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STATE VERSUS PRIVATE SECTOR PROVISION OF WATER SERVICES IN AFRICA: A STATISTICAL, DEA AND STOCHASTIC COST FRONTIER ANALYSIS

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STATE VERSUS PRIVATE SECTOR PROVISION OF WATER SERVICES IN AFRICA: A STATISTICAL, DEA AND STOCHASTIC COST FRONTIER ANALYSIS

Abstract

Under pressure from donor agencies such as the World Bank, a number of developing countries have experimented with the privatisation of water services. This study reviews the existing econometric evidence on the effects of water privatisation in developing economies before presenting new results using statistical, data envelopment analysis (DEA) and stochastic cost frontier techniques and data from Africa. The study finds evidence of better performance in private utilities compared to state-owned utilities according to the statistical and DEA performance measures. But no statistically significant cost differences were discovered between private and public suppliers in the stochastic cost frontier analysis. The paper then considers reasons why water privatisation may prove problematic in lower-income economies, identifying the technology of water provision and nature of the product, transaction costs and possible regulatory weaknesses. However, a second-stage cost function analysis introducing a regulatory variable produced statistically insignificant results.

Key words: water services, privatisation, developing countries, performance, efficiency

INTRODUCTION

Donor agencies advocate the privatisation of public utilities in lower-income economies to promote more efficient operation, increase investment and service coverage, and to reduce the financial burden on government budgets (World Bank, 1995). In response, a range of services including water supply has been opened up to private capital. By the end of 2001 there had been over US$755bn. of investment flows, involving nearly 2500 infrastructure projects in developing countries (Harris, 2003). This paper looks at the economic impact of water services privatisation in Africa using statistical, DEA and stochastic cost frontier measures. Recent studies have suggested that the impact of privatisation has been more complex than expected in telecommunications and electricity generation (e.g. Wallsten, 2001; Zhang et al., 2003a, 2003b). Perhaps the same applies to water services.

The provision of high quality water services remains a priority for most developing economies. According to the World Bank (2003, p.1), more than 1bn people in the developing world lack access to clean water and nearly 1.2bn lack adequate sanitation An estimated 12.2m people die every year from diseases directly related to drinking contaminated water. Improved investment in water services and their more efficient management are a development priority (OECD, 2000). The Millennium Development Goal is to halve the number of people using unsafe water by 2015 (Hulls, 2003, p.32). The pressing question for public policy is the extent to which privatisation is critical to achieving that objective. In this paper, we first review the existing econometric evidence on the impact of water privatisation. We then provide results using a data set for African water utilities and statistical, DEA and stochastic cost frontier measures. The statistical and DEA results suggest that utilities with private capital do seem, in the main, to perform better than pure state-owned water suppliers. However, the stochastic cost frontier analysis finds no statistically significant difference in public-private performance. The paper goes on to consider the difficulties that face privatisation in water services, in terms of the technology of water provision and the nature of the product, transaction costs and regulatory weaknesses. We then separately model the effects of regulation in a repeated stochastic cost frontier analysis, but find no statistically significant effect. This result possibly reflects inadequacies in the available data on water regulation in Africa.

THE EXISTING EVIDENCE

Private water suppliers exist in all developing countries in the form of water vendors at the street level, but there was little privatisation of piped water services in developing countries before 1990 (Snell, 1998; Collignon and Vézina, 2000). Where privatised services existed, for example in Cote d'Ivoire, these were usually French speaking ex-colonies that had inherited a reliance on private firms for water services, as exists in France. Between 1984 and 1990 only eight contracts for water and sewerage projects were awarded to the private sector world-wide and the cumulative new capital expenditure in private water services totalled less than US$1bn.

However, during the 1990s there was increased water privatisation activity, stimulated by donor agency pressures, and in 1997 the total figure for private investment had risen to US$25bn. By the end of 2000, at least 93 countries had privatised some of their piped water services, including Argentina, Chile, China, Colombia, the Philippines, South Africa and the transition economies of Central Europe, as well as Australia and the UK (Brubaker, 2001). Taking the period from 1990 to 2002, there were 106 such projects in Latin America and the Caribbean and 73 in East Asia and the Pacific region. By contrast there were only seven projects in the Middle East and North Africa and 14 in sub-Saharan Africa. In terms of the amounts invested, Latin America and the Caribbean and East Asia and the Pacific accounted together for over 95% of the total investment (calculated on the basis of data from the World Bank PPI Database). Table 1 provides a summary of the largest investments in water services during the period 1990 to 2002. Clearly, a small number of countries accounted for most of the privatisation of water services, and within these countries figures were dominated by a few large contracts. Indeed, one project, Aguas Argentinas, accounted for US$4.9bn or 20% of the investment in the whole of Latin America; while five Philippines contracts accounted for 38.4% of the total private investment in water services in East Asia.

Table 1: Largest Investments in Water Services in Developing Countries, 1990-2002

	US$bn	**No. of projects**
Argentina	7.23	10
Philipines	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: calculated using data from the World Bank PPI Project Database, http://rru.worldbank.org/PPI

Evidence suggests that the privatisation of monopolies produces ambiguous results in terms of improving economic performance (Megginson and Netter, 2001) and it is to be expected that the institutional requirements to ensure that privatised monopolies perform well, notably an effective system of state regulation and supporting governance structures, will be particularly missing in many developing countries (Parker and Kirkpatrick, 2004). Privatising water services is normally associated with contracts that take the following forms, namely service contracts (contracts to provide specialist services such as billing), management contracts and leases for existing facilities (private companies operating existing facilities but without new private sector investment), concessions (requiring the private sector to invest in facilities), divestitures (sale by the state of some or all of the equity in SOEs) and greenfield investments (including build-operate-transfer [BOT] type schemes) (Johnstone and Wood, 2001, pp.10-11). In practice, contracts under which private firms provide the services but government remains the ultimate owner of the water system and may remain responsible for some investment are commonplace (OECD, 2003). Of 233 water and sewerage contracts with the private sector arranged between 1990 and 2002 on the World Bank's PPI Project Database, 40% involved concession contracts and these accounted for 64% of the total amount invested (see Table 2). Where greenfield projects have occurred, for instance in China, they have often involved the building and operation of new water treatment plants; while BOT schemes for water supplies have been largely restricted to Latin America and the Caribbean. Divestitures or the sale of state-owned water businesses to the private sector have been rare, accounting for only 15.6% of all water projects and 8% of the total funds invested. Also, although privatisation of water services has occurred, it is important not to exaggerate its importance. At present little more than 5% of the world's population is provided with drinking water through private operators (OECD, 2003) and since the Asian economic crisis of 1997/98 there has been a marked slow down in infrastructure privatisation in lower-income economies, including in the water sector (Harris, 2003). The forms water privatisation takes raises issues about the transfer of risk from the public to the private sector. We return to this subject later in the paper in a discussion of transaction costs in water service contracting.

Table 2: Types of Private Water and Sewerage Projects in Developing Countries, 1990-2002

Type	**Total investment (US$bn.)***	**%**	**No. of Projects**	**%**
Concessions	22.31	64	93	40
Greenfield	7.00	20	75	32
Operations and management	0.18	0.5	46	20
Divestiture	5.48	15.6	19	8

*This is the total invested in projects with private participation and not necessarily the private sector's commitment alone.
Source: calculated using data from the World Bank PPI Project Database, http://rru.worldbank.org/PPI

The existing case study evidence on the results of water privatisation presents a mixed picture with some improvements in the reliability and quality of services and population served, but instances of much higher water charges and bouts of public opposition leading to cancelled schemes. This evidence is reviewed in Kirkpatrick and Parker (2004). Turning to the few published papers that have attempted a statistical or econometric analysis of the effects of water privatisation in lower-income economies, these too present mixed results. The earliest such study was undertaken by Estache and Rossi (1999). They compared private and public water companies in the Asian and Pacific region, using 1995 survey data from the Asia Development Bank, and found that private operators were consistently more efficient than state-owned ones. The data included 50 utilities and a stochastic cost frontier method was adopted. In stark contrast, however, a follow up study by the same authors came to exactly the opposite conclusion (Estache and Rossi, 2002). Using again stochastic cost frontier modelling and this time applying error components and technical efficiency effects models, but seemingly with data from the same 1995 survey by the Asian Development Bank, they concluded that efficiency was not significantly different in the private and state water sectors. Fifty water enterprises were included in their study from 29 Asian and pacific-region countries, with 22 having some form of private sector participation.

A further study, this time by Estache and Kouassi (2002), used a sample of 21 African water utilities for the period 1995/97. They estimated a production function from an unbalanced panel data set and used Tobit modelling to relate resulting inefficiency scores to governance and ownership variables. The study concluded that private ownership *is* associated with a lower inefficiency score. However, only three firms in their sample had any private capital and levels of corruption and governance were far more important in explaining efficiency differences between firms than the ownership variable.

Finally, 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 that supplies for lower-income households (proxied by educational attainment) were smaller where there was a state-sector operator. Clarke and Wallsten (2002), therefore, concluded that private participation in water schemes leads to more supplies to poorer households than where there is a reliance on state-owned suppliers. Their study suggests that privatisation can improve service provision. However, there may be offsetting service difficulties and especially higher charges when supplies are privatised. In other words, drawing strong conclusions on the desirability of water privatisation based on one measure, such as service coverage, may mislead. In the analysis below we use a range of performance measures in an attempt to address this problem.

ASSESSING PERFORMANCE IN PRIVATISED AFRICAN WATER UTILITIES

To advance understanding of the results of privatisation in water services, we accessed data from the Water Utility Partnership's SPBNET Africa web site (http://www.wupafrica.org/spbnet/angl/index.html). This data base includes up to 110 water utilities in Africa and was developed with financial and technical support from the Department of International Development (DFID) in London. The data collected, usually by questionnaire survey, relate mainly to the year 2000.[1] In our data set nine utilities situated in eight countries reported private sector involvement. However, not all of these firms could be included in each stage of the analysis because of incomplete data entries. Also, ideally we would use information on the forms private-sector involvement takes to judge the degree of privatisation, but unfortunately the data source only permitted ownership to be modelled as a binary variable. This is a limitation of our study, but a limitation shared with the earlier econometric studies, referred to above. Suppliers are categorised as either state owned or privately owned, with the latter capturing most forms of private sector involvement except for leasing and similar, which the data base treat as continued public ownership. As explained above, such arrangements simply involve the use of private contractors to provide specialist services or to operate the system but with no new private investment.

Conclusions on the impact of water privatisation may be sensitive to the precise performance measure used. Therefore, to assess the impact of private capital on performance in water services, a range of performance measures was calculated. Firstly, a number of statistical measures were computed from the data set, including:

- Labour productivity, labour costs to total costs, number of staff to number of water connections and staff per million cubic metres of water distributed – all of these measures will reflect *efficiency in the use of labour*.
- The proportion of operating costs spent on fuel and chemicals – to reflect *economies in non-labour operating costs*.
- The percentage of capital utilised – to reflect *capital stock efficiency*.
- Average tariffs – to reflect the *costs of services to consumers*.
- The percentage 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 and the results are provided in Table 3, with standard deviations shown in parentheses. This stage of the analysis involved between 61and 84 utilities depending upon the performance measure.

Table 3: Performance Ratios in African Water Utilities: 1999-2001

Labour productivity	
Labour costs in total costs:	
Average for state owned firms	29% (17)
Average for privately-owned firms	21% (27)
Staff per thousand water connections	
Average for state owned firms	20.1 (19.9)

Average for privately-owned firms	13.1 (14.4)
Staff per million cu.mts of water distributed	
Average for state owned firms	123 (519.7)
Average for privately-owned firms	78 (151.8)
Operating costs	
Proportion spent on fuel	
Average for state owned firms	20% (16)
Average for privately-owned firms	11% (12)
Proportion spent on chemicals	
Average for state owned firms	17% (16)
Average for privately-owned firms	4% (5)
Capital	
Capital utilisation	
Average for state owned firms	60% (21.6)
Average for privately-owned firms	67% (21.8)
Consumer charges (US$ per cu. mt.)	
Average tariff	
Average for state owned firms	168 (473)
Average for privately-owned firms	305 (440)
Quality of service	
Percentage of population served	
Average for state owned firms	63% (29.8)
Average for privately-owned firms	64% (30.2)
Unaccounted for water	
Average for state owned firms	34.8% (13.5)
Average for privately-owned firms	29.0% (13.1)
Availability of piped water (hours per day)	
Average for state owned firms	17 (6.7)
Average for privately-owned firms	16 (9.3)
% of customers metered	
Average for state owned firms	60 (41.5)
Average for privately-owned firms	79 (38.4)

The figures in Table 3 confirm that, on average, private sector water utilities have higher labour productivity (both a lower number of staff per connection and per million cubic metres of water distributed) and a lower proportional spend on labour in operating costs than state-owned firms. On average, the private sector is also more economic in its use of other inputs, namely fuel and chemicals, and achieves a slightly higher capital utilisation, of 67% as against 60%. Turning to tariffs, charges are on average 82% higher in the private sector and more customers have their water consumption metered where services are privatised. Metering water can be a means of extracting higher revenues from consumers by linking payments to the volumes of water used. The private sector also achieves a lower percentage of water losses, averaging 29% as against 34.8% for state-owned water firms (probably assisted by more metering). But, interestingly, other measures of customer service suggest fewer differences between the private and state sectors. On average, state-owned firms supply piped water for 17 hours per day, while the private sector records a slightly lower figure of 16 hours. The state and private sectors serve about the same percentage of population in their areas, 63% and 64% respectively. These results, however, may simply reflect that it is where services are poor that governments have been most inclined to turn to the private sector for a solution.

What is clear is that there are major differences in the scale of water operations in the state and private sectors. Calculations using the SPBNET data base suggest that in Africa privately-owned water utilities are on average over twice as large as state-owned ones in terms of the total volume of water distributed (92m as against 36.4m cu.mts. per day) and have more connections to their systems (averaging 159,600 in the case of the private utilities, as against 94,500 in the case of the state-owned firms). This suggests that the private utilities' superior performance, in particular in terms of labour use, may be at least partially explained by the different scale of production.

Nevertheless, the performance ratios in Table 3 reveal interesting differences across the private and state-owned water firms in Africa but with the standard deviation figures (in parentheses) confirming a high degree of variance in performance within both the state and private sector categories. This suggests that conclusions based on average performance need to be interpreted with care. To provide a fuller appraisal of relative performance, two further sets of performance measures were calculated drawing on the same data base for Africa, namely:

- Data envelopment analysis (DEA) efficiency scores
- A stochastic cost frontier analysis.

Whereas a cost function analysis is to be favoured because it distinguishes inefficiency from random error, non-parametric DEA analysis does not require a prior specification of the appropriate functional form. Given that our data come from a wide number of countries, where it might be expected that functional forms could differ, DEA has obvious attractions. However, DEA scores can be easily biased by outliers and errors in the data. Therefore, arguably DEA results are best assessed alongside those from the cost function analysis. By computing *both* DEA efficiency scores and stochastic cost function results, using the SPBNET database, each measure provides a cross-check on the other. When both sets of results are considered alongside the statistical ratios above, the result is a triangulation of the analysis of the data. The outcome should be a more robust set of conclusions on the impact of water privatisation than can be obtained from one performance measure alone (Bauer, et al., 1998). The Appendix to the paper provides a brief explanation of both the DEA and stochastic cost frontier models for those unfamiliar with the methods.

The DEA and Cost Function Analyses

A DEA analysis was undertaken in which water distributed represented the volume of output produced and hours of piped water available per day was used as the proxy for the quality of water services (as a cross-check, unaccounted for water was also used as the quality of service proxy and the results were very similar). An input-oriented, variable returns to scale model was used and the number of utilities entered into the analysis was 71, of which eight were privately owned. A constant returns to scale model produced a similar set of results but with lower overall scores,[2] but the utilities vary in size and we would expect variable returns to apply in the water sector. The inputs used were initially the number of staff and number of connections; the latter acting as a proxy for the capital input in the absence of other data on fixed assets. A subsequent Tobit regression of the resulting DEA scores on other possible variables that might affect water outputs, including GDP per capita, water resource availability[3] and a 'freedom index', showed that water resources and the degree of freedom in a country were correlated with the efficiency scores. GDP per capita was found to have a statistically insignificant effect (at the 10% level).

The DEA analysis was therefore repeated but including water resources and the freedom index as additional inputs. The freedom index used, developed by the Fraser Institute (http://www.freetheworld), takes account of policies within countries affecting the size of government (public spending, tax levels and state ownership), legal structure and security of property rights, access to sound money, freedom to trade, and regulation of credit, labour and business. Good governance in the form of sound finance and regulatory systems and protection of property rights has been found to be an important explanation of economic performance differences (North, 1990; Jalilian et al., 2002; Kauffman et al., 2002), including in water services (Estache and Kouassi, 2002). The freedom variable was therefore included to capture wider governance or regulatory effects on performance in water utilities, which might otherwise have been attributed to ownership.[4] Ideally, another factor taken that should be taken into consideration in deriving efficiency scores is the geography of the area served because this can be expected to impact on the amount of water distributed and the quality of service. However, we have no data on topography or other geographical factors that might impact on performance, other than the data on renewable water resources. In the Tobit regression, the water resources variable was found to be negatively correlated with the efficiency scores. While this was initially surprising, it can be explained in terms of countries with large renewable water resources taking less care to distribute available water efficiently through their water systems and by people having better access to informal water services, such as direct extraction from rivers, where water resources are more abundant.

Table 4 summarises the DEA results according to the number of utilities that achieved a score of 100% efficiency, 90% to 99% efficiency and 80% to 89% efficiency under private and state ownership.[5] Although state-owned firms helped to form the efficiency frontier, demonstrating that state ownership does not necessarily lead to low relative efficiency, the number on the frontier amounted to eighteen out of the 63 firms or 29% of the total of state-owned firms in the data set. By contrast, three privately owned firms populated the frontier accounting for 38% of the private-sector firms included in the analysis. All private-sector firms achieved scores of above 80% relative efficiency; while 8% of state-owned firms (5 firms out of 63) recorded scores of less than 80%.[6] The lowest score, 72%, was recorded by a state-owned water utility in Malawi. The DEA results suggest, therefore, that private ownership leads to higher efficiency scores, but also that many state-owned water firms in Africa seem to perform relatively efficiently.

Table 4: A Summary of the DEA Analysis

	Utilities with 100% relative efficiency		**Utilities with efficiency of 90% to 99%**		**Utilities with efficiency of 80% to 89%**	
	Number	Percentage	Number	Percentage	Number	Percentage
State owned	18	29	18	29	22	35
Privately owned	3	38	2	25	3	38

A stochastic cost frontier was also estimated on the basis of the SBPNET database. The reason for choosing a cost frontier instead of a production frontier lies in the fact that most water utility firms are required to meet demand and are not free to choose the level of output. With output set exogenously, the firm is expected to minimise the costs of producing a given level of output. Compared to the deterministic cost function, the stochastic frontier decomposes the error term into stochastic noise and cost inefficiency. When the inefficiency term enters into the cost function (additively after logs are taken), the level of the cost efficiency of individual firms can be estimated.[7]

Various distributions have been suggested for the inefficiency term. But the half-normal distribution (Aigner, Lovell and Schmidt, 1977) is the most commonly used in empirical studies. To avoid imposing such an arbitrary assumption, Stevenson (1980) proposed that the more flexible truncated normal distribution be used. The truncated-normal distribution is a generalisation of the half-normal distribution, obtained by the truncation at zero of the normal distribution, with mean, μ, and variance, $\sigma_\mu{}^2$. Pre-assigning μ to be zero reduces the truncated distribution to the traditional half-normal. Therefore, we first tested the null hypothesis H_0 : μ=0 to choose the appropriate model for estimation.

Estimation of a cost function requires data on the cost level, the output level and input prices. There are, however, no data on capital prices in the SPBNET database. An arbitrary cost function was therefore formulated without including the price of the capital input. The dependent variable used in the cost frontier was operating and maintenance costs (*COST)* or non-capital costs. Average manpower cost per employee (*MP*) was used to reflect the cost of labour. The amount of water distributed per year (*WD*) was included in the cost function as the output variable. Also included in the function was a quality variable, measured by the hours of piped water available per day (*QUALI*).[8] In addition, some environmental variables were included in the model specification. These are variables that may be expected to affect the performance of the firm but are not entirely under its control. Their inclusion ensures that the various water operators are effectively comparable. A density variable, measured by population served per connection (*DEN*), was included because it plays an important role in defining the network infrastructure. Another variable used as a control was the annual water resources per capita (*WRS*). GDP per capita (*GDP*) and the freedom index (*FRD*) were included in an attempt to capture the extent of economic development and the quality of governance, respectively. In order to account for the effects of ownership on performance, a dummy variable (*ONS*) was included in the model, which took the value of 1 if the utility was privately owned. Table 5 lists the variables used in the estimation.

Table 5: Variables in the Stochastic Cost Function

Variable	Definition	Data Source
COST	Operating and maintenance costs (US$)	SPBNET
WD	Water distributed per year (cub m)	SPBNET
QUALI	Number of hours of water availability per day	SPBNET
MP	Manpower costs per employee (US$)	SPBNET
WRS	Water resources per capita	World Resources Institute
DEN	Population served per connection	SPBNET
GDP	GDP per capita (US$)	World Development Indicators
FRD	Freedom index	The Fraser Institute
ONS	Ownership dummy (1=privately owned)	SPBNET

A translog cost function that includes the second-order and cross terms would leave the estimation with very few degrees of freedom, therefore a Cobb-Douglas specification was adopted. All the variables except the ownership dummy were logged. The procedure for estimation was as follows. An Error-Component (EC) model was first estimated with the assumption of a truncated distribution for the inefficiency term. If the hypothesis $\mu=0$ is rejected, this means that the assumption of the truncation distribution is correct and the results based on this model can be adopted. If μ is not significantly different from zero, an EC model assuming a half-normal distribution should be estimated instead. In order to test the robustness of the results, a Technical Efficiency Effects (TEE) frontier was also estimated in which the inefficiency effects are expressed as a function of the ownership dummy.

In total 76 observations were included in the estimations, including nine private sector firms.[9] The program FRONTIER 4.1 was used to obtain the maximum likelihood estimates of the parameters and the efficiency measure. The results of the EC model with the truncation-distribution assumption showed that μ was 0.47 with a standard error of 2.56. A likelihood ratio test was performed and the results showed that the hypothesis μ=0 could not be rejected at the 10% level. Consequently, the results from the model with the half-normal assumption were adopted. Table 6 shows the results along with those from the TEE model.

Table 6: The Error Component (EC) and Technical Efficiency Effects (TEE) results

Variable	**EC model (half-normal)**	**Variable**	**TEE model**
Constant	7.10 (3.01) ***	*Constant*	7.28 (3.18)***
Ln(WD)	0.44 (5.41) ***	*Ln(WD)*	0.45 (4.96)***
Ln(QUALI)	-0.17 (0.70)	*Ln(QUALI)*	-0.23 (0.90)
Ln(MP)	0.68 (10.38) ***	*Ln(MP)*	0.69 (9.77)***
Ln(WRS)	0.23 (2.18)**	*Ln(WRS)*	0.28 (2.50)***
Ln(DEN)	-0.21 (2.80) ***	*Ln(DEN)*	-0.23(2.60)***
Ln(GDP)	-0.28 (1.71) **	*Ln(GDP)*	-0.25(1.53)*
LN(FRD)	-0.98 (0.64)	*LN(FRD)*	-0.99 (0.83)
ONS	0.45 (1.21)	*δ(ONS)*	0.88 (1.10)
γ	**0.86 (9.67)**	γ	0.92 (10.64)
LR test	6.68 ***	*LR test*	8.68 ***
Total observations	**76**	**Total observations**	**76**

Figures in parentheses are *t* statistics.
*** significant at 1% level.
** significant at 5% level
* significant at 10% level

The results from the EC model and from the TEE model are consistent. The values of γ in the two models indicate that the vast majority of residual variation is due to inefficiency effects. This is also confirmed by the generalised likelihood-ratio statistics, both exceeding the critical value at 1% level obtained from Table 1 of Kodde and Palm (1986). As expected, the output variable, ln(WD), has a positive and significant effect on operating costs. So does the variable labour price, ln(MP). The density variable has a negative and significant sign, and accords with the expectation that it is more cost efficient to serve a population located more densely. The negative and significant coefficient of ln(GDP) suggests that the cost of water distribution is lower in wealthier countries. The freedom variable seems to have negative effects on the level of costs, but the impact is not statistically significant. Contrary to our expectation, however, the quality variable results show negative, although not significant, effects and the water resources variable shows positive and significant effects (the latter finding being consistent with the relationship between efficiency scores and water resources in the earlier DEA results). Turning to the role of ownership, which is our main concern, surprisingly the coefficient of the ownership dummy (ONS) in the EC model is positive, suggesting that private ownership is associated with higher costs. However, the result is not statistically significant.

In order to determine the robustness of this result, the inefficiency term was expressed as a function of the ownership dummy in the TEE model. In the TEE model the efficiency error μ has a mean of m_i and $m_i = \delta x_i$. x_i, which is a vector of variables that may influence the efficiency of a firm. This was taken as the ownership dummy in our estimation. The results of the estimation (Table 6, final column) show that the coefficient δ in the contemporaneous auxiliary regression is positive but not significant.[10] The results were consistent with the outcome from the EC model. Overall, the safest interpretation of the cost frontier results is that there are no significant differences in cost efficiency between private and state-owned water companies in Africa.

TRANSACTION COSTS AND WATER CONCESSIONS

The studies of water privatisation in developing countries undertaken, including our own, suggest that private ownership can be associated with higher performance, although it is not axiomatic that private suppliers are more efficient. Indeed, our cost function analysis is consistent with the most recent study by Estache and Rossi (2002), reviewed earlier, in finding no statistically significant difference in terms of cost performance between the private and state water sectors in developing countries. Before concluding the paper, it is interesting to consider why privatisation of water services may be problematic in lower-income economies. The answer seems to lie in a combination of the technology of water provision and the nature of the product, the costs of organising long-term concession agreements or transaction costs, and regulatory weaknesses, to which we now turn.

Past studies of privatisation have indicated that competition is generally more important than ownership, per se, in explaining performance improvements in developing countries (e.g. Zhang et al., 2003a; Parker and Kirkpatrick, 2004). But unlike in the case of telecommunications and parts of energy supply, such as generation, where competition is feasible, competition in the market for water services is usually cost inefficient. While there is scope for introducing some competition into billing and metering and into construction, replacement and repair work within water services, competition in the actual provision of water supplies is normally ruled out by the scale of the investment in fixed assets or network assets that are needed to deliver the product. Moreover, even where actual competition for consumers might seem feasible, for example where the boundaries of different water utilities meet, the costs of moving water down pipes is far higher than the costs of transmitting telephone calls and distributing electricity, and this places a serious limitation on the development of competition. Also, mixing water from different sources can raise complications in terms of maintaining water quality, which can be an important consideration for domestic consumers but more especially water-using industry, such as brewing and food processing.

In other words, the technology of water supply and the nature of the product, together, severely restrict the prospects for competition in the market and therefore the efficiency gains that can result from encouraging competition following privatisation. This leaves rivalry under privatisation mainly in the form of 'competition for the market' or competition to win the contract or concession agreement. However, here serious problems can also arise. These problems relate to the existence of pervasive transaction costs.

As already explained, water privatisations involve various types of contracts. Transaction costs arise in contracting for water services provision, in terms of the costs of arranging the agreements, including organising the bidding process, monitoring contract performance, and enforcing the contract terms where failures are suspected (Williamson, 1985). The economics literature demonstrates that such costs are likely to be high where there are serious information asymmetries at the time of the contract agreement. These information imperfections are likely to be especially prevalent when contracts have to be negotiated to cover service provision over long periods of time because many future events that could affect the economic viability of the contract and the acceptability of the service offering are unforeseen, and may be unforseeable. Concession agreements in water are typically negotiated for 10 or 20 years or more. Inevitably, therefore, the contracts will need to permit periodic adjustment of variables such 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 places a large emphasis on the skills of both government and companies when operating water concessions, to ensure as far as possible that the outcome is mutually beneficial.

The usual approach in water concessions is to have a two-part bidding process. The first stage involves the initial selection of approved bidders, based on technical capacity, and then a final stage in which the winner is selected, based on criteria such as the price offered and service targets. However, the smaller the number of bidders, the greater the scope for either actual or tacit collusion when bidding and the less effective will be the competitiveness of the bidding process. The evidence suggests that water concessions in developing countries are subject to small numbers bidding. For example, in 2001, 18 companies expressed interest in operating a contract for Nepal in the first stage of the process, but in the final stage only two serious bidders remained (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); the ill-fated Cochabama concession had a sole bidder. Prequalification criteria and risk restrict the bidding for water concessions mainly to a small number of players (McIntosh, 2003, p.2). In an attempt to stimulate interest from more potential suppliers, concessions can include sovereign (government or donor agency) guarantees of profitability, but this introduces obvious moral hazard risks – with profits guaranteed, what incentive exists for the concession winner to produce efficiently? Table 7 details the main international players for water concessions today. While there appears to be a number of players, in most bids only a few of these firms choose to become involved, often reflecting preferences regarding regional investment. In practice, this is not a market composed of large numbers of active competitors for all or even most contracts.

Table 7: The Main International Firms Involved in Water Concession Bidding

Company	**Country of origin**
Acea	Italy
Aguas de Barcelona	Spain
Aguas de Portugal	Portugal
Anglian Water (parent company, ARG)	UK
Aquamundo	Germany
Bechtel	USA
International Water (parent companies Edison and Bechtel)	Italy/USA
Ondeo (parent company, Suez)	France
SAUR	France
Thames Water (parent company RWE)	UK/Germany
United Utilities	UK
Vivendi Environnement	France

Source: various.

The literature on transaction costs demonstrates that small numbers contracting is a source of opportunistic behaviour leading to higher transaction costs (Williamson, 1985). The result can be both adverse selection and moral hazard. Adverse selection takes the form of sub-optimal contracts at the outset, resulting from one of the contracting parties acting opportunistically to arrange especially favourable terms; while moral hazard occurs when one of the contracting parties renegotiates the terms of the contract in their favour during its lifetime. During contract renegotiation either the company or the government could be the loser, depending upon the results of the renegotiation. For example, in the concession involving Maynilad in Manila, the company terminated the concession when it was refused a rate adjustment to which it considered it was entitled. By contrast, in Dolphin Bay, South Africa, the municipality felt that it had little alternative but to agree an unplanned price rise when the private sector supplier threatened to withdraw services (Bayliss, 2002, p.16). By transferring operations to the private sector, government loses the internal skills and expertise that enable it to takeover a failing enterprise.

Guasch (1999) concludes that 55% of water concession contracts in Latin America 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 et al., 2000). But even the ability to renegotiate terms may not be sufficient to overcome investor reluctance to participate in water privatisations, thus reinforcing the small numbers bargaining problem. Difficulties arise especially when private investors fear that there is no long term political commitment to water privatisation (Rivera, 1996). Moreover, corrupt payments to win concessions and 'cronyism' undermine the legitimacy of the privatisation process; for example, in Lesotho the Highlands Water Project was associated with bribes to government officials (Bayliss, 2000, p.14). Esguerra (2002) 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' (ibid., p.2). They are also accused of trying to influence the subsequent regulatory process. The way in which the privatisation in Buenos Aires helped promote the interests of elite groups is highlighted by Loftus and McDonald (2001, p.198).

Studying cancelled concession contracts in developing countries, Harris et al. (2003) find that water and sewerage concessions have the second highest incidence after toll roads. Given the existence of substantial potential 'sunk costs' in the water industry, this is not surprising. Tamayo et al. (1999, p.91) note that the specificity of assets in the water industry is three to four times that in telecommunications and electricity. Reflecting this, water companies in Brazil have a high cost of capital compared to the electricity sector, reflecting the bigger regulatory risk (Guasch, 1999). Handley (1997) stresses the problems caused by inadequate risk management techniques in developing countries; while the preference on the part of the private sector for the state to remain responsible for the infrastructure in water contracting, reflects the desire of companies to minimise their sunk costs.

Pargal (2003, p.23) based on an econometric assessment of private investment flows and data from Latin America concludes that: 'the water sector differs materially from [telecoms, electricity and roads]…: private investment in water is not significantly affected by the passage of reform legislation in the sector and public expenditure is very important and only mildly substitutable for private spending.' Studies have shown that in telecommunications (Wallsten, 2001) and electricity generation (Zhang, et al., 2003a, 2003b) the regulatory system put in place to monitor and control the prices and quality of services supplied by the private monopolist is important. However, 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 Tiruppur, Maharashtra and Gujarat. But regulatory systems are underdeveloped and in Tiuppur they are largely under the indirect control of the water operator (Teri, 2003, pp.171-21). As Mitlin (2002, pp.54-55) concludes on the experience in Manila:

> The experience in Manila suggests that the gains [from privatisation] 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.

The decline in private sector infrastructure investments since 1997 is consistent with growing concerns about regulatory capacity and governance within developing countries (Harris, 2003). This is a concern which exists irrespective of the form that ownership takes. Therefore, to assess the effects of regulation on water privatisation in Africa, we repeated our stochastic cost function analysis, but this time incorporating a regulatory variable as a dummy, alongside the existing freedom variable (representing wider good governance in a country). The SPBNET data base provides information on the existence of regulation of prices, water quality and customer services. The different regulatory indicators were combined into a composite regulation dummy, to reflect the existence or lack of existence of regulation in water. Our expectation is that regulation will impact on costs, depending upon the form regulation takes. For example, a good regulatory regime should create more investor certainty and may reduce costs of production. Alternatively, regulation could raise costs by imposing higher and more expensive standards or by raising uncertainty for investors (usually referred to as 'regulatory risk'). The results from the new regression analysis are reported in Table 8. They show that the regulation dummy has a negative sign, suggesting lower costs, but it is not statistically significant. Similarly, the freedom variable is also negative and insignificant, as it was in the earlier analysis. The ownership dummy (ONS) remained positive but insignificant, as before (Table 6).

The results from this stage of the analysis were, therefore, inconclusive.[11] Regulation, both sector specific and as reflected in the general standards of governance in a country, proved to be statistically insignificant, though there was some suggestion that they led to lower costs. Clearly, more research is needed in this area. The regulation variable used was far from ideal and future research would benefit from developing a set of superior regulatory variables - variables that more closely reflect the impact of regulation rather than simply its existence.

Table 8: Testing for the Importance of Regulation

Variable	**EC model (half-normal)**	**Variable**	**TEE model**
Constant	7.80(3.04) ***	*Constant*	6.64 (3.14)***
Ln(WD)	0.43 (5.25) ***	*Ln(WD)*	0.50 (5.72)***
Ln(QUALI)	-0.17 (0.72)	*Ln(QUALI)*	-0.32 (1.05)
Ln(MP)	0.69 (10.28) ***	*Ln(MP)*	0.69 (10.62)***
Ln(WRS)	0.23 (2.17)**	*Ln(WRS)*	0.27 (2.56)***
Ln(DEN)	-0.21 (2.85) ***	*Ln(DEN)*	-0.23(2.06)***
Ln(GDP)	-0.27 (1.70) **	*Ln(GDP)*	-0.26(1.75)*
LN(FRD)	-0.91 (0.68)	*LN(FRD)*	-0.99 (0.89)
ONS	0.45 (1.21)	δ_1 *(ONS)*	0.93 (0.67)
Regulation	-0.62(0.68)	δ_2 *(Regulation)*	-0.89 (0.36)
γ	0.89 (10.04)	Γ	0.92 (10.64)
LR test	6.85 **	*LR test*	8.68 ***
Total observations	**76**	**Total observations**	**76**

For a definition of the variables, see Table 6. Regulation is a dummy variable for regulation, see text; γ is the proportion of the residual variation attributable to inefficiency effects.

CONCLUSIONS

This paper has reviewed the existing econometric evidence on the impact of water privatisation in developing countries and has reported the results of a new analysis for Africa, using a range of performance measures to overcome the limitations of a single performance measure. The study has reported a range of statistical indicators and both DEA and stochastic cost frontier results.

Based on the statistical indicators and the DEA, the study confirms that privatisation can lead to performance gains. However, the stochastic cost frontier analysis found that, while the coefficient on the ownership variable was negative, consistent with lower costs under private ownership, the result was not statistically significant.

The paper then considered some reasons why water privatisation might prove problematic in lower-income economies, identifying potential difficulties stemming from water supply technology and the nature of the product, transaction costs and regulatory capacity. These difficulties may help explain why private ownership does not have an unequivocally positive effect on performance in water supply in our and earlier studies. By including a regulation dummy in the stochastic cost frontier model, we attempted to shed further light on the importance of regulation, but the result was statistically insignificant. This outcome probably reflects the crudity of the regulatory variable used, which simply measures 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 trivial. However, none of these conditions applies to water services and it is to be expected that governance and regulatory variables will be important in determining performance pre and post-privatisation. The challenge is to develop reliable data sets on regulation for use in econometric analysis.

Finally, it needs to be stressed that while the paper has concentrated upon a number of performance measures, a more comprehensive study would take account of possible effects beyond those discussed. For example, we have seen that privatisation tends to lead to more water metering, but what is the impact of this on water consumption and health? Around major cities in developing countries lie shanty towns populated with squatters and others without legal property rights. How are their interests served by water privatisation? Water privatisation usually means the involvement of a handful of major international companies; but what effect does this have in terms of developing indigenous ownership of socially important assets? Also, if privatisation leads to full cost recovery in water, is this outcome compatible with poverty reduction; and what are the environmental implications of privatisation? Clearly, water privatisation raises a complex set of considerations that deserve fuller exploration than has been possible here because of data limitations.

Notes

[1] Data for a few utilities relate to the years 1999 or 2001. Given the closeness of the years, we treat all of the data as applying to one year, 2000, to adopt a cross-sectional analysis of performance.
[2] Constant returns to scale modelling in DEA always leads to lower scores compared to using a variable returns to scale model with the same data, due to the additional restriction introduced.
[3] The data relate to the availability of natural renewable water resources and were obtained from Earth Trends Data tables: http://earthtrends.wri.org. We would like to thank Catarina Figueira for assistance with the DEA analysis.
[4] Water resource data are at the country level. Data do not exist at the utility level and therefore the input used is not ideal. In the absence of the water resource variable as an input and also excluding the freedom variable, which is also calculated at the national level, the DEA scores showed lower overall efficiency levels but the conclusions on ownership were the same. Whereas 38% of private sector utilities formed the frontier, only 13% of state-owned firms did so. Whereas 63% of the private companies achieved scores of 70% or better, the figure fell to 21% for state-owned utilities.
[5] DEA 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% does not imply absolute efficiency but merely efficiency compared to the other units in the analysis.
[6] To assess whether the quality of service proxy might have biased the results, the DEA analysis was undertaken using simply water distributed as the output and number of staff and number of connections as the inputs. The result was less units on or close to the frontier but the overall conclusion on the role of ownership was broadly the same. Whereas 10% of state-owned firms scored 100%, 17% of privately-owned ones did so. Scores of 70% or above were achieved by 17% of state firms and 27% of private sector firms.
[7] For more details on the stochastic cost frontier, see the Appendix.
[8] Again, the results using an alternative quality indicator, namely unaccounted for water, produced similar results.
[9] Because the variables used in the cost frontier analysis and those in the DEA analysis are different, the size of the sample sets for the two methods are different, due to missing data for some of the variables.
[10] A TEE model including a constant term in the inefficiency term was also estimated. The results are similar to those shown in Table 6.
[11] A Tobit model was also used to assess the impact of the regulation variable on the DEA scores discussed earlier. The result was also statistically insignificant.

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Appendix

Data Envelopment Analysis

DEA is a non-parametric method of assessing the relative efficiency of units without the need to establish the appropriate functional form. A best practice frontier is created by comparing each actual decision making unit (DMU), e.g. firm, with "best" comparable DMUs. A fundamental assumption is that if one DMU, e.g. A, can produce X(A) units of output with Y(A) inputs, then other DMUs should also be able to do the same if they are managed efficiently. Similarly, if producer B can supply X(B) units of output with Y(B) inputs, then other DMUs should be able to do the same. DMUs A, B, C etc are then combined to form a composite or virtual DMU with composite inputs and composite outputs. For each DMU a "best" virtual DMU is generated. If the DMU can produce more output with the same input or the same output with less input then the original DMU is deemed *inefficient*. To generate the best virtual DMU, linear programming techniques are used. Analyzing the efficiency of *n* producers is then a set of *n* linear programming problems.

The following notation applies to an input-oriented DEA analysis. Here λ is a vector describing the percentages of other DMUs used to create the virtual DMU and λX and λY are the output and input vectors, respectively, for the DMU under consideration, and X and Y represent the virtual outputs and inputs. The aim is to minimize inefficiency, represented here by θ. An output oriented DEA maximises output given the inputs through a similar procedure.

$$\begin{aligned} &\min \quad \Theta, \\ &s.t. \quad Y\lambda \geq Y_0, \\ &\qquad \Theta X_0 - X\lambda \geq 0, \\ &\qquad \Theta \quad \textit{free}, \quad \lambda \geq 0. \end{aligned}$$

The Stochastic Cost Frontier

Stochastic frontiers are typically classified as production functions and cost functions. The theoretical specification of the cost function is

$$C = f(Y, P, X)\exp(\varepsilon), \qquad (1)$$

where C is total cost, Y is the output vector, P is a vector of input prices, X is a vector of all relevant exogenous variables needed to allow comparison across firms, and ε is the error term. In the stochastic frontier, the error term ε can be decomposed in two parts, namely μ_i and v_i. The random error, v_i, accounts for measurement error and other random factors, such as the effects of weather, strikes, etc., on the level of costs, together with the combined effects of unspecified factors in the cost function. The v_i s are usually assumed to be independent and identically distributed normal random variables with mean zero and constant variance, $\sigma_v^{\ 2}$ .The μ_i component represents cost inefficiency and is assumed to be distributed independently from v_i and the regressors.

Various distributions have been assumed for the inefficiency term – half-normal, gamma exponential and truncated normal. The truncated-normal distribution is a generalisation of the half-normal distribution. It is obtained by the truncation at zero of the normal distribution, with mean , μ, and variance, σ_{μ}^{2}. Estimation of the truncated-normal stochastic frontier involves the estimation of the parameter, u, together with the other parameters of the model. A null hypothesis, H_0 : μ=0, is usually tested by conducting a Wald or a generalised likelihood-ratio test. The purpose is to test which model, the truncated-normal or the half-normal, can capture the distribution of the inefficiency term. If the null hypothesis cannot be rejected, this means that the simpler half-normal model is an adequate representation of the data. Both the half-normal and the truncated-normal distributions are modelled in either LIMDEP or FRONTIER, the two software packages used for stochastic frontier analysis.

Following the parameterisation proposed by Battese and Corra (1977), σ_{μ}^{2} and σ_{v}^{2} are replaced with $\sigma^{2}=\sigma_{\mu}^{2}+\sigma_{v}^{2}$, $\gamma=\sigma_{\mu}^{2}/(\sigma_{\mu}^{2}+\sigma_{v}^{2})$. This is done with the calculation of the maximum likelihood estimates in mind. The parameter, γ, must lie between 0 and 1, with 0 indicating that the deviation from the frontier is due entirely to noise and 1 indicating that deviation is due purely to inefficiency. It can be tested whether any form of stochastic frontier production function is required at all by the following null hypothesis, H_0 : γ =0. If the null hypothesis cannot be rejected, this indicates that σ_{μ}^{2} is zero and hence that the inefficiency term should be removed from the model. This leaves a specification with parameters that can be consistently estimated using ordinary least squares. A one-sided generalised likelihood-ratio test can be used to test the null hypothesis. If the H_0 : γ =0 is true, the generalised LR statistics have an asymptotic distribution, which is a mixture of chi-square distribution (Coelli, 1995). The critical value for the LR test can be obtained from Table 1 in Kodde and Palm (1986), with degrees of freedom equal to the number of restrictions involved.

Two types of models can be estimated for a cost frontier, namely the Error Component (EC) model and the Technical Efficiency Effects (TEE) model. Battese and Coelli (1995) proposed a TEE model, in which technical efficiency effects are assumed to be independently distributed and non-negative random variables. For the ith firm in a sample, the technical inefficiency effect, μ_i, is obtained by truncation of the N(m_i, σ_{μ}^{2})-distribution, where $m_i = \delta x_i$. x_i is vector of observable explanatory variables.