

BENCHMARKING CENTRAL AMERICAN WATER UTILITIES

Maria Luisa Corton
Correspondent author

Research Associate

Public Utility Research Center
University of Florida

PO Box 117142
Gainesville, FL32611-7142
mcorton@ufl.edu
Phone: (352) 214-5132

Sanford V. Berg¹

Distinguished Service Professor of Economics and Director of Water Studies
Public Utility Research Center
University of Florida

PO Box 117142
Gainesville, FL32611-7142
sanford.berg@cba.ufl.edu
Phone: (352) 392-0132

Abstract

This study provides a comprehensive efficiency analysis of water service providers in six countries in the Central American region. Pressures for sector reform have stimulated interest in identifying and understanding the factors that can contribute to network expansion, improved service quality, and cost containment. The aim is to provide policy-makers and investment funds institutions with quantitative evidence on the effectiveness of the regional water sectors and utilities under different perspectives. In addition to key sector performance indicators, the analysis considers several benchmarking methodologies to assess technical and cost efficiency.

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JEL Classifications: D24, L23, L51, L95

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1. Introduction

A recent Inter-American Development Bank (IADB) study reports that investments of US \$40 billion for water assets are needed to meet the United Nation's Millennium Development Goals.² Public and 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 and incentives in measuring system performance.

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 water and sanitation systems network expansion, improved service quality, and cost containment in the sector³ (related research examines how benchmarking might facilitate conflict resolution in Central America; Berg 2008). Policy-makers in Latin America, Asia, and Africa have begun to collect data that can serve as the basis for performance comparisons 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.

The purpose of this study is to analyze the relative performance of water utilities in the Central American region to identify best performers and areas of weakness in the sector. The results can help decision-makers better direct investment funds into projects that will further develop the water sector in this region. A substantial body of technical literature exists regarding how to measure performance. Coelli et al. (2003) present a survey of different methodologies to measure performance. The methodologies considered in this study are performance indicators, total factor productivity indexes, and frontiers.

² "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.

³ Saleth and Dinar (1999)

A limitation associated with studies of Central America is the scarcity of data related to the water sector. The first steps of the study involved examining existing data and defining a set of variables to be collected. A main contribution of this study is the assembly of a current database for the water sector in Central America. During the data collection process, some factors were found to be limiting and others were critical for the success of the process. The subsequent steps of the study relate to performance measurement. With key input, output, and quality information, basic performance comparisons can be made. A set of performance indicators commonly used among practitioners in the water sector was calculated to provide a very simple picture of the sector's performance characteristics in the region. Some of these performance indicators were compared to those presented by the benchmarking task force of Association of Water and Sanitation Regulatory Entities of the Americas (ADERASA)⁴ in its most recent annual report.⁵

The availability of data from 2002 to 2005 allowed assessing performance in the region through the calculation of total factor productivity indexes. Finally, to provide a more comprehensive picture of the efficiencies associated with production practices in the region, a production frontier using data envelopment analysis (DEA) and a stochastic cost frontier were included in the analysis. Differences on some of the values obtained from this variety of performance measures are based on the different assumptions underlying each methodology. A best performer was found consistently through the performance methodologies calculation.

The study is organized as follows. In Section 2, the data collection process is described. Section 3 provides an analysis of core performance indicators. Section 4 utilizes total productivity indexes to examine productivity. Section 5 and 6 contain a non-parametric and parametric frontier analysis. Section 7 concludes.

⁴ Asociación de Entes Reguladores de Agua Potable y Saneamiento de las Americas

⁵ For a description and brief on the characteristics of the countries comprising the ADERASA association refer to Corton and Molinari (2008).

2. Data Collection Process

The starting point of this study was to build a verifiable database taking into account data already available. To this end, the author requested and collected data from ADERASA and the International Benchmarking Network for Water and Sanitation Utilities (IBNET). The ADERASA database is comprised of data that come from the regulatory agencies in each Latin American country. This information is reported by some of the utilities in each sector but not all. Appropriate contact was established with these utilities to verify the existing data and to obtain missing values. In addition, Guatemala and El Salvador are not members of ADERASA, so data for these countries were collected for the first time. The adopted strategy for the collection process was incremental in the sense that data were sent to the source several times for verification. A new and refined data set for the water sector in Central America⁶ emerged from this process. Nevertheless, only a subset of variables was used 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.

Several factors were identified as affecting data availability within the region: the ongoing water sector restructuring, the low level of water infrastructure in place, and the low presence of information technology among the service providers.

From an institutional point of view, Costa Rica, Panama, and Honduras have independent regulatory agencies, but El Salvador, Guatemala, and Nicaragua still have central government bodies overseeing the water sector. Some of these central government institutions are undergoing restructuring such as the transfer of sector responsibilities to municipalities. Some countries have just finished a major restructuring of this type. Because these changes generally imply changes within the company staff, the flow and registering of data may get interrupted, affecting data collection procedures.

⁶ Central America countries included in this study are Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

El Salvador, Honduras, and Nicaragua show a low level of infrastructure in place. This promotes the presence of a large number of local independent water providers which limit the data collection process. Solo (1998) provides a detailed description of the role of these independent providers within the water sector of Latin American countries.

Overall, the water sector in this region is fragmented given the decentralization of service provision into municipalities. For instance, for Honduras with 271 municipalities, and for Guatemala with more than 300 municipalities, the lack of data is evident. Consequently, available data came from the municipalities serving the largest cities. This fragmentation greatly hampers performance analysis for the water sector in this region.

Finally, the development of information technology is central to any data collection initiative. To frame the status of the region on this matter, the information and communication technology (ICT) diffusion index utilized by the United Nations Conference on Trade and Development (UNCTAD) is utilized.⁷ More specifically, the ICT index includes a connectivity index to measure technology infrastructure development. This connectivity index includes per capita number of Internet hosts, number of PCs, number of telephone mainlines, and the number of mobile subscribers. The connectivity index for 2005 was 0.75 for the United States. In the same year, this index was 0.20 for Costa Rica; 0.10 for El Salvador and Panama; 0.08 for Guatemala, and 0.04 for Honduras and Nicaragua. Information technology is the core of any structured data collection procedure. Of no less importance, the availability of an information system specific to the sector is crucial for any data collection process within this region. Initiatives in this respect are only incipient. In a 2004 workshop hosted by Peru, water sector representatives from several Latin American countries gathered initial ideas and directed some efforts into the development of a water sector information system common to the region. A similar initiative hosted by El Salvador developed in late 2006.

⁷ See http://www.rashon.org.hn/noticias_sept.html, last visit 09/17/2008.

The presence of technology is necessary but not sufficient for improved information on water utility performance. When designing rules for the sector, the government needs not only to consider the role of the utilities, the main entities responsible for collecting data, but also the role played by each stakeholder regarding the request of data. For instance, the reporting of data to the regulator from the utilities needs to be stated by law and not taken as an informal relationship between the parties. In the same way it is important to establish formal communication channels among all the sector stakeholders, such as environmental or municipal development agencies, in a way that data collection programs and possible data repositories are well identified and efforts are not duplicated.

Costa Rica, Guatemala, and Honduras are represented in this analysis by two service providers of different sizes, which are referred to as the small and large providers for each of these countries. The rest of countries are represented by only one operator.

3. Sector Performance Indicators

The simplest types of performance indicators are unit-dimensional such as labor productivity, service coverage, and non-revenue water. These indicators focus on a specific area of performance within the production process. Considering the most commonly used performance indicators in this sector, they have been classified in this study as operational, financial and quality indicators. Since several of these indicators were benchmarked against those calculated by the ADERASA Benchmarking group, their definitions were kept the same to maintain consistency across the region. Table 1 shows the values obtained for selected indicators in Central America that were compared to those calculated by the ADERASA group.

In general, the extent of water service provision can be measured by volume of water, number of connections and population served. These factors provide a good picture of the size of the company providing the service. Overall, in the Central American countries, the water utilities can be broadly classified as small, medium, and large based on these three variables. Table 2 is organized by size of the water providers of each country according to their volume of water produced. It shows volume of water,

number of connections, and population served in 2005, as well as the values for the performance indicators examined in the following sections.

3.1 Operational Indicators

Water lost or non-revenue water 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 to 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 distribution network, and are calculated as volume of water produced less water delivered to the distribution network.

Referring to the distribution system, water losses may be either due to water theft, representing commercial losses, or to leaks in pipes. 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 water delivered to its starting point and water billed.⁸ Another way of viewing this indicator is to calculate the ratio of water billed to water delivered to the distribution network which is referred to by the ADERASA benchmarking group as an indicator for commercial efficiency. For utilities in the Central American sample, the median value for this indicator is 55% which is higher than the ADERASA value of 40%.

The metering indicator is calculated as the ratio of the number of connections with an installed meter to the number of total connections. In some countries, there is a direct allocation of metering costs to the consumer, which generally translates into higher tariffs and/or connection fees. A higher level of metering implies that there may be a higher possibility to identify water losses, and that data on bill

⁸ The starting point of a distribution network, generally known as the city gate, is a physical location where the transportation pipes transfer the flow to the distribution pipe system by means of pumps and other specific equipment.

collection may be more accurate. Consequently, revenues may be higher. Overall, the metering median value is 56%, which is lower than the 75% median value for ADERASA members. The higher value for water lost in Central American countries with respect to that in Latin American countries may be a consequence of poor metering systems as it is reflected in the value for the metering indicator. It may also be explained by the amount of pipe leaks which is very high when compared to the same indicator for Latin American countries.

Service coverage is calculated as the ratio of population with water service (population connected to the network) to total population in the area of service of the utility. The median value for water service coverage in this region is 90% which is close to the ADERASA value of 89%. Coverage is equal to 92% for large firms, 66% for medium firms, and 85% for the small utilities group.

Water companies with a similar scale, measured by number of connections, may have different costs due to differences in network characteristics, such as length. Larger firms could have lower costs due to a large amount of customers per kilometer of pipe, rather than due to scale economies originated from total output. To partially explore this issue, network density, measured as the ratio of number of connections to network length, is the performance indicator considered in this analysis.⁹ The median value for network density equals 95 for utilities in Central America. Larger firms have denser networks than medium and small firms which reflect the low investment capacity of small providers. The low coverage and high network density values found for the Guatemalan utility suggest that the system may be expanded by increasing the length of network to reach out to under-served populated areas. This is consistent with the extension of its network system through adding more pipes as it was previously mentioned. The low coverage and low network density depicted by the service provider in Honduras may indicate that the system can be expanded by adding more connections to satisfy the underserved population in the area.

⁹ The impact on costs of a 30% water loss is quite different if the network has 150 connections per kilometer than if it has 50 connections per kilometer.

The ADERASA benchmarking group utilizes the ratio of volume of water billed to population with water service as an indicator of 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. The group of smaller companies is characterized by a higher consumption level of 323 liters per person per day as opposed to a lower value of 222 satisfied by larger firms.

The number of workers per 1,000 connections 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 found for ADERASA members suggesting high labor inefficiencies. Note that the number of workers considered for this indicator is a total figure which includes outsourcing labor. The “suggested” high inefficiency may sound strong if considering that nothing has been said about the other factors of production. And this is exactly the shortcoming of productivity indexes; nothing else is included in the analysis but the two variables under consideration, in this case number of workers and connections. This also illustrates the point of how policy decision-makers may become confused in interpreting productivity indexes if they are not considered under the right framework.

The availability of several years of data allows us to analyze the changes occurring in number of connections and network length which imply system expansion at different stages of the investment cycle. Clearly, national priorities and funding sources affect the pace and pattern of system expansion.

Fig. 1 shows changes in number of water connections and network length as shares on a one hundred percent¹⁰ basis to illustrate system expansion as shares of total system expansion for each country. The service providers from El Salvador and Guatemala show a higher increase in network length with respect to that of number of connections. This may suggest a system expansion of the transportation segment where pipes but not connections are added as opposed to an expansion of the distribution segment where pipes and connections are both added. Alternatively it may indicate earlier stages of the

¹⁰ The percentage change of number of water connections for 2002-2005 and the percentage change of network length in the same period are first calculated and their respective shares on a one hundred percent basis are shown in the graph.

distribution network expansion where customers have not been connected yet. The utility in Nicaragua presents an opposite situation. Here the increase in number of connections is higher than the increase of length of network. This may be explained by connections added to satisfy commercial and industrial customers who generally do not add to population served. These results identify different stages of the investment cycles for each utility.

3.2 Financial Indicators

Operating costs for this region include labor and energy costs, chemicals, administrative, and sales expenses. Depreciation and finance expenses are considered to be part of total costs. On average, operating costs are \$91/connection.¹¹ Higher values of network density are associated with lower values for operating costs per connection. The median operating cost per cubic meter is \$0.10, half the cost of ADERASA member countries. For the large group of the utilities in the region, the median administrative expense per connection equals \$27, whereas it is \$34 for the small group. Both values are lower than the similar indicator for ADERASA members which equals \$47.

Changes in operating costs for 2002-2005 are of small magnitude. The large service provider in Costa Rica displays a significant increase in cost of workers (54%) and administrative expenses (51%) which may explain a higher increase of its operating costs with respect to that of utilities in other countries. On the other hand, the service provider in Panama depicts an increase in operating costs of 18% which may be explained by an increase in its energy costs (54%). The service provider from El Salvador displays a decrease in administrative expenses (18%) which may explain the decrease of its operating costs (10%). Service providers who presented an increase in energy costs may be reflecting a combination of increases in input prices and greater utilization of energy inputs to service larger systems. Significant increases in cost of workers could be due to an increased focus on hiring professionals with managerial skills.

¹¹ Monetary values are converted to US dollar values utilizing the Dollar exchange rate available each year on the Central Bank Website of each country.

3.3 Quality Indicators

Compliance with water quality standards has a median value of 95.96% slightly higher than the similar indicator for the ADERASA members. Continuity measured as the number of hours with water service ranges from 20 to 24 hours. Number of complaints per connection (median value) is similar for both ADERASA and Central American utilities (0.21). The median number of leaks per kilometer of pipe is 2.53 for ADERASA members, almost half the value found in Central American countries, 5.19. This suggests a lower degree of service maintenance for pipes in the Central America water networks compared with the maintenance degree for pipes in the ADERASA countries. This also explains the higher value of water lost in the Central American water utilities compared to this value for utilities in ADERASA countries.

4. Total Factor Productivity Analysis

Productivity indexes represent a way of measuring performance over time since they identify production differences between two time periods. A comprehensive exposition and analysis of such measures is found in Balk (2003). The basic idea behind a Total Factor Productivity (TFP) index is to determine how much output is produced due to each unit of input¹². In practice, there may be more than one output produced from a combination of inputs. In such a case, a TFP index is constructed as the ratio of an output index to an input index. The input index should reflect the relative importance of each input in producing the output(s) and the output index should reflect the relative importance of each output. These relationships are represented by weights. Assume r is the weight given to k outputs and s is the weight to n inputs. Eq. 1 is the general formula to calculate a TFP index measuring productivity change between two periods of time, say from year 0 to year 1.

¹² See Estache and Trujillo (2003), and Saal et al.(2007) as two examples of using TFP methodologies on water industries.

$$\frac{TFP_1}{TFP_0} = \frac{\sum_k r_k Y_{k1} / \sum_n s_n X_{n1}}{\sum_k r_k Y_{k0} / \sum_n s_n X_{n0}} \quad (1)$$

The weights are generally prices for input factors and costs for outputs. In Eq. (1), the weights are assumed to be the same for both periods but they may not be which yields different alternatives for calculating TFP indexes. Two aspects are relevant when setting the above-mentioned weights: whether the weights are the same for the two analyzed periods and the mathematical or functional form that combines them. When considering the prices for time zero or the initial period, Eq. (1) represents a Laspeyres index whereas using prices in the final period produces a Paasche index. The Fisher index utilizes the geometric mean of the two periods.

Regarding the functional form to relate the weights, the indexes described so far imply a linear functional form. The Törnqvist index uses a logarithm form which is more flexible in the sense that it may approximate a production function more appropriately.

Determining the weight for outputs to calculate these indexes requires detailed information on the production technology of the service companies, as well additional data. In order to simplify the analysis such that weights for the outputs are not needed, two sets of TFP measures are calculated: one considering volume of water billed as the output and another considering number of connections. As in most empirical studies related to the water sector, labor, and energy are the input factors under consideration.¹³ However, not all service providers reported energy volume which limited the calculation of these indexes only to a subset of utilities. The weights for the input factors are calculated as the ratio of their respective costs relative to operating costs. See Table 3 for the results.

The Laspeyeres, Paasche, and Fisher TFP indexes yield equal values, so they are depicted under a common title in the first column of Table 3. The fact that these indexes are the same may be explained by the fact that the length of period is short which produces only a small variation when calculating the

¹³ As a sample of water studies utilizing labor and energy as input factors see Tupper and Rezende (2004) for the Brazilian case; Garcia and Thomas (2001) for the French case; Fabbri and Fraquelli (2000) for the Italian case; Saal and Parker (2004) and Saal et al. (2007) for the English and Welsh case.

weights for the different indexes. All companies are more productive from the view point of number of connections as opposed to volume of water billed. The utility in Panama is the only service provider displaying increased productivity over the period when considering both number of connections and volume of water. The increase in productivity for this utility is within 31% and 53%. Service providers from Nicaragua and El Salvador depict a small productivity decrease. Presumably, increases in TFP should track decreases in average cost if all the other factors of production besides labor and energy remain constant. The service provider for Panama is expected to perform better with respect to other providers in the frontier performance assessment.

5. Data Envelopment Analysis (DEA)

This section examines each firm's relative technical efficiency in 2005 using Data Envelopment Analysis (DEA). As in the case of TFP indexes, DEA assumes that the data contain no measurement 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 for the production process without presetting their weights. Rather, these weights are calculated with respect to the combination of these factors found on best producers.

DEA is the most commonly used non-parametric frontier methodology. It is non-parametric because it does not require the analyst to specify a functional form for the production technology. Charnes et al. (1978) were first to present the concept of the relative ranking of decision-making units according to their efficiency. A DEA calculation determines simple relationships among variables. For example, utilities that produce far less output than other utilities, which are using the same input levels, are deemed to be relatively inefficient. This methodology is viewed as an "extreme point" method because it compares production of each firm with the "best" producers. Besides assuming that there are no measurement errors in the sample, efficiency results from a DEA frontier are contingent on 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 since this methodology assumes that there are no errors.

Note that in point number 1, homogeneity implies that there are no outliers in the sample. A DEA analysis 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. This relationship is expressed mathematically in Eq. (2) which states a maximization exercise.

$$\begin{aligned}
 \text{Max... } \lambda_0 = & \frac{\sum_{r=1}^s \alpha_r Y_{r0}}{\sum_{i=1}^m \beta_i X_{i0}} \quad S.T. \quad \frac{\sum_{r=1}^s \alpha_r Y_{rj}}{\sum_{i=1}^m \beta_i X_{ij}} \leq 1 \\
 & \alpha_r, \beta_i \geq 0; \quad j = 1 \dots n; \quad i = 1 \dots m; \quad r = 1 \dots s
 \end{aligned} \tag{2}$$

Here, Y_0 , and 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 an input within a set of m , r an output within a set of s , and j one of 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 obtained from calculation 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 each particular firm (here the firm zero) is rated relative to all firms. The maximization gives firm zero the most favorable weight allowed by the constraints.

The output from a DEA exercise is the proportion by which the observed inputs could be contracted if the firm were to operate efficiently. Intuitively, this means that the same level of output can be produced optimally with fewer inputs, so it is referred to as an input efficiency approach. The implicit

assumption is that managers minimize input usage given output level. In the economic literature, this is referred to as the Farrell's measure of input efficiency (Farrell 1957).

Alternatively, the output efficiency approach considers the maximal proportional output expansion with the input vector held fixed, so managers maximize output given a set of inputs. Unless constant returns to scale are assumed, these measures yield different scalar values meaning different distances from the frontier. A comparison of results from input and output oriented models is found in Orea et al. (2004). A study by Banker et al. (2004) addresses details and applications of input and output efficiency approaches under variable and constant returns to scale.

For regulated industries, such as the water sector in Central America, an input approach is the natural option given that utilities most generally have service obligations to all customers under a pre-fixed tariff. This approach implies that firms are fully capable of reallocating resources when improving efficiency.

The DEA model critical point is the selection of an appropriate set of inputs and outputs to represent production process with a linear technology. For the Central American water sectors, labor and capital were selected as input factors and volume of water billed and number of connections are the outputs. The amount of energy utilized in the production process was used in the calculation of the TFP indexes and is generally used as an input factor in the production process of water utilities. However data availability is limited for this set of companies. To include all firms in the calculation of the frontier, length of network instead of volume of energy is considered as an input factor. Network length is utilized as a proxy to represent capital in the water sector empirical literature. The rationale for doing this is the high amount of capital necessary to lay down pipes compared to capital needs for the rest of the production infrastructure. Labor is represented in the model by the amount of total workers.

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. Indeed, when considering several countries a major challenge is to appropriately account for each country's political, social, and economic differences. In the electricity sector, recent studies have utilized either GDP or GNP per

capita¹⁴ as a covariate to capture main country particularities.¹⁵ Regarding the water sector, De Witte and Marques (2007) utilize GRP per capita¹⁶ on a cross-country study of Australia, Portugal, The Netherlands, England and Wales, and Belgium. Clarke et al. (2004) utilize GNP per capita when analyzing the impact of private participation in the water sectors of Brazil, Argentina, and Bolivia. The World Bank utilizes the level of gross national income calculated by the Atlas method to classify economies and set the lending eligibilities. The GNI adds to the GDP the income received from other countries, less similar payments made to other countries. The Atlas method uses a three-year average of exchange rates to smooth effects of transitory exchange rate fluctuations.

The assumption for this study is that variations of GNI may impact the behavior of firms in a country, so that this variable captures country-specific economic circumstances affecting the performance of the water sector provider's service for the countries under analysis. A way to examine this influence under a DEA framework is to include this variable as an "additional resource." GNI per capita in current US dollars from the World Bank Website is included in the model as an input factor.

Utilities in this region have different sizes, 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 4 shows results for technical efficiency and scale impacts under variable returns to scale.

Overall, higher efficiency values are obtained when including network length and subsequently adding GNI. Including each of these variables implies adding input dimensions to the calculation of the frontier which translates into higher efficiencies, as doing so helps to better describe production

¹⁴ GDP is the value of goods and services produced within a country and GNP (GNI) is the value of goods and services produced by *citizens* of a country irrespective of where they live.

¹⁵ Estache and Rossi (2008) utilize GDP in their cross-country study of 51 developing countries and Zhang et al. (2008) utilize GDP in their panel study of 36 developing countries. Estache et al. (2004) utilize GNP in their cross-country study for South American countries.

¹⁶ GRP is defined as the market value of all goods and services produced within a given area over a specific period of time, is a good measure of the size, income, and productivity of a regional economy.

characteristics. In addition, the sensitivity of results indicates the appropriateness of considering countries differences when explaining efficiency within this region

For purposes of discussing results, values in the third column of Table 4 are considered. According to this, the service providers in Panama, El Salvador, Nicaragua, and the small providers in Costa Rica, Guatemala and Honduras are all 100% efficient. The large provider from Costa Rica could produce the same output with approximately 63% of its resources, in this case, labor, network length and GNI. This means that this provider is only 37% inefficient. In the case of the service provider for Honduras, 44% of its efficiency comes from considering its size in comparison to other providers. Part of the efficiency results for El Salvador, Nicaragua, and the small providers is due to their scale. The fact that such a large number of firms are found to be 100% efficient indicates that the group of firms is not heterogeneous enough in the sense that the set of input and output factors considered are not sufficient to explain possible production differences among these countries. This has a direct relationship with the data collection problem detected in this study.

Fig. 2 shows a production frontier depicting labor as the input factor and number of connections as the output. This graph is incomplete in the sense that it is showing only one dimension of the frontier given that the other input and output factors are not shown. Nevertheless, it gives an idea of a firm's relative positions regarding the use of these resources. For instance, service providers in El Salvador and Nicaragua produce a very similar amount of connections. However, the amount of labor differs widely. While the service provider in El Salvador is found 100% efficient, the one in Nicaragua can work with 60% of its labor amount if considering labor as the only input factor. The water service providers from Costa Rica and Nicaragua show levels of efficiency that are very close (62% and 59%, respectively).

In this DEA analysis, only data from 2005 were utilized. The Malmquist technical efficiency change component for the period 2002-2005 is calculated for all firms except for the large service provider from Honduras. 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.

Following Fare et al. (1994), and considering the input perspective already selected, a Malmquist technology change component based on the geometric mean of the considered periods is defined as follows:

$$\frac{TFP_1}{TFP_0} = \frac{D_0(Y_0, X_0)}{D_1(Y_1, X_1)} \left[\frac{D_1(Y_0, X_0)D_1(Y_1, X_1)}{D_0(Y_0, X_0)D_0(Y_1, X_1)} \right]^{1/2} \quad (3)$$

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). The term within brackets represents technical change calculated as the geometric mean of the shift in technology between two periods. It is important to notice that while a TFP index is calculated only on 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, which is determined by a group of firms.

The utilities from El Salvador, Nicaragua, and the small utilities from Costa Rica and Honduras show no change in technical efficiency over the period. The utilities from Panama and Guatemala show an increase in efficiency of 8% and 3%, respectively. The large service provider from Costa Rica shows a decrease in efficiency of 2%.

6. Stochastic Frontier

So far, inputs and outputs have been considered using calculations from non-deterministic approaches to examining efficiency and productivity in a production technology framework. This section examines cost efficiency by statistically estimating cost relationships according to input prices, given a level of output produced. Any differences between the statistically estimated cost values and the actual cost values are acknowledged as either errors that may be present in the data or missing explanatory variables. 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 associated with 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 that this methodology recognizes the presence of data errors which is an important aspect of the Central American data set.

The economic model is a cost function specified by volume of water billed (VolBil), price of labor, price of energy, and GNI. Operational costs plus administrative expenses divided by number of connections comprise operating costs per connection which is the dependent variable. The price of labor (LabPrice) is equal to total cost of workers divided by total number of workers. The price of energy (EneqPrice) is total energy expenses divided by length of the network. Finally, all variables are divided by number of connections, to control for size of the firms. The economic model translates into the following specification (subscripts for time and firm are omitted for simplicity):

$$UnitOpCost = \alpha + \varphi GNI + \gamma VolBil + \beta_L Lab\ Price + \beta_E Eneq\ Price \quad (4)$$

Where α , φ , γ , β_L , and β_E are parameters to be estimated. All variables are in natural logarithm form. The data set is an unbalanced panel covering 2002 to 2005. 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 economic shocks which occurred over the period.

Nevertheless, time is included in the estimation of the cost frontier to explain possible changes of efficiency over time. Here the basic assumption is that these countries have changed efficiency behavior over time, independently. A stochastic cost panel data frontier using the Battese and Coelli (1993) exponential functional form for the inefficiency term (u) is adopted. This functional form is explicit as the second term of Eq. (5). In this specification, t represents a specific period and T the total amount of periods, which in this case equals 4. 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 utilities within the region.

$$\varepsilon_{it} = u_{it} + v_{it} \quad \text{where} \quad u_{it} = u_i \exp[-\eta(t-T)]; u_i \text{ iid } \sim N(\mu, \sigma^2) \quad (5)$$

Where ε is the error term comprised of two components the idiosyncratic error term (v) and the inefficiency term u . The idiosyncratic error term is independently and identically distributed as $\sim N(0, \sigma_v^2)$ and is independent from the regressors. The frontier estimator assumes that the error term is not correlated to the explanatory variables.

Table 5 shows results from estimation. The statistically insignificant 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 model seems to provide a good fit and variables have good explanatory power (illustrated by the high statistical significance of most coefficients).

The signs of coefficients are as expected, and the statistical significance is high for the output variable and price of labor. Energy price and GNI are not statistically significant. The coefficients' magnitude for the statistically significant variables indicates the economic impact on costs to be higher than 0.5% in both cases.

An increase of 1% in volume of water per connection produces an increase in unit costs of approximately 0.6%. An increase in price per worker per connection of 1% produces an increase in unit costs of approximately 0.7%. Increasing volume has a less than proportional increase effect on costs. On average it indicates the presence of economies of scale in the region. Table 6 shows country ranks according to how far each firm is from the efficient cost frontier and possible reduction of operating costs by 2005. This reduction is calculated as the ratio of the estimated inefficiency to actual operating costs.

The differences between results from the DEA frontier and the estimated cost frontier 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, the DEA abstracts from other factors influencing the production process, such as the price of inputs. However, the utility in Panama has been a constant high performer for all methodologies. Results for the other countries may be considered on a case-by-case basis.

7. Concluding Observations

A major contribution from this study is the creation of a unique database and a comprehensive data collection process. The data collected is very representative from a sector-wide perspective, considering total water service coverage in the region. The quality of the data set is considered good in the sense that it came from and was reviewed and certified by data owners.

A major conclusion from this analysis points towards additional efforts for improving data collection procedures in the region. Besides the scarce presence of information technology limiting record keeping within these utilities, difficulties also may be due to the fragmented service provision in some 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. For instance, coordination is needed among stakeholders regarding what data should be collected and how. In the process of identifying segments of the industry with no data, policy-makers, regulators, and managerial staff have been encouraged to expand efforts to seek disaggregated data. Such data are necessary for further quantitative analysis, providing more complete information regarding sector performance.

For regulatory agencies, related government institutions, and funding agencies, this study may contain additional information for their strategic planning and decision-making processes. 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. The results presented here are expected to serve as a catalyst for more comprehensive data collection/verification initiatives in the region and for additional quantitative studies.

Table 1. A selection of common performance indicators for Central America and ADERASA countries

Median Value	Central America	ADERASA- Latin America
Commercial Efficiency	55%	40%
Metering	56%	75%
Water Coverage	90%	89%
Water Consumption (lt/ person/ day)	219	172
Workers / 1000 connections	6.6	3.3
Operating Cost / Cubic meter	\$0.10	\$0.20
Administrative Expenses	\$27	\$47
Number of Pipe Leaks / Km	5.19	2.53

Table 2. Summary of operational performance indicators in 2005

Country/Units	Vol Del Mill m3	Vol Lost %	Num Conn Miles	Met %	Vol Del Per Person	Pop Serv Miles	Cov %	Net Length Km	Net Dens Conn/km	work/ 1000 conn
Panama	452	58	448	41	126	2,004	92	4,727	95	5.6
Costa Rica-L	305	49	457	94	76	1,978	99	6,437	71	6.7
El Salvador	259	-	619	55	84	3,093	90	4,391	141	4.2
Nicaragua	257	44	457	48	39	2,870	91	4,604	99	6.7
Guatemala-L	122	55	195	84	81	1,045	93	5,013	128	7.5
Honduras-L	75	63	105	35	67	707	69	2,800	38	10.5
Costa Rica-S	28	55	48	97	66	228	100	678	71	2.5
Honduras-S	10	44	11	77	157	53	71	77	144	6.6
Guatemala-S	7.6	-	10	56	183	42	72	232	42	9.6

L refers to large-size companies; S refers to small-size companies; size is measured as volume of water delivered.

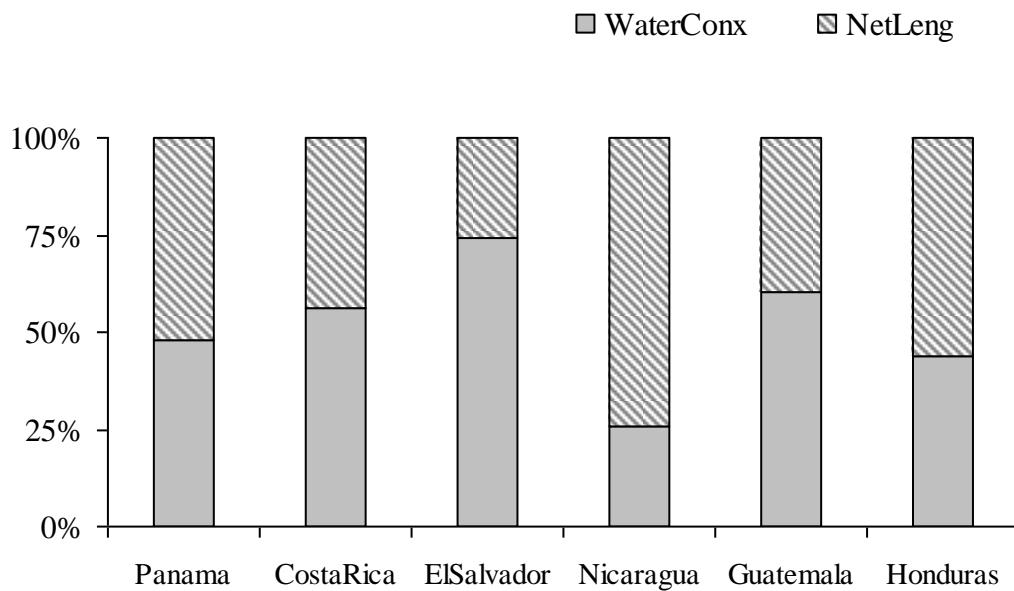


Figure 1. Changes in number of water connections and network length for 2002-2005

Table 3. Total factor productivity indexes for 2002-2005

Output Variable	<i>Laspeyres, Paasche & Fisher</i>		<i>Törnqvist</i>	
	Volume	#Connect	Volume	#Connect
Panama	51%	53%	31%	32%
El Salvador	-17%	-6%	-9%	0
Nicaragua	-5%	1%	-5%	-2%

Table 4. DEA technical efficiency and scale impact on efficiency for 2005

Inputs	Variable Returns			Scale Impact on Efficiency		
	Labor	Labor	Netlength	Labor	Labor	Netlength
		GNI2005	GNI2005		GNI2005	GNI2005
Panama	1.00	1.00	1.00	1.00	1.00	1.00
El Salvador	1.00	1.00	1.00	0.73	1.00	1.00
Costa Rica-L	0.62	0.62	0.63	0.60	0.92	1.00
Nicaragua	0.59	0.70	1.00	0.59	0.99	1.00
Guatemala-L	0.52	0.85	0.85	0.72	0.98	1.00
Honduras-L	0.34	0.38	0.99	0.99	0.97	0.44
Costa Rica-S	1.00	1.00	1.00	1.00	1.00	1.00
Guatemala-S	1.00	1.00	1.00	0.62	0.62	0.62
Honduras-S	1.00	1.00	1.00	0.39	1.00	1.00

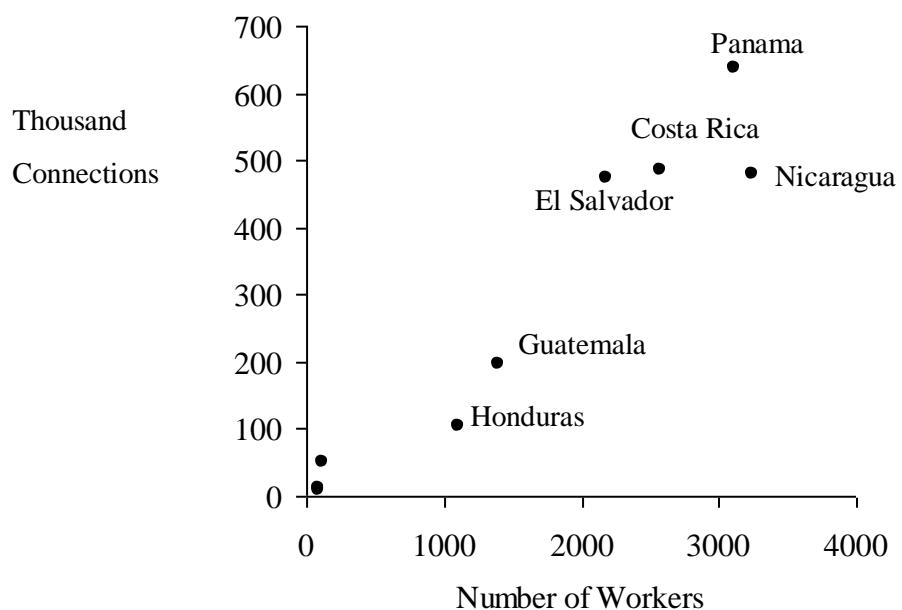


Figure 2. Constant returns to scale frontier for 2005

Table 5. Estimation results for the cost frontier

DepVar= UnitOpCost	Coefficient
Variable	
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%; Standard errors in parenthesis.

Table 6. Efficiency rank and possibilities of operating costs reductions by 2005

Country	Frontier Rank	Possible Cost Reduction
Nicaragua	1	2%
Panama	2	2%
El Salvador	3	3%
Costa Rica-S	4	3%
Guatemala-S	5	4%
Costa Rica-L	6	3%
Guatemala-L	7	12%
Honduras-L	8	14%

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