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# Evaluation and determinants of preschool effectiveness in Chile\*

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## Abstract

*Early intervention in quality education is a way to equalize opportunities, a premise assumed by several countries that has increased interest in preschool education, which is now a relevant area of public policy. However, the performance of preschool education centers has received relatively scarce research attention. Consistent with the above, there are no studies quantifying the level of effectiveness with which these centers operate. This study examines the problem and aims to evaluate the performance of preschool education centers that serve children from lower socioeconomic families in Chile. For this, a centralized DEA Assurance Region model is proposed, which, in addition to avoiding the main criticisms received by the traditional Benefit of Doubt models, shows important differences in the results of efficacy and weights of the composite indicators. In addition, a second stage analysis is carried out using decision trees to identify variables that determine the composition of homogeneous preschool groups according to their effectiveness. The target population evaluated is kindergartens serving families with low socioeconomic status in urban and rural areas in Chile, and results reveal the importance of three structural factors: family income, kindergarten size, and location.*

**Key words and phrases:** assurance region, centralized data envelopment analysis, composite indicators, effectiveness, preschool.

**JEL Classifications:** C61, H52, I21.

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## 1. Introduction

There is a consensus in political and academic circles that Chile must advance in the provision and quality of preschool education in order to correct—at least partly—the problems of quality and equity in its education system and thereby contribute to reducing the country’s significant levels of inequity (Contreras and Puentes, 2017; Alarcón et al., 2015; OECD, 2015).<sup>1</sup> There are two reasons why education is a high priority. First, the nation’s human capital is considered an important explanatory component of wealth and growth rate discrepancies (Bank, 2011); and second, it is an essential component in ensuring equal conditions for all members of a society (Hanushek, 1998, 1986).

The specific case of childhood education is crucial to children’s lives because it is the stage in which the foundations of cognitive, linguistic and physical development are laid. Early life experiences can have a critical impact on an individual’s life course (Mutindi et al., 2016; McCartney et al., 2007). There is consensus in the academic literature that early intervention in quality education is a source of equal opportunities, among other advantages (Taguma et al., 2012). Its importance has been stressed in numerous studies, including recent relevant contributions such as, for instance, Heckman et al. (2013) and García et al. (2019), who focus on the benefits of early childhood programs (García et al., 2018, extend their analysis to include gender differences), or List et al. (2019), who evaluate early childhood effects on social preferences.<sup>2</sup> Due to the obvious benefits of early childhood education from a range of viewpoints, efforts should therefore be devoted to improving learning levels and enabling the whole population to access such education. This will undoubtedly affect not only countries’ wealth but also their levels of equity.

At the political level, various public policies related to the care and integral protection of children have been implemented in Chile over the last decade (Consejo Asesor Presidencial para la Calidad de la Educación, 2006). Similarly, Michelle Bachelet’s government program proposed reforms to preschool education that aimed to increase coverage, improve quality and modernize preschool education institutions, through the creation of the Subsecretary’s Office of Preschool Education in the Ministry of Education.

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<sup>1</sup>An illustration of these problems is reflected by the unrest in the country during October 2019. See, for instance, <https://www.theguardian.com/world/2019/oct/21/chile-braces-after-worst-unrest-in-three-decades-claims-11-lives>.

<sup>2</sup>In this regard, as García et al. (2019) point out, there is a large body of evidence documenting how early childhood programs can affect the skills of disadvantaged children (Almond and Currie, 2011; Duncan and Magnuson, 2013), as well as the long-term benefits in terms of completed education, adult health, labor income, and crime (Heckman et al., 2010; Havnes and Mogstad, 2011; Campbell et al., 2014).

The rationale provided above, based on solid evidence of low levels of quality in Chilean kindergartens, with no noticeable progress made among children living in urban areas, focused mainly on cognitive skills (Strasser et al., 2009; Sun et al., 2011), but also attempted to redress deficiencies in learning environments and materials, educational environments and socio-emotional development (Lien Foundation, 2012; CEDEP, 2011).

Regrettably, compared to the large body of microeconomic research carried out in Chile and around the world evaluating the internal efficiency of other educational institutions (Johnson and Ruggiero, 2014; Johnes, 2015; De Witte and López-Torres, 2019), performance of preschool education centers has received little academic attention, with a few exceptions (e.g., Moyer-Packenham et al., 2015). Consistent with the above, there is an absence of studies quantifying the level of effectiveness with which these centers operate, or the degree to which different educational contexts affect their performance.<sup>3</sup> In order to meet the challenge of developing higher quality and more effective preschool education systems, the magnitude of the challenge must be accurately quantified.

Our study considers these issues, with the specific aim of evaluating the performance of preschool education institutions in Chile catering for students of relatively lower socioeconomic status, from the perspective of their stakeholders: children, families and school staff. We will also analyze the way in which different educational contexts can affect performance. Specifically, we propose a composite effectiveness indicator based on the merger of three previous methodologies to evaluate performance. In particular, we use data envelopment analysis (DEA), but add the concepts of assurance region and centralized DEA to develop a methodological innovation that we refer to as *composite indicators with assurance region centralized data envelopment analysis*. After this first stage, in the second stage we use decision trees (Emrouznejad and Anouze, 2010; Breiman et al., 1984) to classify the determinants of the differences in effectiveness found, which only a few authors have used in the field of education (see, for instance, Masci et al., 2018).

Preschool education institutions make up the first of the three sequential levels in which the Chilean school system is organized: (i) preschool (kindergarten) education (up to 6 years); (ii) basic education (8 years, typically children aged 6 to 13 years old); and (iii) secondary education (4 years, typically children aged 14 to 17 years old). Preschool education is organized into six

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<sup>3</sup> For instance, our contribution to the literature differs from Moyer-Packenham et al.'s paper (2015), in that we consider a different context, methodology and focus—effectiveness instead of efficiency. Actually, their measurement of efficiency is not derived from a set of inputs and outputs but from a less involved—albeit more direct—measure, i.e., learning speed.

levels according to age. It is free for children over the age of two (lower average level). The second one at the second transition level (children between 5 and 6 years old) was also made compulsory in 2014, but its implementation is still underway.

Responsibility for early childhood education policies lies with the Ministry of Education (Ministerio de Educación), the National Board of Kindergartens (JUNJI, Junta Nacional de Jardines de Infancia) and the INTEGRA Foundation (Fundación INTEGRA).<sup>4</sup> Figures for the year 2015 show a total of 633,731 children enrolled in early childhood education centers, broken down as follows: 28% served by the JUNJI, 12% by the INTEGRA Foundation, 20% by municipalities, 33% by private subsidized centers, and 7% by private centers (Ministerio de Educación, 2005). Although the total number of students enrolled has increased significantly during the last few years, it is still below the OECD average, especially at earlier levels of education. Today, Chile has embarked on an ambitious plan of investment in infrastructure for early childhood education that will provide greater coverage at this level.

Efficiency and effectiveness are traditional indicators of organizational performance (Golany et al., 1993). According to Farrell (1957), efficiency refers to the ability of a decision making unit to produce the largest attainable output from a given set of inputs, or of using the lowest possible input to obtain a certain output. In turn, effectiveness is related only to the results of the process evaluated. As Achabal et al. (1984) point out, the effectiveness question is concerned with determining which strategy (process characteristics or structural factors) maximizes organizational goals. In both cases, evaluating the performance of educational organizations is a methodologically complex task that can be undertaken from different approaches (Frankel, 2008). From an academic perspective, particularly in operations research, parametric and non-parametric frontier models have gained considerable importance in recent years (Bădin et al., 2014; Emrouznejad and Yang, 2018). On the other hand, composite indicators have become popular and widely used metrics for assessing complex phenomena which cannot be evaluated with a single variable (Maricic et al., 2019). A significant number of these evaluations correspond to measures of effectiveness of organizations, countries or regions, which are usually transformed into rankings with high degrees of publicity (see, for instance Benito and Romera, 2011; Castillo-Giménez et al., 2019; Ciommi et al., 2017).

Because we are interested in evaluating the performance of a sample of kindergartens be-

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<sup>4</sup>The JUNJI is an autonomous public corporation funded by the state and supervised by the Ministry of Education, whereas the INTEGRA Foundation is a private non-profit foundation, also funded by the state. Both institutions deal with socioeconomically disadvantaged families—usually from the first two quintiles of the per capita income distribution. In addition to these institutions, preschool education is also provided by a series of other agents: municipalities, private kindergartens, and private subsidized kindergartens.

longing to the same organization (INTEGRA Foundation), which has centrally established resource endowment standards for all its kindergarteners (and, therefore, resource provision is not the responsibility of their directors), it might be appropriate to use an effectiveness measure as a performance indicator. To do this, we propose a composite indicator that combines three methodological developments from the two above mentioned approaches, namely, benefit of the doubt, assurance region and centralized DEA. Its application to this type of organization is innovative *per se* since, despite the proliferation of empirical studies in the field of education in recent years, to our knowledge this is the first to be carried out at the preschool level.<sup>5</sup> Finally, we aim to identify the determinants of performance differences in structural aspects that have received less scholarly attention, namely: (i) the kindergarten's human capital; (ii) organization of the service; and (iii) the kindergarten's environmental variables.

The results of the successive stages of refinement of the model reveal significant differences for the benefit of the doubt and assurance region models, but not between the assurance region and unique weights models (centralized DEA). For the unique weights model, the average efficiency index is 70.54%, with significant heterogeneities across regions. Likewise, the centralized (unique) weights obtained are 45% for learning, and 32% for user satisfaction and job satisfaction. A second stage analysis using decision trees reveals the importance of three structural factors that mark the effectiveness of kindergartens: (i) size or specialization of the kindergarten, measured as the number of levels it serves; (ii) family income; and (iii) urban or rural location.

The paper proceeds as follows. After this introduction, Section 2 presents the methodology and Section 3 describes the data. Section 4 then reports the results, and finally, Section 5 presents the conclusions of the study.

## 2. The proposed methodology: measuring education effectiveness

The literature reports numerous methodologies for creating composite indicators (CI) to measure effectiveness (Saltelli, 2007). CI add different subindicators into a single summary measure that gives an idea of the status of a system (Stumbriene et al., 2019). The Joint Research Centre-European Commission (2008) handbook covers most of the methods for constructing CI, being one of them the so-called benefit of the doubt model (BoD) (Melyn and Moesen, 1991; Cher-

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<sup>5</sup> In order to put our research in context with previous related research, the interested reader may refer to previous applications of centralized DEA on primary schools (Mar-Molinero et al., 2014) and BoD models applied to university teachers (Rogge, 2011).

chye et al., 2007b). BoD is based on the use of a data envelopment analysis model (Charnes et al., 1978) without inputs for obtaining endogenous weights (Wang, 2015; Karagiannis, 2017). BoD has been applied to construct CI in numerous fields in the literature. Some examples of applications are Gaaloul and Khalfallah (2014), Despotis (2005), Morais and Camanho (2011), Cherchye et al. (2007a,b), Bowen and Moesen (2011), Stumbriene et al. (2019), Cherchye et al. (2008), De Witte and Rogge (2011), Lauer et al. (2004), Verschelde and Rogge (2012), Guardiola and Picazo-Tadeo (2014), Peiró-Palomino and Picazo-Tadeo (2018) or Zanella et al. (2013).

From a technical point of view, BoD models optimize the weights for each organization such that performance is maximized. In other words, the methodology assigns high weights to well evaluated dimensions and low or zero weights in the opposite case. Let's be  $K$  observations (i.e., the total number of education institutions) from which  $M$  dimensions defined by the vector  $y$  we desire to evaluate. The DEA-benefit of the doubt" model (*DEA-BoD* (Thompson et al., 1986) for a given observation  $o$  is defined as<sup>6</sup> :

$$\begin{aligned} \left[ Z^{DEA-BoD}(y_o) \right] &= \max_{u_r} \sum_{r=1}^M u_r y_{ro} \\ \text{subject to } \sum_{r=1}^M u_r y_{rj} &\leq 1 \quad j = 1, \dots, K, \\ u_r &\geq 0. \end{aligned} \tag{1}$$

Regarding the weights to be assigned to the output variables, previous models are extremely flexible as the only restriction to be met in the optimum is that they must be non-negative. Unfortunately, in many cases this approach leads to undesired results, either organizationally or socially. Take, for example, our case, which has three dimensions (pupils' learning, parental satisfaction and job satisfaction); it would not be acceptable to classify as effective a center where both job and parents' satisfaction were very high but pupils' learning was very low; a more extreme case would be a "Toby club" kindergarten in which only job satisfaction was very high but families' satisfaction and pupils' learning were very low. If we followed this methodology, weights equal to zero would lead to high effectiveness levels.

Nevertheless, when there is additional information reflecting the different importance of the outputs, these value judgments can be introduced into the models by including additional constraints in the optimization model. The "assurance region" methodology (Stumbriene et al.,

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<sup>6</sup>Some additional developments of the *DEA-BoD* model can be found in Cherchye et al. (2007b), Rogge (2011) and ?. From another perspective, the *DEA-BoD* model has also been proposed as a rational way to determine composite indicators (Joint Research Centre-European Commission, 2008).

2019) offers a solution to this problem. Here, a restriction range is defined in which the weights of each outcome variable can be moved. A practical way to determine this range of feasibility of weights is through expert judgment, which is unlikely to coincide in the weights of each variable, thus creating a range of possibilities to use in the “assurance region”. This generates the family of assurance region DEA models (*AR-DEA*). The adaptation of the *DEA-BoD* to introduce value judgments by following the so-called assurance region of type I (i.e. controlling the relative value of the weights) gives rise to the *AR-DEA-BoD model* (Stumbriene et al., 2019) and can be estimated by solving the following optimization model:

$$\begin{aligned}
\left[ Z^{AR-DEA-BoD}(y_o) \right] &= \max_{u_r} \sum_{r=1}^M u_r y_{ro} \\
\text{subject to } \sum_{r=1}^M u_r y_{rj} &\leq 1 \quad j = 1, \dots, K, \\
L_r &\leq u_r / u_1 \leq U_r \quad r = 2, \dots, M, \\
u_r &\geq 0.
\end{aligned} \tag{2}$$

One criticism of previous proposals is that the weights are flexible and different for each DMU (Wang, 2015). Especially, if the study is not purely academic as in our case, the managers involved might want this definition of weights to be applied to everyone (all units). In fact, most of the managerial control literature reports the advantage of establishing a common set of weights for all the units, which should be coherent with the organization’s strategic goals. The usual solution to this problem is to use the average of the experts’ evaluations (see, for instance, Roll et al., 1991). However, this will not eliminate the discretion and lack of optimization of the system as a whole and, therefore, some agents will always be penalized.

To solve this problem, we adapt the method proposed by Mar-Molinero et al. (2014), who extended Lozano and Villa’s (2004) notion to provide, in the optimum scenario, a set of unique weights such that the efficiency of the system as a whole is maximized. Our proposal adds to the above the restriction that the unique weights must belong to the range previously defined by the experts. In this paper, therefore, we propose an innovation that we label assurance region centralized data envelopment analysis. In this way we ensure a method with more properties, which is the best for the system in that it eliminates arbitrary weights and unrealistic results.



This gives rise to the *AR-CDEA-BoD*:

$$\begin{aligned}
\left[ Z^{AR-CDEA-BoD}(y_o) \right] &= \max_{u_r} \sum_{j=1}^K \sum_{r=1}^M u_r y_{rj} \\
\text{subject to } \sum_{r=1}^M u_r y_{rj} &\leq 1 \quad j = 1, \dots, K, \\
L_r &\leq u_r / u_1 \leq U_r \quad r = 2, \dots, M, \\
u_r &\geq 0.
\end{aligned} \tag{3}$$

where  $L_r$  and  $U_r$  represent the lower and upper bound, respectively, of the  $u_r / u_1$  ratio. This helps to reflect any value judgments that we may wish to include in the assessment.

To conclude, it is worth pointing out that our proposal considers the specifics of the case study: all the centers are included in the same network; the operating conditions and the staff structures, are stable across centers; and, crucially in the educational context, the socio-economic level of families is similar. So, the degree of homogeneity in the sample is high, which helps to ensure more robust results because of the lack of extreme observations. When these conditions are not present, more complex estimation methods are required such as, for instance, decentralized DEA methods with specific outputs and inputs for each center (Mar-Molinero et al., 2014) and conditional models that restrict the comparison among centers to those having similar contextual factors (De Witte and Rogge, 2011).

### 3. Sample, variables and value judgments (weight constraints)

The data was obtained from a variety of databases provided by the INTEGRA Foundation. The definition of a “good” kindergarten, akin to the schooling system, is a multidimensional concept that depends not only on pupils’ learning but also on other outputs. Specifically, the definition of a “good” kindergarten is tied to the identity that defines the institution to which it belongs. For this reason, we based the study on the main interest groups and on the organizational mission reported by the institution (INTEGRA, 2018), identifying three key direct players:

- Children, specifically the learning they achieve.
- User families, specifically their satisfaction.
- Internal users, specifically the job satisfaction of kindergartens’ staff.

**From the children's perspective:** an average value-added measure of learning outcomes per kindergarten is used as the output. The learning data corresponds to the results of the standardized "Learning Appraisal Instrument" test (corresponding to the Spanish initials IEA, *Instrumento de Enseñanza y Aprendizaje*), which measures three dimensions of learning: (i) personal and social training; (ii) communication; and (iii) relationship with the natural and cultural environment. An examiner measures the level of compliance with the behaviors/learning expected for children of the same age in these three dimensions, on a scale of three levels. This test is applied on a census basis to all children in the Foundation kindergartens three times a year (at the beginning, mid-year, and end of the year). In this way, each child's progress can be evaluated with respect to the expected behaviors/learning. In our case, we used the measure of "average value added of kindergarten learning", which is obtained by subtracting the average score obtained by each child at the end of the year minus the score obtained at the beginning of the school year for those children who stayed at the same kindergarten; therefore, our sample includes only those children who are enrolled in the same kindergarten in both terms.

**From the user families' perspective:** our analysis is based on the results of the national study to measure satisfaction systematically carried out by the INTEGRA Foundation. This study measures various aspects of user satisfaction, including perceived quality of the kindergarten, continued use and recommendation by the families. This paper uses the Full Satisfaction Index, which corresponds to the percentage of user families with a high probability of being highly satisfied, and of continuing to use and to recommend the kindergarten. That is, the likelihood that in each kindergarten, families fulfill all of the following: (i) are highly satisfied; (ii) would recommend the kindergarten to relatives or acquaintances; and (iii) intend to continue sending their child to the same kindergarten.

**From the staff's perspective:** we use the job satisfaction scale from a national survey measuring climate and job satisfaction, conducted by the INTEGRA Foundation. This output is labeled "Job satisfaction in the kindergarten".

We report descriptive statistics for the effectiveness variables in Table 1. In addition, as mentioned earlier in the paper, we consider 18 variables associated with three dimensions to identify structural variables that determine the composition of homogeneous preschool groups according to their effectiveness. These three dimensions are (i) human capital, (ii) service organization, and (iii) environment. A description of these variables is reported in Table 2.

To define the model weight constraints, we relied on the judgments of nine experts, of whom five were researchers in preschool education, and the rest were members of the INTEGRA Foundation's management team. Each of these nine experts responded to the following questions: (i) which of the following three characteristics should be found in a kindergarten?; and (ii) if the three characteristics are included in the definition, how important (in percentage terms) should each one of them be? The three variables are those listed at the beginning of this section.

In Table 3 we report the data corresponding to the expert responses for the three variables. The last two rows in the table report the ratios corresponding to the weights ( $u_2/u_3$  and  $u_1/u_3$ ), which enter the proposed model. The last two columns (and two rows) of the table report the minimum and maximum of the weights' ratios. The sample consisted of 712 kindergartens, of which 586 were urban and 126 were located in rural areas.

## 4. Results

### 4.1. Effectiveness

The models described in Section 2 were applied to evaluate levels of effectiveness in the kindergartens. Prior to the calculations, the original variables were standardized based on the maximum value of 100. In this way, the interpretation of the weights is not conditional on the unit of measurement for each variable, and can be directly assimilated to the importance that each model assigns to each dimension of the composite indicator of effectiveness.

#### 4.1.1. *DEA-Benefit of the Doubt (DEA-BoD)*

First, the effectiveness of each kindergarten was calculated using Model (1), that is, the conventional "benefit of the doubt" DEA model (?), which considers just three outputs without imposing any restrictions on the weights assigned to each output variable. These weights are endogenously and freely determined by the model. Table 4 shows the average results obtained in this first estimation by region and rural or urban location type.

The average effectiveness levels obtained by kindergartens located in rural areas were somewhat higher than in urban areas (87.08% vs. 83.91%), with an average of 84.47%. The average weights assigned by the model to each of the dimensions in the calculation of the effectiveness composite index (those that most benefit each kindergarten) was 0.07 for the value-added dimension (V1), 0.32 for the family satisfaction dimension (V2), and 0.62 for the job satisfac-

tion dimension (V3). The weights assigned to the first dimension hardly differed according to whether the environment was rural or urban. However, in the case of family satisfaction (V2), the model assigned a lower weight in rural kindergartens (0.29 vs. 0.33) while the opposite occurred for the job satisfaction dimension (0.64 vs. 0.61). The results suggest that there is a higher level of demand in the groups of families and workers in urban areas, and that the greater weight assigned by the model to these dimensions contributed to their outperforming rural areas. The regions with the most effective kindergartens were Aysen (90.90%) and Valparaíso (87.49%). In contrast, the regions of Atacama and Región Metropolitana had the lowest levels of effectiveness, both with 77%.

Interestingly, one variable that *a priori* would seem important in the construction of a kindergarten effectiveness index, namely, the measure of the children's progress (added value), is precisely the one that the model deemed less important. This is because when dealing with a dimension like this with a worse performance in relative terms, the model assigns it a significantly lower importance due to the assumption of freedom of weights. On the other hand, job satisfaction had a greater weight than the rest, showing that in general workers' satisfaction was the most successful dimension in the management of the kindergartens. Undoubtedly, the flexibility of the DEA weights is an advantage, but in turn it can become a weakness if we obtain unrealistic weights that may even completely ignore some of the dimensions. In fact, the minimum values of the weights are zero in all cases, which means that a value of zero was assigned to some of them for the effectiveness index of some kindergartens as a consequence of bad behavior. Therefore, it is interesting to introduce experts' and/or stakeholders' value judgments by restricting the possible values associated with the weights of each dimension. Proceeding in this way allows a certain flexibility in determining the DEA weights while simultaneously adapting to the possible strategies of each evaluated unit.

#### 4.1.2. Results from the Assurance Region model (AR-DEA-BoD)

After consulting nine experts (four professionals from the central administration of INTEGRA Foundation and five academics from the education area),<sup>7</sup> the range in which the weights quotients should be located was determined (known in the literature as the assurance region). Specifically, the weight assigned to family satisfaction with respect to the weight of the added

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<sup>7</sup>Specifically, they were four professionals with more than 10 years of experience in the institution, who are members of the managerial team (*Dirección Ejecutiva* and *Dirección de Planificación y Gestión de la Fundación Integra*), and five academics specialized in educational policies and pre-school education, with vast experience in research in the area of education.

value should range between 0.4 and 0.7, while the weight of job satisfaction with respect to the weight assigned to added value should range between 0.2 and 0.7. Considering these restrictions and after solving model (2), the new results are shown in Table 5. The first consequence of considering the experts' criteria is the change in the average weights assigned by the DEA to each of the dimensions, which indicates that the restrictions introduced were certainly effective from a mathematical point of view. The added value dimension is now allocated the highest weight (0.48), followed by job satisfaction (0.38) and family satisfaction (0.29). Consequently, the absolute freedom of weights in the DEA can lead to unrealistic results, because they are not aligned with what the experts really consider desirable. Hence the importance of introducing some control over them, although without losing the flexibility offered by the DEA to adapt to the different strategies of the units analyzed. In this case, the discrepancies in the importance the experts assigned to each criterion means that different weights can be assigned to each dimension for each kindergarten in order to better adapt to their own strategies and results, but within the limits that the experts considered plausible and recommendable. With this new set of weights, the average level of effectiveness decreased to 71.03%, with no significant differences between rural and urban kindergartens. Similarly, the difference in the weights assigned to the different dimensions between the two areas was also very similar, giving greater consistency to the results obtained. By regions, Araucania, Los Ríos and Valparaíso were the most highly rated, while the lowest rated were Coquimbo, Región Metropolitana and Atacama, confirming the potential for improvement of these two last regions, regardless of the model applied.

#### **4.1.3. Results from the DEA “benefit of the doubt” with assurance region and unique weights (AR-CDEA-BoD)**

Despite the advantages of evaluating each unit with a personalized set of weights, in practice researchers often prefer to calculate composite indices using the same set of weights for all the units in order to facilitate interpretation. The proposed methodology of the DEA “benefit of the doubt” with assurance region also allows us to calculate a unique set of weights. As discussed in section 2, the centralized DEA offers an excellent alternative to determine the set of unique weights that maximizes the overall average efficiency of the system being analyzed, the set of kindergartens in this case. To do this, we simply have to introduce a new fictitious kindergarten representing the average kindergarten in the system. After calculating model (3), the weights assigned to the new unit were 0.45, 0.32 and 0.32, respectively, with an average effectiveness level for the system of 70.54%. These weights do not differ greatly from the average weights

calculated previously, but they have a very interesting property inherent to the centralized DEA model: the average of the effectiveness index calculated with these weights for the entire sample coincides with the level of effectiveness of the fictitious average unit of the system. This allows us to determine how each kindergarten contributes to the overall effectiveness of the system.

Table 6 shows the results obtained after calculating the effectiveness index for each kindergarten using the unique set of single weights of the centralized DEA. As expected due to the reduced flexibility in the determination of weights, the average effectiveness decreased again, falling to 70.54%. As before, there were no large differences between the rural and urban environments (69.14% vs. 70.84%). However, the kindergarten with the worst performance was below 40%, confirming the considerable general potential for improvement. Once more, the regions of Auracanía and Los Ríos were those with the best performance, and Coquimbo, Atacama and the Metropolitan Region emerged as those with the greatest potential for improvement. The fact that the Metropolitan Region repeatedly appears among the worst performing regions seems to indicate that proximity to a developed, competitive environment such as the country's capital coincides with more demanding families and workers, who rate their satisfaction with kindergarten performance more negatively.

#### **4.2. Evaluating the determinants of education effectiveness via decision trees**

The vast majority of studies analyzing the determinants of effectiveness in preschool education focus mainly on factors associated with instructional practices, teacher personality and motivation, leadership and family involvement. On this question, Ma et al. (2016) found that the role of parents (family involvement) is more important than the role of schools and communities. Park et al. (2019) showed that teachers' instructional actions make the greatest difference to students' learning outcomes, although it is not entirely clear which of these actions matter most. In contrast, effective leadership does influence the quality of early childhood education (Hujala et al., 2013). However, the studies examining the relationship between the structural characteristics of kindergartens and their effectiveness are fewer, and report mixed evidence. Within these structural aspects there are three major dimensions: human capital, service organization and environment.

The most commonly studied human capital variables are teachers' educational qualifications and work experience, although results are mixed (Slot et al., 2018). For example, Kuger et al. (2016) and Slot et al. (2017) found a positive relationship between teachers' work experi-

ence and process quality; in contrast, Connor et al. (2005) and Wilcox-Herzog (2004) revealed a negative relationship, and Justice et al. (2008) found neither of these associations. Similarly, findings on teachers' educational qualifications are also inconclusive. Cave and Mulloy (2010) emphasized the importance of continuing professional development for preschool teachers in effective early childhood development and education implementation. However, Lin and Magnuson's (2018) results from hierarchical linear models indicated that teachers' education does not predict children's early academic skills. On the question of hours spent in preschool education, for a demographically comparable group of children Leow and Wen (2017) found no significant differences between children who attended the Head Start half-day program, and those enrolled on the more intensive full-day program in any of the five academic and social outcome measures examined. We are unaware of any studies that associate characteristics of staff age or type of contract with effectiveness in preschool education.

A similar picture emerges for service organization. Several studies showed that lower child-to-teacher ratios and smaller group sizes were related to higher overall process quality (Barros and Aguiar, 2010; Mashburn, 2008; Phillips et al., 2000). However, other studies found no such associations (Pessanha et al., 2007; Slot et al., 2015).

The only conclusive results are found in environmental characteristics. Sheridan et al. (2014) concluded that rural children experienced greater difficulties with parent-reported externalizing behaviors. Li et al. (2019) obtained similar results; their findings are used to argue that high quality preschool education serving rural children should be prioritized to narrow the achievement gap between rural and urban children. On the question of different ethnicities in the classroom, most research has shown that process quality is lower in classes with higher proportions of ethnic minority children; Kuger et al. (2016) and Slot et al. (2015) analyzed this question in Germany, for instance.

In sum, despite the limited evidence, there is initial support for the indirect relationship of structural teacher and classroom characteristics with children's outcomes through process quality, and strong evidence of environmental characteristics as factors of successful preschool education. Therefore, after measuring efficiency and effectiveness in the first stage, we conducted a second stage analysis to evaluate their determinants. Several methodologies are available for this process, some of which have been reviewed by Léopold Simar and Paul Wilson in a series of papers (Simar and Wilson, 2007, 2011) and, more recently, by Bădin et al. (2014). Other contributions have reviewed the specific literature dealing with two-stage approaches in contexts such as local government (Narbón-Perpiñá and De Witte, 2018; Aiello and Bonanno,

2018a), or banking (Aiello and Bonanno, 2016, 2018b).

One of the main factors motivating these studies, particularly those by Simar and Wilson (2007, 2011) and Bădin et al. (2014), is related to the problems derived from combining linear programming problems in the first stage of the analysis with parametric methods such as logistic regression or OLS in the second one—given that the scores obtained in the first stage are dependent in the statistical sense. Some proposals attempting to avoid these problems have been developed by Simar and Wilson (2007) and Banker and Natarajan (2008), among others.

In this case we considered a different non-parametric option, namely, a decision tree mathematical model. The decision tree algorithm helps to classify a sample according to binary (the so-called classification trees) or continuous variables (the so-called decision trees). The decision tree is one of the best known data mining algorithms and serves to create knowledge by analyzing the characteristics of the sample under study. As they mimic human thinking, they are easy to understand, which helps interpretation of the results. In non-parametric efficiency evaluation, decision tree methods have been used in Sohn and Moon (2004), Wu (2009) and Emrouznejad and Anouze (2010).

The main objective in this section is to identify the structural variables of kindergartens that determine the composition of homogeneous preschool groups according to their effectiveness. In our case, the dependent variable to be explained in the decision tree algorithm corresponds to the effectiveness indicator of model (3) (i.e., model  $AR - CDEA - BoD$ ). In this model we used the AID (automatic interaction detection) algorithm since it allows the dependent variable to be continuous (Breiman et al., 1984). In turn, the independent variables used in the second stage correspond to structural variables of the kindergarten, which we grouped into the three dimensions indicated above: human capital, service organization and environment variables, not previously considered as inputs, which are described in Table 2.

As shown in Figure 1, kindergartens can be grouped into four segments (nodes 2, 4, 5 and 6) according to their level of effectiveness. From this segmentation we can conclude that the first determining factor in the observed differences in effectiveness corresponds to the number of levels (variable of service organization), and that accounts for the size of the kindergarten. According to this result, kindergartens with more than six levels (large) obtained a lower effectiveness indicator, which on average for this segment corresponded to 65.42%, lower than the average of the total sample (70.50%). This conclusion supports the thesis in the literature on effectiveness in preschool education that size matters, in this case, the size of the kindergarten. This segment represents 10.3% of the total kindergartens in the sample.



From this first classification, node 1 (those with six or fewer education levels) was divided among kindergartens serving populations of children from families with a monthly income of less than and greater than CH\$335,402 (approximately US\$500) (environmental variable). In contrast to findings in the literature, the kindergartens with lower average family incomes were more effective than those serving higher income families. This may be due to two factors. First, the mission of the Institution that oversees these kindergartens is to work with low-income families; as a result, they are specialized in working with low-income populations and are therefore more effective in caring for them. Second, the effectiveness index includes an indicator of family satisfaction, which reflects the higher demands from families with higher incomes who give lower scores to the kindergartens their children attend. Based on the above, we found a second segment with a lower degree of efficiency corresponding to small kindergartens (with six or fewer levels) with an above-average socioeconomic level served by the INTEGRA Foundation and comprising 17.7% of all the kindergartens.

Similarly, from node 3 (representing 72.1% of kindergartens), which has an average efficiency level higher than the national average and serves lower income families, we extracted the last two segments, according to whether the kindergarten was in a rural or an urban location (environmental variable). One better performing segment, with an average efficiency of 72.53%, corresponded to small kindergartens located in urban areas serving low-income families, and accounted for 57.2% of kindergartens in the sample. A second poorly performing segment representing 14.9% of the sample corresponded to small kindergartens, serving low-income families, but located in rural areas. This result is also in line with the literature and highlights the need for greater attention to kindergartens in rural areas.

## **5. Conclusions and discussion**

The importance of early childhood education has been extensively documented from several perspectives and in various knowledge fields, including—apart from education—psychology, economics and less closely related areas such as law (in general) and criminology (in particular), medicine or biology. This area of research has produced some important contributions published in leading general science journals (e.g., Campbell et al., 2014).

In the field of economics, important recent contributions are those by Havnes and Mogstad (2011), Duncan and Magnuson (2013), Heckman et al. (2013), García et al. (2019) and Rosales-Rueda and Triyana (2019), among others. However, some particular issues within this field

remain unexplored. Specifically, whereas a substantial body of the education literature has evaluated either the efficiency or effectiveness with which educational centers operate in primary, secondary or higher education levels, there are no similar initiatives for early childhood education, a gap that can be found regardless of the context examined.

This article aimed to bridge that gap. The study contributes on two broad levels: methodological and empirical. From a methodological point of view, it follows the line of work proposing a composite indicator using data envelopment analysis (DEA), but adds the concepts of assurance region and centralized DEA to develop a methodological innovation that we call composite indicators with assurance region centralized data envelopment analysis. This methodological proposal addresses and overcomes the main criticisms of composite indicators relating to: (i) the normalization of data; (ii) the subjectivity and arbitrariness of weights; (iii) the existence of weights equal to zero; and (iv) the distance of the solution to a desired theoretical framework. It is particularly interesting to note that when the units to be evaluated belong to the same organization, there is a higher interest in maximizing the efficiency of the system, or simply finding a set of weights that fit within a social or corporate ideal, and that shows the best facet of each organizational unit in this pre-established framework. Other advantages of the proposed model are its simplicity and the ease with which it is accepted by the agents or organizations under evaluation.

The article contributes empirically by evaluating the effectiveness of kindergartens, a level of schooling that has not been commonly considered in this type of study, unlike schools and universities, and that represents a very high social and economic value for any society. For this purpose, we used a sample of 712 preschool establishments belonging to the same institution in Chile. Additionally, unlike the vast majority of previous studies in the educational area, we considered not only the results of academic achievement as antecedents for the conceptualization of a good educational establishment, but also the perceptions of the user families and the workers.

The analysis showed, in successive stages, the refinement of the model, and allows the comparison of results. A first “benefit of the doubt” model found an average efficiency of 84.47%, with approximately 3% difference between rural and urban kindergartens. In the same way, and as we predicted when proposing this new methodology, the weights of the three dimensions were very significantly different from any criterion of acceptable suitability—with average values of 7% for pupils’ learning, 33% for user family satisfaction, and 61% for job satisfaction. Likewise, a large amount of weights equal to zero was obtained, which also moves

away from any social or organizational ideal.

A second assurance region model incorporated restrictions from a panel of experts setting limits for these weights according to professional and academic criteria. The results of this model showed a significant fall in the efficiency of the system to 71.03% but provided weights of the different dimensions according to a desired or normative framework. In this way, the weights of each dimension changed significantly, with an average weight of 48% for pupils' learning, 29% for user satisfaction and 32% for job satisfaction. Despite this, the results suffer from not being unique weights, which is why a certain degree of unsought arbitrariness persists.

The third model incorporated the additional restriction of looking for a set of unique weights with which to evaluate all units, but restricted to maximizing the effectiveness of the system as a whole. In this case, the efficiency index decreased slightly to 70.54%, with significant heterogeneities between regions of the country. Likewise, the centralized (unique) weights obtained were 45% for learning, and 32% for user satisfaction and job satisfaction.

A second stage analysis using hierarchical classification established the existence of four types or segments of kindergartens according to their effectiveness (centralized model). A first point to emphasize is that this classification reveals the importance of three structural factors that mark the effectiveness of kindergartens: (i) size of the kindergarten, measured as the number of levels it serves; (ii) family income; and (iii) urban or rural location of preschool education establishments.

From this segmentation, we should be particularly concerned with the largest kindergartens, and prioritize the implementation of preschool programs (kindergartens) with fewer levels, in order to facilitate better management. Secondly, the differences among kindergartens with children from families of both higher and lower socioeconomic levels also calls for further analysis; this would enable the implementation of differentiated pedagogical and managerial practices beyond their specialization in very low income levels. Finally, it would also be useful to focus on rural kindergartens, in order to bridge the gap between the performance of urban and rural centers.

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**Table 1:** Variables for the effectiveness model, descriptive statistics

Stakeholder	Variable	Indicator	Mean	Std.dev.	Min.	25% percentile	Median	75% percentile
Pupils Families Staff	Pupils' learning	Learning value added	51.17	14.74	11.46	41.07	49.62	60.53
	Family satisfaction	Full satisfaction index	69.49	17.96	4.70	58.29	69.74	83.40
	Job satisfaction	Job satisfaction index	78.92	13.92	2.03	71.87	80.54	88.65

**Table 2:** Determinants of effectiveness, descriptive statistics

Variable	Variable description	Categories	Average	Min.	25% per-centile	Median	75% per-centile	Max.	Total
<i>Manager_age</i>	Managers' age (average)		41.5	26.0	35.0	41.0	47.0	69.0	
<i>Teachers_age</i>	Teacher' age (average)	34.1	24.0	30.0	33.0	37.0	60.0		
<i>Technical_staff_age</i>	Technical staff's age (average)		38.1	23.0	34.0	38.0	42.0	51.0	
<i>TP_dir</i>	Head with university degree	0 = NO 1 = YES							153.0 548.0
<i>%_TP_educ</i>	% of teachers with university degree		80.5	0.0	60.0	100.0	100.0	100.0	
<i>%_CF_educ</i>	% of teachers with a permanent contract		78.2	0.0	50.0	100.0	100.0	100.0	
<i>%_JC_educ</i>	% of full time teachers		95.1	50.0	100.0	100.0	100.0	100.0	
<i>%_CF_tecn</i>	% of technical staff with a permanent contract		97.5	0.0	100.0	100.0	100.0	100.0	
<i>%_JC_tecn</i>	% of full time technical staff		82.3	40.0	60.0	100.0	100.0	100.0	
<i>Tipo_JI</i>	Type of kindergarten	Kindergarten and crèche Kindergarten only Crèche only							486.0 212.0 14.0
<i>Extra_timetable</i>	Kindergarten with extra timetable	0= NO 1= YES	0.0						177.0 535.0
<i>Start_year</i>	Year when kindergarten started		1991	1970	1983	1991	1998	2010	
<i>#levels</i>	# of kindergarten levels		1.0	2.0	3.0	5.0	12.0		
<i>N_educ_100n</i>	# of teachers as a percentage of pupils	3.7	0.3	0.0	0.0	0.0	0.0	4.0	
<i>N_tecn_100n</i>	# of technical staff as a percentage of pupils		12.4	4.0	8.0	10.0	18.0	25.0	
<i>N_serv_100n</i>	# of administration (service) staff as a percentage of pupils		3.5	2.0	2.0	4.0	4.0	5.0	
<i>Decile_revenues Urb_rural</i>	National family decile income Kindergarten location	Rural Urban	2.5	1.0	2.0	2.0	3.0	4.0	126.0 586.0
<i>%_malnutrition_risk</i>	Percentage of children at risk of malnutrition		1.9	0.0	0.0	0.0	2.0	18.0	

**Table 3:** Experts' constraints, scores and descriptive statistics

Variable	Expert									Min.	Max.	Average
	1	2	3	4	5	6	7	8	9			
Pupils' learning	50	45	40	35	45	50	60	50	33.3	33.3	60	45.4
Families' satisfaction	30	20	30	35	35	30	30	25	33.3	20	35	29.8
Job satisfaction	20	35	30	30	20	20	10	25	33.3	10	35	24.8
$u2/u1$	0.6	0.4	0.6	0.7	0.7	0.6	0.6	0.5	0.67	0.4	0.7	0.6
$u3/u1$	0.4	0.7	0.6	0.6	0.4	0.4	0.2	0.5	0.67	0.2	0.7	0.5

To define the model weights' constraints, we used judgments from nine experts, of whom five were researchers in preschool education, and the rest were members of the INTEGRA Foundation's management team. Each of these nine experts responded to the following questions: (i) "which of the following three characteristics should be found in a kindergarten?"; and (ii) "if the three characteristics are included in the definition, how important (in percentage terms) should each one of them be?". The three variables were human capital, service organization and environment.

**Table 4:** Effectiveness results. Model DEA “benefit of the doubt”

Region	Effectiveness (%)				Weights added value ( $V_1$ )			Weights family satisfaction ( $V_2$ )			Weights staff satisfaction ( $V_3$ )		
	Rural	Urban	Average	Rural	Urban	Average	Rural	Urban	Average	Rural	Urban	Average	Rural
Antofagasta	82.04	82.58	82.49	0.00	0.05	0.04	0.50	0.38	0.40	0.50	0.58	0.57	0.57
Araucanía	81.22	86.05	85.62	0.24	0.11	0.12	0.05	0.34	0.32	0.73	0.57	0.59	0.59
Arica y Parinacota	78.82	86.64	85.66	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
Atacama	83.50	77.24	77.86	0.00	0.09	0.08	0.50	0.65	0.64	0.50	0.27	0.29	0.29
Aysén	93.68	88.12	90.90	0.00	0.03	0.01	0.00	0.49	0.24	1.00	0.51	0.75	0.75
Bio-Bio	90.31	85.67	86.48	0.18	0.13	0.14	0.23	0.24	0.24	0.61	0.65	0.65	0.65
Coquimbo	90.08	81.99	83.96	0.01	0.03	0.03	0.26	0.28	0.28	0.74	0.69	0.70	0.70
O'Higgins	86.14	85.15	85.45	0.02	0.11	0.08	0.39	0.39	0.39	0.60	0.52	0.54	0.54
Los Lagos	85.05	87.00	86.60	0.06	0.03	0.04	0.12	0.36	0.31	0.84	0.62	0.67	0.67
Los Ríos	—	86.48	86.48	—	0.09	0.09	—	0.32	0.32	—	0.60	0.60	0.60
Magallanes y Antártica	—	86.63	86.63	—	0.00	0.00	—	0.28	0.28	—	0.72	0.72	0.72
Maule	88.84	84.79	86.25	0.01	0.06	0.04	0.44	0.35	0.38	0.56	0.60	0.59	0.59
Región Metropolitana	76.24	78.07	77.94	0.01	0.06	0.05	0.58	0.35	0.37	0.42	0.61	0.59	0.59
Tarapaca	83.12	86.08	85.24	0.38	0.06	0.16	0.04	0.09	0.08	0.60	0.85	0.78	0.78
Valparaíso	90.86	86.65	87.49	0.11	0.04	0.06	0.29	0.35	0.34	0.62	0.62	0.62	0.62
Average	87.08	83.91	84.47	0.08	0.07	0.07	0.29	0.33	0.32	0.64	0.61	0.62	0.62
Std. Dev.	12.01	10.03	10.47	0.21	0.20	0.20	0.41	0.41	0.41	0.44	0.43	0.43	0.43
Max	100.00	100.00	100.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Min	49.25	52.07	49.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: the authors’.

**Table 5:** Effectiveness results. Model DEA “benefit of the doubt” with assurance region

Region	Effectiveness (%)			Weights added value ( $V_1$ )			Weights family satisfaction ( $V_2$ )			Weights staff satisfaction ( $V_3$ )		
	Rural	Urban	Mean	Rural	Urban	Mean	Rural	Urban	Mean	Rural	Urban	Mean
Antofagasta	61.06	67.43	66.27	0.48	0.47	0.48	0.26	0.31	0.30	0.34	0.31	0.31
Araucanía	72.90	76.65	76.32	0.50	0.48	0.48	0.28	0.30	0.30	0.31	0.31	0.31
Arica y Parinacota	67.34	67.47	67.45	0.51	0.49	0.49	0.21	0.25	0.25	0.36	0.34	0.34
Atacama	56.49	66.42	65.43	0.53	0.48	0.48	0.30	0.32	0.31	0.24	0.30	0.29
Aysen	65.04	78.56	71.80	0.48	0.47	0.48	0.26	0.30	0.28	0.34	0.32	0.33
Bio-Bio	74.28	73.86	73.94	0.50	0.48	0.49	0.29	0.29	0.29	0.31	0.32	0.31
Coquimbo	63.82	63.91	63.89	0.48	0.47	0.48	0.27	0.31	0.30	0.34	0.30	0.31
O'Higgins	74.76	71.31	72.35	0.48	0.48	0.48	0.28	0.29	0.29	0.33	0.32	0.32
Los Lagos	65.63	73.68	72.02	0.49	0.47	0.48	0.26	0.30	0.29	0.34	0.32	0.32
Los Ríos	—	74.62	74.62	—	0.48	0.48	—	0.30	0.30	—	0.31	0.31
Magallanes y Antártica	—	69.44	69.44	—	0.46	0.46	—	0.31	0.31	—	0.32	0.32
Maule	72.59	72.39	72.46	0.48	0.47	0.47	0.29	0.30	0.30	0.31	0.32	0.32
Región Metropolitana	64.18	65.24	65.17	0.48	0.48	0.48	0.32	0.29	0.29	0.29	0.32	0.32
Tarapaca	58.79	70.44	67.12	0.54	0.48	0.49	0.25	0.29	0.28	0.29	0.33	0.32
Valparaíso	76.42	73.95	74.44	0.48	0.47	0.47	0.29	0.30	0.30	0.31	0.31	0.31
Mean	70.10	71.23	71.03	0.49	0.48	0.48	0.28	0.30	0.29	0.32	0.32	0.32
Std. Dev.	12.02	9.67	10.13	0.04	0.04	0.04	0.06	0.05	0.05	0.06	0.04	0.04
Max	100.00	100.00	100.00	0.67	0.67	0.67	0.39	0.39	0.39	0.36	0.36	0.36
Min	41.48	40.57	40.57	0.45	0.45	0.45	0.21	0.21	0.21	0.11	0.11	0.11

Source: the authors’.



**Table 6:** Effectiveness results. Model DEA “benefit of the doubt” with assurance region and unique weights (centralized DEA)

Region	Effectiveness (%)		
	Rural	Urban	Average
Antofagasta	59.66	67.24	65.87
Araucania	72.36	76.27	75.93
Arica y Parinacota	66.11	66.55	66.49
Atacama	53.08	66.06	64.76
Aysen	63.92	78.47	71.19
Bio-Bio	73.37	73.34	73.35
Coquimbo	63.41	63.42	63.41
O’Higgins	74.39	70.83	71.90
Los Lagos	64.39	73.38	71.52
Los Ríos	—	74.38	74.38
Magallanes y Antártica	—	69.39	69.39
Maule	71.66	72.05	71.91
Región Metropolitana	63.84	64.83	64.76
Tarapaca	56.46	69.78	65.97
Valparaíso	75.04	73.65	73.93
Average	69.14	70.84	70.54
Std. Dev.	12.66	9.74	10.33
Max.	100.00	99.73	100.00
Min.	39.56	40.57	39.56

Source: the authors’.

**Table 7:** Centralized weights. Model DEA “benefit of the doubt” with assurance region and unique weights (centralized DEA)

Dimension	Rural	Urban	Average
Pupils’ learning	0.45	0.45	0.45
Families’ satisfaction	0.32	0.32	0.32
Job satisfaction	0.32	0.33	0.32
Source: the authors’.			

**Figure 1: Results for decision trees**

