BENCHMARKING CENTRAL AMERICAN WATER UTILITIES

[RS-T1271: Benchmarking de Empresas Públicas de Agua y Saneamiento en Centroamérica]

By Maria Luisa Corton and Sanford V. Berg

Public Utility Research Center, University of Florida

November 2, 2007

Final Report

Abstract

This report provides an overview of the water sectors for Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. After describing the data collection procedure, the study examines performance patterns across countries, focusing on three core indicators: operational performance, cost, and quality. The study examines trends for 2002-2005 and computes total factor productivity indicators (TFP) for water utilities in each country. Two other quantitative analyses are presented: performance comparisons using Data Envelopment Analysis (DEA) and Stochastic Cost Frontier Analysis. Both methodologies are widely used in the economic literature; they yield different results due to underlying assumptions and techniques for comparing performance. The results provide insights into the relative performance of water utilities in the region.

BENCHMARKING CENTRAL AMERICAN WATER UTILITIES

[RS-T1271: Benchmarking de Empresas Públicas de Agua y Saneamiento en Centroamérica]

Table of Contents

1. CONTEXT OF THE STUDY

A recent IADB study reports that investments of $40 billion for water assets are needed to meet the United Nation's Millennium Development Goals (MDGs), and wastewater treatment would significantly raise that funding requirement.[1] A survey of 400 stakeholders included in the study identified inappropriate pricing policy and lack of clarity in regulatory processes as the two major constraints for increasing investment in water and sanitation systems (WSS) in Latin America and the Caribbean (LAC). Private sector funding could play a role in expanding or improving urban water systems through either equity investments or the purchase of municipal bonds. However, external financial flows are unlikely to increase significantly absent major improvements in measuring system performance and developing incentives for better WSS performance.[2] In this context, *WSS performance* is defined as the quality of service provided to retail customers and the cost efficiency of the utility system's operations.

Developments over the past decade in quantitative techniques and pressures for sector reform have stimulated interest in identifying and understanding the factors that can contribute to WSS network expansion, improved service quality, and cost containment in the sector[3]. Policymakers in Latin America, Asia, and Africa have begun to collect data that can serve as the basis for performance comparisons—creating yardsticks that help decision-makers identify weak and strong performers. Utility managers, water associations, regulators, and other groups have begun to undertake statistical analyses of water systems—over time, across geographic regions, and across countries. Benchmarking has become an important tool not only for the service provider per se but also for policy decision makers within the sector.

---

[1] "Obstacles and Constraints for Increasing Investment in the Water and Sanitation Sector in Latin America and the Caribbean: Survey," Inter-American Development Bank, December 2003, 1-13. The Principal Investigator for this project participated in the survey and attended the associated IADB International Conference on "Financing Water and Sanitation Services: Options and Constraints" (November 10-11, 2003).

[2] Local capital can be an important complement to international capital and managerial expertise. Given costs and ability to pay, rural systems and smaller towns will likely have to depend on development banks and multinational donor projects for support. See Peter Reina (2002), "Latin Lessons for the Private Sector," *Water21*, April, 19-21.

[3] An empirical study of water institutions identified four policy elements that explain sector performance: the economic orientation of project selection criteria, level of cost recovery, policy reform linkages, and water law and water policy linkages. Benchmarking is crucial for several of these elements. R. Maria Saleth and Ariel Dinar (1999), *Evaluating Water Institutions and Water Sector Performance,* World Bank Technical Paper No. 447.

This study provides insights aiming at helping decision-makers become more effective producers *and* consumers of benchmarking studies. While benchmarking is not a panacea for overcoming impediments to private investment, it does provide key inputs into public policy debates and managerial evaluations, with wide-ranging implications for the following:
(1) Sustainability of capital inflows, public deficits, and reform initiatives;[4]
(2) Poverty reduction and public perceptions regarding infrastructure reforms;[5]
(3) Development and implementation of incentives for improving WSS service performance;[6] and
(4) Appropriate roles for multinational organizations, donor nations, and regional cooperation in the provision of WSS services.

Empirical procedures allow analysts to measure cost or productivity performance and identify performance gaps. Benchmarking tools are important to:

- Document past performance,
- Establish baselines for gauging productivity improvements, and
- Make comparisons across service providers.

Rankings can inform policymakers, those providing investment funds (multilateral organizations and private investors), and customers regarding the cost effectiveness of different water utilities. If decision-makers do not know where they have been or where they are, they cannot set reasonable targets for future performance. Robust performance comparisons require analysts to obtain comparable data across firms, select appropriate empirical methodologies, and check for consistency across different methodologies. This study addresses these three aspects and provides a starting point for assessing service providers' performance in the region.

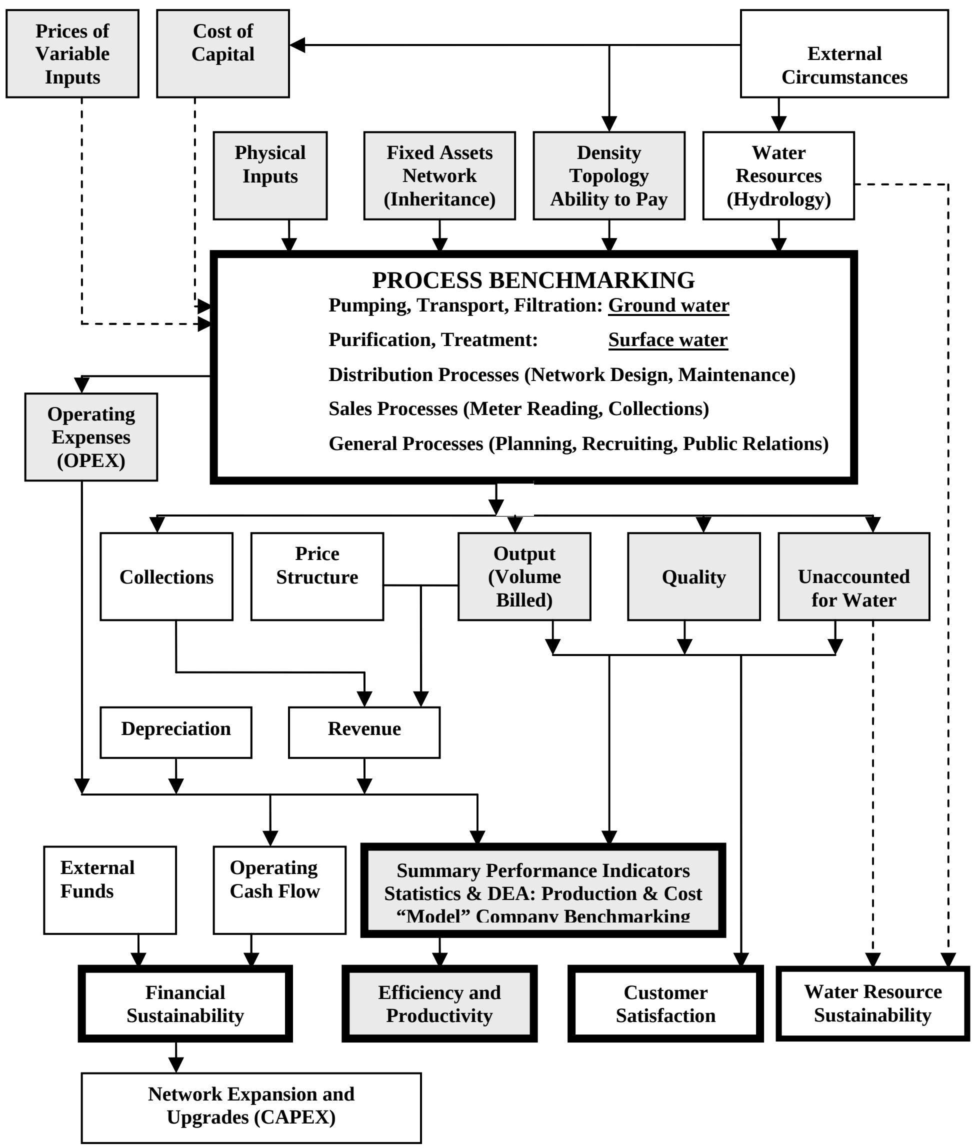
Figure 1 shows how input prices, input levels, and external circumstances enter into the production process. Some variables are under current management's control (like variable inputs), while others are the result of past managerial decisions, like the network (reflecting inherited

---

[4] Typically, investors seek government guarantees, but guarantees can blunt incentives to select efficient projects. In addition, guarantees can become liabilities affecting government budgets. For an overview of public and private initiatives, see William Easterly and Luis Serven (2003), *The Limits of Stabilization: Infrastructure, Public Deficits and Growth in Latin America*, World Bank, xv-208.
[5] *Water Governance for Poverty Reduction: Key Issues and the UNDP Response to Millennium Development Goals* (2004), United Nations Development Programme, 1-93.
[6] Mehta Meera (2003), *Meeting the Financing Challenge for Water Supply and Sanitation: Incentives to Promote Reforms, Leverage Resources, and Improve Targeting,* World Bank, May, 1-136.

assets and past maintenance outlays). For a given level of output, the cost of capital and the prices of variable inputs determine total costs. Due to data difficulties for the cost of capital, analysts sometimes can only identify the determinants of Operating Expenses. Of course, many factors affecting the production process and associated costs are determined external to the utility (population density, topology of the service territory, customer ability to pay, and access to water resources). Performance scores based on production or cost models need to take such factors into account, so that analysts are comparing apples to apples.

Figure 1: Inputs, Processes, Outcomes, and Performance Benchmarking



The figure includes a box labeled Process Benchmarking. This project will not explore the various sub-processes that link inputs to outputs. Such engineering analyses can improve performance, once decision-makers are committed to changes in corporate cultures and/or regulatory environments. Thus, efficiency and productivity are emphasized, using cost and production models to gauge relative performance. To have a comprehensive characterization of benchmarking issues, the bottom of the Chart includes boxes reflecting two other aspects of water sector performance: financial sustainability and water resource sustainability. These important issues will not be examined in this project, but could be the subjects of follow-on initiatives.

2. OBJECTIVES OF THE STUDY

The purposes of this Central America Benchmarking Project are threefold:

(a) Assemble verifiable benchmarking data for the Central American nations;

(b) Prepare studies that identify the relative performance of utilities in the region;

(c) Design a workshop to promote sustainable data collection procedures, making information available to key stakeholders. The bottom line is that without data, managers cannot manage and analysts cannot analyze.

The first task involved obtaining verifiable benchmarking data for six nations over the time period 2002 to 2005. The starting point to implement the data base was to consider data collected by the Asociación de Entes Reguladores de Agua Potable y Saneamiento de las Americas (ADERASA) and the International Benchmarking Network for Water and Sanitation Utilities (IBNET). However, there were some limitations to this approach. ADERASA data comes from the regulatory agencies and not directly from the data source – the utilities. In addition, Guatemala and El Salvador are not members of ADERASA so data for these countries needed to be collected for the first time. The IBNET data set was still in its preliminary stages so several data values were missing for some of the analyzed countries.

Consequently the adopted strategy for collecting data was to address the data source directly. This was done as an incremental process in the sense that data was sent to the source several times for verification. This process is described in the next section. A new and refined data set emerged from this study which includes the following:

- El Salvador data for 2002-2005
- Guatemala, EMAPET-data for 2006
- Guatemala, EMPAGUA – data for 2002-2005
- Honduras, SANAA (Tegucigalpa) – data for 2005-2006
- Costa Rica, ESPH – data for 2002-2003

Regarding the second objective of this study, once several years of consistent data were available for an adequate sample of utilities, the issue becomes one of model selection. A substantial body of technical literature exists regarding this subject. Core indicators like labor productivity, percentage of households receiving service, and water quality represent the simplest types of indicators. With key input, output, and quality information, one can obtain basic performance comparisons. In this study we present a set of core performance indicators commonly used among practitioners: operational performance, cost, and quality.

These performance indicators are very simple but provide a picture of the performance characteristics of the Central American water sector. Some of these performance indicators are compared to those presented by the ADERASA benchmarking group in its most recent annual report for Latin America. These comparisons provide a first step in evaluating relative performance. Yet, many factors affect these specific indicators, including population density, ability to pay (income levels), topography, and distance from bulk water sources. In addition, a performance indicator fails to account for the relationships among factors. A firm that performs well on one measure may do poorly on another, while one company doing reasonably well on all measures may not be viewed as the “most efficient” company.

Thus, the focus of this project will be to move beyond performance indicators to more comprehensive performance metrics and production and cost frontiers. After presenting core performance indicators for the region, this study assess productivity by means of Total Factor Productivity indices (TFP) – the basic idea is to relate how much output is produced using a particular level of input. The productivity of each firm using TFP indices is calculated for the period 2002-2005. This approach considers the mix of inputs used to produce the selected mix of outputs providing a more comprehensive performance assessment compared with overall performance indicators described earlier.

To address relative technical efficiency of the group of firms, we calculate a technical frontier for year 2005 using Data Envelopment Analysis (DEA) which is a non-parametric approach to identifying high and low performing firms. This methodology is viewed as an "extreme point" method because it compares production of each firm with the "best" producers. Analysts apply this quantitative technique to determine relationships among variables: for example, utilities that produce far less output than other utilities (who are using the same input levels) are deemed to be relatively inefficient. Firm and country specific characteristics besides the ones included in the model are considered to be similar to one another. Consequently, the components of the group are critical on determining efficiency rank results.

In addition, technical efficiency change is calculated by means of a DEA frontier for year 2002 and 2005 (utilizing the Malmquist index). Finally, statistical techniques are also applied to the data. A Stochastic Cost Frontier is used to analyze cost efficiency among firms. This methodology represents a higher level of sophistication because it takes into account a functional form for the production technology which recognizes the relationship among factors entering the production process. Each factor's impact on costs is derived after considering all other factors being held constant. A utility might have much higher costs than expected (based on observations of others producing the same output level but having lower costs). A finding of excessively high costs with this methodology would trigger more in-depth studies to determine the source of such poor performance.

The limitation of this statistical technique is that it requires a specific number of observations to produce reliable estimates (approximately10 to 15 observations per variable). For the Central America case, the small number of observations restricted the specification of the technology functional form and the number of variables included. The resulting cost efficiency levels permit the ranking of firms; however, given the limitations of the model, these rankings must be interpreted with great care and should include the consideration of each firm specific production circumstances. Each methodology is described in subsequent sections.

Finally, the last step of this project was the promotion of a workshop which was held in San Jose, Costa Rica in October 15-16, 2007. The workshop objective was to promote data collection procedures within the region. Through a combination of presenters and panel discussions, nearly forty regulators and managers in the region shared their experiences with and perceptions of benchmarking. In the final session, small groups identified critical aspects from lessons learned during the workshop. Appendix A contains individual groups' lessons and a summary of the main points discussed during the panels as factors having an impact on data quality and data collection; in addition, groups discussed the use of benchmarking methodologies and possible policy and regulatory implications. The following is a summary of key lessons from the workshop:

1. Information helps both the operator and the regulator – working as a team is recommended: this should not be an adversarial process. Clear definitions and logical structure for data collection and verification are key factors for successful programs.
2. Service delayed is service denied. Making information available (public) improves performance. Customer awareness of baselines and trends improves their understanding of what is feasible and can put citizen pressure on utility regulators and managers.
3. Benchmarking is a valuable tool for the operator; it is an incremental process involving steps that strengthen organizational capabilities. Once basic information has been processed, the experience yields improvements in procedures as managers better understand information flows and performance outcomes in segments of the utility. Clear and timely information can help managers identify emerging problems—reducing the costs associated with delayed responses.
4. Companies need comprehensive information systems in order to improve data quality and provide timely information. Such systems need not involved highly advanced information technologies that integrate Geographical Information Systems with real-time measurement of system pressure and consumption. Rather, careful reporting of basic data to a centralized data library provides a good starting point.
5. Identification and prioritization of goals in a benchmarking process is critical: the procedures determine the path to be taken. Results should be packaged for different audiences (managers, government agencies, legislative bodies, journalists, citizen advisory boards and non-governmental organizations). Transparency is fundamental for achieving citizen confidence in the system and customer perceptions of legitimacy.
6. Small companies and entities need support to obtain and to use data for benchmarking purposes. Such data is first and foremost a managerial requirement—managers can only manage what they measure. Records document what has happened in the past which provides

a baseline for future developments.

7. A centralized data base helps avoid duplication – a change organizational culture is as important as developing technical capabilities. The latter can be accomplished via training programs; however, these are necessary, but not sufficient, for performance improvements.
8. Performance indicators help to save resources by showing possible performance weakness efforts can be directed in a more focused manner.
9. Benchmarking should be comprehensive; thus, it should cover social information as well as firm financial and operational data. Social information goes beyond production processes to include coverage, access for the poor, and related issues.
10. Benchmarking water sectors at a country level and policy rankings provides a wider perspective for analyzing service provider's performance.
11. Benchmarking is part of tariff review; it can be used as a yardstick for comparing the performance of similar utilities. In addition, it helps potential investors and donors analyze the sustainability of service providers.
12. Benchmarking should include rural areas to bring awareness to policy makers regarding resource allocation within the sector.
13. Data quality is central to any benchmarking process: decision makers need to be included in the process to promote both accountability and sound business practices.
14. Benchmarking is a developing field: the starting point is having clear definitions. In addition, political leaders, managers, and other stakeholders must commit themselves to maintaining and enhancing the data collection/verification process.

3. OBTAINING DATA FOR ANALYSIS

<u>The Process</u>

The data collection process was conducted in incremental steps via e-mail and phone calls to designated data contacts. Project announcement letters were sent to each regulatory agency and service provider in each country (see Appendix B for a sample of project announcement letter). The main idea of this letter besides announcing the project was to commit high level authorities to the project by giving them the responsibility of designating within the institution a data person of their choice who would responsible for collecting and verifying the data. This process parallels data collection procedures utilized by professional practitioners within the auditing and information systems field. These data professionals have identified as a critical issue the commitment of top authorities to the data collection process. By designating the person responsible for collecting the data, the authority figure promotes a verifying process before the data is reported to the external entity.

The invitation letter included the suggestion that the person responsible for data to be the same already designated for the ADERASA Benchmarking group. This was done with the purpose of avoiding any duplication of work within the institution. Indeed, for most of the regulatory agencies the data person is the same individual as the one reporting to ADERASA. Given that ADERASA had limited contacts with the service providers, each regulatory agency was asked to provide this information. Thus, in all cases regulatory agencies were made aware of our direct contact to water service providers. This awareness enabled us to follow possible information links that could exist between the regulatory agency and the utility. See Appendix C for utilized data contacts names, e-mail address and telephone numbers.

The data collection process started by assembling a data base which contained the data made available by ADERASA; some data gaps were filled with a few variables from the IBNET website. The announcement letter included a list of variables and their description which covered general characteristics, outputs, inputs and quality variables. The intent of the data collection process was to remain as simple as possible so the set of selected variables is only a small subset of the ADERASA benchmarking group data set. The following is the short list of variables requested (see definitions in Appendix D):

TABLE 1: VARIABLES REQUESTED FOR THE ANALYSIS

OUTPUTS

1) Volume of water: produced, billed and lost
2) Number of water connections and sewerage: total, residential, with meter
3) Total population, population served, number of inhabitants per connection
4) Network length – for water and sewerage

INPUTS:

1) Number of workers and its costs (or expense): total, by contract and fixed.
2) Volume of energy and its cost (kWh or another unit).

3) Capital stock: non-current assets, accumulated depreciation, annual depreciation.
4) Administrative Expenses, Financial Expenses, Operating costs, Total Costs

QUALITY:

1) Water quality: any variable defining water quality according to each country, such as percentage of residual chlorine.
2) Continuity: number of hours a day customers receive water service
3) Number of complaints
4) Number of network leaks

The data base was assembled in separated Excel files; each individual file was sent to each utility data contact for review, for filling in variable gaps and for additional years of data when necessary. It is important to make a distinction between the data collection process utilized in this project and an *in house* data collection procedure which is generally used by financial or accounting auditors and by information systems analysts when implementing computer information systems. The use of the latter procedure implies significant higher costs due to the use of specialized personnel located in each company (if addressed in parallel) or hired for longer periods of time (if data verification is to be addressed sequentially). The need for local office space and other complementary inputs raises the cost of such a data collection process. In fact, the costs of such an House data collection process can exceed the benefits, depending upon the final objective of data collection. The critical point to consider in any data collection process collapses is the commitment to the process from the data source; this pilot PURC/IADB project successfully achieved assembling and analyzing water utility data from the region--for the first time.

Once data requested was obtained from its owner source and put together into the main data base, only a subset of variables were selected for the analysis because not all countries reported all variables or all years. Consequently, the number of observations was reduced to allow the data set to be comparable for all utilities and to include all countries.

After calculating the set of performance indicators, some outliers were identified. In other words, there were some data values standing out from the set of observations for a company and/or they stood out of the group of comparable data among utilities. These identified values were sent again to the data contact, asking for additional verification.

This process was repeated a few times until all the data providers accepted that the data to be used in the study were correct and valid. From the view point of a formal data collection process the final step consists in the data source signing a form certifying that the provided data is verifiable and of good quality. The signatures were not collected, but a final acceptance e-mail was received from each data provider. Consequently, the data collection process was considered as complete in April 2007—with some further revisions and extensions provided by cooperating institutions .

Overall, reactions to data request from the utilities were good in the sense that all participants showed willingness to participate. However, response was slow in some countries. Nicaragua's Presidential change resulted in high level staff changes (either president or directors) for both the regulatory agency and service provider (INAA and ENACAL respectively).

In addition, ERSAPS and SANAA from Honduras are going through technological and structural changes as new computers are being installed and SANAA service is transferred to municipalities. SANAA's financial data is not on digital media which limited its availability.

Regarding Guatemala, the water sector service is under the responsibility of municipalities, so data are highly dispersed among the 331 municipalities. Nevertheless, we were able to reach EMAPET - Empresa Municipal de Agua Potable y Alcantarillado Flores San Benito – which initiated operations in 1997, and finally EMPAGUA which is the largest service provider, serving the country's capital.

Factors Affecting the Data Collection Process

Several factors were identified as affecting data availability within the region: the on going water sector restructuring (from an institutional point of view), low level of water infrastructure in place, and the low development of the sector's information technology. From an institutional point of view, Costa Rica, Panama and Honduras have independent regulatory agencies. El Salvador, Guatemala and Nicaragua, still have central government institutions overseeing the water sector. From the infrastructure perspective, El Salvador, Honduras and Nicaragua show a low level of infrastructure in place; of the number of local and independent water providers (such as juntas vecinales de agua) complicate the data collection/correction process.

Finally, the development of information technology is central to any data collection initiative. According to United Nations agencies' statistics on measuring Information and Communication Technologies, the diffusion index (ICT) which includes connectivity and access to computers for these countries - from high to low - is approximately 40% for Costa Rica; 30% for Guatemala; 25% for Panama and Honduras and 15% for El Salvador and Nicaragua . Information technology is the core to any structured data collection procedure. The availability of an information system Specific for the sector is crucial[7] for any data collection process within this region.

However, the presence of technology is *necessary but not sufficient* for improved information on water utility performance. Besides utility managers, who are ones main responsible for collecting appropriate data for running their businesses, the role of other stakeholders (citizens, journalists, governmental organizations, and public officials) should be considered by government when designing rules regarding the sector. For example, it is essential that regulatory agencies be allowed by law to collect data from utilities. There are no strategic or competitive reasons why a water utility should not "open its books"—whether state-owned or privately-owned. In the same way it is important to establish formal communication channels among all the institutions related to the sector (such as environmental or municipal development agencies) so that data collection programs and possible data repositories are well identified.

Data from all service providers is not available for this study so knowing the share of the population served by each utility with respect to total country population allow us to identify the comprehensiveness of this study and to identify possible directions for future efforts toward data collection. Appendix E describes the sector structure for each country regarding the presence of service providers and regulatory bodies. This review evidences fragmentation of service provision on some countries which may act as a restriction (or difficulty) on data collection procedures. By identifying segments of the industry with no data, policy decision makers, regulators and service provider's managerial staff may be encouraged to introduce additional efforts regarding data

---

[7] Recent initiatives within Latin-American countries are the 2004 workshop for the development of a water sector information system hosted by Peru with the assistance of Honduras; in 2006, El Salvador hosted a similar event with the presence of Honduras.
http://www.rashon.org.hn/noticias_sept.html

collection procedures. Table 2 summarizes the set of service providers by country and their water service coverage for this study.

TABLE 2: SERVICE PROVIDERS BY COUNTRY 2005 - SUMMARY

COUNTRY	SERVICE PROVIDER	POP SERVED/TOTAL
Costa Rica	AYA & ESPH	51% & 0.5%
El Salvador	ANDA	94%
Guatemala	EMPAGUA &EMAPET	10% & 0.005%
Honduras	SANAA	20%
Nicaragua	ENACAL	52%
Panama	IDAAN	66%

4. PERFORMANCE INDICATORS

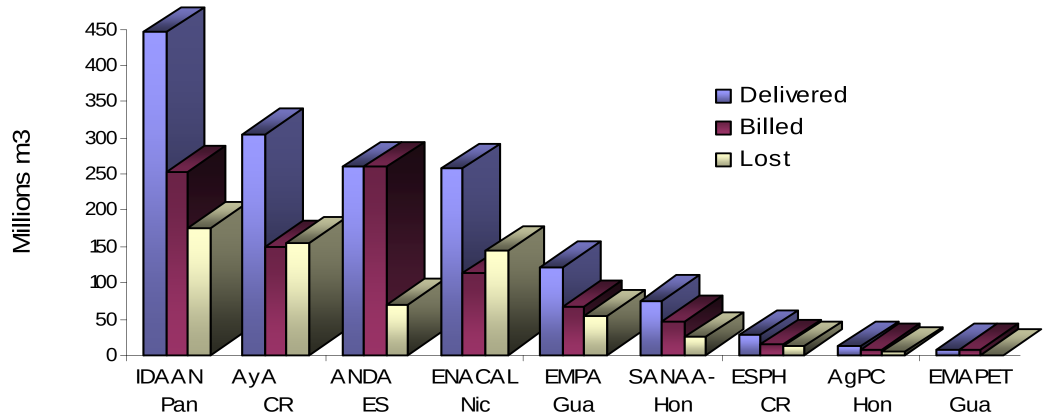
The first stage of analyzing sector performance involves calculating core performance indicators commonly used by managers and researchers for evaluating specific company trends. The ADERASA Benchmarking group has calculated a set of operational, cost and quality indicators[8] which will in some cases be compared to those indicators obtained for the Centro American region. This comparison is one way to evaluate the impacts of public policy and managerial incentives in the region. To maintain consistency, definitions of these indicators are the same as those developed by the ADERASA group.

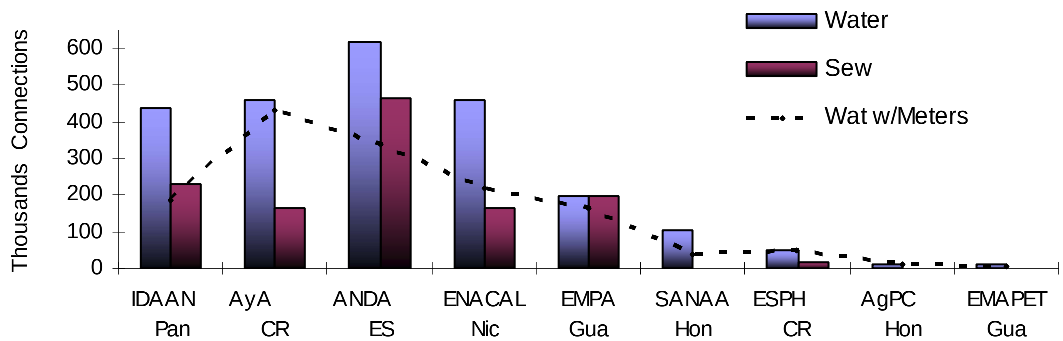
Water service provision can be measured by three factors: volume of water, number of connections and population served. Based on these dimensions, three groups of utilities are identified for the Central American countries: *large utilities*, comprised of IDAAN, AYA, ANDA and ENACAL, *medium size utilities* comprised by EMPAGUA and SANAA, the *small utilities* group which includes ESPH, Aguas de Puerto Cortes (APC), and EMAPET.

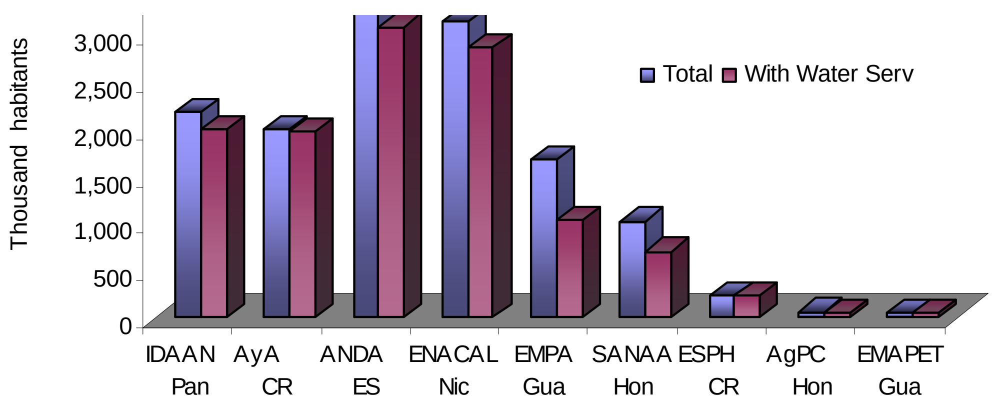
From a volume of water point of view, IDAAN-Panama and AYA-Costa Rica are the largest providers. **Figure 2** shows average volume of water delivered billed and lost for 2002-2005. ANDA-El Salvador has the larger system from a number of connections point of view.

[8] Benchmarking de empresas de agua y saneamiento de Latinamerica (Anos 2003-2004, 2005). Hereafter referred to as ADERASA Benchmarking report 2005-2006

Figure 2: Average Volume of Water Delivered, Billed and Lost







The following is the list of performance indicators calculated for the utilities in the region:

<u>Operational Performance Indicators:</u>

- ✓ Water Lost or commercial efficiency[9]

---

[9] SANAA-Honduras covers Tegucigalpa only; EMAPET (Guatemala) has not reported water lost.

- ✓ Metering
- ✓ Coverage
- ✓ Network Density
- ✓ Water Consumption
- ✓ Number of Workers per one thousand connections

Cost Indicators:

- ✓ Operating Cost per connection
- ✓ Operating Cost per cubic meter of water delivered
- ✓ Share of labor and energy costs, and administrative expenses

Quality Indicators:

- ✓ Quality of water
- ✓ Continuity of service
- ✓ Number of complaints per connection
- ✓ Number of leaks per km of pipe

Operational performance indicators

Water lost or commercial efficiency: This performance indicator reflects deficiencies in either operational or commercial practices. The extent of water losses may reflect a cost tradeoff between increasing water production and repairing network leaks to keep up with water demand. In other words, to satisfy demand, managers may find it more costly to repair leaks and to control water losses than increase water production. Pipe leaks on the transmission segment require costly maintenance outlays, particularly on long or dispersed networks. Operational water losses arise in transit while in the transport or main network, and are calculated as volume of water produced less water delivered to the distribution[10] network.

Referring to the distribution system, water losses may be either due to water theft or to pipes' leaks. It is plausible to argue that given the characteristics of this sector it may be hard for firms to control commercial losses if that entails denying the service to the poorest segments of the population. For the distribution network, water losses are measured as the difference between

[10] Water is lost during treatment as material is flushed out (perhaps 5-10%), however the starting point distinction between water produced after treatment or water taken by the plant is not considered here.

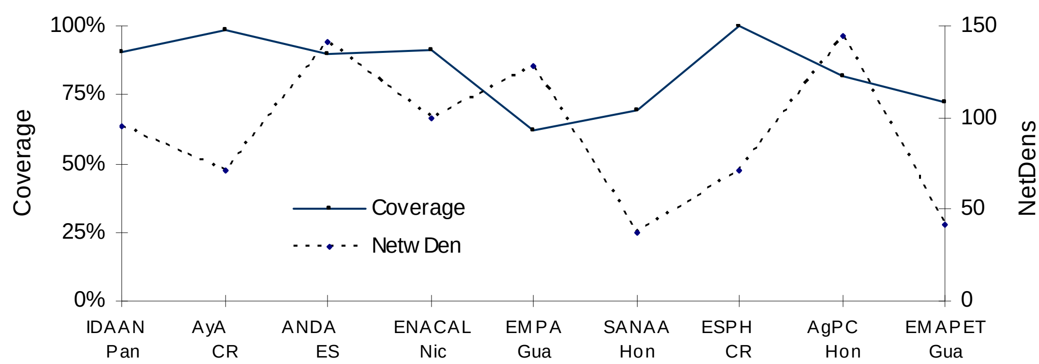
water delivered to its starting point and water billed: commercial losses. Another way of viewing this indicator is to calculate the ratio of water billed to water delivered to the distribution network which is referred by the ADERASA benchmarking group as an indicator for commercial efficiency. Higher than the ADERASA value for this indicator, which equals 40%, the medium value of **55%** found in utilities of the Centro America region indicates a generalized water lost (it can be noticed from figure 2 above).

Metering: This indicator is calculated as the ratio of the number of connections with a meter in place to number of total connections. Meter installation costs are high. In some countries there is a direct allocation of metering costs to the consumer, which may translate into higher tariffs. The higher is the level of metering, the higher the possibility of identifying water losses from the distribution system and the more accurate will be revenue and collection information. From figure 3 above, both utilities from Costa Rica, AYA and ESPH show the highest level of metering within the region (both above 90%) followed by EMPAGUA-Guatemala (84%), and APC-Honduras (77%). Overall, metering median value is **56%**, which is lower than the 75% median value for ADERASA members.

Service coverage: This operational performance indicator is calculated as the ratio of population with water service to total population in the area. The median value for water service coverage in this region is **90%** which is very close to the ADERASA value of 89%. There is a noticeable coverage gap between large and medium-small utilities. Coverage is equal to 92% for large firms, 66% for medium firms and 85% for the small utilities group. These differences are illustrated on figure 4 above.

Network density: Water companies with a similar scale, measured by number of connected properties, may have different costs due to differences in network characteristics, such as length. Larger firms could have lower costs due to a higher network density (customers per kilometer of pipe) rather than a scale economy (total output). To explore this issue, network density - the ratio of number of connections to network length - is considered in this analysis. The median value for number of connections per km of pipe equals 95 Central American utilities. Larger firms have denser networks than medium and small firms (102 connections per km as opposed to 83 and 86 respectively). APC-Honduras, with 144 connections per km of network, ANDA-El Salvador with 141 connections per km, and EMPAGUA-Guatemala with 128 connections per km are the utilities with networks presenting higher densities. Notice that although both utilities from Costa Rica have a coverage close to one hundred percent, their network density (71 connections/km) is lower than the medium value for the region. **Figure 5** shows coverage and network density for the region.

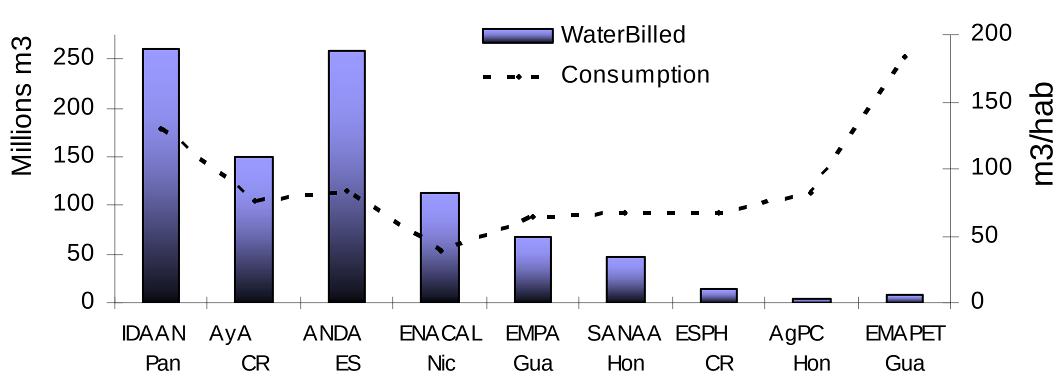
Figure 5: Coverage and Network Density



The low coverage and high network density values found for EMPAGUA signals that the system can be expanded by increasing the length of network to reach populated areas with no water service. The low coverage and low network density for SANAA may indicate that the system can be expanded by adding more connections to satisfy water demand within the area of service.

Water consumption: The ADERASA benchmarking group utilizes the ratio of volume of water billed to population with water service as an indicator for water consumption. The median consumption value for the region equals **219** liters per person per day, which is slightly higher than the ADERASA value of 172. Smaller companies are able to satisfy a higher consumption level - 323 liters per person per day- as opposed to a lower 222 satisfied by larger firms. **Figure 6** depicts this indicator.

Figure 6: Volume of Water Billed vs Consumption



Number of workers per one thousand connections: This indicator is used in the water sector literature as signaling labor efficiencies or inefficiencies. A large value suggests the company is using a higher than efficient number of workers on its production process. The median value for this indicator equals 6.6, which is twice the value for that on ADERASA members suggesting labor inefficiencies (or lack of scale economies). It is important to notice that number of workers considered for this indicator is a total figure which includes contracting or outsourcing labor for some of the utilities. Figure 7 portrays this indicator.

Figure 7: Number of Workers per 1000 connections vs. Total Workers

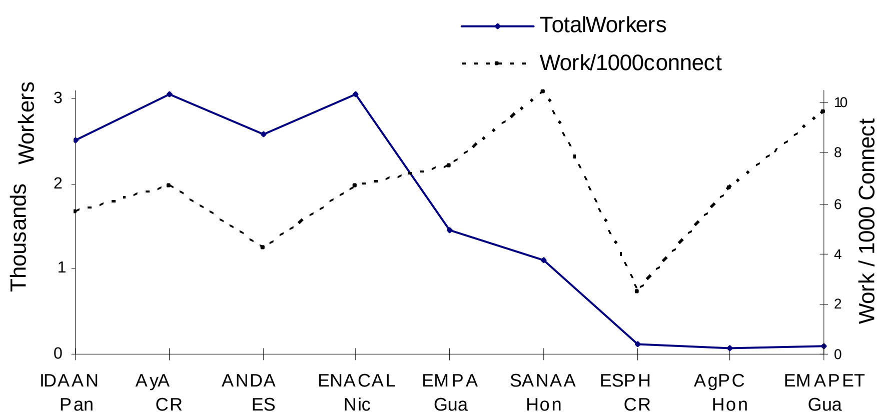


Table 3 presents a summary for the operational performance indicators discussed above. Making comparisons based on individual indices is fraught with difficulty. Clearly, national priorities and funding sources affect the pace and pattern of network expansion. Nevertheless, these numbers and ratios can serve as a starting point for more comprehensive analyses.

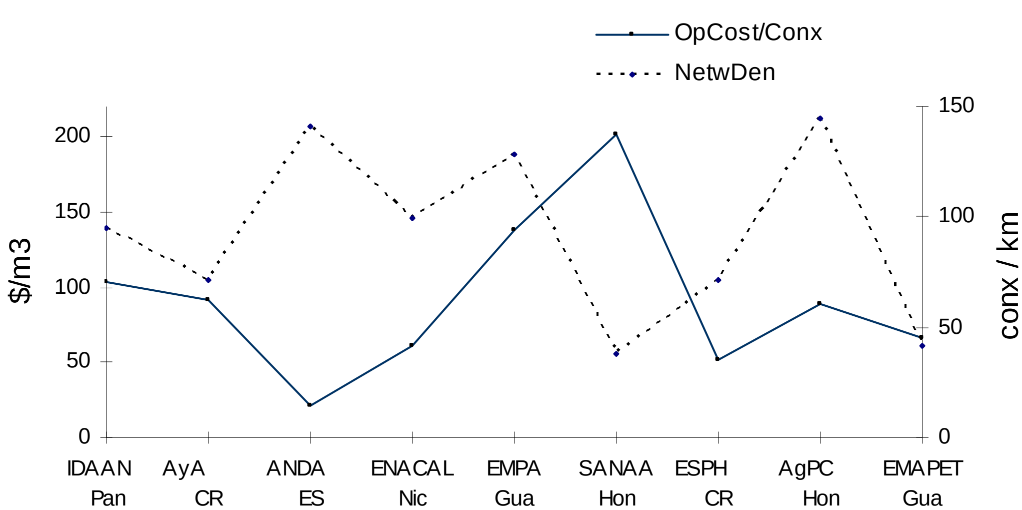
TABLE 3: OPERATIONAL PERFORMANCE INDICATORS, 2005

Utility-Country	Vol Del Millm3	Vol Lost %	Num Conn Miles	Met %	VolDel perPerson	PopSer Miles	Coverage %	NetLength Km	NetDensity Conn/km	#workers/ 1000 conx
Panama-IDAAN	452	58	448	41	126	2,004	92	4,727	95	5.6
Costa Rica-AYA	305	49	457	94	76	1,978	99	6,437	71	6.7
El Salvador-ANDA	259	-	619	55	84	3,093	90	4,391	141	4.2
Nicaragua-ENACAL	257	44	457	48	39	2,870	91	4,604	99	6.7
GuatemalaEMPAGUA	122	55	195	84	81	1,045	93	5,013	128	7.5
Honduras-SANAA	75	63	105	35	67	707	69	2,800	38	10.5
Costa Rica-ESPH	28	55	48	97	66	228	100	678	71	2.5
Honduras-APC	10	44	11	77	157	53	71	77	144	6.6
Guatemala-EMAPET	7.6	-	10	56	183	42	72	232	42	9.6

Cost indicators

Operating costs include labor and energy costs, chemicals, administrative and sales expenses. Depreciation and finance expenses are considered as part of total costs. On average, operating costs are $91/connection. **Figure 8** shows operating costs per connection and its relationship to network density. Higher values of network density are associated with lower values for operating costs per connection as it is expected.

Figure 8: Operating cost per Connection vs. Network Density



Average operating cost per cubic meter of water delivered per utility is depicted in **Figure 9**. The median operating cost per cubic meter is $0.10, half the cost of ADERASA member countries. However, medium firms present an average cost of $0.25/m3 as figure 9 illustrates but it is still lower than the maximum value for ADERASA members ($0.52 /m3).

Figure 9: Average Operating Cost/m3

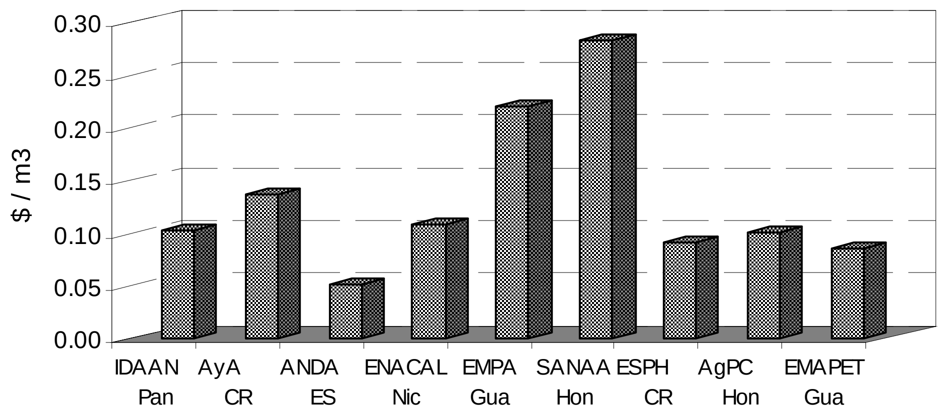


Figure 10 illustrates the share of labor cost, energy, and administrative expenses per cubic meter per firm with respect to operating cost. For the large group, the median administrative expense per connection equals $27, whereas it equals $34 for the small group. Both values are lower than the similar indicator for ADERASA members ($47).

Figure 10: The share of labor costs, energy and administrative expenses per m^3

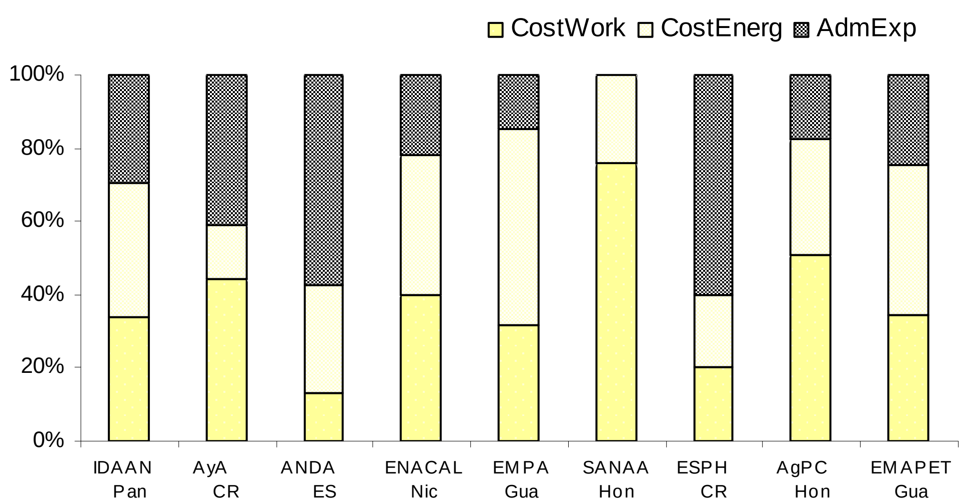


Table 4 summarizes cost indicators discussed so far. These ratios (or core indicators) are commonly used to make comparisons across water utilities.

TABLE 4: FINANCIAL PERFORMANCE INDICATORS

Country	OpCosts /VolDel $/m3	CostWok /VolDel $/m3	CostEner /VolDel $/m3	AdmExp /VolDel $/m3	FinExp /VolDel $/m3	OpCosts /Conx $/m3
Panama-IDAAN	0.10	0.04	0.04	0.03	0.004	103
Costa Rica-AYA	0.14	0.07	0.02	0.07	0.041	91
El Salvador-ANDA	0.05	0.01	0.01	0.03	0.006	21
Nicaragua-ENACAL	0.11	0.07	0.06	0.04	0.027	61
Guatemala- EMPAGUA	0.22	0.07	0.12	0.03	0.034	138
Honduras-SANAA	0.28	0.11	0.03	0.00	0.000	201
Costa Rica-ESPH	0.09	0.02	0.02	0.06	0.022	51
Honduras-AgPtoC	0.10	0.03	0.02	0.01	0.000	89
Guatemala-EMAPET	0.08	0.05	0.06	0.03	0.000	66

Quality indicators

Compliance with water quality standards has a median value of 95.96% for ADERASA members. The Central America countries group displays a slightly higher value: 72.61%. Continuity - the number of hours with water service - ranges from 20 to 24 hours[11]. Number of complaints per connection (median value) is similar for both ADERASA and Central American utilities[12]. The median number of leaks per km of pipe is 2.53 for ADERASA members, almost half the value found on Central America countries, 5.19. This suggests a lower degree of pipes service maintenance for Central America water networks compared with the Latin American set of water networks[13]. Table 5 shows average values for the quality indicators discussed.

[11] ANDA has not reported this indicator.
[12] Complaints can have some peculiar characteristics as it was indicated on a previous revision. Complaints may rise after management improves operational procedures if the phone is actually answered by someone.
[13] However, as indicated by Hubert Quille, "A good comprehensive indicator should include pressure as one of its components."

TABLE 5: QUALITY PERFORMANCE INDICATORS - SUMMARY

Country	Quality	Continuity	Complains /Conx	Leaks /km
Panama-IDAAN	69	21	0.03	6
Costa Rica-AYA	98	24	0.70	3
El Salvador-ANDA	90	0	0.20	10
Nicaragua-ENACAL	100	20	0.24	3
Guatemala - EMPAGUA	100	9	0.01	5
Honduras-SANAA	100	7	0.13	0
Costa Rica-ESPH	99	24	0.30	22
Honduras-AgPtoC	98	24	0.13	12
Guatemala-EMAPET	0	22	0.11	5

System expansion and cost trends: 2002-2005

This section describes changes occurring during 2002-2005 for a subset of performance indicators. In particular, changes occurring in number of connections and network length imply system expansion: so utilities can be at different stages of the investment cycle. A system expansion associated with the network distribution segment generally implies an increase in number of connections and additional pipes. As a result, water delivered and population served should naturally increase.

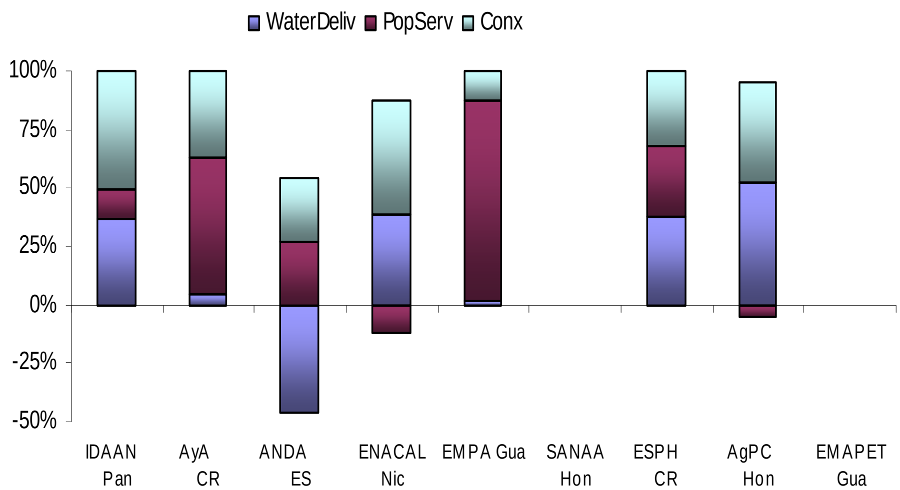
On the other hand, expansions on water transmission pipes do not imply adding more connections only increasing network length. **Figure 11**[14] depicts percentage changes in water delivered, population served and number of connections. **Figure 12** show changes in network length and number of connections on a one hundred percent basis to illustrate the type of system expansion.

IDAAN and ESPH show proportional increases for all system expansion variables. AYA and ANDA exhibit a proportional change in number of connections and population served but expansion associated with volume of water delivered is very small and even negative for ANDA. This suggests an expansion with a reduction on average consumption (as the ratio of water

[14] For SANAA-Honduras and EMAPET-Guatemala there is just one year data available so there is nochange. ANDA does not have information on network length from past years so there is no change for this variable.

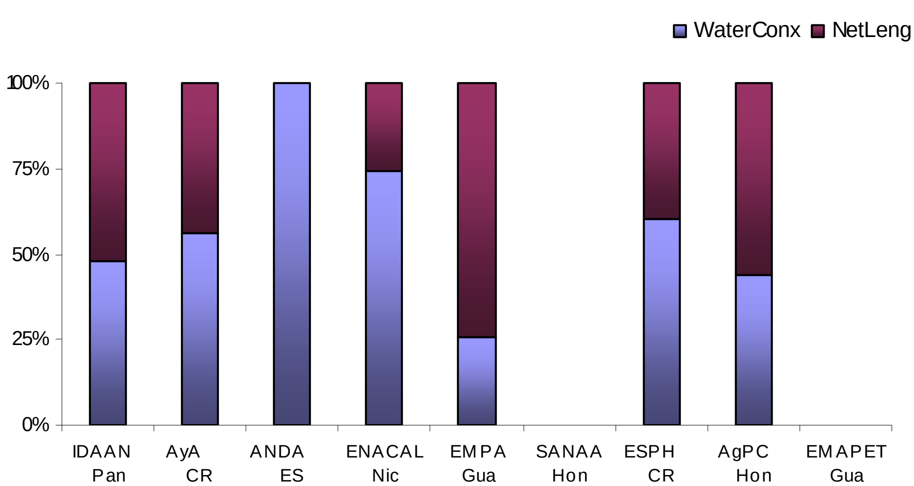
delivered to population served). The incomes and demographics of new customers may explain this pattern. ENACAL and APC displays a proportional increase on number of connections and water delivered but surprisingly population served has decreased. A possible explanation for this happening may be a lack of consistency for the data available regarding population. It may be the case that population was only estimated rather than taken from the national census or vice versa.

Figure 11: Changes on Water Delivered, Population Served and Number of Connections



With respect to the increase in number of connections and network length, EMPAGUA shows higher increase in network length than in number of connections. This may suggest a system expansion from the transportation system rather than on the distribution system. Alternatively it may indicate earlier stages of the distribution network expansion where customers have not been connected yet.   ENACAL's increase in number of connections is higher than the increased length of network. The fact that population served does not show a proportional increase may suggest that those connections are added to satisfy commercial and industrial customers which generally do not add to population served.

Figure 12: Changes on Water Connections and Network Length



Figures 13 to 16 display several cost trends for 2002-2005 with upside arrows meaning increase and down side arrows a decrease[15]. Changes are small in magnitude for all variables. Costa Rica-AYA displays a significant increase in cost of workers and administrative expenses which may explain the increase on its operating costs. On the other hand, IDAAN increase on operating costs may be explained by an increase on energy costs. ANDA displays diminishing administrative expenses which may explain the decrease on its operating costs. Overall, operating cost changes are small for the period 2002-2005.

Figure 13: Change in Cost of Workers

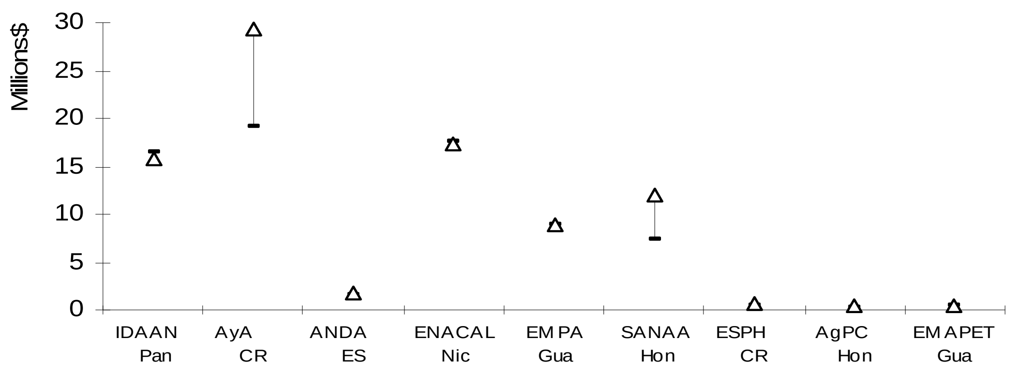
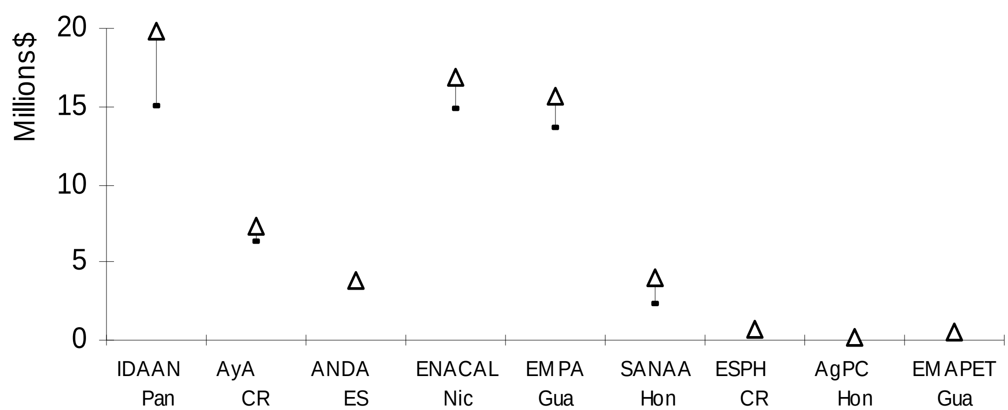


Figure 14: Change in Energy Costs



[15] **Starting point** is 2002 for IDAAN, ANDA, and ESPH; 2003 for AYA, AgPtoCortez; 2005 for SANAA; **Ending point** is 2005 for all but SANAA, AgPtoCortez, IDAAN and EMAPET which is 2006.

Figure 15: Change in Administrative Expenses

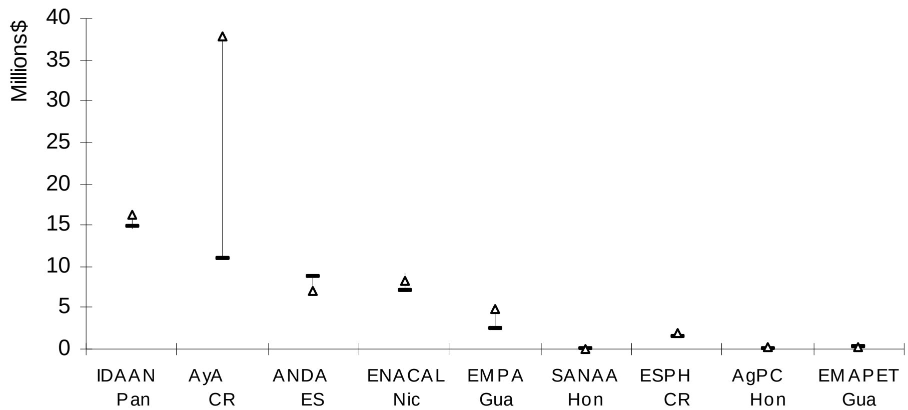


Figure 16: Changes in Operating Costs

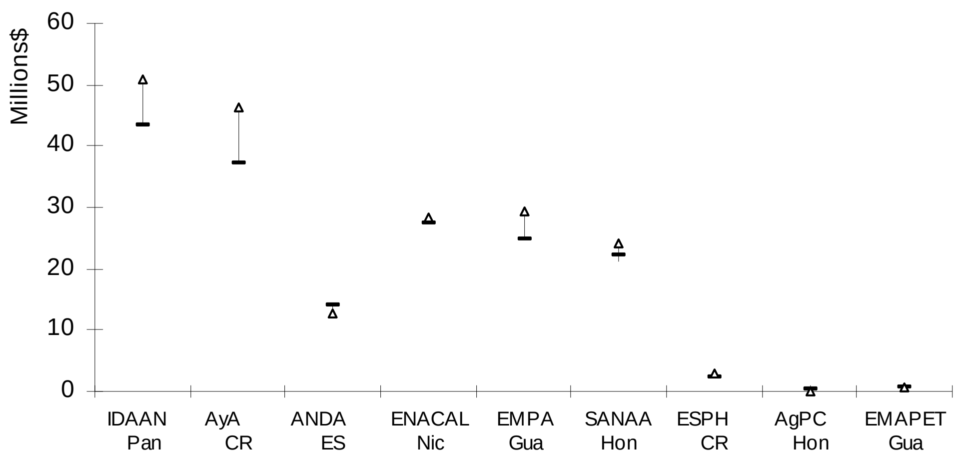


Table 6 presents a summary of percentage changes for the different variables. Costs are dollars per cubic meter of water delivered. No simple pattern emerges. Connections and Population served have tended to rise together. Energy costs show fairly dramatic increases, reflecting a combination of input price increases and greater utilization of energy inputs to service larger systems. Significant increases in cost of workers could be due to a re-classification of professions (purely an accounting phenomenon) or to increased focus on hiring professionals with managerial skills. The out of range values for Aguas de Pto Cortes (Honduras) signal the presence of data problems.

Table 6: Percentage of Change Values for 2002/2005 – summary

Country	Vol Water Delivered	Population Served	Number Connections	Network Length	Cost of Workers	Energy Costs	Admin Expenses	Operating Costs
Panama-IDAAN	17%	6%	24%	26%	2%	54%	-22%	18%
Costa Rica-AYA	2%	27%	17%	13%	54%	15%	251%	25%
El Salvador-ANDA	-11%	7%	7%	0%	8%	2%	-18%	-10%
Nicaragua-ENACAL	11%	-4%	14%	5%	-1%	14%	17%	4%
Guatemala-EMPAGUA	1%	24%	4%	10%	1%	16%	95%	18%
Honduras-SANAA	0%	0%	0%	0%	0%	0%	0%	0%
Costa Rica-ESPH	12%	10%	10%	7%	16%	109%	45%	29%
Honduras-AgPtoC	14%	-4%	30%%	38%	57%	18%%	297%	315%
Guatemala-EMAPET	0%	0%	0%	0%	0%	0%	0%	0%

5. SUMMARY OF FINDINGS FROM PERFORMANCE INDICATORS

The following is a list of findings from individual performance indicators for water and sewerage service providers in the Centro American region:

Firm Specific Performance

1. IDAAN and AYA are the largest providers from a volume of water delivered point of view and ANDA from a number of connections perspective.
2. ANDA has the denser network and the lowest operating cost per connection and per cubic meter of water delivered.
3. Both utilities from Costa Rica, AYA and ESPH and EMPAGUA from Guatemala have the highest metering level.
4. The low coverage and high network density values found for EMPAGUA signals that the system can be expanded by increasing the length of network to reach populated areas with no water service. The low coverage and low network density for SANAA may indicate that the system can be expanded by adding more connections to satisfy water demand within the area of service.
5. IDAAN, AYA and ENACAL have approximately half the amount of sewerage connections with respect to those of water. This may signal cost restrictions to expand the sewerage system.
6. Costa Rica-ESPH has the smallest labor indicator (2.5 workers per one thousand connections).

Operational Performance

1. Commercial efficiency (60%) is higher than that found among Latin America countries (40%).
2. Metering (55%) is significantly lower for Central America compared with the metering value found among utilities from Latin America (75%). Metering costs are in some cases directly allocated to customers. If keeping a low level tariff is a government objective, a more aggressive assessment of the metering issue within the region may face some difficulties.
3. The median level of service coverage is close to that found in Latin American utilities. A noticeable gap in coverage is found between large and medium firms (92% and 66% respectively).
4. Large firms have networks with greater density than medium and small firms (102connections/km, 83connections/km, and 86connections/km respectively).
5. The median value for water consumption is approximately 27% higher for Central American countries compared with Latin American countries (219 and 172 liters per person per day, respectively). Small companies serve customers with higher level of consumption than large firms (323 liters per person per day and 222 liters per person per day respectively).
6. Labor inefficiencies were found in this region compared to Latin America. Central American water utilities labor indicator is twice the value found on Latin American water utilities (6.6 and 3.2 respectively).

Cost Performance.

1. The median operating cost per cubic meter of water for the Central American utilities is half that found on Latin American utilities ($0.10/m3 and $0.20/m3 respectively).
2. Medium and small firms have higher operating costs per cubic meter than large firms.
3. Lower operating costs per connection are associated with higher network density.
4. The median value for operating costs per cubic meter of water for the Centro American utilities is half that for the Latin American utilities.
5. The Central America group of utilities has lower administrative expenses than Latin American utilities. The median value for administrative expenses per connection for the large group of utilities equals $27 and $34/connection for the small group. The ADERASA value is $47/per connection.

Quality Performance

1. Overall, compliance with water quality standards, continuity (hours of service per day) and customer complaints indicators are similar to those found in Latin American utilities.
2. The median number of leaks per km of pipe for Central America utilities is twice that for Latin American utilities. The natural relationship between administrative (maintenance) expenses and number of pipe leaks may be the base line for concerns on this matter within the region.

System expansion and costs trends 2002-2005

1. IDAAN and ESPH show proportional increases in number of connections and network length.
2. AYA and ANDA exhibit a proportional change in number of connections and population served but expansion associated with volume of water delivered is very small and even negative for ANDA. This suggests an expansion with a reduction on average consumption (as the ratio of water delivered to population served). The incomes and demographics of new customers may explain this pattern.
3. ENACAL and APC displays a proportional increase on number of connections and water delivered but a decrease in population served. Lack of consistency for the data available regarding population may explain this.
4. Overall, changes in operational costs for the period are relatively small.
5. AYA's increase in operational costs may be explained by an increase in cost of workers and administrative expenses.
6. IDAAN's increase in operational costs may be explained by its increase in energy costs.
7. ANDA displays a decrease in operational costs which may be partly due to a decrease in administrative expenses.

6. TOTAL FACTOR PRODUCTIVITY ANALISIS

Performance indicators are "partial" in nature: they consider one dimension of performance at a time. By contrast, total factor productivity (TFP) analysis focuses on firms productivity change over time and takes several inputs and outputs into account.

Productivity may differ over a period of time for the following reasons:

1. Technological change (frontier shift): a technological change has occurred within the sector

producing a variation on firm's productivity.

2. Technical efficiency change (catch-up): A firm has varied its production efficiency over time.
3. Scale efficiency change: A firm change in production efficiency is product of a change in its scale of production.
4. Input mix allocative efficiency: A firm has varied its efficiency by producing outputs using a different mix of inputs, given the input prices the firm faces;
5. Output mix allocative efficiency: A firm has varied its efficiency by producing a different level of outputs with the same mix of inputs; given the input prices the firm faces.

By understanding the sources of productivity change, managers can focus improvement in areas that seem weak. At the same time, by understanding the sources of productivity change, policy makers, investors and other stakeholders can point to the most productive firms as examples of strong performance—promoting the diffusion of best practice to all firms.

To decompose productivity into the above components requires knowledge of the firm's production technology – the particular way a firm mixes inputs to produce its set of outputs which generally translates into a functional mathematical form for the production process. Quantitative methodologies can be used to isolate the roles of these various components which are generally accomplished by employing econometric procedures to estimate a functional form for the production technology. Statistical tests are performed to check how properly represented is the technology by the selected functional form. Data limitations for the Central American region limit the possibility to perform such decomposition. However, the calculation of total factor productivity indexes represents a good starting point to assess performance within the region.

The basic idea behind a Total Factor Productivity (TFP) index is to know how much output is produced due to each unit of input, which can be expressed by the following equation:

$$TFP = Y / X$$

Y is the level of output and X de level of input utilized in the production process. In practice, there may be more than one output which is produced from a combination of inputs. If so, a TFP index is constructed as the ratio of an output index to an input index, in such a case it captures the input mix that produces the output mix. The input index should reflect the relative importance of each input in producing the output(s). In the same way, the output index should reflect the relative importance of the outputs. A simple way to represent this is by using weights, which are the prices or costs of inputs and outputs with respect to some reference point, usually, total or operating costs. Assume **r** is the weight given to **k** outputs and **s** the weight to **n** inputs. The equation to calculate a TFP index to measure productivity change between two periods of time, say from year 0 to year 1 including weights is the following:

$$\frac{TFP_1}{TFP_0} = \frac{\sum_k r_k Y_{k1} / \sum s_n X_{n1}}{\sum_k r_k Y_{k0} / \sum s_n X_{n0}}$$

Three aspects are relevant when setting the above mentioned weights: the selection of *the elements* that represent the weights (prices or costs), the mathematical or *functional form* that combine them and whether the *weights are the same* for the two analyzed periods or not (in the above equation, the weights are assumed the same for both periods but they may not be). These aspects produce different alternatives for calculating TFP indexes. When considering the initial set of prices (base period) yields a ***Laspeyres*** index while using the final period prices produces a ***Paasche*** index. The index most common used is the ***Fisher*** index which uses the geometric mean of the two periods. All these TFP indexes are calculated for the Central American utilities.

Regarding the functional form to relate the weights, the three indexes previously defined imply a linear functional form. The ***Tornqvist*** index uses a logarithm form[16] which from the point of view of economic theory is more flexible because it can actually reflect actual production technologies.

In order to simplify the analysis, two sets of TFP measures are calculated: one considering volume of water billed as the output and another considering number of connections[17] so weights for the outputs are not required.

As in most empirical studies, labor and energy volume are the input factors considered on both TFP indexes. Not all service providers reported energy volume in the data collection so, these TFP index are calculated only for a set of them. The weights for the input factors are calculated as the ratio of their respective costs relative to direct operating costs. See Appendix F for data used to

---

16 $\ln\left(\frac{TFP_1}{TFP_0}\right) = \frac{1}{2}\sum_k (r_1 + r_0)\ln\left(\frac{Y_1}{Y_0}\right) - \frac{1}{2}\sum_n (s_1 + s_0)\ln\left(\frac{X_1}{X_0}\right)$

17 EMPAGUA reported same value for energy volume all years so it is not considered for calculation.

calculate these TFP indexes and Table 7 for the results.

TABLE 7: PRODUCTIVITY CHANGE OVER 2002-2005 (USING TFP)

PRODUCTIVITY CHANGE	TFP	Laspeyres, Paasche & Fisher	TFP Tornqvist	
OUTPUT	Volume	#Connect	Volume	#Connect
IDAAN – Panama	51%	53%	31%	32%
ANDA – El Salvador	-17%	-6%	-9%	0
ENACAL – Nicaragua	-5%	1%	-5%	-2%

The calculation of TFP index produces similar results when using all TFP indexes: Laspeyeres, Paasche and Fisher methods. This result is explained by the fact that weight magnitude's variation between the first and last period are very small given that the period is short (only four years).

All companies are more productive from the view point of number of connections as opposed to volume of water billed. **IDAAN** is the only company displaying increased productivity over the period when considering both, number of connections and volume of water. Its productivity increase ranges from 31% to 53% depending upon the selected method. **ENACAL** displays a very small decrease in productivity ranging from 2% to 5%. Finally, **ANDA** displays a small productivity decrease ranging from 6% to 17%.

These TFP indexes illustrate one way to determine performance trends for a water utility (or any firm, for that matter). In the Central America case, the calculation is restricted by the fact that only one output is considered at a time and that the amount of labor and energy are the only inputs considered in the production process. Presumably, increases in TPF should track decreases in average cost if all the other factors of production besides labor and energy remain constant. Of course, decomposing the sources of productivity represents the next step for such an exercise.

7. DATA ENVELOPMENT ANALYSIS - DEA

This section examines each firm's relative technical efficiency by 2005 using Data Envelopment Analysis (DEA). This metric benchmarking methodology does not require the analyst to specify a particular functional form and the framework assumes that data is free of errors and noise. This methodology is viewed as an "extreme point" methodology because it compares production of each firm with "best" producers from a group of firms at a point in time. The assumption for this methodology is that if firm A is capable of producing Y units of output with X units of inputs, then other firms should also be able to do the same if they were to operate efficiently. The core of the analysis collapses down on finding "best producers" relative to each firm, which are also referred in the literature as "virtual benchmarks" or "peer groups".

As in the case of TFP indexes, DEA assumes that the data contains no errors. A difference with respect to the TFP analysis is that the DEA methodology allows us to consider a linear combination of outputs and inputs of the production process without presetting their weights. Rather, these weights are calculated with respect to the combination of these factors found on best producers. See Appendix G for more technical details on DEA methodology.

Efficiency results from a DEA frontier are contingent to three main factors:

1. The composition (homogeneity) of the sample set of firms to be analyzed which is critical in determining the set of best producers to be compared with each firm
2. The set of selected inputs and outputs which establishes the comparison terms
3. The quality of the data measured as the presence of data errors

The output from a DEA exercise is the proportion by which the observed inputs could be contracted if the firm where to operate efficiently. Intuitively this means that the same level of output can be produced optimally with fewer inputs, so it is referred as an input DEA approach. Alternatively, the output approach considers the maximal proportional output expansion from a given set of inputs. Typically, water sector empirical researchers use an input perspective, provided that utilities most generally have service obligations to all customers under a pre-fixed tariff. Thus, firms' choice is not on output quantity, but on input quantities.

To include all firms in the calculation of the technical frontier, length of network instead of volume of energy is considered as an input factor given that it was reported by all firms. Two economic model specifications are presented:

1. Model 1 considers number of total workers and network length as inputs.
2. Model 2 considers labor as the only input.

Both models consider volume of water billed, population served and number of connections as the set of outputs. Even when the inefficiency or efficiency of a service provider may be due to its production process per se, a firm can be favored (or hindered) by country specific circumstances. For instance, the level of gross national income (GNI) per capita[18] may impact the behavior of firms in a country. The assumption is that this variable captures specific economic circumstances affecting service providers' performance. One way to examine this influence is to include this variable in the model specification as an "additional resource". Thus GNI is included in both models, which yields models 3 and 4 respectively.

Output from the DEA frontier calculation for all models is included on Appendix H. Firms have been previously identified by size so it is appropriate to account for firms' scale when measuring efficiency. A variable returns to scale approach allows increasing or decreasing efficiency based on size of the firms. Alternatively, a constant return to scale approach means that firms are able to linearly scale the inputs and outputs without increasing or decreasing efficiency. The ratio of these two measures produces the scale impact on efficiency for each firm. Table 8 shows results under the variable returns to scale approach for all models. The stars indicate that the firm scale has an impact on efficiency. The peer group for inefficient firms is in parenthesis.

[18] GNI comprises the total value of goods and services produced within a country together with its income received from other countries (interest and dividends) less similar payments made to other countries. GNI is calculated by the Atlas method, in current Dollars – source World Development Indicators 2006 – World Bank website query.

TABLE 8: DEA TECHNICAL AND SCALE EFFICIENCY FOR 2005

Inputs Utility	Model 1 Labor+NetLeng	Model 2 Labor	Model 3 Labor+NetLeng + GNI	Model 4 Labor +GNI
IDAAN	1	1*	1	1
AYA	0.62* (ANDA & ESPH)	0.62* (ANDA & ESPH)	0.63 (ANDA & ESPH)	0.63 (ANDA & ESPH)
ANDA	1	1*	1	1
ENACAL	0.79* (ANDA & APC)	0.67* (ANDA & ESPH)	1	1
EMPAGUA	0.99* (ANDA & APC)	0.63* (ANDA & ESPH)	0.99 (ANDA & APC)	0.68* (ANDA & ESPH)
SANAA	0.46 (ANDA & ESPH)	0.46* (ANDA & ESPH)	0.99* (ANDA & ENACAL)	0.99* (ANDA & ENACAL)
ESPH	1	1	1	1
APC	1	1*	1	1*
EMAPET	1*	1*	1*	1*

Overall, higher efficiency values are obtained from models including GNI (3 and 4). ENACAL for example becomes 100% efficient when including this variable. The sensitivity of results to the inclusion of the GNI variable illustrates the importance of country characteristics for explaining efficiency within the region.

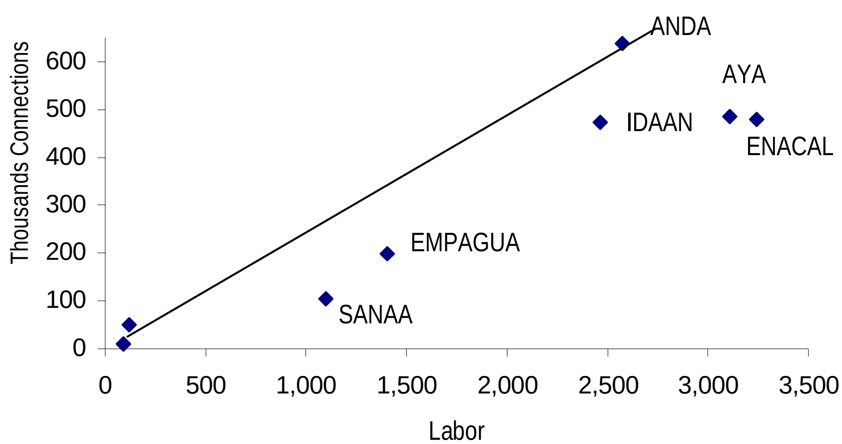
Higher inefficiency is found in the model considering only number of workers as the input factor (model 2). Including network length implies adding another dimension to the model which translates into a better fit according to actual production characteristics.

Efficiency results from model 3, which includes GNI, and considers two input factors, indicate that IDAAN, ANDA, ENACAL, ESPH, Aguas de Pto Cortes and EMAPET are all on the frontier (100% efficient). This outcome is typical when a larger number of variables are used in DEA. Results indicate that AYA could produce the same output with approximately 63% of its resources – amount of labor and network size - (38% inefficient); EMPAGUA and SANAA with 99%, which means they are only 1% inefficient.

Note that as it was mentioned before, such comparisons exclude a number of factors affecting production conditions (hydrology, population geography, topology, service quality levels, and other elements affecting the production technology). Nevertheless, such results provide a first cut at evaluating relative performance when considering number of workers and size of the network to produce water and water connections to a given population.

Figure 17 shows the constant returns to scale framework for model 1 depicting labor as input and number of connections as output. In this case ANDA, ESPH and AgPtoCortes are the firms determining the frontier by being 100% efficient. In the figure, the production technology is constant returns to scale so the straight line depicts the relationship between higher levels of the input (X) and the output (Y). The distance between AYA and IDAAN for example is the technical efficiency to be estimated under a variable returns to scale frontier. IDAAN, AYA and ENACAL have close values for number of connections; however, there is a noticeable difference in number of workers as the main input. IDAAN performs better than ENACAL with respect to labor when number of connections is the output.

Figure 17: Constant Returns to Scale Frontier



Besides level of efficiency and the peer group composition, the DEA frontier calculation yields efficient input and output targets for inefficient firms, which correspond to decreases in inputs and increases in outputs with respect to the level of inputs and outputs of the peer group (see Appendix G for specific values).

In some cases, the decrease in inputs is not enough to bring a company to the frontier so an increase in output is also necessary. All models point towards the need of AYA, SANAA (and EMPAGUA to a lesser degree) to increase actual volume of water billed to reach the efficient target level considered at the frontier. Of course, this is another instance where this suggestion needs to be considered carefully. Increasing commercial efficiency might increase volume of water billed, as would an increase in the level of metering (if this implies increasing control).

Technical Efficiency Change

A Malmquist index measures the Total Factor Productivity change between two time periods utilizing the ratio of the distances of each data point relative to a common production technology. When calculating this index it is common practice to utilize DEA to calculate these distances. Considering the input perspective already selected, a Malmquist technology change component based on the geometric mean of the considered periods is defined as follows:

$$\frac{TFP_1}{TFP_0} = \frac{D_0(Y_0, X_0)}{D_1(Y_1, X_1)}\left[\frac{D_1(Y_0, X_0)D_1(Y_1, X_1)}{D_0(Y_0, X_0)D_0(Y_1, X_1)}\right]^{1/2}$$

The first ratio term indicates a measure of input-oriented technical efficiency change for the analyzed period (the catching up effect or movement towards the frontier). Negative values indicate efficiency has declined over the period (the initial efficiency value is higher than the final value); Positive values indicate increased efficiency. A value equal to zero indicates no efficiency change. The term within brackets represents technical change calculated as the geometric mean of the shift in technology between two periods. This term is not calculated in this study.

It is important to notice that while a TFP index is calculated only with reference to a particular firm – a firm change of productivity over time – the efficiency change component of the Malmquist index is calculated with respect to the movement of a firm towards the optimal frontier determined by a group of firms. In the earlier DEA analysis, only data from 2005 were utilized and all utilities were included. The Malmquist index is calculated here for the period 2002-2005 for all firms but SANAA and EMAPET given that data was reported for only one period. Table 9 presents results for the four DEA models.

For the data observations available and the model specifications used, **ANDA, ESPH** and **APC** show no change in their technical efficiency over the period. **IDAAN** and **EMPAGUA** are the only utilities displaying increased efficiency when utilizing labor and energy to produce volume of water billed, connections given a population. IDAAN increase ranges from 8% to 10% and EMPAGUA from 3% to 15%. **AYA** shows a decrease of 2% on its efficiency. ENACAL displays a significant decrease when utilizing the models that do not include GNI.

TABLE 9: Malmquist - CATCHING UP EFFECT FOR 2002-2005

	Model 1	Model 2	Model 3	Model 4
IDAAN – Panama	8%	10%	8%	10%
AYA – Costa Rica	-2%	-2%	-2%	-2%
ANDA – El Salvador	0	0	0	0
ENACAL – Nicaragua	-16%	-21%	0	0
EMPAGUA - Guatemala	3%	15%	3%	3%
ESPH – Costa Rica	0	0	0	0
APC – Honduras	0	0	0	0

8. STOCHASTIC COST FRONTIER

So far, inputs and outputs have been considered using calculations of non-deterministic approaches to examining efficiency and productivity (in a production technology framework). This section develops a very general picture regarding cost efficiency by statistically estimating cost relationships according to the choice of input prices, given a level of output produced. The ideal framework would be to completely specify a cost function including outputs, input prices and those specific factors capturing possible cost differences among firms and countries. The limitation on data availability restricts the analysis to the inclusion of only four explanatory variables in the economic model.

The merit of performing this econometric exercise is to provide a general approximation for the ranking (not the level) of firms regarding cost efficiency. In addition, this methodology recognizes the presence of data errors which is an important aspect for the Centro American analysis. However, the discussed limitations to the model bring about the possibility that the inefficiency term may contain firm specific and country specific factors not considered in the model so variable coefficients and the inefficiency term may be larger than they actually are. Consequently, the results should be interpreted with caution.

The DEA approach considers efficiency with respect to the best performers, given the variables selected whereas the estimated cost frontier is a measure of central tendency considering all firms not just those on the frontier.

The economic model is a *cost function* specified by volume of water billed, price of labor, price of energy, and GNI. Operational costs plus administrative expenses divided by number of connections is the variable to be explained (operating costs per connection). All variables are divided by number of connections, so size of the firm is controlled for. There is another reason to perform this normalization: to capture cost differences among firms[19]. The price of labor is equal to total cost of workers divided by total number of workers; the price of energy is total energy expenses divided by length of the network. The economic model translates into the following specification (time and firm specific subscripts are omitted for clarity):

$$UnitOpCost = \alpha + \varphi GNI + \gamma VolBil + \beta_L LabPrice + \beta_E EnegPrice \qquad \textbf{(1)}$$

Where $\boldsymbol{\alpha}$, $\boldsymbol{\varphi}$, $\boldsymbol{\gamma}$, $\boldsymbol{\beta_L}$, and $\boldsymbol{\beta_E}$ are parameters to be estimated. All variables are in natural logarithm form. The data set is an unbalanced panel covering 2002 to 2005. Data utilized for estimation are shown in Appendix I. Empirical researchers often introduce a time trend in the model to capture possible technology shifts explaining technological changes. Given the short period of time plus the limitation on the number of explanatory variables, GNI instead of a time trend is included to capture possible technological changes occurred over the period. Nevertheless, time is included in the estimation of the panel frontier to explain possible efficiency changes over time. According to estimation results, the operating costs for the region are represented by the following equation (see Appendix J for estimation results and details on the stochastic cost model):

$$UnitOpCost = (-5.3) - 0.1 * GNI + 0.6 * VolBil + 0.7 * LabPrice - (0.1) * EnegPrice$$

---

[19] A regression where normalization is not performed yields no statistical significant variables.

The signs of coefficients are as expected and the statistical significance is high (except for energy price), indicating a good explanatory power for selected variables. Coefficients' magnitudes are small indicating a small economic impact.

As **GNI** per connection increases by 1%, the effect on unit costs is a decrease of approximately 0.1%. Countries with higher GNI have lower operating costs. An increase of 1% in **volume of water per connection** produces an increase in unit costs of approximately 0.6%. Increasing volume of water billed increases operating costs. An increase on **price per worker per connection** of 1% produces an increase in unit costs of approximately 0.7%. The impact on costs by increases in labor costs is the greatest relative to the impacts from 1% changes in the values of other variables. This finding underscores the importance of labor costs within the sector. The coefficient for **energy price** is not statistically significant, so nothing can be said about it.

Increasing volume has a less than proportional increase effect on costs; on average it indicates the presence of economies of scale in the region. According to estimation results, cost inefficiencies changes over time have no impact on costs. Table 10 shows firm ranks according to how far each firm is from the cost frontier and possible reduction of operating costs by 2005 (calculated as the ratio of the estimated inefficiency to actual operating costs).

TABLE 10: EFFICIENCY RANK AND OPERATING COST REDUCTION BY 2005

	Frontier Rank	Possible Cost Reduction
IDAAN – Panama	2	2%
AYA – Costa Rica	6	3%
ANDA – El Salvador	3	3%
ENACAL – Nicaragua	1	2%
SANAA-Honduras	8	14%
Empagua-Guatemala	7	12%
ESPH – Costa Rica	4	3%
AgPtoC - Honduras	9	20%
EMAPET-Guatemala	5	4%

As has been previously explained, there are differences between results from the DEA frontier and the estimated cost efficiencies that can be explained by the fact that when calculating the DEA frontier we were looking at a contraction of inputs for a given level of output. A cost frontier looks at minimizing costs given input prices and output. When assuming the minimum set of inputs for a given level of output, we are abstracting from other factors influencing the production process, such as the price of inputs.

8. SUMMARY OF EFFICIENCY FINDINGS

Table 11 shows a summary of efficiency results under each methodology using the model that better performs for each of them. When considering productivity changes over the period 2002-2005, the calculation of several TFP indexes yield the same value which is explained by the fact that the period is short (only four years). All companies are more productive from the view point of number of connections compared with volume of water billed. **IDAAN** is the only company displaying increased productivity over the period under any of the TFP indexes. IDAAN productivity increase ranges from 31% to 53% depending upon the selected method. **ENACAL** displays a very small decrease in productivity ranging from 2% to 5%. Finally, **ANDA** displays a small productivity decrease ranging from 6% to 17%. Of course, firms could be deferring maintenance or other expenses, which could raise costs in the future (via leakages or the need to replace pipes). In addition, differences in continuity (or other dimensions of water quality) are not taken into account due to current data limitations. So these findings need to be qualified by recognizing that they represent the first attempt to quantify the performance of water utilities in the region.

TABLE 11: SUMMARY OF EFFICIENCY FINDINGS

	Cost Frontier Rank 2002-2005	Possibility of Cost Reduction by 2005	Productivity change: TFP Tornsqvist index 2002-2005	DEA Tech Frontier: Labor+Energy+GNI Technical Efficiency by 2005	Malmquist: Tech Efficiency Change 2002-2005
IDAAN – Panama	2	2%	32%	100%	8%
AYA – Costa Rica	6	3%	-	63%	-2%
ANDA – El Salvador	3	3%	0	100%	0
ENACAL – Nicaragua	1	2%	-2%	100%	0

SANAA-Honduras	8	14%	-	99%	-
Empagua-Guatemala	7	12%	-	99%	3%
ESPH – Costa Rica	4	3%	-	100%	0
AgPtoC - Honduras	9	20%	-	100%	0
EMAPET-Guatemala	5	4%	-	100%	-

Zero indicates no change or increase.

When calculating a technical frontier for 2005 by means of the DEA methodology, higher efficiency values are obtained from models that include GNI as an additional factor in addition to number of workers and network length. The sensitivity of results to the inclusion of the GNI variable illustrates the importance of country characteristics in explaining efficiency within the region.

Higher efficiency is found when network length (size of the system) and number of workers are both included as input factors in the production process. Including network length implies adding the capacity dimension to the model which translates into both a better statistical fit and a closer approximation to actual production characteristics.

DEA technical efficiency results indicate that IDAAN, ANDA, ENACAL, ESPH, Aguas de Pto Cortes and EMAPET are 100% efficient. On the other hand, AYA could produce the same output (number of connections, volume of water billed and population served) with approximately 63% of its resources (labor and network length). Inefficiency is very small for EMPAGUA and SANAA. The suggested reduction in network length can be interpreted as an increase in network density, which means an increase in number of connections. Obviously, the feasibility of such a strategy depends on several factors including the present population density (or actual demand for connections) and the network engineering characteristics.

IDAAN and **EMPAGUA** are the only utilities displaying increased technical efficiency over 2002-2005 when utilizing labor and energy to produce volume of water billed, number of connections and serve population in the area. The IDAAN increase ranges from 8% to 10% and EMPAGUA from 3% to 15%. **AYA** shows a decrease of 2% in its efficiency.

Results from the stochastic cost frontier estimation indicate that the higher the value of the country **GNI** per connection, the lower the firm cost per connection (a 1% increase on GNI implies a decrease of approximately 0.1% on costs). The greatest influence on operating costs per connection is increased labor prices.

Estimated firm's ranks according to how far is each firm from the cost frontier shows ENACAL as the most efficient firm. Nevertheless, when considering results from all methodologies, IDAAN is positioned as the best performer: its productivity has increased over the period by 32%. Its technical efficiency has increased by 8% over the period; it is at the technical frontier for the DEA methodology and ranks number two on the frontier cost estimation, requiring only a 2% decrease in operating costs to be at the cost efficient frontier.

On the other hand, Aguas de Puerto Cortes is positioned as the weakest performer when considering all the results together. It has not changed technical efficiency over the period, it ranks number nine on the cost frontier estimation and the potential cost reduction is significant: 20% to be at the cost efficient frontier. Again, it is important to note that these results are the first to be obtained for utilities in the region. Data limitations affect model specification: not all elements affecting cost (such as dimensions of service quality) are in the model. Furthermore, the fact that these firms have supplied data indicates that they are at least collecting data now—suggesting that these utilities are likely out-performing those utilities whose managerial teams have no historical records of core indicators and no interest in being compared to other teams. Non-participants may fear greater transparency since that would alert citizens to utility shortcomings. Without a census of utilities, this sample is subject to self-selection bias: these are likely to be the high performing utilities in the region. This is not a problem for frontier analysis, but this means that very weak firms are unlikely to have volunteered to participate in this benchmarking initiative.

10. CONCLUDING OBSERVATIONS

The description of each country' sector structure provides information on water provision by the identified service providers. The data utilized in this study represents approximately 50% of the water sector region with respect to service coverage. The quality of the data set utilized is considered to be good in the sense that it came from and it was reviewed and certified by the owners of the data.

A major conclusion from this analysis points towards additional efforts for improving data collection procedures. Besides the low level of information technology development within the region, possible restrictions (or difficulties) may be due to the fragmented service provision in these countries. A higher level of coordination is needed if data are to be collected and trends analyzed. Such an initiative may require an analysis of stakeholders' responsibilities regarding monitoring and storage of data. Information technology is central to any structured data collection procedure: the availability of an information system specific for the sector is crucial for any data collection process within this region. However, data is necessary but not sufficient for identifying strong and weak performers.

By identifying segments of the industry with no data, policy-makers, regulators and managerial staff are encouraged to expand efforts to seek disaggregated data to facilitate quantitative analysis which will provide more complete information regarding sector performance. This study is comprehensive, ranging from the examination of the water sector structure characteristics of each country within the region to particular firm performance behavior under very specific scenarios. Hopefully, the information obtained as a result from this analysis may be seen by the participating firms as a new way to look at their production processes and performance. For regulatory agencies, related government institutions and funding agencies, this study may contain additional information for their strategic planning and decision making processes.

Lessons from the workshop point towards the need for increasing awareness of data management both within and outside service providers. Coordination is needed among stakeholders regarding what and how to collect data. Government, policy decision makers and fund providers need to consider the role of technology improvement in the region. The role of benchmarking was is fundamental for better allocation of resources from a company and sector point of view.

This study should be viewed as a first step in the analysis of water utilities in Central America. As additional years become available and more utilities provide information, analysts will be able to conduct much more thorough analyses of sector performance. Hopefully, the present results will serve as a catalyst for more comprehensive data collection/verification initiatives in the region and for additional quantitative studies.

APPENDIX A: LECCIONES APRENDIDAS DURANTE EL WORKSHOP PRESENTADAS POR LOS GRUPOS DE DISCUSIÓN

Grupo 1: Honduras, Nicaragua, Panamá.

1) Debe haber un entendimiento entre el operador y el regulador. El operador debe estar convencido de que no se trata solo de rendir cuentas sino que los datos solicitados son útiles para su propia gestión como empresa. En este sentido, los datos solicitados deben estar claramente definidos y con el mismo significado para ambos.

2) Hacer pública la información de la empresa produce resultados positivos – si se logran cambios.

3) El benchmarking como metodología debe iniciarse con datos simples, básicos para la empresa y para el regulador y entenderlo dentro de un proceso evolutivo de mejoras a medida que las experiencias suceden. Dentro de este proceso se entiende la importancia de la oportunidad y claridad de la información.

Grupo 2: Guatemala, Honduras y Nicaragua.

1) Se recomienda una empresa mixta donde participe el gobierno la sociedad civil, empresas privadas, y las comunidades desconcentradas de las municipalidades.

2) Cada empresa operadora debe tener un sistema de información que recopile datos confiables y que sean oportunos para la toma de decisiones.

3) Que este sistema de información permita evaluar metas en base a indicadores operacionales y financieros de calidad de desempeño y que a la vez sirva para rendir cuentas en un marco de transparencia. Es importante compartir las experiencias en este tipo de eventos donde en forma amplia se exponen fortalezas y debilidades del sector.

Grupo 3: Costa Rica, Guatemala, Costa Rica

1) Fue importante conocer la existencia del WOP pues es una iniciativa dirigida al desarrollo de las empresas de agua.

2) Se reconoció la importancia de los datos (su obtención y calidad) en la obtención de información en la empresa. Al pedir información hay que tener en cuenta que primero hay que obtener los datos.

3) El crear una base de datos centralizada para aportar datos de una sola vez y no desgastar a las instituciones haciendo informes similares con formatos diferentes.

4) Incentivar el aporte de información confiable.

5) El benchmarking es una herramienta que significa ahorro de recursos para la empresa por cuanto indica las áreas sobre las cuales se debe actuar.

Grupo 4: Costa Rica, Nicaragua

1) Promover el trabajo en equipo entre operadores y reguladores donde funcionen como aliados en metas y proyectos.
2) Los proyectos de benchmarking deben tener una visión holística donde se incluyan también indicadores sociales.
3) Comparar políticas de agua a nivel país.
4) La empresa ideal debe ser conceptualizada por el organismo regulador donde se identifiquen los proyectos y se establezca gradualidad en las metas.
5) El benchmarking no debe ser solo un ejercicio por cumplir.

Grupo 5: Panamá, Costa Rica, Costa Rica

1) Se le da importancia al benchmarking como proceso de mejora continua de prestación, regulación y política institucional.
2) Se reconoció la importancia de utilizar diferentes metodologías para evaluar el desempeño de las empresas (definir el factor x).
3) La recolección de datos se debe extender también al sector rural para lograr evaluar el sector completo.
4) Se da importancia al uso del benchmarking en la fijación de tarifas y a promover la gestión eficiente del operador.
5) Llama la atención el conocer la existencia de políticas opuestas – en Honduras se descentraliza a las municipalidades; en Costa Rica el proceso se esta centralizando.

Grupo 6: Costa Rica, Belize, USA

1) Calidad de los datos – los operadores deben recolectar datos y almacenarlos pero que sean confiables y verificables por auditores.
2) Aspectos técnicos: los objetivos deben estar claramente definidos; al establecer la mejor práctica se debe considerar quien es el más efectivo.
3) ¿Cual es la mejor manera de comparar a las empresas prestadoras de servicio? Que tan comparables son estas empresas realmente. Las definiciones deben estar claras.

APPENDIX A (ENGLISH): LESSONS LEARNED DURING THE WORKSHOP PRESENTED BY THE DISCUSSION GROUPS

Group 1: Honduras, Nicaragua, and Panamá.

1) There must be an understanding between the operator and the regulator. The operator should be convinced that it is not just about fulfilling a requirement of a financial statement, but also about how the data that he/she is asked for is useful for his/her own management as a company. In this sense, the data that is requested should be clearly defined and have the same meaning for both.

2) Making the information of the company public yields positive results – if you can make changes.

3) Benchmarking as a methodology should start with simple data, basic for the company and the regulator, and should be understood within an evolutionary process of improvements in relation to when the experiences take place. Within this process, the importance of the opportune nature and clarity of the information are understood.

Group 2: Guatemala, Honduras and Nicaragua.

1) A mixed company in which the government, civil society, private companies and the communities that are decentralized (fragmented) from the municipalities could participate is recommended.

2) Each company of operators should have an information system that compiles trustworthy data, opportune for decision making.

3) That this information system allows for the evaluation of goals on the basis of operational and financial indicators of performance quality while being able to account for expenses in a transparent way. It is important to share the experiences in this type of event in which the strengths and weaknesses of the sector are exposed.

Group 3: Costa Rica, Guatemala, and Costa Rica

1) It was important to know about the existence of the WOP, since it is an initiative that is geared towards the development of water companies.

2) The importance of data (obtaining it and its quality) in the acquirement of information in the company. When asking for information, one must take into consideration that the data must be obtained first.

3) Creating a centralized database so as to provide data just once and not wear out institutions by developing and providing similar reports that are formatted differently.

4) Creating incentives for contributing reliable information.

5) Benchmarking is a tool that results in resource savings for the company; it pinpoints the areas that should be acted upon.

Grupo 4: Costa Rica, Nicaragua

1) Promoting teamwork between operators and regulators in which they function as allies for goals and projects.

2) The benchmarking projects must have a holistic view, incorporating social indicators.

3) Comparing water policies at the country level.

4) The ideal company must be conceptualized by the regulatory organism at which the projects are identified and a gradual progression for the goals must be established.

5) Benchmarking should not just be an exercise that has to be complied with.

Grupo 5: Panamá, Costa Rica, and Costa Rica

1) Importance is given to benchmarking as a process of continuous improvement of service deliver, regulation, and institutional politics.

2) The importance of using different methodologies in evaluating the performance of the companies was recognized (defining the X factor—productivity off-sets in price cap rate reviews).

3) In order to be able to evaluate the entire sector, data collection must also be extended to the rural sector.

4) Importance is given to the use of benchmarking in the fixing of prices and in promoting the efficient management of the operator.

5) The existence of opposing policies stands out, in Honduras municipalities are being decentralized; in Costa Rica the process is being decentralized.

Group 6: Costa Rica, Belize, and USA

1) Quality of the data: The operators must collect data and store it; the data should be reliable and verifiable by auditors.

2) Technical aspects: The objectives must be clearly defined; when establishing the “best practice” whoever is more effective should be taken into consideration.

3) What is the best way to compare the companies that render services? How truly comparable are these companies? The definitions must be clear.

Summary of the main points discussed during the panels: A number of factors have an impact on data quality, data collection, benchmarking methodologies, and possible policy and regulatory implications of performance rankings:

1. The person (and the company) responsible for the data (collection, verification, storage, and processing) must be convinced about the importance of his (or her) role. Besides serving as a report to the regulator or to any external institution, data must be viewed as important and useful for the company – for strategic, operational, administrative and commercial purposes.
2. Duplication of data storage files inside the firm and data reports (in specialized formats) to external institutions must be avoided or reduced. Duplication raises administrative costs and opens up the possibility for little "Information Empires" where individuals exercise power by withholding data from those who should have access to information.
3. There needs to be a person responsible for data within the company; however, it is the position (rather than the person) that must have continuity over time within the company. This formalized role is needed to address internal turnover problems which limit data collection, causing gaps in time series and in cross-section observations.
4. Clear variable definitions allow outsiders to interpret information; consistency and clarity are fundamental to the management process.
5. Factors external to the company may have an impact on the collection and storage of data. For example, the existence of records and maps of the city; the frequency of the country census; municipal or city restrictions regarding the network design; number of connections per km, and type of users of the network.
6. Data disaggregation improves decision-making. Clear customer classification (residential, industrial, and commercial) allows for more accurate information regarding operation and performance of the company. In addition, maintaining data series on particular regions or divisions of a company allows top managers to develop strategies for rewarding strong performance. Disaggregated data allow managers to target areas of sub-standard performance and facilitate quantitative studies of cost and productivity.
7. Better operational data collection procedures are needed: timely reports that identify patterns mean that network repairs can be addressed in a more comprehensive and cost-effective manner.
8. While information technology is necessary, but not sufficient, for sound management: information systems should link financial-commercial-operational data. Leaders can only

manage what they measure.

9. The company information needs to be public to promote managerial accountability and citizen confidence in infrastructure services. Even rough comparisons can put pressure on political leaders to fulfill promises to provide funds for network expansion and on managers to deliver services at least-cost.
10. Overall, there is a need within the firm for more information regarding benchmarking methodologies and their application. Larger water utilities have engineers who are familiar with process benchmarking. There is also a need for capacity building in the area of metric benchmarking—starting with trends in Core Indicators, and moving to basic statistical reports and DEA studies.

APPENDIX B– PROJECT ANNOUNCEMENT LETTER TO REGIONAL CONTACTS

Tenemos el placer de anunciarle el inicio del proyecto diseñado para fortalecer el desempeño de las empresas de servicio de agua y saneamiento de los países centroamericanos. Recientemente el Directorio Ejecutivo del Banco Interamericano de Desarrollo adoptó una política que amplía la posibilidad de hacer préstamos a gobiernos y entidades nacionales sin garantía soberana. El presente estudio mostrará, entre otros aspectos, a potenciales prestatarios del Banco que podrían ingresar bajo esta modalidad.

Para estos efectos el BID ha contratado al Public Utility Research Center (PURC) quien estará a cargo de esta investigación y como primer paso de la misma se encargará de recolectar aquellos datos que complementen los previamente existentes en la región y preparará los estudios que identifican el funcionamiento relativo de las empresas de los servicios de agua potable y saneamiento del sector. Como tarea final se organizará un taller regional para promover procedimientos sostenibles de recolección de datos, haciendo la información disponible para todos los entes involucrados.

La colaboración de las instituciones relacionadas al sector en cada país tales como empresas de servicio de agua, entes reguladores y organismos gubernamentales es fundamental para lograr los objetivos de este proyecto, pues son estas instituciones quienes recibirán el beneficio final y más tangible al contar con los resultados de un análisis que permitirá establecer acciones a futuro en cuanto al funcionamiento y desarrollo del sector.

En línea con este objetivo es fundamental para efectos de consistencia y continuidad de los proyectos previos desarrollados en la región amablemente le solicitamos que su institución designe a una persona de contacto, si es posible la misma que viene trabajando en el grupo de benchmarking de ADERASA, en este caso el *Ing. Daniel Echeverría* Estimamos que su vinculación no implicará una carga adicional de trabajo, debido a su familiaridad con los datos..

La participación de su institución se basará principalmente en verificación de datos y eventualmente en suministro de aquellos datos que puedan complementar los ya existentes. Igualmente, al momento de obtención de resultados, estos serán consultados con ustedes para garantizar la consistencia y privacidad de la información.

Por parte del PURC Maria Luisa Corton (mcorton@ufl.edu) estará a cargo de esta labor y próximamente contactará al responsable de benchmarking designado por usted. Para mayor información, a continuación se describen las actividades del proyecto:

1) Ensamblaje de datos de benchmarking para los países centroamericanos.
   Estos datos serán organizados en tres grupos a saber:
   - ✓ Contexto institucional: caracterizan los aspectos sociales, económicos y políticos de cada país y comprenden datos de
     - o Estabilidad política (indicadores de riesgo),
     - o Medio ambiente (topología y densidad de población) y

    - Variables macroeconómicas (GDP per capita)
- ✓ Forma de gobierno: caracterizan el marco regulatorio, las instituciones y empresas de servicio y comprenden
    - Tipo de regulación o contratos de incentivo
    - Tipo de propiedad, privada, municipal, estatal
- ✓ Datos de la industria: caracterizan el sector
    - Productos (Outputs)
    - Insumos (Inputs)
    - Calidad del servicio

2) Elaboración de estudios que identifiquen el desempeño relativo de las empresas de servicio de la región.

3) Organización de taller de trabajo para promover procedimientos de recolección de datos que sean sostenibles en el tiempo haciéndolos disponibles a los entes interesados.

Con respecto a la primera tarea, es bien sabido que el Grupo de Trabajo Regional de Benchmarking de ADERASA viene desde hace tres años trabajando sostenidamente en la recolección de datos del sector agua y saneamiento de los países latinoamericanos. A fin de no duplicar esfuerzos y con el propósito común de lograr una base de datos robusta y consistente para el sector de agua y saneamiento centroamericano, el grupo de trabajo del PURC luego de ensamblar la base de datos para el proyecto con los datos ya existentes, estará realizando consultas y revisiones puntuales acerca de los datos referentes a su organización. En anexo encontrará la lista y descripción de variables que serán utilizadas en el estudio.

Los resultados que se obtendrán en la segunda tarea serán indudablemente de valor para su organización por tratarse de la aplicación de metodologías de benchmarking de punta, cuyos resultados compartiremos en su debido momento y que no serán divulgados sin su debido consentimiento. Es de esperar que en esta etapa sucedan varias consultas preferiblemente y directamente con usted o con la persona que usted tenga a bien designar.

En relación con la tercera tarea, el diseño del taller de trabajo se realizará una vez concluidas las etapas de recolección y análisis de la información de acuerdo con el cronograma de ejecución del proyecto y le informaremos de los detalles y persona responsable a su debido momento.

Por último, le manifestamos nuestro sincero aprecio, y de antemano agradecemos la participación y colaboración, seguros de que esta experiencia particular será valiosa tanto para su organización como para el sector de agua en su país y en Centro América.
Un cordial saludo,

Sanford V. Berg
Distinguished Service Professor of Economics
Director of Water Studies, PURC

sberg@ufl.edu

Rubén Darío Avendaño
Especialista de Saneamiento
División de Administración de Environment & Natural Resources, BID

rubenav@iadb.org

APPENDIX C: DATA RESPONSIBLES

Country	Organization	Title	Name	Country code	Fax	Phone	E-mail
CostaRica	ARESEP	Ing	Daniel Echeverria	506	2966419	2200102	decheverria@aresep.go.cr
	AYA	Lic	Beatriz Bolaños	506	2425042	2425110	bbolaños@aya.go.cr
	ESPH	Licda	Lissette Montoya	506		5623736	lmontoya@esph-sa.com
El Salvador	ANDA	Lic	Ana Lisseth Quijano	503	22472812	22472774	lquijano@anda.gob.sv
Guatemala	EMAPET	Ing	Augusto Javier Pinelo Guzman	502	79262229	79264456	javierpinelo@yahoo.com
	EMPAGUA	Ing	Julio Campos	502	22320601	22858747	jcampos@muniguate.com
Honduras	ERSAPS/ENACAL	Ing	Ramon Cuellar	504	2382598	2386852	ramon.cuellar@yahoo.es
Nicaragua	ENACAL	Ing	Guillermo Leclair	505		2651882	gpdesarrollo@enacal.com.ni
Panama	ASEP	Ing	Euripides Amaya	507	5084561	5084561	eamaya@ansp.gob.pa
	IDAAN	Lic	Magda Quiros	507		5238533	mquiros@idaan.gob.pa

APPENDIX D – LIST AND DESCRIPTION OF DATA VARIABLES

GENERAL CARACTERÍSTICS FOR EACH COUNTRY AND SERVICE PROVIDER

1) Service provider name and year beginning operations
2) Public (government) or private operation
3) Scope of the company according to country jurisdictional organization: state, municipal, district
4) Type of service: water, sewerage or both.
5) Source of water: surface or underground
6) Localities: refers to the number of localities where the company provides service according to the country jurisdictional organization (districts, municipal or status)
7) Region: refers to the region the company is located in case the country has specific regions regarding some type of geographic or topological characteristics, eg mountains or coast. In case the company serves different locations indicate region for each location.

OUTPUTS

1) Volume of water (cubic meters or litters - annual):
   a) Produced: total annual gross volume extracted from its origin point, whether surface or underground.
   b) Delivered: total annual volume entering into the distribution network.

c) Billed: total annual volume that is billed to customers.
d) Collected: total annual volume for those bills that have been collected.
e) Treated: volume of water treated alter used by customers.
f) Total volume lost
g) Commercial lost: difference between volume delivered to the distribution network and volume billed.
h) Operational lost: difference between volume produced and volume delivered to the distribution network.

4) Number of water connections and sewerage:
   a) Total
   b) Residential, Commercial and Industrial
   c) With meter
   d) Active
3) Number of consumers water and sewerage:
   a) Total population (usually from country census)
   b) Population served with water and sewerage
   c) Number of inhabitants per connection: if the company does not have its own, the number of inhabitants per household can be used.
5) Network length - water and sewerage (km): total network length including the distribution network.

INPUTS:

4) Number of workers and its costs (or expense):
   a) Total
   b) By contract(limited time or money amount)
   c) Fixed (they receive company benefits)
   d) Types of workers – administrative, operational, managerial
5) Volume of energy and its cost (Kva or another unit).
6) Capital stock:
   a) Non-current assets
   b) Accumulated depreciation
   c) Annual depreciation

5) Administrative Expenses
6) Financial Expenses
7) Operating costs
8) Total Cost

QUALITY

5) Water quality: any variable defining water quality according to each country, such as percentage of residual chlorine.
6) Continuity: number of hours a day customers receive water service
7) Quality of service:
    a) Number of complains received or served
    b) Number of failures or problems received or fixed
8) Number of network leaks

APPENDIX E: DESCRIPTION OF WATER SECTRS WITHIN THE REGION

COSTA RICA: ARESEP –"Autoridad Reguladora de los Servicios Publicos" – was created by law in September 1996. ARESEP regulates a wide range of infrastructure services, from electricity to transportation. The institutional branch responsible for water and environment is "Dirección de Servicios de Agua y Ambiente". ARESEP publishes performance indicators and financial statements from AYA and ESPH on its website.

Water and sewerage services are offered by "Instituto Costaricense de Acueductos y Alcantarillados" (AYA), Empresa de Servicios Publicos de Heredia (ESPH), municipalities, "Asociaciones Administradoras de Sistemas de Acueductos y Alcantarillados" (ASADAS) and Comite de Agua y Alcantarillado Rural (CAARS). At the national level, AYA is the larger service provider and it is additionally responsible for:

- ✓ Determining technical rules;
- ✓ Guaranteeing continuity of the service;
- ✓ Supervising water infrastructure construction, operation and planning;
- ✓ Providing technical advice to municipalities;

ESPH was created in 1998 as a public association of the Heredia municipalities to facilitate infrastructure administration. Other municipalities in charge of water systems at the time AYA was created were able to continue with their administration. Municipalities have budgetary autonomy. AYA may delegate the administration of water systems to local government organizations, particularly in the rural areas; this explains the presence of the ASADAS and CAARS as service providers. Table A-1 shows the extent of water service for each of these utilities regarding population served by 2005. For this study, data was available only for AYA and ESPH. Together they serve 54% of the country population.

TABLE A-1: COSTA RICA – POPULATION WITH WATER SERVICE BY 2005

UTILITY	POP. SERVED
AYA	2,154,641
ESPH	213,121
Municipalities	785,246
ASADAS/CAARS	1,078,719
Total pop with water service	4,231,727
Total Country Population	**4,371,733**

EL SALVADOR: The water sector is administered and served by a governmental institution: Administración Nacional de Acueductos y Alcantarillados (ANDA). The country is organized in fourteen departments comprising 262 municipal entities; 149 (56.9%) are served by ANDA and the rest by decentralized systems and municipal entities. Table A-2 shows the extent of water and sewerage service by 2005. Data considered in this study comes from ANDA, which covers approximately 94% of urban population and 14% of rural.

TABLE A-2: EL SALVADOR – POPULATION SERVED BY 2005

	WATER/URB	WATER/RURAL	SEW/URB	SEW/RURAL
ANDA	3,325,684	506,649	2,407,220	40,800
ANDA Sis ex-Plansabar	4,725	600,700	680,100	1,690,100
Alcaldias	20,603	235,210	0	0
Comunidades	72,800	290,840	159,925	46,000
Total	3,423,812	1,633,260	3,247,245	1,776,900

	Urban	**Rural**	**Total**
Country Population	**3,528,833**	**3,403,958**	**6,932,791**

GUATEMALA: Water service responsibility is decentralized to the municipalities. Data provided for this study comes from EMPAGUA serving the capital, Guatemala City and EMAPET, "Empresa Municipal de Agua de Peten", which serves two municipalities, Flores and San Benito.

TABLE A-3: GUATEMALA – POPULATION WITH SERVICE BY 2005

	WATER/URB
EMPAGUA	1,154,240
EMAPET	58,000
Country Population	11,024,000

HONDURAS: The regulatory agency, Ente Regulador de los Servicios de Agua Potable y saneamiento (ERSAPS), was created by law in 2003. Policy-making and strategy is the responsibility of "Consejo Nacional de Agua Potable y Saneamiento (CONASA), which also was created in 2003. Honduras is comprised of 298 municipalities which are entitled to undertake responsibility of the water and sanitation services by the 2003 law. In addition, there are 5,000 "Juntas Administradoras de Acueductos Rurales" which provides service to rural areas. Under the 2003 law, the "Servicio Autonomo Nacional de Acueductos y Alcantarillados" (SANAA) has technical advisory responsibility to CONASA, ERSAPS and municipalities, and will continue as service provider while its operation is transferred to the municipalities. Table A-4 shows the number of cities and population served by SANAA and municipalities by 2003. The data obtained for this project comes from SANAA which covers around 20% of country's population.

TABLE A-4: HONDURAS - WATER SERVICE BY SANAA AND MUNICIPALITIES

	Number of Cities	Population
SANAA	32	1,332,784
Municipalities	271	1,718,941
Total pop with water service		3,051,725
Country Population		**6,968,512**

NICARAGUA: The sector is administered by the government institution "Instituto Nacional de Acueductos y Alcantarillados" (INAA) since 1979. ENACAL, the government company created by 1998, serves 181 cities. In addition there are two municipal companies serving 26.000

connections. INAA has a 15 year concession contract with ENACAL; the contract establishes 69 performance indicators to be measured for monitoring the company's service. ENACAL provides service to around 50% of country population.

TABLE A-5: NICARAGUA – POPULATION WITH WATER SERVICE BY 2005

	POP. SERVED
ENACAL	2,838,985
Country Population	5,480,000

PANAMA: The national regulatory authority, "Autoridad Nacional de los Servicios Publicos" (ASEP) was created in 1996, by law, as part of the Panama government objective of allowing for private investment into the service sectors of the country. The state company "Instituto de Acueducto y Alcantarillados Nacionales" (IDAAN) provides water and sanitation service to approximately 66% of country population (see Table A-6). Other service providers are very small. Table A-7 shows number of customers per water service provider for the entire water service sector by 2005.

Table A-6: PANAMA – Population with water service by 2005

	POP. SERVED
IDAAN	2,081,149
Country Population	3,172,360

Table A-7: PANAMA – Number of Customers per service provider

	SERVICE COMPANY	CUSTOMERS
1	IDAAN	444, 041
2	Autoridad del Canal de Panamá	Agua en bloque
3	Aguas de Panamá, S.A.	Agua en bloque
4	Municipio de Boquete	3,000
5	Altos de Vista Mares, S.A.	650
6	Costa Esmeralda, S.A.	600
7	Sociedad Bayona Service Inc.	130
8	Constructora Tía María, S.A.	545
9	Villa del Lago,S.A.	8
10	Juan Francisco Guerra	75
11	Cooperativa Charco Azul, R.L.	75
12	Inmobiliaria Valle del Rey, S.A.	691

APPENDIX F: DATA USED IN CALCULATING TFP INDEXES

	OUTPUTS				INPUTS			
	VolBilled		Number of	Connections	Labor		Energy	
	2002	2006	2002	2005	2002	2005	2002	2005
IDAAN	237,498,108	290,496,277	401,120	497,113	2,536	2,185	255,807,560	206,755,000
weight					0.57	0.33	0.52	0.45
ANDA	276,762,400	244,954,000	597,289	638,027	2,658	2,576	439,483,008	484,340,368
weight					0.12	0.14	0.28	0.31
ENACAL	109,971,345	117,561,849	420,676	480,392	3,070	3,242	163,477,060	184,902,771
weight					0.86	0.86	0.73	0.84

APPENDIX G: DATA ENVELOPMENT ANALYSIS TECHNICAL DETAILS

DEA is a non deterministic methodology that does not require the analyst to specify a functional form for the production technology. It consists of measuring the efficiency of any firm as obtained by the ratio of weighted outputs to weighted inputs subject to the condition that similar ratios for every firm are less or equal to unity .which can be expressed mathematically as:

$$Max \ldots \lambda_0 = \frac{\sum_{r=1}^{s} \alpha_r Y_{r0}}{\sum_{i=1}^{m} \beta_i X_{i0}} \quad subject \quad to \quad \frac{\sum_{r=1}^{s} \alpha_r Y_{rj}}{\sum_{i=1}^{m} \beta_i X_{ij}} \leq 1; \quad \alpha_r, \beta_i \geq 0; \quad j = 1 \ldots n; \quad i = 1 \ldots m; \quad r = 1 \ldots s$$

Where Y_0, X_0 are observed output and input variable vectors of the firm under evaluation; α and β are the weights to be applied to all units; i represents the m inputs, r the s outputs and j the n firms. With this specification, each firm can weight inputs and outputs differently as long as the ratio of their linear combination is less or equal to one. However, this flexibility may raise concerns referring to whether the efficiency value is a product of efficiency per se or is originated by the choice of weights. Yet, if the firm turns out to be inefficient even under the most favorable weights, then there is no doubt about the result.

The efficiency of firm zero is rated relative to all firms. The maximization gives firm zero the most favorable weighting that the constraints allow. Under a linear programming framework, the dual expression of this problem is

$$
\begin{aligned}
&\min_{\lambda} \quad \lambda \\
&\textit{subject to} \\
&Y_0 \le \rho Y \\
&\rho X \le \lambda X_0 \\
&\rho \in R_+^N
\end{aligned}
$$

where rho *(ρ)* is a vector of intensity parameters which allows for the convex combination of the observed inputs and outputs. In other words, for an inefficient firm the efficient level of each production factor gets expressed as a linear combination of these intensity parameters as weights of the production factors of the peer group. The output from a DEA exercise is the proportion by which the observed inputs could be contracted if the firm were efficient. In the economic literature, this is the Farrell's measure of input efficiency.

APPENDIX H: DATA ENVELOPMENT ANALYSIS

CRS	DMU Name	Efficiency	scale	Sum oflambdas	RTS	OpLamb	with Benchmarks	with	peers	Slack-Labor	netlength		Slack-VolBil	Conx	Pop Serv	TargLabor	netlength		VolBil	Conx	Pop Serv
	1 IDAAN	1.00		1.00	Constant	1.00	IDAAN			0	0		0	0	0	2,465	5,050		268,774,868	473,860	2,081,149
	2 AyA	0.57		2.70	Decreasing	0.59	ANDA	2.11	ESPH	0	0		27,773,821	0	252,918	1,782	4,084		177,582,596	486,048	2,397,648
	3 ANDA	1.00		1.00	Constant	1.00	ANDA			0	0		0	0	0	2,576	4,391		244,954,000	638,027	3,190,135
	4 ENACAL	0.78		9.25	Decreasing	0.67	ANDA	8.58	AgPtoC	0	0		83,804,102	41,972	0	2,517	3,657		201,365,951	522,364	2,701,396
	5 EMPAGUA	0.95		10.30	Decreasing	0.15	ANDA	10.15	AgPtoC	0	0		13,010,852	12,102	0	1,329	1,517		81,490,598	209,738	1,154,640
	6 SANAA	0.46		1.02	Decreasing	0.16	ANDA	0.86	ESPH	0	0		3,533,898	38,909	0	508	1,293		51,646,595	144,109	707,250
	7 ESPH	1.00		1.00	Constant	1.00	ESPH			0	0		0	0	0	119	700		15,198,068	50,743	238,243
	8 AgPtoC	1.00		1.00	Constant	1.00	AgPtoC			0	0		0	0	0	92	83		4,320,802	11,006	65,473
	9 EMAPET	0.74		0.09	Increasing	0.02	IDAAN	0.07	ESPH	0	0		0	5,382	25,475	69	171		7,632,215	15,062	67,185
VRS	1 IDAAN	1.00	1.00	1.00	IDAAN					0	0		0	0	0	2,465	5,050		268,774,868	473,860	2,081,149
	2 AyA	0.62	0.92	0.74	ANDA	0.26	ESPH			0	1,012		35,688,341	0	281,506	1,940	3,436		185,497,116	486,048	2,426,236
	3 ANDA	1.00	1.00	1.00	ANDA					0	0		0	0	0	2,576	4,391		244,954,000	638,027	3,190,135
	4 ENACAL	0.79	0.98	0.84	ANDA	0.16	AgPtoC			371	0		89,753,895	59,561	0	2,187	3,718		207,315,744	539,953	2,701,396
	5 EMPAGUA	0.99	0.96	0.35	ANDA	0.65	AgPtoC			431	0		19,718,844	31,931	0	958	1,585		88,198,590	229,567	1,154,640
	6 SANAA	0.46	1.00	0.16	ANDA	0.84	ESPH			0	10		3,589,803	38,853	0	509	1,287		51,702,500	144,053	707,250
	7 ESPH	1.00	1.00	1.00	ESPH					0	0		0	0	0	119	700		15,198,068	50,743	238,243
	8 AgPtoC	1.00	1.00	1.00	AgPtoC					0	0		0	0	0	92	83		4,320,802	11,006	65,473
	9 EMAPET	1.00	0.74	1.00	EMAPET					0	0		0	0	0	93	232		7,632,215	9,680	41,710
CRS	1 IDAAN	1.00		1.00	Constant	1.00	IDAAN			0	0	0	0	0	0	2,465	5,050	4,630	268,774,868	473,860	2,081,149
	2 AyA	0.63		0.97	Increasing	0.74	ANDA	0.23	ESPH	0	1,028	0	35,818,645	0	281,977	1,943	3,425	2,870	185,627,420	486,048	2,426,707
	3 ANDA	1.00		1.00	Constant	1.00	ANDA			0	0	0	0	0	0	2,576	4,391	2,450	244,954,000	638,027	3,190,135
	4 ENACAL	1.00		1.00	Constant	1.00	ENACAL			0	0	0	0	0	0	3,242	4,711	910	117,561,849	480,392	2,701,396
	5 EMPAGUA	0.99		1.64	Decreasing	0.34	ANDA	1.30	AgPtoC	401	0	0	19,259,469	30,573	0	983	1,580	2,370	87,739,215	228,209	1,154,640
	6 SANAA	0.52		0.24	Increasing	0.22	ANDA	0.02	ESPH	0	471	0	6,141,868	36,301	0	570	980	617	54,254,565	141,501	707,250
	7 ESPH	1.00		1.00	Constant	1.00	ESPH			0	0	0	0	0	0	119	700	4,590	15,198,068	50,743	238,243
	8 AgPtoC	1.00		1.00	Constant	1.00	AgPtoC			0	0	0	0	0	0	92	83	1,190	4,320,802	11,006	65,473
	9 EMAPET	0.74		0.09	Increasing	0.02	IDAAN	0.07	ESPH	0	0	1,349	0	5,382	25,475	69	171	422	7,632,215	15,062	67,185
VRS	1 IDAAN	1.00	1.00	1.00	IDAAN					0	0	0	0	0	0	2,465	5,050	4,630	268,774,868	473,860	2,081,149
	2 AyA	0.63	1.00	0.74	ANDA	0.22	ESPH	0.04	AgPtoC	0	1,037	0	35,859,576	0	282,495	1,945	3,423	2,874	185,668,351	486,048	2,427,225
	3 ANDA	1.00	1.00	1.00	ANDA					0	0	0	0	0	0	2,576	4,391	2,450	244,954,000	638,027	3,190,135
	4 ENACAL	1.00	1.00	1.00	ENACAL					0	0	0	0	0	0	3,242	4,711	910	117,561,849	480,392	2,701,396
	5 EMPAGUA	0.99	1.00	0.35	ANDA	0.65	AgPtoC			431	0	748	19,718,844	31,931	0	958	1,585	1,629	88,198,590	229,567	1,154,640
	6 SANAA	0.99	0.52	0.05	ANDA	0.28	ENACAL	0.67	AgPtoC	0	1,190	0	0	67,927	247,880	1,090	1,583	1,179	48,112,697	173,127	955,130
	7 ESPH	1.00	1.00	1.00	ESPH					0	0	0	0	0	0	119	700	4,590	15,198,068	50,743	238,243
	8 AgPtoC	1.00	1.00	1.00	AgPtoC					0	0	0	0	0	0	92	83	1,190	4,320,802	11,006	65,473
	9 EMAPET	1.00	0.74	1.00	EMAPET					0	0	0	0	0	0	93	232	2,400	7,632,215	9,680	41,710

DMU No.	DMU Name	Efficiency		lambdas	RTS	with Benchmarks				*Labor*	*GDP*	VolBil	Conx	Pop Serv	*Labor*	*GDP*	VolBil	Conx	Pop Serv
1	IDAAN	1.00		1.00	Constant	1.00	IDAAN			0	0	0	0	0	2,465	4,630	268,774,868	473,860	2,081,149
2	AyA	0.63		0.97	Increasing	0.74	ANDA	0.23	ESPH	0	0	35,818,645	0	281,977	1,943	2,870	185,627,420	486,048	2,426,707
3	ANDA	1.00		1.00	Constant	1.00	ANDA			0	0	0	0	0	2,576	2,450	244,954,000	638,027	3,190,135
4	ENACAL	1.00		1.00	Constant	1.00	ENACAL			0	0	0	0	0	3,242	910	117,561,849	480,392	2,701,396
5	EMPAGUA	0.66		0.51	Increasing	0.35	ANDA	0.16	ESPH	0	0	19,694,715	33,776	0	921	1,576	88,174,461	231,412	1,154,640
6	SANAA	0.52		0.24	Increasing	0.22	ANDA	0.02	ESPH	0	0	6,141,868	36,301	0	570	617	54,254,565	141,501	707,250
7	ESPH	1.00		1.00	Constant	1.00	ESPH			0	0	0	0	0	119	4,590	15,198,068	50,743	238,243
8	AgPtoC	0.48		0.13	Increasing	0.01	ANDA	0.12	ESPH	0	0	340,389	2,455	0	44	572	4,661,191	13,461	65,473
9	EMAPET	0.68		0.35	Increasing	0.01	IDAAN	0.35	ESPH	0	0	0	12,039	58,986	63	1,625	7,632,215	21,719	100,696
VRS 1	IDAAN	1.00	1.00	1.00	IDAAN					0	0	0	0	0	2,465	4,630	268,774,868	473,860	2,081,149
2	AyA	0.63	1.00	0.74	ANDA	0.22	ESPH	0.04	AgPtoC	0	0	35,859,576	0	282,495	1,945	2,874	185,668,351	486,048	2,427,225
3	ANDA	1.00	1.00	1.00	ANDA					0	0	0	0	0	2,576	2,450	244,954,000	638,027	3,190,135
4	ENACAL	1.00	1.00	1.00	ENACAL					0	0	0	0	0	3,242	910	117,561,849	480,392	2,701,396
5	EMPAGUA	0.68	0.96	0.35	ANDA	0.00	ESPH	0.65	AgPtoC	0	0	19,711,609	31,947	0	958	1,639	88,191,355	229,583	1,154,640
6	SANAA	0.99	0.52	0.05	ANDA	0.28	ENACAL	0.67	AgPtoC	0	0	0	67,927	247,880	1,090	1,179	48,112,697	173,127	955,130
7	ESPH	1.00	1.00	1.00	ESPH					0	0	0	0	0	119	4,590	15,198,068	50,743	238,243
8	AgPtoC	1.00	0.48	1.00	AgPtoC					0	0	0	0	0	92	1,190	4,320,802	11,006	65,473
9	EMAPET	1.00	0.68	1.00	EMAPET					0	0	0	0	0	93	2,400	7,632,215	9,680	41,710

CRS	DMU Name	Efficiency		lambdas	RTS	with Benchmarks		Labor	VolBil	Conx	Pop Serv	Labor	VolBil	Conx	Pop Serv
CRS 1	IDAAN	0.85		17.68	Decreasing	17.68	ESPH	0	0	423,520	2,132,132	2,104	268,774,868	897,380	4,213,281
2	AyA	0.38		9.86	Decreasing	9.86	ESPH	0	0	14,130	203,653	1,173	149,808,775	500,178	2,348,383
3	ANDA	0.74		16.12	Decreasing	16.12	ESPH	0	0	179,820	649,733	1,918	244,954,000	817,847	3,839,868
4	ENACAL	0.42		11.34	Decreasing	11.34	ESPH	0	54,766,405	94,974	0	1,349	172,328,254	575,366	2,701,396
5	EMPAGUA	0.41		4.85	Decreasing	4.85	ESPH	0	5,177,391	48,289	0	577	73,657,137	245,925	1,154,640
6	SANAA	0.34		3.17	Decreasing	3.17	ESPH	0	0	55,438	46,959	377	48,112,697	160,638	754,209
7	ESPH	1.00		1.00	Constant	1.00	ESPH	0	0	0	0	119	15,198,068	50,743	238,243
8	AgPtoC	0.37		0.28	Increasing	0.28	ESPH	0	0	3,420	2,259	34	4,320,802	14,426	67,732
9	EMAPET	0.64		0.50	Increasing	0.50	ESPH	0	0	15,802	77,932	60	7,632,215	25,482	119,642
VRS 1	IDAAN	1.00	0.85	1.00	IDAAN			0	0	0	0	2,465	268,774,868	473,860	2,081,149
2	AyA	0.62	0.60	0.74	ANDA	0.26	ESPH	0	35,688,341	0	281,506	1,940	185,497,116	486,048	2,426,236
3	ANDA	1.00	0.74	1.00	ANDA			0	0	0	0	2,576	244,954,000	638,027	3,190,135
4	ENACAL	0.67	0.62	0.83	ANDA	0.17	ESPH	0	89,351,910	60,400	0	2,169	206,913,759	540,792	2,701,396
5	EMPAGUA	0.63	0.65	0.31	ANDA	0.69	ESPH	0	18,044,660	35,426	0	882	86,524,406	233,062	1,154,640
6	SANAA	0.46	0.74	0.16	ANDA	0.84	ESPH	0	3,589,803	38,853	0	509	51,702,500	144,053	707,250
7	ESPH	1.00	1.00	1.00	ESPH			0	0	0	0	119	15,198,068	50,743	238,243
8	AgPtoC	1.00	0.37	1.00	AgPtoC			0	0	0	0	92	4,320,802	11,006	65,473
9	EMAPET	1.00	0.64	1.00	EMAPET			0	0	0	0	93	7,632,215	9,680	41,710

APPENDIX I: DATA UTILIZED FOR THE COST MODEL

id	t	GNI	Facturado	Vol	Connect	Workers	CostWor	CostEnerg	OpCost	UopC	Plabor	Peneg	Uvolbil	Ugni	lUopC	lPlab	lPeneg	lUvolbil	lugni
1	5	2,400	7,632,215	9,680	232	93	373,669	436,770	640,385	66	4,018	1,883	788		4.19	8.3	7.54	6.67	-1.39
2	2	970	4,157,832	9,727	60	51	240,052	183,105	328,599	34	4,707	3,052	427		3.52	8.46	8.02	6.06	-2.31
2	3	1,040	4,257,322	10,414	80	55	317,313	199,225	1,238,528	119	5,769	2,490	409		4.78	8.66	7.82	6.01	-2.3
2	4	1,190	4,320,802	11,006	83	92	396,189	227,487	1,363,363	124	4,306	2,741	393		4.82	8.37	7.92	5.97	-2.22
3	1	3,920	15,220,433	45,945	655	119	512,116	361,222	2,165,648	47	4,304	551	331		3.85	8.37	6.31	5.8	-2.46
3	2	4,120	14,901,553	47,736	670	119	544,814	447,530	2,405,770	50	4,578	668	312		3.92	8.43	6.5	5.74	-2.45
3	3	4,470	15,241,347	49,234	685	124	586,094	555,738	2,562,554	52	4,727	811	310		3.95	8.46	6.7	5.74	-2.4
3	4	4,590	15,198,068	50,743	700	119	595,434	755,788	2,788,419	55	5,004	1,080	300		4.01	8.52	6.98	5.7	-2.4
4	4	1,040	46,450,997	105,200	2,800	1,100	7,308,000	2,259,000	22,038,000	209	6,644	807	442		5.34	8.8	6.69	6.09	-4.62
4	5	1,190	48,112,697	105,200	2,800	1,100	12,107,000	4,028,000	24,046,000	229	11,006	1,439	457		5.43	9.31	7.27	6.13	-4.48
5	1	1,790	65,489,920	190,824	1,450	1,468	8,789,447	13,497,672	24,819,840	130	5,987	9,309	343		4.87	8.7	9.14	5.84	-4.67
5	2	1,960	66,851,594	194,647	1,500	1,454	8,508,359	13,888,411	26,420,052	136	5,852	9,259	343		4.91	8.67	9.13	5.84	-4.6
5	3	2,190	68,120,460	196,413	1,550	1,485	7,813,018	14,625,499	26,631,199	136	5,261	9,436	347		4.91	8.57	9.15	5.85	-4.5
5	4	2,400	68,479,746	197,636	1,600	1,402	8,846,091	15,596,099	29,390,427	149	6,310	9,748	346		5	8.75	9.18	5.85	-4.41
6	1	740	109,971,345	420,676	4,489	3,070	17,508,100	14,835,235	27,298,084	65	5,703	3,305	261		4.17	8.65	8.1	5.57	-6.34
6	2	770	109,880,441	459,767	4,536	2,879	16,718,379	16,912,892	27,944,923	61	5,807	3,729	239		4.11	8.67	8.22	5.48	-6.39
6	3	830	114,972,958	468,898	4,681	3,020	15,313,210	16,375,689	27,244,902	58	5,071	3,498	245		4.06	8.53	8.16	5.5	-6.34
6	4	910	117,561,849	480,392	4,711	3,242	17,304,929	16,849,732	28,416,303	59	5,338	3,577	245		4.08	8.58	8.18	5.5	-6.27
7	1	2,080	276,762,400	597,289	4,391	2,658	1,637,703	3,842,088	14,088,943	24	616	875	463		3.16	6.42	6.77	6.14	-5.66
7	2	2,190	269,095,300	613,121	4,391	2,547	1,556,149	3,981,503	12,587,931	21	611	907	439		3.02	6.42	6.81	6.08	-5.63
7	3	2,330	246,563,200	625,982	4,391	2,596	1,710,069	3,707,667	12,388,924	20	659	844	394		2.99	6.49	6.74	5.98	-5.59
7	4	2,450	244,954,000	638,027	4,391	2,576	1,770,274	3,905,660	12,726,214	20	687	889	384		2.99	6.53	6.79	5.95	-5.56
8	2	4,120	151,251,985	455,623	6,078	3,150	19,140,287	6,321,039	37,057,919	81	6,076	1,040	332		4.4	8.71	6.95	5.81	-4.71
8	3	4,470	149,080,965	471,809	6,246	3,188	18,863,345	8,121,125	41,461,808	88	5,917	1,300	316		4.48	8.69	7.17	5.76	-4.66
8	4	4,590	149,808,775	486,048	7,123	3,107	29,382,805	7,289,635	46,373,459	95	9,457	1,023	308		4.56	9.15	6.93	5.73	-4.66
9	1	3,820	237,498,108	401,120	4,087	2,536	16,395,000	14,888,000	43,519,000	108	6,465	3,643	592		4.69	8.77	8.2	6.38	-4.65
9	2	3,900	244,523,982	410,478	4,667	2,715	16,485,000	15,150,000	40,499,000	99	6,072	3,246	596		4.59	8.71	8.09	6.39	-4.66
9	3	4,310	260,513,626	456,206	4,681	2,668	16,994,000	16,968,000	45,528,000	100	6,370	3,625	571		4.6	8.76	8.2	6.35	-4.66
9	4	4,630	268,774,868	473,860	5,050	2,465	15,791,000	19,822,000	50,865,000	107	6,406	3,925	567		4.68	8.77	8.28	6.34	-4.63
9	5	4,630	290,496,277	497,113	5,151	2,185	16,659,000	22,928,000	51,249,000	103	7,624	4,451	584		4.64	8.94	8.4	6.37	-4.68

APPENDIX J: STOCHASTIC COST FRONTIER ESTIMATION APPROACH

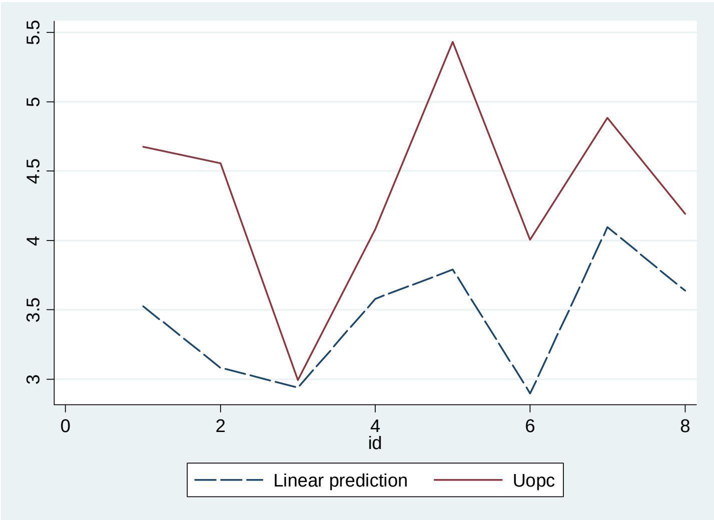
A stochastic cost panel data frontier using the Battese and Coelli (1993) exponential functional form for the inefficiency term is the choice to estimate the model. The weakness of this specification is that it assumes all firms have followed the same trend, which is a restriction but still a reasonable assumption for the water sectors within the region. The specification for the econometric model includes equation **(1)** plus the error term ***ε***:

$$\varepsilon_{it} = u_{it} + v_{it} \quad \text{where} \quad u_{it} = u_{it}\exp[-\eta(t-T)]; u_{it} iid \sim |N(0,\sigma_u^2)|$$

The idiosyncratic error term ***(v)*** is independently and identical distributed as $\sim N(0,\sigma_v^2)$ and independently from regressors. The only panel-specific effect is the random inefficiency term ***(u)***.

Figure 18 show unit cost linear predictions for the cost frontier. The thick line represents actual unit operating costs and the long dashed line corresponds to the estimated frontier. The frontier estimator assumes the effects (error term) are not correlated to the explanatory variables.

FIGURE 18: LINEAR PREDICTIONS FOR UNIT OPERATING COSTS



The gap between the thick line and the long dashed line (the distance from the frontier to actual costs) represents cost inefficiency which in this case may be mixed with possible missing variables. Table A-7 summarizes results. The no statistical significant coefficient for the parameter eta implies that inefficiency has not changed over time, or if it has, it does not follow an exponential path. The sign for price of energy is not as expected; however, it must be recognized that the cost function has not been checked for regularity conditions. The model seems to provide a good fit and variables have good explanatory power (illustrated by the high statistically significance of some coefficients).

Table A-7: Estimation Results for the Cost Frontier

DepVar=UnitOpCost	Panel Frontier
GNI	-0.103
	(0.084)
Volume Billed	0.598**
	(0.265)
Labor Price	0.698***
	(0.129)
Energy Price	0.071
	(0.178)
Constant	-5.28***
	(1.81)
	LogLikelihood= -4.081924
	Mu=-5.55
	Eta=-0.175
	(0.125)

Confidence levels: *** 99%; ** 95%; * 90%