not be rejected at the 10 percent level. Consequently, the results from the model with the half-normal assumption were adopted.

TABLE 3. The Stochastic Cost Frontier Results

Variable	Error-Component Model (Half-Normal Distribution): Ordinary Least Squares	Error-Component Model (Half-Normal Distribution): Maximum Likelihood	Technical Efficiency Effects Model: Ordinary Least Squares	Technical Efficiency Effects Model: Maximum Likelihood
Constant	4.17 (2.60)***	1.18 (1.65)*	4.05 (2.47)**	1.55 (0.29)
lnWD	0.76 (13.22)***	0.88 (29.49)***	0.76 (13.02)***	0.86 (23.97)***
lnQUALI	0.12 (0.81)	0.14 (1.88)**	0.06 (0.38)	0.11 (1.80)**
lnMP	0.26 (3.76)***	0.15 (4.33)***	0.25 (3.62)***	0.17 (5.28)***
lnMAT	0.56 (8.20)***	0.65 (15.84)***	0.56 (7.99)***	0.63 (8.25)***
lnWRS	−0.001 (0.01)	−0.09 (1.48)*	0.0009 (0.01)	−0.08 (0.22)
lnDEN	−0.02 (0.44)	0.00003 (0.001)	−0.028 (0.65)	−0.02 (0.10)
lnGDP	0.09 (0.85)	−0.01 (0.26)	0.15 (1.40)*	−0.03 (0.31)
FRD	−0.13 (1.28)	−0.08 (0.22)	−0.12 (1.18)	−0.02 (0.54)
PROPERTY	−0.11 (1.38)*	−0.05 (4.03)***	−0.13 (1.59)*	−0.06 (1.83)**
BALANCE	0.02 (0.64)	−0.004 (0.32)	0.02 (0.53)	0.004 (0.09)
ONS	0.42 (2.00)**	0.15 (1.05)		0.11 (0.15)
δONS				0.11 (.015)
γ		0.98 (0.63E+07)		0.98 (0.21E+06)
Generalized likelihood ratio test		34.63		44.53
Number of observations	76	76	76	76

*Significant at the 10 percent level.
**Significant at the 5 percent level.
***Significant at the 1 percent level.
Source: Authors' analysis based on data described in text.

test the robustness of the results on ownership, a technical efficiency effects frontier is then estimated in which the inefficiency effects are expressed as a function of the ownership dummy variable.[12]

The value of γ in the error-component model suggests a high ratio of the variance of inefficiency to the total residual variance (0.98; table 3).[13] Analogously, the high value of γ means that the stochastic frontier is superior to OLS modeling in explaining the cost structure of water utilities (both results are presented in table 3, for comparison). This is also confirmed by the generalized likelihood ratio statistic, which exceeds the critical value at the 1 percent level.[14]

The results of the half-normal error-component model show that the output variable, water distributed annually (lnWD), has a positive and significant effect

12. The technical efficiency effects model can be used to investigate the determinants of technical inefficiencies among firms. The technical efficiency effects frontier is a stochastic frontier model that explicitly formulates technical inefficiency effects in terms of firm-specific factors. All parameters are estimated in a single-stage maximum likelihood procedure.

13. A referee has pointed out that the error term may be capturing more than just inefficiency where there is misspecification because of heterogeneity or measurement problems.

14. The critical value was obtained from Kodde and Palm (1986).

on operating costs. This is in line with expectations. Similarly, the variables of service quality (ln*QUALI*), labor price (ln*MP*), and material cost (ln*MAT*) are all significant and correctly signed. The negative and statistically significant (at the 10 percent level) coefficient for the water resource variable (ln*WRS*) is also consistent with expectations. The costs of water production and distribution would be expected to be lower in countries where water resources are abundant. The negative coefficients of income per capita (ln*GDP*) and the freedom index (*FRD*) suggest that the operational costs of the utilities may be lower in countries that are wealthier, with sounder institutional governance. However, the effects are not statistically significant. More robust evidence of the influence of institutional development is provided by the property rights variable (*PROPERTY*), which shows negative and significant effects on the cost level, indicating that costs are lower in countries where property rights and therefore private investment are better protected. The impact of the government fiscal management measure (*BALANCE*) appears to be trivial. Contrary to expectations, however, the results for the density variable (ln*DEN*) are statistically insignificant. The coefficient of the ownership dummy variable (*ONS*) is positive, suggesting that private ownership is associated with higher costs. However, the result is not statistically significant.

To assess the robustness of these results, a technical efficiency effects model is estimated in which the inefficiency term is expressed as a function of the ownership dummy variable. In this model, the inefficiency error, μ_i, has a mean of m_i and $m_i = \delta x_i$, where x_i is a vector of variables that may influence the efficiency of a firm. This is taken as the ownership dummy variable in the estimation. The maximum likelihood estimation shows that the coefficient δ_{ONS} is positive but not statistically significant (table 3). This finding is consistent with the ownership outcome from the error-component model.

The Data Envelopment Analysis

A data envelopment analysis was also undertaken.[15] Water distributed is represented by the volume of output produced, and the number of hours of piped water available per day is used as the proxy for the quality of water services. (Unaccounted-for water and the share of samples that failed to meet the quality standards were also used as a proxy for quality of service, and the results were very similar.) An input-oriented variable returns to scale model was adopted to allow for variations in the size of the utilities.[16] The analysis includes 66 utilities, nine of them private. The inputs are personnel cost per employee (because number of staff would not reflect the average skill level of staff[17]), material cost per unit of water distributed, and number of water treatment works. The efficiency scores from the initial data envelopment analysis are regressed on the control variables (*DEN*, *WRS*, *GDP*, *FRD*,

15. The authors are grateful to Catarina Figueira for assistance with the data envelopment analysis.
16. A constant returns to scale model produced a similar set of results but with lower overall scores.
17. The authors thank a referee for drawing this to their attention.

TABLE 4. Summary of the Data Envelopment Analysis Results

Ownership	Utilities With 100 Percent Relative Efficiency	Utilities With 90–99 Percent Efficiency	Utilities With 80–89 Percent Efficiency	Utilities With 70–79 Percent Efficiency	Utilities With Less Than 70 Percent Efficiency
State	32 (53)	7 (12)	9 (16)	5 (9)	4 (5)
Private	6 (67)	1 (11)	1 (11)	1 (110)	0 (0)

Values are expressed as *n* (%).
Note: The lowest score, 52.5, was recorded by a state-owned water utility in South Africa.
Source: Authors' analysis based on data described in text.

PROPERTY, and *BALANCE* as defined earlier) using a Tobit model. Only population served by connection, *DEN*, and the property rights variable, *PROPERTY*, are statistically significant, and these two variables are included as control variables in a second-stage data envelopment analysis.[18]

The final data envelopment analysis results were tabulated by efficiency scores: the number of private and state utilities that achieved a score of 100 percent efficiency, 90–99 percent, and 80–89 percent (table 4).[19] Significantly, state-owned firms help to form the efficiency frontier, suggesting that state ownership does not necessarily lead to low relative efficiency. More than half of the state-owned firms in the data set (32 of 57) were on the frontier. Six of the nine private operations included in the analysis populated the frontier. Therefore, the data envelopment analysis results appear to be consistent with the stochastic frontier analysis in suggesting that the efficiency performance of state-owned water firms in Africa is comparable to that of private enterprises. However, the results provide stronger evidence for possible higher relative efficiency in the private sector as a whole. For example, no utilities with private-sector involvement have less than 70 percent relative efficiency, and 67 percent of private as against 53 percent of state operations populate the frontier. It should be noted, however, that there are only nine private firms in the sample.

III. TRANSACTION COSTS AND WATER CONCESSIONS

With the results of the analysis presented here, it is interesting to consider why privatization of water services may be problematic in lower-income economies. The answer seems to lie in a combination of the technology of water provision

18. The inclusion of control variables in data envelopment analysis is widely practiced in empirical studies; see, for example, Rugggiero (1996, 2004) and Paradi and Schaffnit (2004). Wang and Schmidt (2002), however, are critical of this two-step procedure in data envelopment analysis.

19. Data envelopment analysis provides scores relative to peers with similar operating characteristics based on an estimated efficiency frontier. The resulting scores are relative, not absolute, scores. Therefore, a score of 100 percent does not imply absolute efficiency but merely efficiency compared with the other units in the analysis. Similarly, a stochastic cost frontier approach creates a frontier based on actual performances in the data set.

and the nature of the product, the costs of organizing long-term concession agreements, and regulatory weaknesses.

As explained, the technology of water supply and the nature of the product severely restrict prospects for competition in the market and therefore the efficiency gains that can result from encouraging competition following privatization. This leaves rivalry under privatization mainly in the form of competition for the market—competition to win the contract or concession agreement. However, serious problems can arise related to pervasive transaction costs in contracting for water services provision. These include the costs of organizing the bidding process, monitoring contract performance, and enforcing contract terms where failures are suspected (Williamson 1985). The economics literature suggests that such costs are likely to be high where there are serious information asymmetries at the time of contract negotiation.

Information imperfections are especially likely when contracts have to be negotiated to cover service provision over long periods of time. Many future events that could affect the economic viability of the contract and the acceptability of the service offering are unforeseen, and some may be unforeseeable. Concession agreements in water are typically negotiated for 10–20 years or more. Inevitably, therefore, the contracts will need to permit periodic adjustment of such variables as price, volume, and quality during the contract life. The contract will be incomplete in terms of specifying all of the contingencies that may trigger such adjustments and the form the renegotiation might take. This requires considerable skills on the part of both government and companies when operating water concessions, to ensure that the outcome is as mutually beneficial as possible.

The usual approach in water concessions is a two-part bidding process: selection of approved bidders based on technical capacity and then selection of a winner based on such criteria as the price offered and the service targets. However, the smaller the number of bidders, the greater the scope for actual or tacit collusion in bidding and the less competitive will be the bidding process. The evidence suggests that water concessions in developing countries are subject to small-numbers bidding (McIntosh 2003, p. 2). For example, in 2001 in Nepal, 18 companies expressed interest in operating a water contract in the first stage of the process, but only two serious bidders remained in the final stage (cited in Mitlin 2002, p. 17). In Argentina, there have usually been only a small handful of applicants for water concessions, typically between two and four (Estache 2002). To stimulate greater interest, concessions can include sovereign (government or donor agency) guarantees of profitability, but this introduces obvious moral hazard risks—with profits guaranteed, what incentive does the concession winner have to operate efficiently?

The literature on transaction costs also suggests that small-numbers bidding is a source of opportunistic behavior (Williamson 1985), leading to both adverse selection and moral hazard. Adverse selection takes the form of suboptimal contracts at the outset, as one of the contracting parties acts opportunistically to arrange especially favorable terms. Moral hazard occurs when one of the contracting parties renegotiates the terms of the contract in its favor during the lifetime of the contract. During contract renegotiation, either the company or the government could be the loser, depending on the results.[20]

Guasch (2004) concludes that 75 percent of water and sanitation concession contracts in Latin America and the Caribbean were renegotiated significantly within a few years of being signed. In Buenos Aires, prices were raised within months of the start of the water concession (Alcazar, Abdala, and Shirley 2000). But even the ability to renegotiate terms may not be sufficient to overcome investor reluctance to participate in water privatizations, thus reinforcing the small-numbers bargaining problem. Difficulties arise especially when private investors fear that there is no long-term political commitment to water privatization (Rivera 1996). Moreover, cronyism and corrupt payments to win concessions may compromise the legitimacy of the privatization process. For example, in Lesotho, the Highlands Water Project was associated with allegations of bribes to government officials (Bayliss 2000, p. 14). Esguerra (2002, p. 2) shows how the water concessions in Manila were backed by the Philippines' two wealthiest families with support from multinationals: "It appears that the two companies' approach was to win the bid at all costs, and then deal with the problems of profitability later."

Studying concession contracts in developing countries, Harris and others (2003) find that water and sewerage concessions have the second highest incidence of contract cancellation after toll roads. This is not surprising given the substantial potential sunk costs in the water industry. Tamayo and others (1999, p. 91) note that the specificity of assets in the water industry is three to four times that in telecommunications and electricity. Handley (1997) stresses the problems caused by inadequate risk management techniques in developing countries. The preference by the private sector for the state to remain responsible for the infrastructure in water contracting reflects the desire of companies to minimize their sunk costs. Transaction costs in water concessions reinforce serious weaknesses in government-regulatory capacity in developing countries (Spiller and Savedoff 1999, pp. 1–2). For example, in India, there have been some local moves to attract private capital into water supply, notably in Gujarat, Maharashtra, and Tiruppur. But regulatory systems are underdeveloped, and in Tiuppur, they appear to be largely under the indirect control of the water operator (TERI 2003, pp. 171–221). As Mitlin (2002, pp. 54–55) concludes on the experience in Manila:

> The gains [from privatization] may be less than anticipated because the assumption that the involvement of the private sector would remove political interference from the water sector was wrong. It may be that processes and outcomes have simply become more complex because the water supply industry now has the interests of private capital in addition to a remaining level of politicisation and an acute level of need amongst the poorest citizens.

20. For example, in the concession involving Maynilad in Manila, the company terminated the concession when it was refused a rate adjustment to which it felt entitled. By contrast, in Dolphin Bay, South Africa, the municipality believed that it had little alternative but to agree to an unplanned price rise when the private-sector supplier threatened to withdraw services (Bayliss 2002, p. 16).

To assess the effects of regulation on water privatization in Africa, the stochastic cost function analysis was repeated, this time incorporating a regulatory variable as a dummy variable alongside the freedom variable (representing wider good governance in a country). The SPBNET database provides information on regulation of prices, water quality, and customer services. The different regulatory indicators are included separately in the regressions and are also combined into a composite regulation dummy variable to reflect the presence or absence of regulation in the water sector.

Regulation is expected to influence costs depending on its form. For example, a good regulatory regime should create more investor certainty and may reduce the costs of capital. Alternatively, regulation could raise costs by imposing higher and more expensive quality standards or by raising uncertainty for investors. The regression results show a negative sign for the composite regulation dummy variable and for the water quality and services dummy variables, suggesting that regulation lowered operating costs. However, these results are not statistically significant. The regulation dummy variable for tariff regulation is positively signed and statistically significant, suggesting that regulation of prices increased costs.

The findings from this stage of the analysis are therefore inconclusive.[21] Regulation, both sector specific and as reflected in the general standards of governance in a country, are statistically insignificant. The single exception is related to tariff regulation, and the result is consistent with recent concerns that state regulation can raise costs (World Bank 2004a). However, the regulation variables used are far from ideal, and future research would benefit from developing a set of superior regulatory variables that more closely reflect the form of regulation rather than simply its existence.

IV. CONCLUSIONS

In principle, privatization has the potential to improve water services in developing countries, reversing decades of underinvestment and low productivity under state supply. However, the results, taken together, do not provide strong evidence of differences in the performance of state-owned water utilities and water utilities involving some private capital in Africa. While the data envelopment analysis results point tentatively to private-sector superiority, the stochastic cost frontier analysis provides some evidence that state-owned utilities have better cost performance, but the results are statistically insignificant. The descriptive statistics suggest no statistically significant differences.

The results therefore complement those of Estache and Rossi (2002), who also failed to find evidence that the performance of privately owned water

21. The detailed results can be obtained from the authors. A Tobit model was used to assess the impact of the regulation variables on the data envelopment analysis scores discussed earlier. The results were also statistically insignificant.

utilities in developing countries is superior to that of state-owned firms. Estache and Kouassi (2002) report a statistically significant result for the effect of privatization. However, this is based on data for only three privatized utilities in a total sample of 21 water utilities in Africa, and governance and institutional factors were found to be much more significant in explaining performance.

Admittedly, the results here contrast with the findings of Crampes and Estache (1996) and Galiani, Gertlier, and Schargrodsky (2002), who concentrate on service coverage. They conclude that privatization increased the number of people provided with safe water and sanitation. This study found no real difference in the share of the population served between private and state-owned utilities, but the limited availability of data precluded detailed exploration of this dimension of service. As with any study, the findings are dependent on the data used, and these were far from ideal. There is also the possibility that governments in Africa turned to private capital for the worst performing water utilities, thus making it less likely that the private sector would exhibit superior performance.

Other reasons why water privatization might prove problematic in lower-income economies were also identified and may help to explain why this and earlier studies have not found an unequivocally positive effect of private ownership on performance. Regulation dummy variables were included in the stochastic cost frontier model to shed further light on the importance of regulation, but most results were statistically insignificant. This outcome may reflect the crudity of the regulatory variables used, which simply measure the existence of water regulation not its impact on the management of utilities. Under conditions of perfect competition, perfect information, and complete contracts, ownership does not matter (Shapiro and Willig 1990) and the regulatory environment becomes inconsequential. However, none of these conditions applies to water services, and governance and regulatory variables are expected to be important in determining performance before and after privatization.

Finally, it needs to be stressed that providing affordable, safe, and accessible water to the poor is a fundamental priority for low-income countries. Policymakers and regulators are likely to face difficult tradeoffs between ensuring that poor households are provided with affordable water supplies and allowing firms to charge prices high enough to recover costs and attract the foreign capital and technical capabilities needed to upgrade and expand the water supply network.

This study found that private operation of water facilities is associated with much higher average water charges and with greater use of water metering. But what are the impacts of this on water consumption and health? Water privatization usually means the involvement of a handful of major international companies. But what effect does this have on the development of indigenous ownership and regulation of socially important assets?[22] Also, if privatization of

22. Kirkpatrick and Parker (2005) discuss the implications of liberalization of water services under the World Trade Organization's General Agreement on Trade in Services for domestic regulation of water utilities.

Appendix

Table A.1. Descriptive Statistics

Statistic	Minimum	Maximum	Mean	Standard Deviation
Availability of piped water (hours per day)	2.00	24.00	17.17	6.99
Labor cost per employee (in PPP units)	134.49	88,478.92	12,806.64	17,851.00
Material cost per unit water distributed (in PPP units)	0.00024	0.67	0.17	0.15
Number of connections (in thousands)	0.01	526.14	61.78	100.34
Total operating cost (in PPP units)	62,812.45	1,107,688,842.80	53,038,864.01	157,294,171.22
Total volume of water distributed per year (cubic meters)	8200	668,000,000	48,258,663.55	95,605,864.54

Note: PPP is purchasing power parity.
Source: Authors' analysis using data from the Water Utility Partnership for Capacity Building in Africa's Service Providers' Performance Indicators and Benchmarking Network Project database (http://www.wupafrica.org).

water services leads to full cost recovery, is this outcome compatible with poverty reduction and what are the environmental implications of privatization? Clearly, water privatization raises a complex set of political economy questions that deserve fuller exploration than has been possible here because of data limitations.

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