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Abstract

Benchmarking has been suggested as a useful regulatory tool for water companies in both developed and developing countries, specially due to the predominance of public firms in these sectors. However, in order to be effective, the comparisons should reflect differences in the firms' performances, rather than capture differences in their operating contexts. In this paper I apply a conditional data envelopment analysis (DEA) benchmarking technique that specifically controls for this, i.e., the conditional DEA approach. As a result, I find that conditioning on the population density in each firm's area of operation affect the estimated efficiencies in a significant way. The results are consistent with previous findings in other countries (which use different methodologies), and are new in the case of Peru.

1 Introduction

Providing incentives for the efficient performance of water companies in developing countries is a complex issue, not least because of the prevalence of state-owned companies in these sectors. While the theoretical incentive regulation literature has largely focused on profit-maximizing firms, empirical studies have simultaneously shown evidence that would contradict this behavioral paradigm in the case of government-owned firms.[1]

The empirical evidence in the water sector, however, points to a slow productivity growth in most instances, irrespectively of the ownership configuration. For example, Saal et al. (2007) found increased technical change in the UK in the years following the privatization, but, also, equally significant efficiency losses in the newly-privatized water and sewerage companies, summing up to a non-existent net effect .[2] In the case of Peru, where the companies have not been

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[1]For example, Dewenter and Malatesta (2001), studying a very heterogeneous sample of firms in several sectors, find that government-owned firms are significantly less profitable than private firms, and tend to be more labor intensive. On the other hand, Seim and Waldfogel (2013), in study about of liquor retail stores, conclude that the behaviour of the public monopoly is best rationalized as "profit maximization with profit sharing".

[2]Portela et al. (2011) extended the analysis for the period 1993-2007, and even finds a *decline* in productivity starting in 2005.

privatized, Lin and Berg (2008) did find some productivity growth in the period 1998-2002 (mostly from technical change, no efficiency gains), but very modest.[3]

Therefore, the question of how to provide incentives for efficient performance to public companies remains open. One common approach taken by the regulatory agencies, as in Peru, has been the use of publicly benchmarking the companies in the sector, with the hope that the public pressure from stakeholders provide the incentives for efficient performance. In fact, in the case of Netherlands, De Witte and Saal (2010) found a positive effects on prices and efficiency from this simple approach, named as "sunshine regulation" by the authors.

The objective of this study is to contribute to this literature by proposing a method, within the DEA framework, to benchmark the productive efficiency of the firms in the Peruvian water sector, but taking into account the heterogeneity in the operating context that the companies face. As suggested by Berg and Lin (2008), "to be of use to regulators (...), and to be accepted by other stakeholders, performance comparisons must be robust to promote confidence that the performance rankings do indeed reflect managerial skill rather than accidents of geography or history" (p. 794). Although DEA as a benchmarking technique has been proposed and implemented in previous studies (Berg and Lin, 2008; Lin, 2005), these studies did not take into account the heterogeneity in the firms' operating contexts.

In the context of input-oriented efficiency analysis, this means that input usage requirements can be different in different operating contexts. For example, in cities with low population density, the amount of inputs (i.e., length of water network) required to reach a certain output level can be higher than in more highly densely populated areas. In this sense, the ideal would be to perform the comparison conditional on having relatively similar levels of population density. This is precisely the objective of the conditional DEA method, proposed in Daraio and Simar (2005). In order to keep the practical applicability at a simple level, this method is applied within a deterministic DEA approach.[4]

The previous literature in the Peruvian case suggest the importance of the contextual (also called "environmental") heterogeneity, beyond the control of the firms, to partially explain differences in performance. Corton (2003), for example, shows that the number of districts in the area of operation and the natural region where the firm is located are statistically significant to explain the variation in operating costs (controlling for length of mains).

The concern in controlling for the heterogeneity of the operating context is shared with studies about other countries. For example, Tupper and Resende (2004) proposed a regression-based method to clean the effect of contextual variables on the estimated efficiencies (they take away the variation explained by the contextual variables, using a Tobit regression model), and applied it to the water sector in Brazil. The main difference between their methods and the ones applied here is that the conditional DEA methodology does not impose parametric constraints on the relation between the contextual variable and the unconditional DEA estimated efficiencies.

In regards to the empirical evidence in developed countries, De Witte and Saal (2010) applied the method proposed in this study for the Dutch case, but under an stochastic DEA framework. They also found important to condition the DEA estimates on the population density. Similarly, Vidoli (2011) applied a novel nonparametric method to evaluate the dependency of the efficiency estimates on contextual variables in the Italian case, and finds a predominant role to the population density.

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[3]Also, Estache et al. (2005) concludes that there is scant evidence of any differential overall performance between public and private operators in the water sector, after surveying productivity studies in developing countries.

[4]Berg and Lin (2008) show that deterministic DEA can be considered a robust benchmarking technique in the Peruvian case, by showing that the performance rankings produced with this technique are not too dissimilar to those produced with stochastic DEA techniques, theoretically more robust to outlier observations.

The remaining of the paper is organized as follow: Section 2 briefly describes the main institutional features of the water industry in Peru, Section 3 describes the benchmarking methodologies applied, Section 5 describes the details of the model specification, as well as the main features of the data at hand, Section 5 presents the main results, and Section 6 concludes.

2 The Water Sector in Peru

The water and sewage sectors in Peru are a decentralized system, formed by the municipality-owned companies that are under the supervision of SUNASS (Superintendencia Nacional de Servicios de Saneamiento), the agency in charge of regulating the operation of the firms in the sector.

Starting in 1999, SUNASS established a benchmark system to evaluate the performance of the companies under its supervision. This system was based, originally, on nine indicators, grouped into four areas:[5] quality, coverage, management efficiency, and managerial finance efficiency. The indicators are expressed as a percentage, and averaged (with equal weight). Finally, the firms are ranked according to the score obtained within four groups, determined by the number of connections (small, with less than 10,000 connections; medium, with between 10,000 and 40,000 connections; and big, with more than 40,000 connections). See the results of the benchmarking for 2013 in Table 3, in Appendix A.

Berg and Lin (2008) evaluate the consistency of SUNASS's benchmarking method, in comparison to other frequently-used methodologies, such as regression, DEA (deterministic and stochastic), and stochastic frontier. The advantage of the alternative methodologies is that, generally, they consider the role of each indicator as either input, output, or "contextual" variable - that is, variables that characterize the operating environment of the firm, i.e., (1) they are outside the control of the firm, and (2) affect either input usage, or output production.[6]

Given the above discussion, unsurprisingly, the study found that the DEA and SFA-based methods generally produce consistent rankings, differently to those of the SUNASS and regression methods. In particular, the authors trace the major differences between methodologies that acknowledge input-output causality relations and SUNASS's simple benchmarking methodology in units that, although show low output levels, also show low input usage. These units would obtain low scores by definition under the simple average of SUNASS's indicators. The optimization-based techniques, on the other hand, would recognize that some of this output performance might be explained by the low availability of inputs.

I extend the deterministic DEA methodology used in the previous study, by incorporating the influence of the firms' context of operation. In particular, I consider the influence of the population density, given the extensively documented economies of density present in the sector - see De Witte and Saal (2010), Vidoli (2011).

3 Methodology

Consider a vector of inputs, $X \in \mathbb{R}^p$, used to produce a vector of outputs, $Y \in \mathbb{R}^q$. Then, the production set is defined as: $\Psi = \{(x, y) | x \text{ can produce } y\}$. In this context, the Farrell's radial input efficiency measure for a DMU using input vector x to produce output y can be defined

[5] The number of indicators has risen in recent years, so that, for example, thirteen indicators were used in the 2013 benchmarking exercise.

[6] Besides the previously referenced studies, see also Thanassoulis (2000), for a review of the use of DEA techniques in the regulation of water companies in the UK.

as:

$$\theta(x,y) \equiv \inf\{\theta | (\theta x, y) \in \Psi\}$$

This is an input-oriented efficiency measure: it calculates the maximum proportional (i.e., radial) decrease in input usage, θ, that is technically feasible while keeping the production vector y constant.

DEA is an empirical way to assess the Farrell input efficiency of a firm, relative to the observed performance of a group of comparable firms, or peers. That is, DEA takes all the units' input and output combinations and use them to form an empirical set of production possibilities, $\hat{\Psi}$. This set reveals what combinations of inputs and outputs are possible, *given the observed input-output combinations of the real units* (plus additional assumptions specified below). Given that it assess the unit's efficiency based on the observed performance the firm's peers, DEA can be seen as a benchmarking tool.

To be more concrete, consider the following typical assumptions for the empirical production possibilities set, $\hat{\Psi}$, under the DEA approach:

- Convexity: given two observed input-output configurations, any linear combination of them also belongs to $\hat{\Psi}$.
- Free disposal: given an input-output configuration in $\hat{\Psi}$, any other configuration with either lower output or higher input also belongs to $\hat{\Psi}$.
- Constant (CRS) or variable (VRS) returns to scale: under CRS any input-output configuration in $\hat{\Psi}$ is scalable, that is, it can be implemented any number of times. Under VRS, this is not the case.

Now consider a group of decision-making units (DMUs), $j = 1, ..., J$. Under the previous assumptions, the CRS and VRS empirical production possibilities can be determined in reference to the observed performance of all the units in the group, as follows:

$$\hat{\Psi}^{CRS} = \{(x,y) \in \mathbb{R}_{+}^{M+P} |\ x \leq \sum_{j\in J} \lambda_j x_j,\ y \geq \sum_{j \in J} \lambda_j y_j,\ \lambda_j \geq 0,\ \forall j \in J\}$$
$$\hat{\Psi}^{VRS} = \{(x,y) \in \mathbb{R}_{+}^{M+P} |\ x \leq \sum_{j\in J} \lambda_j x_j,\ y \geq \sum_{j \in J} \lambda_j y_j,\ \sum_{j\in J} \lambda_j = 1,\ \lambda_j \geq 0,\ \forall j \in J\}$$

Then, the DEA input usage efficiency can be calculated by applying Farrell's efficiency definition to any of these production possibilities sets (under the CRS or VRS assumption, respectively). For example, under the VRS assumption, a firm i with observed input-output configuration (x_i, y_i) has an input usage efficiency of:

$$\theta_i^{VRS} \equiv \theta^{VRS}(x_i, y_i) = \inf\{\theta | (\theta x_i, y_i) \in \hat{\Psi}^{VRS}\}$$

For example, if $\theta_i^{VRS} = 0.7$, it would mean that DMU i could reduce its inputs usage by up to 30% (in every input dimension), and still be able to produce the same output vector y_i. A fully input efficient unit would have $\theta^{VRS} = 1$ (no proportional input reduction is possible). This would mean that there is no other unit in the sample (or linear combination of them) that produces the same level of output, with a lower amount of inputs. As can be seen, this is a *relative* measure of efficiency because it defines efficient performance based on the observed performance of other units, not up to an ideal or absolute standard of efficiency.

Notice that the previous definition considers all the units as comparable. However, what if the contexts in which the units operate are *too* different? In the case of water distribution, it could be very different to provide the service in cities with different population densities.

Arguably, it could be much less input-demanding to increase the coverage of the service in cities with higher population density. More generally, consider a *contextual* variable Z, that captures this diversity. One would want to compare cities with relatively similar values of this variable. Consider a firm i, with input-output configuration (x_i, y_i) and contextual variable z_i. We can define a production possibilities set, conditional on the value of its contextual variable z_i (I only present the CRS case for brevity):

$$\hat{\Psi}^{CRS}(z_i) = \{(x, y)|\ x \leq \sum_{j \in J} \lambda_j x_j,\ y \geq \sum_{j \in J} \lambda_j y_j,\ \lambda_j \geq 0, \\ \forall j \in J \text{ such that } z_i - h \leq z_j \leq z_i + h\}$$

In this definition, the comparison set for unit i is formed following a similar procedure as before, but now considering only the units (indexed as j) that have a value z_j within a distance h of z_i. That is, the comparison group here considers units with a relatively similar value of z (the similarity is controlled by appropriately choosing the bandwidth parameter, h). Following Daraio and Simar (2005), we denote this as a *conditional* DEA efficiency index.

4 Model Specification and Data

I study the performance of 43 firms from 2006 to 2013, which is the full set of firms operating in the sector with the exception of the firm operating in the capital city, SEDAPAL, and a few small companies (due to missing data). This firm is excluded because its operating environment is radically different from the rest of the country: it serves almost 1.4 million active connections, compared to an average of 38 thousand for the firms in other cities. Given that having such a different observation in the sample may distort the performance comparisons, it is therefore excluded.

In order to deal with the panel data structure, I pool the information for all the years and calculate a single efficient frontier. In this way, the observed performance of every unit is compared to a single benchmark, which is intended to be formed by the best observed performances along all the years in the sample. With this practice I follow Estache et al. (2004) in their study of electric utilities in South America, as well as previous studies about the Peruvian water sector specifically, such as Berg and Lin (2008).

I also follow the last study, as well as the applied literature in the sector and in this industry in particular (Corton, 2003; Lin, 2005), to specify the inputs and outputs of the production model. The list of inputs includes the operating costs, the number of employees and the total length of the distribution network. The operating costs are used as a proxy for the use of intermediate inputs in the production and delivery process, while the number of employees measure the amount of labor (given the absence of more precise measures of labor input usage), and the length of the distribution network proxies the amount of the capital input utilized (given the usual problems in measuring capital).

Regarding the outputs, the list include the total amount of water billed, the coverage ratio, and the degree of continuity of the service. This intends to capture not only output, but also quality dimensions (Lin, 2005; Picazo-Tadeo et al., 2008). For example, the amount of water billed indirectly measures a (negative) dimension of quality, such as the amount of water losses in the network. This problem is regarded as highly relevant in the Peruvian case (Berg and Lin, 2008) - e.g., by 2013 only around 65% of the water produced was actually billed, in average for all operators.

The other two variables included as outputs, the coverage and continuity of the service provision, can be seen as fully quality indicators. As shown in Lin (2005) (a benchmarking study, in the stochastic frontier analysis framework), these variables seem to have a significant

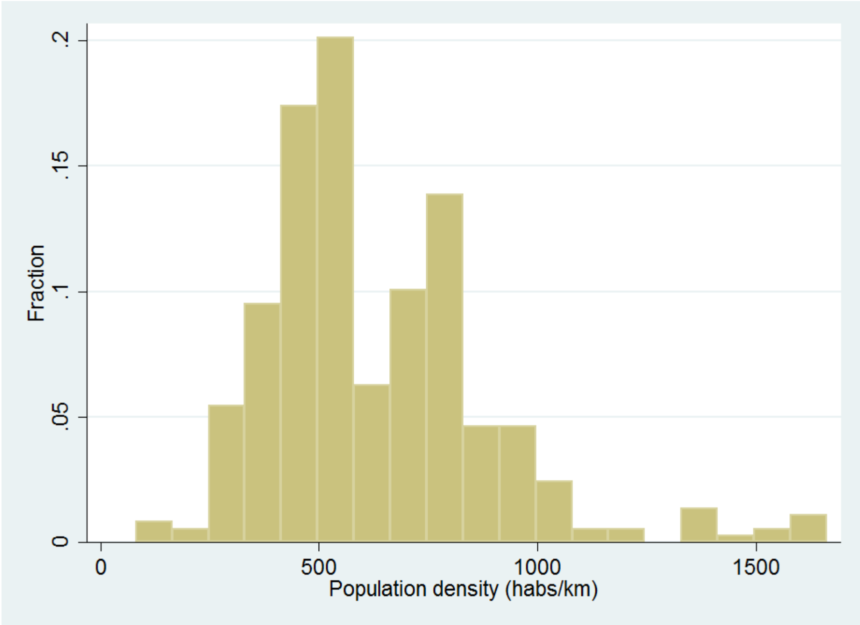

Figure 1: Histogram of Population Density

incidence on the firms' operating cost efficiencies in this sector. I consider, therefore, fruitful to include them also as determinants of productive efficiency. The coverage is calculated as the ratio between the estimated population served by the operator, and the total amount of population within the area of service. Continuity is measured as the average number of hours that the service is operating on a daily basis.

Table 1: Summary Statistics

	Mean	St. Dev.	Min	Max
Outputs				
Water Billed (m3)	7766287	9067781	348231	44531840
Coverage (%)	83	12	29	100
Continuity (hs/day)	15	6	0	24
Inputs				
Operating costs (S/.)	11275086	16503797	260677	92253000
Workers	132	144	2	740
Total water network length (kms)	336	388	28	2044
Context				
Population density (habs/km)	627	255	82	1662

Table 1 shows the summary statistics of the aforementioned variables. Notice that there is still a considerable degree of heterogeneity left in the sample, in spite of having excluded the operator in Lima and those with a high degree of missing information (mostly very small networks). In particular, the population density (our proposed determinant of the operating context) has a big range of variation, from 82 to 1662 inhabitants by kilometer of water network. Figure 1 shows an histogram for this variable, which illustrates the high heterogeneity present in the sample. This suggests that the differing contexts could be relevant to explain part of the observed operating performance.

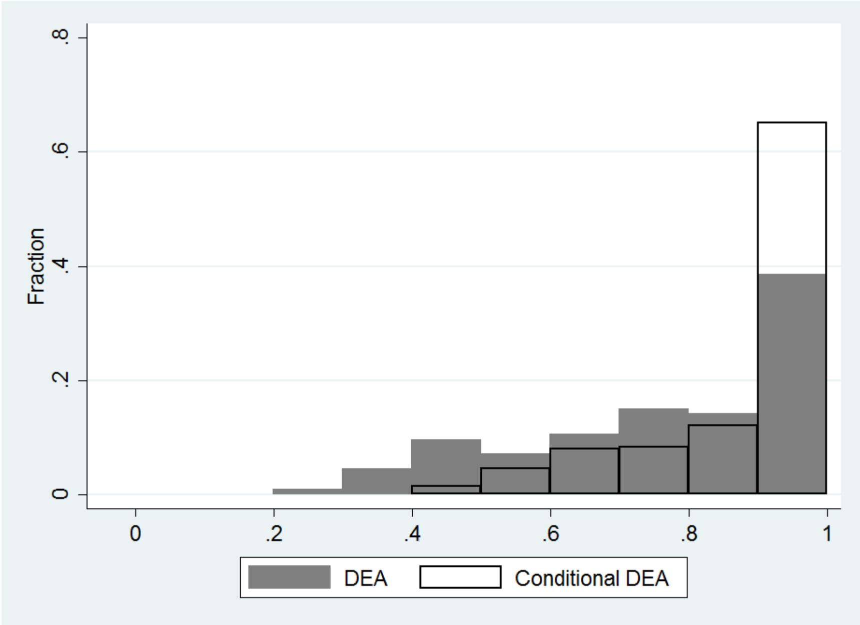

Figure 2: Histogram of DEA Efficiency Scores (VRS)

5 Results

The Table 2, and Figures 2 and 3, show the statistics and histograms, respectively, of the DEA efficiency scores calculated under the VRS and CRS assumptions - the detailed results for every firm in every year are shown in Tables 4 and 6 in Appendix A. It is important to remember at this point that the efficiency assessments are *relative*: a fully efficient firm under this approach (i.e., with an efficiency score of 1) does not necessarily mean that the firm is technically fully efficient, but only than its performance is the best of the pool of firms under evaluation.

The distribution of the unconditional efficiency scores in both, the VRS and CRS cases, show an ample variability (particularly in the CRS case, as expected). Taken at face value, the VRS results imply that at the average observed performance (0.788), input usage could have been decreased by 21.2% in every dimension without affecting the output and quality produced, only taking as a reference the observed performance in the sample chosen. In the CRS case, given the more ample distribution, the average performance is of only 0.588.

Table 2: Efficiency Scores Statistics

	Mean	St. Dev.	Min	p25	p50	p75	Max
Unconditional							
CRS	0.588	0.221	0.234	0.416	0.507	0.767	1.000
VRS	0.788	0.206	0.262	0.658	0.830	1.000	1.000
Conditional							
CRS	0.797	0.193	0.387	0.639	0.830	1.000	1.000
VRS	0.901	0.145	0.441	0.837	0.994	1.000	1.000

The distribution of the conditional DEA estimates are, naturally, less disperse - this is expected because with conditional DEA each performance is compared only to a subset of the sample, those observations with similar levels of population density. In both the CRS and VRS cases, the average efficiency increases substantially. In the CRS case it reaches 0.797 (up from 0.588 in the unconditional DEA), while in the VRS case is now 0.901 (up from 0.788). That is, the distance between the observed best and worst performances could be explained in

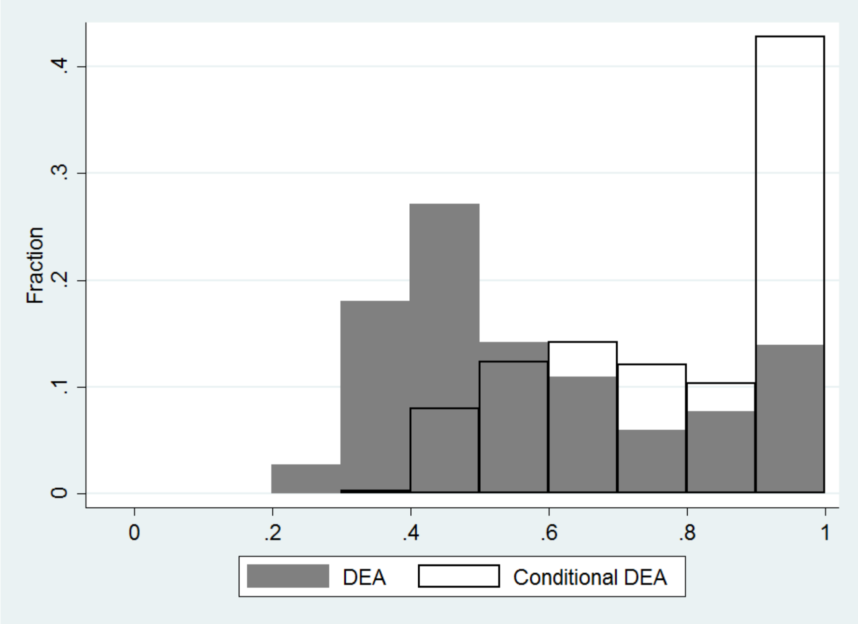

Figure 3: Histogram of DEA Efficiency Scores (CRS)

a significant degree by different contexts in which the firms perform. The detailed calculated scores are presented in Tables 5 and 7 in the Appendix A.

To get a sense of how much the context of operation could be affecting the production possibilities of the firms, I compare the ratio of the unconditional over the conditional DEA scores with the population density. Figures 4 and 5 plots these observations (denominated as R in the figures), along with a non-parametric (lowess) regression estimate. The ratio of the DEA efficiency scores measures the distance between the unconditional and conditional production possibilities ($\hat{\Psi}$ and $\hat{\Psi}(z)$ in the methodological section). When the ratio is closer to one it means that the both estimates are exactly equal, so conditioning on the context would not affect the production possibilities of the firms. The farther the measure deviates from one, on the contrary, would mean that there is a significant effect. We can see that in both the CRS and VRS cases there seems to be positive relation between the ratios and population density, stronger in the CRS case. We can interpret this as saying that low population densities seem to affect the production possibilities of the firms.

6 Conclusions

In this study I applied production performance benchmarking techniques, within the DEA framework, to compare the input usage efficiency of the water companies in Peru. The advantage of the DEA approach is that it does not only compares output and quality performance across companies, but also takes into consideration the input usage level. As noticed by Berg and Lin (2008), simple performance measures, like those used by SUNASS, mostly omit the input side of the production process.

On the other hand, in the DEA approach it could be complicated to account for the different contexts in which the companies operate, in comparison to regression methods, for example. At the same time, there is also the concern that the perceived differential performance could actually be explained in some degree by these differing contexts (Tupper and Resende, 2004). In this study I apply an extension of the usual input-oriented DEA benchmarking methodology to account for the possibly differential contexts. The conditional DEA method (Daraio and Simar, 2005) relies on comparing units with approximately similar contexts of operation, where

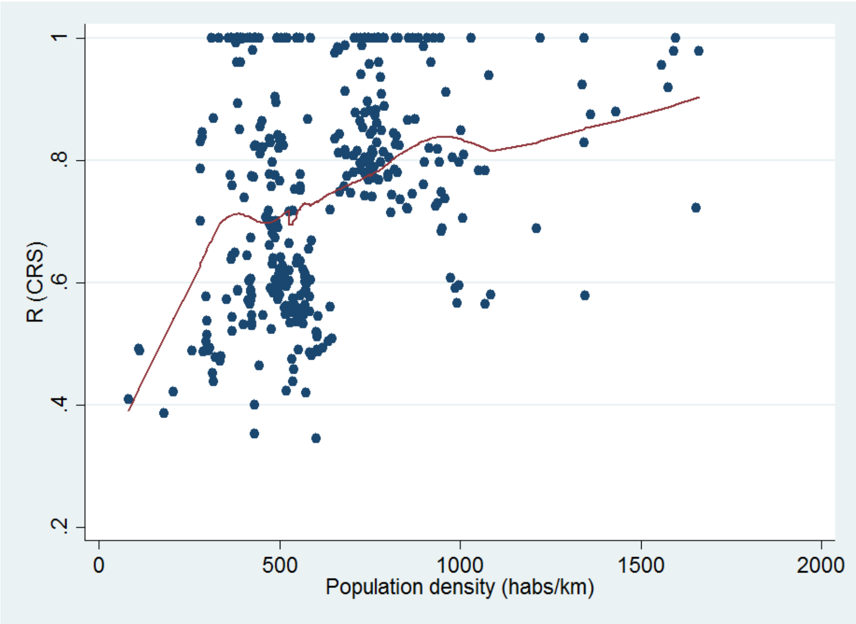

Figure 4: Ratio of Unconditional over Conditional DEA versus Population Density (CRS)

Figure 5: Ratio of Unconditional over Conditional DEA versus Population Density (VRS)

this is quantified by a so-called “contextual variable”.

I calculated conditional DEA scores by conditioning on the population density in the area of operation of each company. I find that controlling for the context of operation in this way affects in an economically significant amount the calculated efficiencies, and therefore can affect the performance benchmarking of water companies in Peru.

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A Efficiency Scores

In this section I present the efficiency scores calculated by SUNASS, as well as those calculated with the DEA methodologies proposed in this study - under the CRS and VRS assumptions.

Table 3: SUNASS's Efficiency Scores

Rank	Firm	Connections	Score	Grade 2013	Grade 2012
1	EPS MOQUEGUA	20225	74.03	B+	B-
2	SEDAPAL	1412305	73.16	B+	B+
3	EPS ILO S	24247	73.03	B+	C+
4	EMUSAP SRL (Amazonas)	6733	68.7	B-	B-
5	EPS TACNA SA	88836	68.15	B-	B-
6	SEDACUSCO SA	73850	66.49	B-	B-
7	SEDAPAR S	265264	65.16	B-	B-
8	EPSASA	52066	64.68	B-	B-
9	SEDACAJ SA	38854	60.46	B-	C+
10	SEDA HUÁNUCO SA	41353	60.19	B-	C+
11	EPS NOR PUNO SA	8653	58.56	C+	C+
12	SEDACHIMBOTE SA	84995	56.91	C+	C+
13	EMUSAP ABANCAY SA	12957	56.62	C+	B-
14	EMAPA Y SRL	4768	56.31	C+	D+
15	SEMAPACH SA	44702	56	C+	C+
16	EPS CHAVIN SA	26280	55.99	C+	C+
17	EMAPA HUANCAVELICA SA	8024	55.88	C+	C+
18	EPS MARAÑÓN SRL	16494	55.83	C+	C-
19	SEDAPAR SRL (Rioja)	5733	55.74	C+	C-
20	SEDALIB SA	165558	55.66	C+	C+
21	EPS SIERRA CENTRAL SRL	9796	55.41	C+	C+
22	EPS GRAU SA	185947	54.89	C+	C+
23	EMAPISCO SA	24898	54.04	C+	C+
24	EMAPA HUARAL SA	15510	53.7	C+	C+
25	EMAPICA SA	50305	53.66	C+	C+
26	EMAPA MOYOBAMBA SRL	11689	53.15	C+	B-
27	EPS MANTARO SA	17565	52.9	C+	C+
28	EMSAP CHANKA SRL	4436	52.81	C+	C+
29	EMAPAT SRL	15046	52.75	C+	C-
30	EMAPA SAN MARTÍN SA	39974	52.55	C+	C+
31	EPSEL SA	154748	52.42	C+	C+
32	SEDAJULIACA SA	48278	52.34	C+	C+
33	EPS AGUAS DEL ALTIPLANO SRL	6304	51.7	C+	C-
34	EMAPA HUACHO SA	25755	51.68	C+	C+
35	AGUAS DE TUMBES SA	41392	51.58	C+	C-
36	EMAQ SRL	6692	51.15	C+	C-
37	EMPSSAPAL SA	13558	50.97	C+	C+
38	EMSA PUNO SA	42371	50.96	C+	C-
39	SEDAM HUANCAYO SAC	67892	50.89	C+	C-
40	SEMAPA BARRANCA SA	16297	48.74	C-	C-
41	EMSAPA CALCA SRL	3150	47.25	C-	C-
42	EPSSMU SRL	7578	46.51	C-	C-
43	EMAPA CAÑETE SA	31884	45.83	C-	C-
44	EMAPAVIGS SAC	8504	45.58	C-	C-
45	EPS SEDALORETO SA	88418	44.02	C-	C-
46	EMSAPA YAULI SRL (La Oroya)	3215	41.6	C-	D+
47	EMAPACOP SA	24515	40.03	C-	C-
48	EMAPA PASCO SA	11343	39.93	D+	D+
49	EPS SELVA CENTRAL SA	22088	39.48	D+	D+
50	EMAPAB SRL	4759	39.32	D+	D+

Source: SUNASS (2013).

Table 4: Efficiency Scores: Unconditional DEA (CRS)

Firm	2005	2006	2007	2008	2009	2010	2011	2012	2013
EMUSAP AMAZONAS	1.000	1.000	1.000	0.961	1.000	1.000	0.981	0.893	0.824
SEDA HUANUCO S.A.			0.442	0.453	0.461	0.474	0.465	0.536	0.548
EMAPACOP S.A.	0.416	0.358	0.405	0.396	0.372	0.353		0.442	0.416
EPS SEDALORETO S.A.	0.722	0.690	0.378	0.373	0.419	0.465	0.478		0.319
EMAPA CAÑETE S.A.	0.575	0.548	0.591	0.595	0.563	0.688	0.529	0.581	0.641
EMSA PUNO S.A.	0.392	0.752	0.356	0.358	0.366	0.369	0.501	0.445	0.356
EPSSMU S.R.LTDA	0.821	0.824	0.884	0.903	0.683	0.695	0.733	0.794	0.832
AGUAS DE TUMBES	0.321	0.251	0.390	0.435	0.407	0.368	0.366	0.251	
EMAPA PASCO S.A.		0.719			1.000	0.650		0.914	1.000
EMAPISCO S.A.		0.323	0.281	0.234	0.278	0.297	0.319	0.303	0.346
SEDACAJ S.A.	0.350	0.843	0.377	0.378	0.331	0.312	0.301	0.320	0.344
EPS TACNA S.A.	0.396	0.397	0.403	0.425	0.412	0.441	0.435	0.481	0.466
EMAPAVIGSSA	0.741	0.812	0.854		0.950	1.000	0.798	0.836	0.936
SEDACHIMBOTE S.A.	0.444	0.467	0.431	0.491	0.453	0.423	0.386	0.367	
EPSASA	0.511	0.489	0.452	0.455	0.448	0.412	0.414	0.436	0.473
EMAPA SAN MARTIN S.A.	0.375	0.410	0.868	0.413	0.396	0.387	0.539	0.373	0.367
EMAPAT S.R.LTDA.	0.434	0.457	0.376	0.358	0.356	0.246	0.330	0.353	0.400
SEMAPACH S.A.	0.365	0.362	0.398		0.353	0.436	0.456	0.474	0.492
EPS SELVA CENTRAL S.A.	0.705	0.503	0.724	0.740		0.783	0.940	0.848	1.000
EMAPA MOYOBAMBA S.R.LTDA.	0.761		0.774	1.000	0.985	0.783	1.000	0.805	0.812
EMAPA HUANCAVELICA S.A.C	0.960	1.000	0.848	0.614	0.668	0.763	1.000	0.611	0.620
EPS MOQUEGUA S.R.LTDA.	0.559	0.599	0.594	0.603	0.529	0.471	0.479	0.421	0.409
EMAPA HUARAL S.A.	0.919	1.000	0.979	0.956	0.879	0.875	0.829	1.000	0.924
EMAPA HUACHO S.A.	0.471	0.433		0.440	0.433	0.425	0.432	0.451	0.488
EPS ILO S.R.LTDA.	0.268	0.274	0.275	0.280	0.278	0.292	1.000	0.294	0.298
SEDALIB S.A.	0.385	0.393	0.421	0.414	0.440	0.420	0.473	0.493	0.464
EPSEL S.A.	0.684	0.610	0.687			0.539		0.546	0.868
SEDAPAR S.A.	0.416	0.413	0.434	0.913	0.377	0.363	0.359	0.423	0.438
EPS - SEDACUSCO S.A.	0.412	1.000	1.000	0.901	0.418	0.405	0.495	0.412	0.734
EPS GRAU S.A.	0.597	0.371	0.460	0.470	0.496	0.591	0.628	0.768	0.714
EPS CHAVIN S.A.	0.480	0.476	0.497	0.503	0.499	0.525		0.805	
EMAQ S.R.LTDA.		1.000	1.000	1.000		1.000	0.957	1.000	1.000
EMAPAB S.R.LTDA.	0.712	0.751	0.787	0.801	0.644	0.677	0.777	0.742	0.758
SEMAPA BARRANCA S.A.	0.554	0.562	0.570	0.526	0.540	0.487	0.399	0.418	0.436
EMAPICA S.A.					0.456	0.503		0.539	0.489
EMPSSAPAL S.A.	0.846	0.783	0.705	1.000	0.535	0.548	0.533	0.864	1.000
EPS SIERRA CENTRAL S.A.	0.695	0.658		0.767	0.668	0.660	0.699	0.821	0.803
NOR PUNO S.A.	1.000	1.000	1.000	0.903	1.000	1.000	1.000	0.998	0.869
SEDAJULIACA S.A.	0.502	0.479	0.516	0.533	0.522	0.558	0.500	0.607	0.525
EPS MANTARO S.A.	1.000	0.406	0.538	0.550	0.472	0.513	0.489	0.491	0.489
EMUSAP ABANCAY	0.604	0.544	0.571	0.539	0.477		0.468	0.469	0.468
EPS MARAÑON	0.579	0.565	0.579	0.567	0.818		0.912		0.504
SEDAM HUANCAYO S.A.C		0.614	0.678			0.441	0.450	0.439	0.387

Table 5: Efficiency Scores: Conditional DEA (CRS)

Firm	2005	2006	2007	2008	2009	2010	2011	2012	2013
EMUSAP AMAZONAS	1.000	1.000	1.000	1.000		1.000	0.988	1.000	0.969
SEDA HUANUCO S.A.			0.543	0.563	0.588	0.561	0.523	0.690	0.738
EMAPACOP S.A.	0.523	0.408	0.459	0.466	0.448	0.443	0.471	0.646	0.742
EPS SEDALORETO S.A.	1.000	0.705	0.468	0.514	0.525	0.622	0.656	0.581	0.391
EMAPA CAÑETE S.A.	0.779	0.901	1.000	1.000	0.712	1.000	0.699	0.750	0.822
EMSA PUNO S.A.	0.465	1.000	0.688	0.692	0.662	0.654	0.766	0.666	0.537
EPSSMU S.R.LTDA	0.982	1.000	0.988	1.000		0.826	0.894	0.954	0.995
AGUAS DE TUMBES	0.448	0.447	0.609	0.685	0.538	0.474	0.482	0.387	0.702
EMAPA PASCO S.A.		1.000			1.000	0.650		0.914	1.000
EMAPISCO S.A.		0.511	0.464	0.427	0.471	0.567	0.613	0.556	0.605
SEDACAJ S.A.	0.420	1.000	0.461	0.466	0.670	0.639	0.717	0.664	1.000
EPS TACNA S.A.	0.615	0.657	0.714	0.723	0.722	0.772	0.682	0.820	0.792
EMAPAVIGSSA	1.000	1.000	0.978	1.000	0.989	1.000	0.878	0.970	1.000
SEDACHIMBOTE S.A.	0.799	0.767	0.717	0.797	0.748	0.706	0.657	0.625	0.669
EPSASA	1.000	0.892	0.804	0.830	0.812	0.747	0.751	0.755	0.864
EMAPA SAN MARTIN S.A.	0.581	0.693	1.000	0.844	0.690	0.723	0.842	0.636	0.629
EMAPAT S.R.LTDA.	0.701	1.000	0.791	0.849	0.603	0.516	0.710	1.000	1.000
SEMAPACH S.A.	0.458	0.467	0.576	0.502	0.454	0.608	0.658	0.697	0.731
EPS SELVA CENTRAL S.A.	1.000	0.599	0.984	0.928		1.000	1.000	1.000	1.000
EMAPA MOYOBAMBA S.R.LTDA.	0.879	1.000	0.972	1.000	1.000	1.000	1.000	1.000	1.000
EMAPA HUANCAVELICA S.A.C	1.000	1.000	1.000	1.000	0.954	0.914	1.000	1.000	0.967
EPS MOQUEGUA S.R.LTDA.	0.965	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EMAPA HUARAL S.A.	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000
EMAPA HUACHO S.A.	0.536		0.519	0.499		0.498	0.501	0.605	0.603
EPS ILO S.R.LTDA.	0.521	0.544	0.560	0.573	0.566	0.593	1.000	0.650	0.679
SEDALIB S.A.	0.477	0.493	0.530	0.537	0.573	0.535		0.664	
EPSEL S.A.	0.948	0.845	0.922	0.885	1.000	0.657	0.701	0.719	1.000
SEDAPAR S.A.	0.658	0.666	0.796	1.000	0.777	0.681	0.663	0.862	1.000
EPS - SEDACUSCO S.A.	0.526	1.000	1.000	0.912	0.538	0.520	0.641	0.577	
EPS GRAU S.A.	0.731	0.477	0.572	0.585	0.638	0.767	0.811	1.000	0.904
EPS CHAVIN S.A.	0.951	0.936	0.509	0.513	0.507	0.532		1.000	0.575
EMAQ S.R.LTDA.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EMAPAB S.R.LTDA.	0.842	0.896	1.000	0.966	0.919	0.816	1.000	0.988	1.000
SEMAPA BARRANCA S.A.	0.711	0.681	0.692	0.586	0.574		0.697	0.673	0.754
EMAPICA S.A.					0.848	0.937		1.000	0.920
EMPSSAPAL S.A.	0.979	0.915	0.868	1.000	0.649	0.666	0.690	0.881	1.000
EPS SIERRA CENTRAL S.A.	0.967	0.991	1.000	1.000	0.952	0.947	0.989	1.000	0.979
NOR PUNO S.A.	1.000	0.999	1.000	0.941	1.000	1.000	1.000	1.000	1.000
SEDAJULIACA S.A.	0.906	0.852		0.995	0.976	1.000	0.906	0.882	0.909
EPS MANTARO S.A.	1.000	0.726	0.858	0.895	0.610	0.693	1.000	1.000	1.000
EMUSAP ABANCAY	1.000	0.902	0.942	0.801	0.815	0.805	0.808	0.858	0.876
EPS MARAÑON	1.000	1.000	1.000	1.000	0.999		1.000		0.675
SEDAM HUANCAYO S.A.C		0.547	0.628			0.764	0.838	0.902	1.000

Table 6: Efficiency Scores: Unconditional DEA (VRS)

Firm	2005	2006	2007	2008	2009	2010	2011	2012	2013
EMUSAP AMAZONAS	1.000	1.000	1.000	1.000	0.958	1.000	1.000	1.000	0.933
SEDA HUANUCO S.A.			0.748	0.805	0.796	0.809	1.000	1.000	1.000
EMAPACOP S.A.	0.417	0.363	0.413	0.421	0.378	0.356	0.372	0.461	0.434
EPS SEDALORETO S.A.	1.000	1.000	0.572	0.598	0.677	0.706	0.732	0.731	0.585
EMAPA CAÑETE S.A.	0.728	0.552	0.596	0.598	0.605	0.699	0.537	0.596	0.670
EMSA PUNO S.A.	0.457	0.753	0.514	0.559	0.572	0.555	0.727	0.649	0.667
EPSSMU S.R.LTDA	0.875	0.888	0.892	1.000	0.807	0.801	0.755	0.801	0.874
AGUAS DE TUMBES		0.262	0.391	0.460	0.427	0.424	0.407	0.349	0.486
EMAPA PASCO S.A.		0.885						0.924	1.000
EMAPISCO S.A.		0.434	0.457	0.298	0.382	0.431	0.580	0.519	0.915
SEDACAJ S.A.	0.471	0.843	0.486	0.547	0.500	0.519	0.376	0.405	0.458
EPS TACNA S.A.	0.916	0.921	0.909	1.000	0.967	0.983	0.940	0.985	1.000
EMAPAVIGSSA	0.947	0.930	1.000	1.000	1.000	1.000	0.795	0.905	1.000
SEDACHIMBOTE S.A.	0.956	1.000	0.806	0.893	0.828	0.783	0.711	0.758	0.693
EPSASA	0.889	0.889	0.792	0.834	0.820	0.775	0.778	0.823	1.000
EMAPA SAN MARTIN S.A.	1.000	0.641	1.000	0.770	0.864	0.964	1.000	0.921	0.780
EMAPAT S.R.LTDA.	0.447	0.463	0.381	0.372	0.416	0.275	0.435	1.000	
SEMAPACH S.A.	0.377	0.377	0.408	0.387	0.520	0.677	0.681	0.744	0.648
EPS SELVA CENTRAL S.A.	0.786	0.510	0.728	0.741		0.783	1.000	0.995	1.000
EMAPA MOYOBAMBA S.R.LTDA.	0.869	0.994	1.000	1.000	1.000		1.000	0.822	0.933
EMAPA HUANCAVELICA S.A.C	1.000	1.000	0.871	0.624	0.689	0.769	1.000	0.673	0.751
EPS MOQUEGUA S.R.LTDA.	1.000	1.000	1.000	0.825	0.720	0.739	0.790	0.886	1.000
EMAPA HUARAL S.A.	0.940	1.000	0.979	0.957	0.999	0.923	0.829	1.000	0.982
EMAPA HUACHO S.A.	0.469	0.454	0.480	0.504		0.554	0.590	0.670	0.729
EPS ILO S.R.LTDA.	0.396	0.441	0.450	0.432	0.423	0.426	1.000	1.000	0.695
SEDALIB S.A.	0.612	0.642	0.658	0.671	0.708	0.703	0.714	0.742	0.720
EPSEL S.A.	1.000	0.921	0.950	0.996	1.000	1.000	1.000	0.987	1.000
SEDAPAR S.A.		0.948	1.000	1.000	1.000	0.964		0.958	1.000
EPS - SEDACUSCO S.A.	0.757	1.000	1.000	0.914	0.867	1.000	0.753	0.721	1.000
EPS GRAU S.A.	0.753	0.661	0.701	0.714	0.744	0.859	0.897	1.000	1.000
EPS CHAVIN S.A.	0.679	0.688	0.750	0.749	0.853	1.000		1.000	1.000
EMAQ S.R.LTDA.		1.000	1.000	1.000	1.000	1.000	0.956	1.000	1.000
EMAPAB S.R.LTDA.	0.871	0.906	0.914	0.846	0.856	0.992	1.000	0.958	0.963
SEMAPA BARRANCA S.A.	0.734	0.789	0.963	0.867	0.947	0.863	0.511	0.585	0.536
EMAPICA S.A.					0.726	0.814	0.881	0.955	0.957
EMPSSAPAL S.A.	0.888	0.870	0.882	1.000	0.661	0.708	0.883	1.000	1.000
EPS SIERRA CENTRAL S.A.	0.724	0.759	0.919	1.000	0.809	0.811	0.930	1.000	1.000
NOR PUNO S.A.	1.000	0.960	1.000	0.938	1.000	1.000	1.000	1.000	1.000
SEDAJULIACA S.A.	0.599	0.632	0.776	0.771	0.804	0.843	0.754	0.856	0.803
EPS MANTARO S.A.	1.000	0.418	0.539	0.551	0.477	0.526	0.658	0.841	0.943
EMUSAP ABANCAY	1.000	0.943	1.000	0.840	0.830	0.859	1.000	0.993	1.000
EPS MARAÑON	0.760	0.712	0.684	0.642	0.828		0.918		0.523
SEDAM HUANCAYO S.A.C		1.000	1.000			0.981	1.000	0.984	1.000

Table 7: Efficiency Scores: Conditional DEA (VRS)

Firm	2005	2006	2007	2008	2009	2010	2011	2012	2013
EMUSAP AMAZONAS		1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
SEDA HUANUCO S.A.				0.854	0.878	0.878	1.000	1.000	1.000
EMAPACOP S.A.	0.610	0.547	0.633	0.662	0.624	0.581	0.603	0.660	0.731
EPS SEDALORETO S.A.	1.000	1.000	0.899	0.662		0.756	0.762	0.755	0.781
EMAPA CAÑETE S.A.	0.957	0.893	0.987	1.000	0.830	1.000	0.763	0.798	0.891
EMSA PUNO S.A.	0.632	1.000	0.688	0.692	0.693	0.670	0.787	0.692	0.725
EPSSMU S.R.LTDA	1.000	1.000	1.000	1.000	0.818	0.826	0.896	0.958	1.000
AGUAS DE TUMBES	0.456	0.457	0.609	0.695	0.751	0.713	0.741	0.506	1.000
EMAPA PASCO S.A.		1.000			1.000	0.670		0.928	1.000
EMAPISCO S.A.		0.517	0.476	0.441	0.476	0.581	0.753	0.716	1.000
SEDACAJ S.A.	0.640	1.000	0.692	0.716	0.676	1.000	0.775	0.664	1.000
EPS TACNA S.A.	0.959	0.959	0.948	1.000	0.960	0.972	0.963	1.000	1.000
EMAPAVIGSSA	0.772	0.856	0.927	1.000	0.968	1.000	0.943	1.000	1.000
SEDACHIMBOTE S.A.	1.000	1.000	0.935	1.000	0.959	0.892	0.837	0.837	0.857
EPSASA	1.000	1.000	0.955	1.000	0.984	0.972	0.951	0.992	1.000
EMAPA SAN MARTIN S.A.	1.000	0.799	1.000	0.887	0.887	1.000	1.000	0.977	0.878
EMAPAT S.R.LTDA.	1.000	1.000	0.812	1.000	0.603	0.521	0.573	1.000	
SEMAPACH S.A.	0.484	0.500	0.614	0.508	0.554	0.811	0.898	1.000	1.000
EPS SELVA CENTRAL S.A.	1.000	0.825	1.000	0.944		1.000	1.000	1.000	
EMAPA MOYOBAMBA S.R.LTDA.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EMAPA HUANCAVELICA S.A.C	1.000	1.000	0.897	1.000	0.956	0.928	1.000	1.000	0.966
EPS MOQUEGUA S.R.LTDA.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EMAPA HUARAL S.A.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EMAPA HUACHO S.A.	0.545	0.611	0.654	0.670	0.736	0.742	0.810	1.000	1.000
EPS ILO S.R.LTDA.	0.587	0.642	0.670	0.586	0.669	0.686	1.000	1.000	1.000
SEDALIB S.A.	0.726	0.783	0.788	0.938		0.832	0.839	0.855	0.854
EPSEL S.A.	1.000	0.938	0.961	0.999	1.000	1.000	1.000	0.971	1.000
SEDAPAR S.A.	0.957	0.952	1.000		1.000	0.975	0.946		1.000
EPS - SEDACUSCO S.A.	0.920	1.000	1.000	0.919		1.000	0.978	0.906	1.000
EPS GRAU S.A.	1.000	0.791	0.825	0.844	1.000	0.981	0.957	1.000	1.000
EPS CHAVIN S.A.	0.954	0.938	0.896	0.923	0.935	1.000		1.000	1.000
EMAQ S.R.LTDA.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EMAPAB S.R.LTDA.	1.000	0.981	1.000	1.000	0.960	1.000	1.000	1.000	1.000
SEMAPA BARRANCA S.A.	0.962	0.954	1.000	1.000	1.000	0.990	0.707	0.709	0.770
EMAPICA S.A.					0.917	0.948	1.000	1.000	1.000
EMPSSAPAL S.A.	1.000	0.957	0.907	1.000	0.671	0.721	0.883	1.000	1.000
EPS SIERRA CENTRAL S.A.	1.000	0.994	1.000	1.000	0.954	0.947	0.996	1.000	1.000
NOR PUNO S.A.	1.000	1.000	1.000	0.966	1.000	1.000	1.000	1.000	1.000
SEDAJULIACA S.A.		0.864	0.973	1.000	1.000	1.000	0.907	1.000	0.944
EPS MANTARO S.A.	1.000		0.860	0.898	0.618	0.859	1.000	1.000	1.000
EMUSAP ABANCAY	1.000	0.973	1.000	0.841	0.873	0.885		0.993	1.000
EPS MARAÑON	1.000	1.000	1.000	1.000	1.000		1.000		0.675
SEDAM HUANCAYO S.A.C		1.000	1.000			1.000	1.000	1.000	1.000