NON-PARAMETRIC VALUE-ADDED OF TVET HIGHER EDUCATION INSTITUTIONS IN CHILE

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ABSTRACT
DEA (data envelopment analysis) was used to explore the efficiency of IP and CFT institutions that provide technical and vocational training in Chile. Several inputs and outputs were included: years of accreditation (quality certification), total assets of the IP/CFT, total student enrollment, percentage of former high school students coming from public schools, charter schools, and private schools, teachers´ years of education, total number of teachers, and the infrastructure in squared meters (m^2). Results indicate that 15 out of 27 CFT institutions (55%) and 12 out of 31 IP institutions (38,7%) are efficient. On the other hand, 12 CFT institutions out of 27 (45%) and 19 out of 31 IP are inefficient (61,3%). There is no correlation between the accreditation awarded by the CNA (National Accreditation Commission) and the efficiency measures obtained with DEA Analysis suggesting the need to establish a measurement of quality for TVET (technical and vocational) institutions in Chile.
Keywords: Technical education, Higher education, Educational Efficiency.

Introduction
Organizational effectiveness measures are common in the assessment of the impact of educational institutions around the world (Szuwarski, 2019). Such approach generally includes multiple factors or inputs and then assigns them different weights depending on their importance for organizational effectiveness (Charnes, Cooper & Rhodes, 1978). As an example, a study measured 6 conditions of productive change within schools: the institutions with a higher impact were those with vision, higher standards, focus on assessments, accountability, cooperative culture and collaboration (Gemberling, Smith, & Villani, 2000).

The core of value-added measures is getting to know the relative change in student´s skills depending on certain inputs such as teacher's contributions to individual student standardized scores (Douglas, 2011). Production functions such as the Cobb-Douglas parametric function is used to establish the added value of higher-education institutions (Dawson & Lingard, 1982). The latter relates a group of inputs with a series of outputs. The function calculates the returns to scale, which is the amount of output that will be obtained when a certain amount of inputs is used whenever inputs change proportionally (Ospina, 2017). This can represent the efficiency that institutions have regarding student learning and progress. The Cobb-Douglas function is defined by:

$$Q(L, K) = AL^{\beta} K^{\alpha} \quad \textit{Equation 1}$$

Equation 1 above indicates that a product (Q) is a function of a constant (A), an amount of labor (L) plus an amount of capital (K). Labor and Capital are raised to the power of the constant beta (β) and alfa (α), which range between 0 and 1. They represent elasticity per each of the variables (the percentage change in the outcome variable whenever Labor or Capital change) (Maddala & Miller, 1991). In educational research, "L" and "K", would be replaced by a set of institutional variables or inputs (number of teachers, infrastructure, total enrollment, etc.).

DEA (Data Envelopment Analysis) is a technique used to establish the non-parametric added value by institutions such as schools and universities. It differs from parametric techniques because it compares an institution to their peers and it does not use a fixed benchmark and neither includes measurement error because all error in DEA is considered just inefficiency (Worthington, 2001). The term envelopment stems from the fact that the production frontier envelops a set of observations (Alfonso & Santos, 2008). DEA can be described as follows:

Decision Making Units –the target of evaluation under DEA techniques – by performing the same type of functions and having identical goals and objectives, can be understood as, for instance, firms, government bodies, non-profit institutions or even countries. When a DMU attains the optimal level of output with a given amount of inputs, taking technology as a given, we say that this DMU is technically efficient, that is, it is operating at the production possibility frontier. In opposition, when it produces less than the output that could be attained with the current bundle of inputs, the DMU is said to be inefficient (Cunha & Rocha, 2012, p.8).

Education may not be fully modeled as a production function because many environmental and contextual variables have an impact in the process of teaching and learning of children and youth. For example, Astin (1991) proposes an Input-Environment-Output model in which outputs (such as degrees awarded, number of graduates, etc.) depend on inputs (for example, student ability, teaching quality, etc.) considering contexts (peers, faculty, programs). However, in the present study non-parametric added value of Technical and Vocational Education and Training institutions (TVET) is used. The aim is to account for gains in the number of graduates and retention within the first year of TVET education (outputs) by taking advantage of DEA analysis, a non-parametric value added technique. DEA has the capacity to capture the efficiency of these institutions and also serves the purpose to develop a ranking based on the efficiency index (Mizala, Romaguera, & Farren , 2002).

The goal of this paper is to provide an initial approach to the efficiency of TVET institutions in Chile. Chile is a Latin American country that has overcome economic and developmental challenges and now is part of the OECD countries (OECD, 2017). In few years, Chile has increased access to tertiary education, mainly due to TVET education (an equivalent to the American community college institutions) which reaches 44% of total enrollment in higher education (Arroyo & Pacheco, 2018). The TVET system is composed of IP (professional technical institutions) and CFT (Center for technical training/ community colleges) which completed a total enrollment of 503.772 students in 2018 (CNED, 2019). The IP awards a professional title after 4 years of technical training, while CFT award a diploma after 2,5 years. Universities can also award technical diplomas, but IP and CFT cannot provide the equivalent to a University diploma. Universities in Chile reached a total enrollment of 673.143 students in 2019.

As private education providers are increasing their offer to Chilean students, quality concerns in TVET education are raised. 70% of CFT institutions and 60% IP institutions are not quality accredited yet (see Arroyo y Pacheco, 2018). Measurements such as non-parametric value-added can help decision makers and governmental agencies to improve education for children and youth. In this article, a measure of effectiveness is presented by using non-parametric value added in TVET education. The analysis focuses on IP and CFT institutions with complete data for the 2017 academic year.

Literature review

Alabdulmenem (2017) studied 25 public universities and their value added to outcomes such as number of new entrants, number of enrollees, and number of graduates to these public institutions. Input variables included number of faculty and administrators. Only 15 institutions were operating with perfect efficiency. The most inefficient universities had suboptimal and less productive inputs. The first one had 1000 more administrators than the number that would make it perfectly efficient (2003 against 1907 administrators), the second institution had a perfectly efficient number of faculty and administrators (inputs) but produced less new associates enrollees. The study concludes that universities in an economic affluent country such as Arab Emirates may be sub-optimally efficient with the proper amount of inputs. Finally, the study underscores two properties of DEA, it compares equivalent DMUs (units such as universities or schools) relative to one another, and their comparison may involve several inputs and outputs, which makes non parametric measures proper to capture the efficiency of higher education institutions.

A similar study of efficiency, in Portugal, by Alfonso & Santos (2008) used DEA analysis in order to estimate a frontier to separate universities that might qualify as "performing well" from inefficient ones depending on educational spending. Inputs included the "University spending" and "number of teachers". Outputs included "undergraduate success rate" and "number of doctoral dissertations". The analysis concludes that in the 52 universities studied the average overall efficiency scores ranged from 0. 77 to 0.83. This means that performance was between 23 and 17 percent less efficient than it should be if it were located on the production possibility frontier.

In a study regarding school efficiency, Al-Enezi, Burney, Johnes & Al-Musallam (2010) evaluated the value added of public schools in Kuwait with DEA analysis. In this study, the output variables were the "number of students" and the "number of graduates". Inputs included the number of teachers, administrative staff and number of classrooms. The results indicate that efficiency could be improved if inputs decreased by improving managerial practices. In addition, returns to

scale for all schools are generally increasing, suggesting that schools could be more efficient by expanding their size. The average efficiency in Kuwait in a scale 0 (inefficient) to 1(efficient), is 0.621 for kindergarten, 0.801 for primary, 0,590 for middle school and 0,718 for high school.

Szuwarzynski (2019) assessed the performance of 37 public Australian universities based on data from year 2015. The study includes inputs such as the “number of publications and citations”, “number of completed doctoral degrees”, “amount of research grants”, and “percentage of science graduates·. The results provide a ranking in which the public universities score 0.50 to 1.80 in the efficiency index.

In Europe, Agasisti & Haelermans (2016) compared the efficiency of public universities finding that different incentives (funding based on outcomes or basal funding) may cause variations in performance. Output variables included: “total graduates” and “research grants”. The analysis included 71 universities from the Netherlands and Italy. Results show that the cost for performance (average percent efficiency) calculated in a trans-log production function is slightly higher for Netherlands (Mean= 0,555, SD =0.08) compared to Italy (Mean= 0,534, SD =0.10). The results confirm that Dutch universities spend less money than their counterparts in transforming a student into a graduate.

Finally, in Chile, Mizala, Romaguera, & Farren (2002) estimated the parametric value added of schools in a sample of 2000 schools using data of SIMCE tests of 4th grade students. Several inputs were included: i) student’s characteristics: including socioeconomic level, vulnerability index, ii) School characteristics: including the type of school, school size, pupil-teacher ratio, whether pre-k is provided, gender, iii) Teacher characteristics: average teacher experience. Average efficiency for these schools is 0.953, which is higher than schools in developed countries which generally exceeds 0.70. However, the authors estimated that 708 schools had below average achievement (low scores in standardized tests) and below average efficiency (calculated with DEA).

From the previous review of literature, it can be concluded that DEA analysis is generally used to account for efficiency in Universities and analysis are performed in one country at a time (except the cross country study of Agasisti & Haelermans, 2016). Analysis are also focused on institutions instead of curricular programs and TVET (technical and vocational) education has not been addressed by using efficiency analysis with DEA. The present study contributes to literature by providing an analysis of TVET institutions and their value added in the context of Chile.

Method

Participants

Chile has a total of 42 IP (professional) institutions and 49 CFT (Community colleges) registered. From these institutions, a sample of 27 IP and 31 CFT with complete information in all variables was used for the DEA analysis.

The sample necessary for DEA is expressed as three times the number of inputs times the number of outputs. The sample used in this study exceeds the desirable size to have enough discriminatory power (Spaho, 2015).

Data

Data was obtained from public records from the Ministry of Education of Chile. Data regarding input variables include the following:

Institutions with Autonomy: IP and CFT that have completed a license process that formally enable them to provide and open new undergraduate technical programs. The Ministry of Education grants the license.

Institutions Under Supervision: IP and CFT which were not granted full autonomy and cannot apply for accreditation (verification of quality of programs and institutions)

Institutions Under Licensing: New or recent IP and CFT which are open and allowed to offer approved programs of undergraduate training.

Years Accredited: Years of accreditation. The process of accreditation is voluntary and it is headed by the CNA (Commission of National Accreditation) after IP and CFT undergo a process of self-assessment and external assessment of quality. The more years of accreditation granted mean that IP and CFT are better qualified to train technical and vocational students.

Total Assets: Total resources invested by the IP or CFT institution.

Total Enrollment: Total number of students enrolled in an IP or CFT institution.

% of Public Schools student´s enrollment: Percentage of students enrolled in higher technical and vocational education who were former high school students in public schools.

% Private school student´s enrollment: Percentage of students who were former high school students in private schools.

Avg. Number of teachers with Bachelor degree: Average number of instructors with a Bachelor Degree at IP and CFT institutions.

Avg. Number of teachers with Masters: Average number of instructors with master´s degrees at IP and CFT institutions.

Infrastructure (m^2): squared meters built in infrastructure serving IP and CFT students.

Retention rate (first year): percentage of students who are retained after the first year of higher education studies.

Total Graduated students per cohort: Number of graduated students from IP and CFT per cohort (2017).

Procedure

DEA analysis (Data envelopment analysis), is a non-parametric linear programing method, that uses various inputs and outputs to account for production (outputs) (Emrouznejad & DeWitte, 2010). Linear programming refers to the use of different equations and inequations, as well as restrictions that help define an optimization problem (i.e., minimize cost to improve production) and provides an efficiency scores for each institution (DMU or Unit) represented in this study by the IP and CFT institutions. Main characteristics of DEA are that it is not dependent on a functional form (i.e., linear function), it helps to compare institutions to their peers (instead of a comparison to an ideal unit), and the researcher is able to assign different weights to different productive factors (inputs).

DEA calculates efficiency as defined in equation 1, where *u* and *v* represent the weights of the outputs and inputs:

$$efficiency = \frac{u1 * (output1) + u2 * (output2)}{v1 * (input\ 1) + v2 * (input\ 2)} \quad equation\ 2$$

In order to define the weights for inputs and outputs a linear programming problem is solved per each unit or DMU (Sarmha, 2018).

$$Maximize\ for\ DMU \quad = \frac{u1 * (output1) + u2 * (output2)}{v1 * (input\ 1) + v2 * (input\ 2)}, with\ the\ following\ constraints:$$

$$\frac{u1 * (output1) + u2 * (output2)}{v1 * (input\ 1) + v2 * (input\ 2)} \leq 1\ for\ the\ DMU1$$

$$\frac{u1 * (output1) + u2 * (output2)}{v1 * (input\ 1) + v2 * (input\ 2)} \leq 1\ for\ the\ DMU2$$

$$\frac{u1 * (output1) + u2 * (output2)}{v1 * (input\ 1) + v2 * (input\ 2)} \leq 1\ for\ the\ DMU3$$

$$u1, u2, v1, v2 \geq 0$$

In the present study DEA analysis is used to evaluate the comparative effectiveness of higher education TVET (technical and vocational training and education) institutions with their peer institutions. The analysis will inform if the use of resources (the number of students, the academic staff, the financial resources of the institutions, etc.) is according to the output produced by institutions (ranking of quality /accreditation, rate of employment, number of alumni per cohort). The analysis is based in a frontier of best practices of institutions against which the use of resources and outputs by other institutions are compared (Worthington, 2001). The method has been widely used in educational research due to its characteristics:

Part of the usefulness of DEA relies on the fact that, besides producing a ranking of sampled educational institutions based on efficiency measured by a technical efficiency score, it also identifies the over-use of specific resources that cause any given institution to fall where it does in the analysis, providing as well a custom list of peers for any given institution. These peer institutions are the ones to whom an administrator should look when trying to determine to what extent operational procedures might be copied – or at least learned from – in order to address the over-use of resources (Cunha & Rocha, 2012, p.3)

Another benefit of DEA is that it provides a single index number indicating the proportional reduction of inputs (or augmentation of outputs) necessary (or desirable) for an institution to reach the efficient frontier (Worthington, 2001, p. 251). However, “DEA can tell us how well we are doing compared to our peers but not compared to a “theoretical maximum” (Cunha & Rocha, 2012, p. 9) due to its non-parametric nature. In this context, CRS or “constant returns to scale” mean that DMU´s (IP and CFT institutions in the present study) are able to linearly scale the inputs and outputs without increasing or decreasing efficiency (Alfonso and Santos, 2008). Thus no matter the magnitude of the DMU (institution), it can transform their inputs to outputs (i.e., big as well as small institutions can do it).

The only downsize reported in the literature is that in DEA there are no parameter estimates for the function and hence no significance test is presented for the parameters calculated (Al-Enezi, Burney, Johnes & Al-Musallam, 2010). However, efficiency estimates in DEA can be correlated to other measurements of efficiency to test for validity (e.g., correlation between efficiency and quality accreditation as presented in this study). Also, it is important to consider the importance of inputs in relation to outputs to implement a reliable analysis (Emrouznejad & DeWitte, 2010)

Results

The analysis of non-parametric value added with DEA analysis encompasses a measure of efficiency of the institutions that does not depend on any functional form (e.g., linear function). The present analysis includes an initial approach to the non-parametric value added of IP and CFT institutions in Chile. Technical and Vocational Education has gained importance in Chile, a country in which higher education is available for free for low income students (up to the sixth level of income).

In the present study the first analysis encompasses a correlation of the variables included for the case of IP and CFT institutions. The second analysis, presented in Tables 2 and 3 introduces the DEA (Data envelopment analysis) or non-parametric value added for the technical and vocational institutions that currently enroll students in Chile. Table 2 includes the effectiveness of CFT institutions and Table 3 for IP institutions.

The approach is a naïve value added measure in which the effectiveness of institutions to achieve student´s on-time graduation and retention is tested. Variables include: years of quality accreditation, total assets of the IP/CFT, total student´s enrollment, percentage of former high school students coming from public schools, charter schools, and private schools, teachers´ education (percentage of teachers with a Master´s, University or Technical degree), total number of teachers, and the infrastructure in squared meters (m^2)

Descriptive analysis

Table 1, includes the descriptive statistics of the sample of CFT and IP institutions grouped by total enrollment. The first and second panel in table 1 represents the varying size of IP and CFT institutions. They include IP institutions with total enrollment under and above 3191 students (the median number of students for the full sample). The second panel includes two groups of CFT institutions with total enrollment under and above 861 students.

The smaller IP and CFT institutions are autonomous and they are accredited (recognized as quality institutions) for an average of years ranging from 0.15 to 1.5 years (maximum accreditation is 7 years). They vary in total assets, being the CFT not as economically affluent as the IP institutions. Total enrollment is also higher in small IP institutions but CFT are accepting more public high school graduates (44%) compared to IP (31%). Also, CFT institutions have less teachers with Bachelor (5.3 teachers in average) and Master`s degrees (0.8 teachers in average). The retention rate is above 50% for IP and CFT, but the graduation is low compared to total enrollment in both small IP and CFT institutions.

Table. 1
Groups of Chilean TVET institutions and total enrollment.

Inputs/Outputs	Small IP (Professional Institutions) Total Enrollment under 3191 students	Small CFT (Community Colleges) Total Enrollment under 861 students
Institutions with Autonomy	22 IP	12 CFT
Institutions Under Supervision	1 IP	3 CFT
Institutions Under Licensing	2 IP	4 CFT
Years Accredited	1.52 years	0.15 years
Total Assets	$3.171.878	$96.535
Total Enrollment	2840 students	277.8 students
% of Public Schools student	31%	44%
% Private school students	13%	8%
Avg. Number of teachers Bachelor	46.78	5.3
Avg. Number of teachers Masters	12.52	0.85
Infrastructure (m^2 built)	5277 m^2	2454 m^2
Retention rate (first year)	64%	58%
Total Graduated students per cohort	920	77
Inputs/Outputs	**Larger IP (Professional Institutions) Total Enrollment above 3191 students**	**Larger CFT (Community Colleges) Total Enrollment above 861 students**
Institutions with Autonomy	6 IP	19
Institutions Under Supervision	0 IP	0
Institutions Under Licensing	0 IP	0
Years Accredited	4.1 years	2.68 years
Total Assets	$57.775.302	$9.180.567
Total Enrollment	49478	6861
% of Public Schools student´s enrollment	40%	45%
% Private school student´s enrollment	2,9%	2%
Avg. Number of teachers with Bachelor	473	110.65
Avg. Number of teachers with Masters	101.94	24.4
Infrastructure (m^2 built)	161.329 m^2	8214 m^2
Retention rate (first year)	69%	64%
Total Graduated students per cohort	8960	1509.4

Larger IP and CFT have full autonomy granted by the Ministry of Education to provide undergraduate technical programs and they have an average of 2 to 4 years of quality accreditation. Total assets are higher for IP institutions compared to CFT. As in the small size group of institutions, IP are larger in total enrollment but CFT accept more public high school students. Also, IP have more resources (infrastructure, teachers with bachelor and master´s degrees) compared to CFT´s. The retention rate is around 60% and the total graduate students per cohort are 8960 in IP and 1509 in CFT which is a low rate compared to total enrollment.

Graphical Representation of outcomes

Figures 1 and 2 represent the relation between inputs and outputs used in the data envelopment analysis performed. A few IP institutions show higher total assets and higher graduation rates compared to CFT institutions which score lower in graduation rates but have a higher percentage of public school students (figure 1).

Figure 2 displays the retention of first year students in both IP and CFT institutions. A few IP institutions have more assets compared to the CFT institutions. CFT with larger assets also have more impact on the graduation rate of students. CFTs tend to have more students who come from public high schools. In summary, CFT show higher retention in the first year compared to IP, but IP tend to have more graduates and this can be related to institutional characteristics such as less enrollment of public highs school students and higher assets.

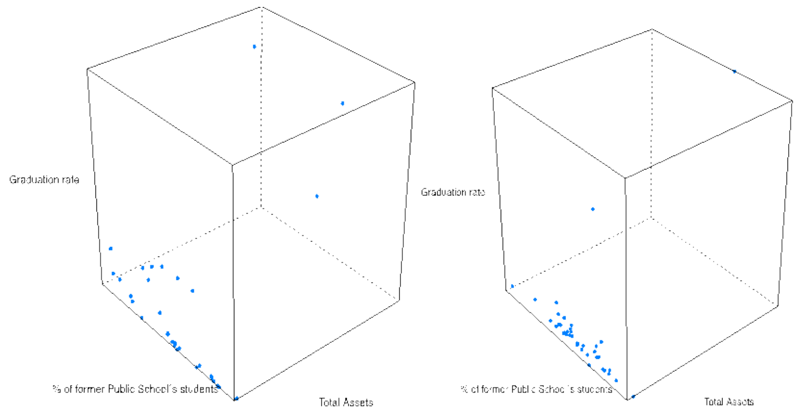

Figure 1. Graduation rate as an outcome of total assets and % of former Public school students enrolled. IP is represented on the left and CFT institution on the right cube.

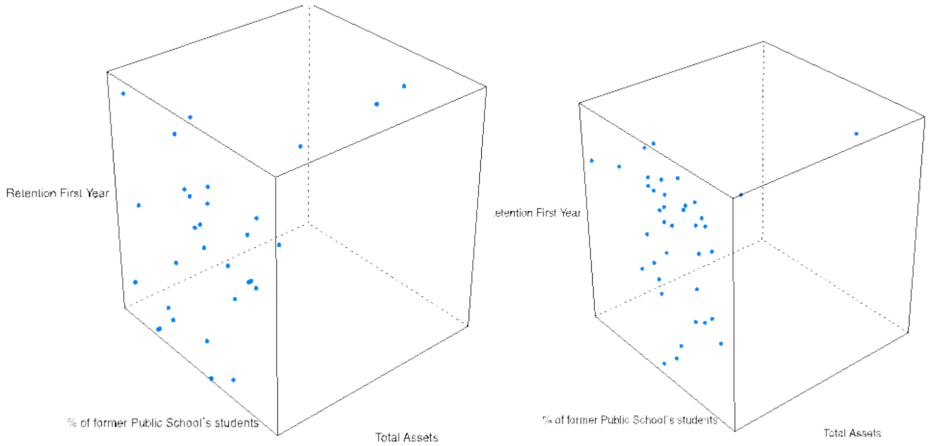

Figure 2. Retention per year as an outcome of total assets and % of former Public school students enrolled. IP is represented on the left and CFT institution on the right cube.

DEA Analysis.

The software R and the package “DEA” were used to calculate the efficiency of each IP and CFT institutions. The efficiency is presented in table 2 (for CFT institutions) and 3 (for IP institutions). Each institution was identified with a unique “ID “ number and the efficiency value (theta) is displayed in a scale from 0 (inefficient) to 1 (efficient).

The DEA (Data Envelopment Analysis) includes the units for which data was complete in the databases open to the public by the Ministry of Education. The first analysis shown in table 2, indicates that 15 out of 27 CFT institutions (55%) are efficient reaching a coefficient of 1. On the other hand, 12 institutions out of 27 could improve their efficiency (45%). Regarding IP, 12 out of 31 institutions are efficient (38,7%) and 19 out of 31 institutions are inefficient (61,3%). It is important to notice that the present study has used only two outcome variables that may not fully tap onto the definition of “quality”. However, it is a first approach to implement the non-parametric value- added measurement in TVET institutions in Chile.

The efficient CFTs in table 2 (panel 1) differ in the number of years accredited as high quality institutions (ranging from 0 to 7 years), they also vary in size (total enrollment of students ranging from 38 to 50423 students) and infrastructure (from 200 m^2 to more than 10.000 m^2) and they tend to have a higher proportion of public education enrollees (reaching up to 60% of students) and a short proportion of students coming from private high schools (up to 9%). For efficient CFT the average retention rate is 65% and the average graduation rate is 1695 students per cohort (with a range between 12 and 12000 students)

The efficient IP`s in table 3 (see panel 1) include institutions that vary in size (total enrollment varies from 88 students to 100.200 students). These institutions vary in the proportion of public high school students (from 4% to 57%) and they are staffed with more educated teachers compared to effective CFTs (where the number of master´s degree teachers range from 1 to 540). For effective IP, retention reaches in average 68% and graduation is around 3808 students (with a range between 12 and 22696 students).

Further steps in DEA analysis are finding out the excesses or the lack of resources that make an institution inefficient (panel 2 in tables 2 and 3). In order to estimate the causes of inefficiency the multipliers were calculated. They are the outcome of multiplying the lambda values (obtained per institution in the DEA analysis) times the value of each input. The lambdas are the values of input variables that restrict the constraints limiting the efficiency of each unit to be no greater than 1. When the multipliers are calculated for all IP and CFT, all outcomes are 0. This means that is not excess or lack of resources that impact efficiency, but efficiency could be increased with the current resources in IP and CFT institutions.

Table 2.
Efficiency in CFT Institutions (Efficient CFT displayed in panel 1, Inefficient CFT in panel 2) (n= 27 CFT)

ID	**534**	**241**	**782**	**285**	**236**	**312**	**701**	**390**	**374**	**280**	**498**	**536**	**367**	**260**	**430**
Efficiency	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***
Autonomy	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Accredited	N	N	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	Y
Years Accredited	0	0	0	0	0	0	3	0	0	0	2	3	5	3	7
Enrollment	38	39	50	52	60	844	879	903	1399	2951	2994	3088	5461	37972	50423
%Public	0,261	0,061	0,313	0,640	0,370	0,573	0,221	0,345	0,326	0,494	0,500	0,564	0,642	0,443	0,396
%Charter	0,739	0,091	0,479	0,360	0,556	0,374	0,622	0,558	0,586	0,481	0,404	0,428	0,341	0,498	0,495
%Private	0,000	0,848	0,000	0,000	0,037	0,004	0,097	0,028	0,023	0,004	0,013	0,006	0,002	0,017	0,034
Retention	0,480	0,813	0,735	0,496	0,704	0,725	0,651	0,525	0,459	0,678	0,569	0,796	0,766	0,680	0,702
Graduation	12	12	49	94	9	355	253	558	533	482	779	721	1016	7853	12624
Magister	0,545	0,000	0,727	0,000	0,000	9,527	0,568	1,659	0,455	12,500	10,114	4,409	0,523	80,446	322,481
Professional	0,932	1,818	2,182	0,477	0,545	25,94	12,864	23,318	10,639	66,023	51,795	20,705	66,22	658,255	843,351
Technical	0,523	0,000	0,545	0,386	0,818	0,143	2,114	3,523	1,241	0,364	7,591	0,659	1,545	75,714	135,794
total teachers	2,341	1,818	3,455	0,864	2,636	40,62	15,614	28,591	12,580	79,614	71,000	26,068	70,13	826,382	1379,100
m^2	220	1500	7765	1923	200	763,6	2511,6	8214	14616,56	16474	5689,8	14224	1735	204480	345966

ID	**427**	**492**	**273**	**591**	**691**	**305**	**319**	**229**	**398**	**382**	**261**	**307**
Inefficiency	***0.27***	***0.33***	***0.44***	***0.52***	***0.53***	***0.57***	***0.58***	***0.61***	***0.65***	***0.81***	***0.84***	***0.93***
Autonomy	Y	Y	N	Y	Y	Y	Y	N	N	Y	Y	N
Accredited	N	N	N	N	N	N	N	N	N	N	N	N
Years Accredited	0	0	0	0	0	0	0	0	0	0	0	0
Enrollment	600	223	451	73	169	77	333	74	554	157	533	130
%Public	0,598	0,442	0,537	0,250	0,543	0,529	0,944	0,411	0,527	0,223	0,572	0,174
%Charter	0,335	0,558	0,454	0,327	0,449	0,221	0,049	0,375	0,438	0,568	0,401	0,678
%Private	0,002	0,000	0,000	0,000	0,000	0,250	0,007	0,161	0,019	0,151	0,005	0,074
Retention	0,589	0,333	0,500	0,699	0,703	0,466	0,676	0,375	0,660	0,500	0,528	0,458
Graduation	28,000	44,000	84,000	9,000	17,000	35,000	80,000	5,000	158,000	19,000	279,000	9,000

Master`s	0,000	0,000	0,182	0,000	0,250	0,000	0,000	0,000	1,500	0,886	0,500	0,341
Professional	8,091	2,045	7,795	4,750	3,614	2,636	3,273	1,040	6,909	4,227	11,000	1,864
Technical	2,909	1,841	0,841	1,341	0,000	0,773	0,000	0,443	0,136	2,182	1,545	3,659
Total teachers	12,023	3,886	8,818	6,091	3,864	3,409	3,273	1,483	8,682	7,295	13,205	5,864
m^2	3424	5892	2120,59	5637	960	1825	877	454	1518	959	4438,88	913,58

Table .3
Efficiency in IP Institutions (Efficient IP displayed in panel 1, Inefficient IP in panel 2) (n=31 IP)

ID	714	767	99	676	126	176	139	155	152	117	143	111	137	101	108
Efficiency	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***1.0***	***0.90***	***0.88***	***0.81***
Autonomy	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Accredited	N	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	N	N	N
Years Accredited	0	0	5	0	2	0	3	0	3	0	5	7	0	0	0
Enrollment	88	152	586	764	3292	4809	8571	9568	11462	13105	95914	100219	676	371	324
%Public	0,108	0,104	0,333	0,044	0,446	0,612	0,505	0,332	0,576	0,526	0,439	0,275	0,138	0,428	0,191
%Charter	0,205	0,385	0,548	0,313	0,500	0,338	0,371	0,569	0,370	0,402	0,478	0,610	0,654	0,407	0,631
%Private	0,675	0,481	0,013	0,642	0,009	0,006	0,019	0,021	0,011	0,029	0,024	0,054	0,158	0,010	0,134
Retention	0,673	0,792	0,876	0,768	0,470	0,476	0,777	0,596	0,845	0,529	0,697	0,815	0,671	0,510	0,473
Graduation	12	14	58	128	4843	3517	2628	3452	1739	667	22696	17377	121	102	37
Master`s	3,273	1,500	2,386	8,159	13,614	8,795	91,295	27,106	14,932	126,477	70,250	540,864	7,477	0,614	4,409
Professional	10,864	4,705	11,500	21,068	62,295	110,628	108,614	132,084	149,614	221,250	1626,932	1410,477	14,955	5,636	5,614
Technical	1,227	0,000	0,795	14,023	2,750	2,434	9,523	4,505	21,795	4,318	226,318	181,455	0,682	0,455	0,000
teachers	18,864	6,409	15,159	44,568	78,841	122,648	213,182	163,696	200,568	356,364	1925,318	2165,636	23,795	6,705	10,023
m^2	945	845	4858,52	3725	46663	9491	27157,1	34744,59	8906	2182	146411	228227	1226	1201,850	1110

ID	**171**	**144**	**129**	**193**	**120**	**116**	**183**	**123**	**162**	**132**	**103**	**106**	**100**	**165**	**104**	**693**
Inefficiency	***0.30***	***0.35***	***0.41***	***0.42***	***0.42***	***0.44***	***0.44***	***0.49***	***0.49***	***0.50***	***0.56***	***0.57***	***0.60***	***0.63***	***0.68***	**0.77**
Autonomy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Accredited	N	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	Y	N	Y	N
Years	0	4	4	3	0	3	0	4	3	3	5	0	6	0	3	0
Enrollment	1182	3198	987	1022	2671	24132	1181	26134	1088	3191	4291	4532	37361	4799	1813	383
%Public	0,274	0,267	0,191	0,300	0,478	0,456	0,290	0,389	0,286	0,321	0,383	0,493	0,371	0,544	0,139	0,127
%Charter	0,583	0,593	0,516	0,562	0,436	0,480	0,585	0,539	0,607	0,566	0,531	0,445	0,514	0,402	0,720	0,479
%Private	0,027	0,099	0,283	0,106	0,018	0,021	0,079	0,009	0,017	0,018	0,014	0,020	0,042	0,007	0,026	0,380
Retention	0,437	0,758	0,619	0,710	0,445	0,681	0,673	0,720	0,504	0,696	0,736	0,435	0,753	0,657	0,751	0,678
Graduation	32	282	50	177	744	3659	260	3736	161	588	1159	911	5624	169	262	42,000
Master´s	7,082	7,659	2,778	2,886	3,500	77,411	1,364	20,881	2,352	17,273	17,341	15,932	205,825	34,341	14,727	2,409
Professional	42,468	51,818	48,733	13,318	52,818	423,610	11,114	254,267	13,318	62,614	62,750	29,795	523,619	114,477	20,773	8,091
Technical	4,339	5,409	3,261	2,818	6,682	21,834	2,477	43,295	3,466	0,114	5,136	0,114	76,437	1,682	0,000	0,068
Teachers	55,355	75,227	60,392	19,091	63,000	531,052	15,227	321,205	20,000	80,091	85,909	46,000	857,911	153,568	38,295	15,386
m^2	6017,61	8832,00	6118,0	3015,00	12553,4	189116	4623	64373	2420	5872	14519	5277	337666	16474	4188	1590

Correlation analysis.
The correlation between the effectiveness obtained with DEA analysis and the years of accreditation (a proxy variable of institutional quality) was $\gamma =$-0.123 for IP institutions and $\gamma =$0.0729 in the analysis for CFT institutions. This indicates that the accreditation of quality may not be a precise measure of the efficiency of institutions. In the case of IP institutions, the relationship is negative and small in magnitude. On the other hand, the relation is positive but close to 0 in the case of CFT institutions, meaning no strong relationship between the measurements exists.

Discussion
It is important to notice that the efficiency measure obtained in the present study relates to two outcomes (retention and graduation), excluding all others such as employability, satisfaction of students, relationship with other institutions or applied research. Other outcomes may provide a bigger picture of the quality of IP and CFT institutions.

DEA analysis has the advantage that efficiency is calculated regarding other institutions that are similar in inputs to obtain certain outcomes. Thus the non-parametric approach allows a more precise estimation of the value-added by an institution.

In the present study we did not have access to outcomes such as student grades or any other measure of achievement. However, the analysis was carried with retention of first year students and the graduation rate as outcomes. Although these measures may not be sufficient to account for the quality of institutions, they are a first approach to measure quality in the context of Chilean TVET institutions.

One of the shortcomings of the present study is the difficulty to provide a finer analysis including TVET curricular programs instead of institutions. However, the approach used enabled us to compare institutions with varying characteristics and the data on inputs and outputs is reliable and rich (it was obtained from the Ministry of Education in Chile).

The findings of the present study indicate that IP and CFT institutions have a retention rate above 50%, but the graduation is low compared to total enrollment in both small and large IP and CFT institutions. Also, CFT show higher retention in the first year compared to IP, but IP tend to have more graduates than CFT. Although there is varying composition in the student body and institutional resources, IP tend to be more affluent and enroll more students while CFT tend to have less resources and a larger share of public school students. This finding is interesting because despite public funding for higher education is now devoted to low income students (in the form of full scholarships) resources in TVET do not match those for Chilean CRUCH Universities (a selective group or "ivy league" universities) which are 6 times higher according to Arroyo & Pacheco (2018).

DEA analysis indicates that 15 out of 27 CFT institutions (or 55%), and 12 out of 31 IP institutions (or 38,7%) are efficient, whereas 12 CFT institutions out of 27 (45%) and 19 out of 31 IP are inefficient (61,3%). This is a large proportion of inefficient institutions. It is striking that the DEA analysis indicates that there is not a lack or excess of resources in inefficient institutions but a need to improve outcomes (graduation and retention) with the current inputs. The analysis shows that the number of graduated students does not match the total enrollment and retention in TVET institutions (slightly above 50%). The analysis also reveals that efficient CFT have an average retention rate of 65% and the average graduation rate is 1695 students per cohort. For efficient IPs, retention reaches in average 68% and student graduation is equal to 3808 students.

Finally, the correlation between the years of accreditation and the efficiency (theta) calculated in the present study (DEA Analysis) means no strong relationship between the measurements. This may mean that quality can be defined in different ways, however, non-parametric analysis such as DEA may help understand the inefficiencies in context. This because IP and CFT are compared to each other instead of being compared to a standard based on mean values or ideal values. Also, DEA permits to include several input variables to account for the efficiency of IP and CFT institutions.

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Syntax

```
# DEA
library(readr)
DAE_IP <- read_csv("~/Desktop/DAE IP.txt")
View(DAE_IP)

library(rDEA)
IP<-1:31
Y<-DAE.IP[IP,c("TituladosPregrado2017", "Retencionprimerano")]
X<-DAE.IP[IP,c("matriculatotal", "anosacredita", "Municipal","mconstruidos")]

di_naive = dea(XREF=X, YREF=Y, X=X[IP,], Y=Y[IP,], model="input", RTS="variable")
write_csv(di_naive, file = "deaIP")
```

```
CFT<-1:38
X<-DAE.CFT[CFT,c("matriculatotal", "anosacredita", "Municipal","mconstruidos")]
Y<-DAE.CFT[CFT,c("TituladosPregrado2017", "Retencionprimerano")]

di_naive1 = dea(XREF=X, YREF=Y, X=X[CFT,], Y=Y[CFT,], model="input", RTS="variable")

write.csv(di_naive1, file = "deaCFT")

#Generate new database with Multipliers (lambda values * variable values for inefficient IP/CFT)

CFTmultipliers<-merge(DAE.CFT,CFTconstant) ## Merges original database "DAE.CFT" with the output of "dea" analysis which we renamed as "CFT constant" to produce a dataframe in which lambda (multipliers) and theta opt (inefficiency) values are included

CFTmultipliers1<-as.data.frame(CFTmultipliers)
view(CFTmultipliers1)

CFTmultipliers1$M1<-CFTmultipliers1$lambda.1*CFTmultipliers1[,1]

View(CFTmultipliers1$M1)


#Graphics

## 3d plots of variables (x,y,z)

install.packages(car)
install.packages("car")
install.packages("lattice")
install.packages("scatterplot3d")
install.packages("rgl")
Library(lattice)

cloud(DAE.CFT$TituladosPregrado2017~ DAE.CFT$Patrimonio.total+ DAE.CFT$Municipal, xlab = "Total Assets", ylab = "% of former Public School´s students", zlab= "Graduation rate", main= "Non-parametric Added Value Chilean Colleges 2018", pch= 16,par.settings= par.set,Groups= DAE.CFT$ID,plot=TRUE, aspect= c(1,1),panel.aspect= 1)

 cloud(DAE.IP$Retencionprimerano~ DAE.IP$Patrimonio.total+ DAE.IP$Municipal, xlab = "Total Assets", ylab = "% of former Public School´s students", zlab= "Retention First Year", main= "Non-parametric Added Value Chilean Professional Institutes 2018", pch= 16,par.settings= par.set,Groups= DAE.IP$ID,plot=TRUE, aspect= c(1,1),panel.aspect= 1)
```

