Incubator efficiency vs survival of start-ups

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Abstract

Purpose – The purpose of this paper is to contribute to the knowledge on the efficiency of the incubators in Mexico, from a double-managerial approach (incubator and start-ups) measuring the efficiency oriented to the survival growth in the employment.

Design/methodology/approach – The efficiency of 25 business incubators of a university in a Mexico was analyzed from 2012 to 2014. Through the envelope data analysis (DEA) technique, composed of five inputs and three outputs, which help to determine the decision-making units (DMUs) that are in the best practice border, being able to know the factors relevant and how they have been managed in the different incubators.

Findings – One of the three years observed was identified as the most efficient, with 13 start-ups at the most efficient border. The projection shows some entries that must be modified to maximize the creation of new incubated business with a focus on survival and growth. The authors propose the resources that must be modified to adopt efficient management practices for incubators and start-ups small size.

Research limitations/implications – This analysis recognizes the size and restriction of resources as a determinant in the efficiency of intermediate technology business incubators. However, an obvious limitation is the non-standardized sample of 25 incubators does not allow generalizing the results.

Practical implications – The special support received by start-ups linked to a university with strong financial and non-financial support.

Originality/value – Dual management (incubator and incubated start-ups) approach to efficiency analysis and the use of the DEA for the incubation topic and to fill a gap persists in the understanding of creation of new business in intermediate technology.

Keywords DEA, Start-ups, Spin-off, Survival, Incubators, Intermediate technology

Paper type Research paper

To the university institute that facilitated access to data on entrepreneurial initiatives in intermediate technology for the development of this research work.

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1. Introduction

The establishment and development of micro, small and medium enterprises (MSMEs) strongly contribute to the economy through promoting economic and social development of a region, consequently helping promoting society to better distribute its resources and wealth. In addition, those created in incubators generate jobs, favouring stability in the labour markets. Unfortunately, for each 100 small businesses created, 90 do not survive more than two years of operations (Cabello, Conde, & Reyes); therefore, the generated employment does not contribute enough to create economic wealth either. Some MSMEs have activities on intermediate technology sector, and as would Bobsin, Petrini and Pozzebon (2019) postulate, the business incubators as non-profit organizations lack theoretical and empirical investigations on management in general and specifically on technology management (Hackett & Dits, 2004a). The incubators are some type of organization designed to accelerate growth and ensure the success of entrepreneurial projects through a wide ride range or resources and business services, usually based in an educational institution. That is the reason of this approaching the creation of start-ups.

The importance of this research can be approached from three interrelated perspectives: operational, governmental, or public policy, and academic. From an operational or business outlook, business incubators are considered as a great support for entrepreneurs, as they offer them an adequate ecosystem for the of new companies, helping them both to recognize new business opportunities and to provide support in the three basic functions of entrepreneurship: innovation and technological development; financial risk; and administrative management of the business, to guarantee its sustainability (Allen & Rahman, 1985; Fernández-Fernández, Blanco Jiménez, & Cuadrado Roura, 2015; Lukeš, Longo, & Zouhar, 2019).

In addition, business incubators not only provide support for the creation of new businesses but are also considered key organizations for their growth and development (Cooper, 1985; Lukeš et al., 2019). Under this assumption, it highlights the importance of measuring efficiency in the generation of successful companies.

On a government or public policy perspective, business incubators have become a key tool to promote entrepreneurship and the creation of new businesses, as they are considered a key factor for job creation, economic growth and strengthening of the business fabric. Likewise, it has recently been shown that incubators the generation of start-ups and the development of innovation (Reynolds, 2000; Lukeš et al., 2019).

Authors such as Cabello et al. (2007) and Ortega-Cachón (2012) affirm that thanks to business incubators, both recently created companies and those that have more time in the market, survive and are sustainable. Additionally, they generate tax revenues to the public sector and contribute to GDP and to the generation of wealth in a country. In this sense, as Reynolds (1991) affirms, there is no doubt that government policy can influence the generation of opportunities for entrepreneurial behaviour. These opportunities are usually offered through support institutions such as business incubators with the purpose of promoting entrepreneurship and promoting business activity, stimulating the emergence of new business projects.

The academic standpoint observed a lack literature on university business incubators on efficiency model operation and their effects on the most employments and spin-offs – generally and specifically the case of Mexico. Likewise, the reviewed literature on business incubators applying the envelope data analysis (DEA) methodology is scarce and mainly focussed on Asian countries, whose focus on the efficiency analysis of the factors that lead to success both incubators and start-up or spin-off business is scarcely explored from a dual perspective (incubator and newly created company). That is, on the one hand, the management of resources by the incubator is important, as, on the other, it is relevant to create companies that can survive in competitive markets and grow in the number of employees, a basic indicator of economic growth of a society.

Finally, talking about economic aspects of a country leads to the identification of different factors that affect its development and growth. A determining link in the progress of a society is the MSMEs, and those at countries such as Mexico represent the great majority. That is why many government organizations seek to support the creation of MSMEs through business incubators that allow greater certainty in its creation, operation, performance and growth. Hence, the importance of studying the management of these incubators for the creation of new businesses whose economic contribution is reflected in the creation of employment as a result of the permanence in the market and its operational efficiency.

Concretely, MSMEs in Mexico represent 99.8% of economic units, and their jobs contribution is 71% (Salgado & Pérez, 2010). Despite having greater flexibility to adapt to changes in the environment and undertake innovative projects, most of them disappear. Escalera (2007) reports that 90% of micro and small business do not survive more than two years in the Mexican market (Cruz, 2013). Then, if the phenomenon of creating successful companies is alludes to the nominations of North (1994, pp. 362–363). Take into consideration beliefs as transformative of institutions and in turn of social and economic structures. At that point, business incubators represent an important support to lower the failure rates of their incubated start-ups or spin-offs – technology-based companies created from research covered in an incubator – and promote their long-term permanence in the market. Valera (2011) states that business incubation has become a support process that accelerates the successful development of new business, providing entrepreneurs with training for optimal management through a precise set of resources and services.

From the above said, there is a need to analyze successful business incubators, which are created with assistance of government and educational agencies to support and accelerate the development and success of their incubated businesses (Sofouli and Vonortas, 2007; Scillitoe and Chakrabarti, 2010). Its role is fundamental in the development of new companies in regional and national economies. In fact, the incubation studies, there have been few empirical contributions that examine the incubator variables associated to the success the incubation (Hackett & Dilts, 2004b), so this work aims to contribute to the field of business creation from the process of business incubation point. The objective is to analyze their efficiency levels of the new technology companies (spin-offs) using the DEA technique measured by incubator resource management and the performance of a new companies created through the generation of jobs. This study has as research objective is analyzing their levels of efficiency using the DEA technique, contrasting the management of their resources that lead their start-ups created to survive as a basis to generate jobs.

2. Review of the Literature

Business incubators provide support, especially to MSMEs at the intermediate technology sector, which need to have certain resources and capabilities to support the generation of competitive advantages, being scarce and valuable, are critical for achieving the objectives of new companies in order to survive in competitive markets, generating employment and ensure enough sales levels.

The evaluation of incubators favoured qualitative analysis with strong theoretical support; however, efficiency has been gaining strength from the quantitative perspective, taking weight away from the theoretical explanation. The works of Wang and Wang (2012) or Zhang and Yin (2010a, 2010b) represent this trend in the context of incubation. Therefore, the theory of resources and capabilities focuses its attention on the analysis of the assets that organizations own and control, as well as on their differences, and on the importance 37 of this fact to explain the evolution of the results (Barney, 1991).

Based on this approach, the organization is considered as a unique set of resources and capacities; further, from an economic approach, Reynoso (2005) highlights that the success of the organization dependent both on the performance and management tasks and internal coordination and efficiency with which the company competes. Therefore, the theory of resources and capabilities explain.

2.1 Efficiency of business incubators

The measurement of the transformation processes company assimilated to a company by a business incubator should be measured by its efficiency, considering that government funding to technology-based companies' creation in Mexico. As of 2001, the systematic financing of the government is suspended, then the units of creation of technological companies create conditions for graduated companies to be inserted, to keep growing in the national or international market (Pérez & Márquez, 2006).

Design decisions of institutions or business units include efficient performance strategies, whose measurements are evaluated ex post in this investigation (Herrera-Restrepo, & Triantis, 2018). The purpose is to inform business incubators of the changes they could make to improve their efficiency, and this approach has received less attention in the academy.

Some researchers affirm about an efficiency measurement system improve the performance organization (Hannis, Sorooshiah, Bin, & Duvvuru, 2016), in this case, the Mexican incubators. According to Neely, Gregory, and Platts (2005), the measurement of efficiency can be defined as the quantification of a process; therefore, the term efficiency has often been confused with productivity (Achabal, Heineke, & Mcintyre, 1984; Siegel, 1980). In any case, and according to (Klasseny, Rusell, & Chrisman, 1998), the term efficiency is always used in a context that encompasses the comparison of an organization against a standard or the comparison with different organizations in the same sector.

Therefore, the how researchers use various methods to establish an evaluation system that can be divided into subjective and objective weighting. However, objective-weighting assessment methods are better seen to carry out efficiency studies, of which, the DEA is a tool that has had a greater boom in the measurement of performance. In incubators, the study by Yin and Zhang (2010a) applied it to 45 business incubators in China, and with the results of his study, he proposed to adjust the production of 33 incubators.

2.2 Data envelopment analysis

The basic idea of using the DEA is to identify the efficiency frontier and determine the best practices according to the good management of the resources, so that the incubators lead to the success of their incubated companies. This technique (DEA) compares the values of the input and output variables of the inefficient unit with the values of the efficient units that serve as reference, which allows knowing the intensity of the variables and projects that action should be taken for those inefficient units will allow resources to be better managed to maximize their production, in this case, the successful new business for their survival and job creation. Charmes, Cooper, and Rhodes (1978) highlight the importance of the unit analysis, which are called decision-making units (DMU).

2.2.1 Output variables. Business incubators have attracted the interest of many researchers who have assumed that the use of support mechanisms for the formation of new companies can have positive repercussions, by the number of companies created, their rate of growth in employment and their survival rate (Gallani, Kajiwara, & Krishnan, 2015). In this analysis framework, this study focusses on the survival of MSMEs owing to the fundamental the economies of the countries and their effect on employment, as well as the growth of a society (Massa, Farneti, & Scappini, 2015; Gherhes, Williams, Vorley, & Vasconcelos, 2016; Padachi, Lukea Bhiwajee, & Lukea Bhiwajee, 2016; Valaei, & Rezaei, 2017).

Pertinently, Gallani, Kajiwara, and Krishnan (2015) comment that this measure should be prospective instead of all measures; therefore, they claim that survival may determine some factor success of the new company, by staying in competitive markets.

Mubaraki, & Busler (2013) saw it the most finance focusing within the economy, the prosperity seen as its accumulation since the creation, development and maturity of the entrepreneurial initiative and networking, among others. However, although it is recommended to use the number of graduates as an incubator success factor, many researchers question the financial success and the degree of impact on the economic development of these graduated companies (Kilcrease, 2011), this propitiate the focus of the present study to obtain a robust model of efficiency of the incubator as a driver for consolidated firms to survive.

Likewise, the success factors of incubators (Hackett, & Dilts, 2004a; Schwartz, 2011) point out the importance as one of the measures of efficiency, the degree of growth of the graduated companies have been considered as an indicator of growth for the rate of employment. According to the United States Agency for International Development (USAID, 2001), the standard measure used in studies of new MSMEs is the change in the number of workers since the beginning of their operations. Liedholm and Donald (1999) consider that the creation of employment is the most important social factor for the development of a community. Following Liedholm and Donald (1999) and Goedhuys (2002) to measure the growth in employment of a new company, you can use the standard growth rate = (Employment year 2)/(Employment year 1) considering full-time workers.

2.2.2 Input variables. There has been a limited amount of research focused on the resources of the incubation process which have been identified as a valuable tangible and intangible factor associated with its success (Lee & Osteryoung, 2004, Scillitoe & Chakrabarti, 2010). The managerial distinction that Phan, Siegel and Wright (2005) and Cooper and Park (2008) made of the types of resources of an incubator were: human, physical, financial and technological, which provide the support for the creation and success of both incubators, as well as their incubated companies. These will be the input indicators taken for this analysis.

However, there is literature that highlights some of the input indicators described above, so it is necessary to analyze it in greater depth; this is access to funding sources is one of the critical factors for performance and the survival of MSMEs (Olawale & Garwe, 2010; Ramukumba, 2014). In this regard, the Global Entrepreneurship Monitor (GEM) (Garza, 2014) contemplates it as the great enhancer or inhibitor of business activity owing to its critical importance. An outstanding fact that demonstrates the restriction to the creation and business growth establishes that of every 100 companies in Mexico, only 16 have had access to financing (INEGI, 2015). For this reason, two input indicators have been determined in the efficiency analysis:

(1) the total amount of funds obtained by the new company; and

(2) the number of financial institutions that are linked to the incubator and that provide resources to the incubated.

In summary, the analysis framework-oriented survival, linking the growth in employment and number of graduates, which ones will be the exit indicators to determine the success as measure of efficiency. The input factors for the analysis of efficiency factors are physical, human, financial, technological and access to financing such as indicators of exit, employment, survival and graduates.

3. Method

The DEA technique is an alternative to the ratios and regression models, as it is possible to work with multiple input and output variables, which allows analysing the success factors of the incubators. It does not even require that the variables of the model meet special or similar characteristics. It is also an application of linear programming methods used to measure the relative efficiency of organizational units that present the same goals and objectives. This technique has been chosen for the efficiency analysis of business incubators in Mexico owing to its applications as a possible tool for obtaining synthetic indices from partial indicators (Charmes et al., 1978, pp. 429–444). The authors affirm that DEA is a mathematical programming technique that allows to obtain relative efficiency indexes comparing each DMU requires resources (inputs) to produce goods or services (outputs) and that is a very appropriate method to evaluate the efficiency in entities such as universities. The DEA analysis technique does not require direction in the hypotheses, its methodology is inputs and outputs. It is a data-driven, non-parametric, non-stochastic methodology that evaluates the DMUs' conversion of inputs into outputs, using a linear programming technique and that will allow the evaluation of the relative efficiency of a set of homogeneous production units.

Each unit's relative efficiency estimated is calculated by comparing its production function with the production frontiers. In this way, each DMU's performance compared directly with the best performance of each pair or combination of pairs. This model does not require a function to relate inputs and outputs and frees him/her from having to select just one measure of efficiency (Sanjuan et al., 2011). Moreover, the inputs and outputs can have different units. This model accounts for returns to scale, that is, the relationship between increases in production (output) and increases in the factors of production (input).

Furthermore, the model can be either input- or output-oriented. Whereas with an input-oriented model the linear programming model configured to determine when an incubator could reduce input, if used efficiently, to obtain the same level of output, an output-oriented model calculates the potential improvement in output given the existing level of input (Banker et al., 1999). The main advantage of this technique is its flexibility, as it does not require that all the analysis units give the same importance to the same partial indicator. Both Yin and Zhang (2010a) and Wang and Wang (2012) estimated the technical efficiency of incubators using the DEA technique with interesting and useful.

The procedure to validate the DEA followed the sequence:

(1) A–Y is coded to each of the 25 DMUs;

(2) the universities are grouped by size (number of students): 1 – large, 2 – medium, 3 – small and 4 – micro;

(3) the descriptive statistics are estimated;

(4) the model is validated to ensure its viability according to the sample size;

(5) they execute a multi-collinearity analysis and their levels of significance to establish the robustness of the model;

(6) the DEA analysis is performed to identify the efficiency index (GTE, PTE and EE) in years 2012, 2013 and 2014; and

(7) a benchmarking analysis is performed to compare the inefficiency and efficiency index by means of a global sensitivity analysis (Charmes et al., 1978).

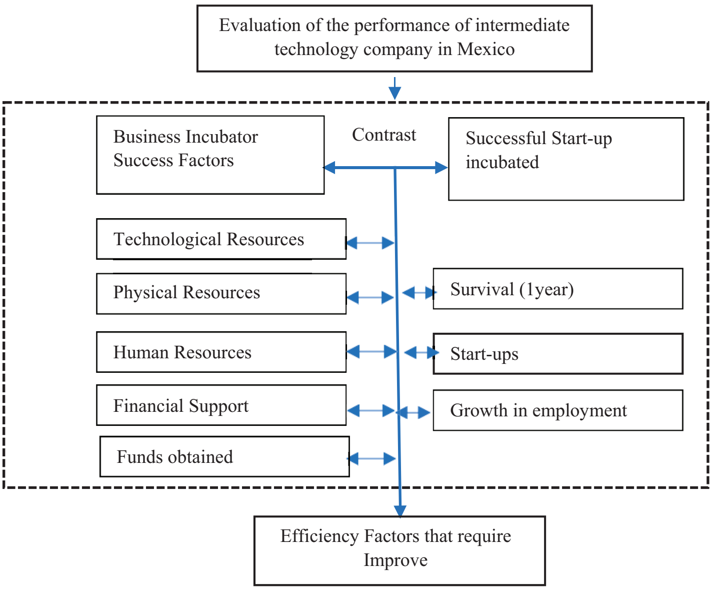
Particularly, to confirm the efficiency in 2013, we examine:

- the dispersion of DMUs at the efficiency frontiers;

- a radar analysis is performed to analyze the individual behaviours of DMUs and define groups by their efficiency;
- the efficiency level evaluated for the four types of incubators (G, M, P and M) from 2012 to 2014;
- a cluster analysis is carried out for the types of incubator in the year of highest efficiency (2013) in each of the efficiency models ET, EP and EE; and
- finally, the projection of the optimal management of incubator resources are estimated from the management perspective.

3.1 Sample

The evaluation of the efficiency status of 25 Mexican university business incubators in the period 2012–2014 is described through the proposed model (Figure 1) applying the DEA. Each of the 25 incubators represents a single DMU. The activities are the same in each incubator, the services are homogeneous; the size is established according to the city and state where they are located, and then, the intensity and complex work, being in five micro-level, nine small, six medium and five largest. The information was obtained from the web of Mexican university selected for this study by the maximum representation, and at the same time, some incomplete of confuses dates were validated by telephone with the incubators, with the incubators, which allowed to complete database.



Note: The hypothetical model describes the inputs and outputs to contrast through the DEA technique

Figure 1. Model of contrast of the efficiency of the Mexican incubators of intermediate technology

The incubator is the analysis unit while incubation outcomes, measured by incubate growth at exit time from incubator, will provide indicators of success. The efficiency models offer implications for management practice and policy regarding incubator management.

The success factors showed in Figure 1 have been considered in literature as input and output indicators to measure the success of incubators and incubated companies.

Following recent studies as Zhang and Zhang (2014), the number of professional service personnel, including the professional technical staff of the incubator and mentors, the total area of the incubator site, the technological and communication equipment, the total incubation fund and the amount of support obtained are control indicators. The number of graduated companies, growth in employment and survival in the first year of operation are indicators of results. The variables established as inputs/inputs and outputs/outputs depict in the Table 1.

The hypothetical model describes the inputs and outputs to contrast through the DEA technique. Variables that it incorporates are depicted.

3.2 Variables

According to Zhang and Yin (2010a, 2010b), this study establishes the incubator's resources include professional advice, including the technical staff of the incubator and mentors, financial resources, the total area of the site of the incubator, financing opportunities, training and training, access to research centres, physical and virtual technological resources, academic level of tutors and managers. None of the variables were considered as control variables, that is, they all influence those of dependent variables. Being the number of companies graduated, the growth of employment and survival to the first year of operation as a critical variable of the indicators for MSMEs of intermediate technology.

The first filter to ensure the viability of the model is to monitor the combination of inputs and outputs with respect to the proposed DMUs; for this, it has been accepted that the sample size of DMU must be greater than twice the sum of inputs and outputs to obtain

Variables	Authors	Indicator
Inputs		
Technological resources	Zhang and Yin (2010a, 2010b), Cooper and Park (2008)	X1: Total number of resources as computers and else
Physical space destined for administration and operation	Zhang and Yin (2010a, 2010b	X2: Number of square meters
People in contact with users	Zhang and Yin (2010a, 2010b	X3: Number of people involved with time and full responsibility, excluded mentors
Affiliated financial institutions	Ramukumba (2014), Hackett and Dilts (2004a, 2004b)	X4: Number of financiers guaranteed to provide financing
Financial resources obtained		X5: Investment available to start operations
Outputs		
Graduate firms	Hackett and Dilts (2004a, 2004b), Kilcrease (2011)	Y1: Annual rate of graduates
Survival of spin-offs	Hackett and Dilts (2004a, 2004b)	Y3: Annual rate of survival
Survival of spin-offs growth in employment	Al-Mubaraki and Busler (2013), Goedhuys (2002), Hackett and Dilts (2004a, 2004b)	Y4: Annual rate of growth in employment

Table 1.
Input and output variables of the efficiency model of Mexican incubators

reliable results Nooreha, Mokhtar, and Suresh (2000), although Banker et al. (1989) establish generally that the number of companies be equal to or greater than three times the variables included in the model. In this study, both criteria are met, which allows the model to be compared.

3.3 Definition of software

The programme used to calculate the model was MAXDEA Version 2.1: a data envelopment analysis, computer programme, whose operation in detail appears in (Coelli, 1996). This programme has the widest range of updated DEA models, which allows generating more analysis.

3.4 Selection of the most appropriate data envelopment analysis model

Once the scope of this study has been defined, the DEA model that best allows explaining the analysis to be performed should be selected. There are different variants of the DEA model susceptible of application, and in this work, it has been considered appropriate to select the following alternative: Initially, apply the constant scale returns (CSR) model, which allows to know the global technical efficiency (GTE) of the analyzed DMUs, for later develop the BCC model (variable scale yields), which shows pure technical efficiency (PTE). Thus, once both results have been obtained for each decision nit, its scale efficiency (EE) can be calculated through the quotient between both values (GTE/PTE).

Both models (CCR and BCC) are applied considering the output orientation (maximization of production from a given level of inputs), according to Charmes *et al.* (1978), one unit cannot be characterized as efficient if it is possible to increase any output without increasing any input. The application of the output orientation is justified in the case of business incubators because this type of institution usually works with a predetermined and predetermined level of resources, starting from the budgets that allow it to support a specific number of entrepreneurs to beginning new business.

4. Results

Once the database of the incubators (DMUs) was organized, a label was assigned in alphabetical order to each DMU, being A for 1, B for 2, and so on until Y was 25; this is done to maintain the confidentiality of the information. Also, the DMUs were grouped into four groups according to the classification of the university that sponsors them, based on the number of students enrolled in their different academic programmes, being as follows: large, medium, small and micro, and they were assigned a number from 1 to 4, respectively.

	Min	Max	Average	SD	DMUs
X1: Total number of resources	5	60	32	13.853	25
X2: Number of square meters	80	1,000	562.4	296.264	25
X3: Number of people responsible	10	42	22.987	11.64	25
X4: Number of financially endorsed to provide financing	2	4	2.947	0.0787	25
X5: Investment available to start operations	120,000	10,500,000	3,527,493.333	2,605,214.68	25
Y1: Annual rate of graduates	30	100	61.133	16.817	25
Y2: Annual survival rate new companies	20	95	62.387	19.472	25
Y3: Annual employment growth rate	0	100	61.067	25.233	25

Table 2. Descriptive statistics; indicators entry and exit for the period 2012–2014

Firstly, Table 2 presents the descriptive values of each of the GTE variables considered as input and output indicators defined for the DEA model.

As can be seen, the most outstanding data are those corresponding to the input variable X5, which corresponds to the amount that the incubators helped manage to finance the projects that would result in the creation of new companies. The maximum and minimum point out the differences between the DMUs.

On the other hand, Table 3 shows the degree of linear association between each pair of variables in the period 2012–2014, by means of Pearson's linear correlation coefficient. The objective here is to detect those independent variables that are highly correlated with each other and reduce the presence of sample multi-collinearity, especially with respect to each subset of inputs and outputs. The existence of multi-collinearity influences the significance of the results obtained and distorts their interpretation. For this study, the subset of inputs or resources does not present significant correlations between them, which favours the robustness of the model.

In contrast, we have outputs, these are not correlated either, that is, there is no significant relationship between the graduated companies with the survival and growth in employment during the first year, so there is no need to make any adjustment with the variables, eliminating that or those that correlate significantly, which continues to strengthen the model by being able to incorporate all the variables selected for this study.

Furthermore, there is a significant relationship between the X5 input and the Y1 output, that is, the financial resources obtained are related to the new graduated enterprise because resources are important to be able to create the new business, which it can be assumed that the increase of graduate companies is usually accompanied by a higher level of financial resources managed and received. However, these correlations between inputs and outputs are not particularly problematic, as they identify the existence of strong cause–effect relationships between the resources and results analyzed, which is the fundamental premise of the DEA technique.

Once the correlation analysis has been performed to demonstrate that there is no multi-collinearity and that the model is valid to perform with the previously selected inputs and outputs, in the next part of this study, it executes the DEA model.

The analysis of the slacks of the variables in the DEA models provides the direction in which the efficiency levels of the DMUs should be improved. Therefore, an exit authorization value represents the additional level of outputs needed to convert an inefficient DMU into an efficient DMU. The data surpassed the test Nooreha et al. (2000) to validate the number of inefficient units; therefore, no additional problem is generated with the free spaces for each efficient incubator.

Technically, Table 4 shows the synthesis of the main results derived from the application of the DEA model variants for each of the analyzed years. In this way, the GTE average has a variable behaviour, having a decrease in 2013 with respect to 2012 although it grows again in 2014 to reach a 90.7% of GTE, which implies that, on average, the incubators of analyzed companies could have reached an increase in the output level of 9.3%, keeping their input levels constant. Likewise, the correlation between the efficiency indices for the three years measured through the Pearson correlation index, reaches 91.5%, statistically significant.

On the other hand, the number of efficient DMUs in global terms (GTE = 1) remains constant between 2012 and 2014 at 48%; however, 2013 was better with 52% despite its decrease in the average of GTE. Also, we must highlight the volume of units that act under increasing returns of scale, as neither in 2012 nor 2014 they are produced, and only one incubator in 2013 operates under these returns. The foregoing is contrary to the results with decreasing and constant return to scale, which are predominant in the model in each of the

Table 3. Correlation matrix between the input and output indicators for the DEA model

	X1: resources	X2: square meters	X3 people	X4 financial	X5 investment	Y1: graduates	Y2: survival	Y3: employment
X1	1							
X2	0.389003	1						
X3	0.356418	0.321370009	1					
X4	0.431584	0.30602527	0.18613977	1				
X5	0.458412	0.38422355	0.41767343	0.2497338	1			
Y1	0.352686	0.22668744	0.21852143	0.3366348	0.5977336	1		
Y2	0.239573	0.12664313	0.06211408	0.3542744	0.0233093	–	1	
Y3	0.194853	−0.1086338	−0.1114469	0.0029049	0.0100217	0.036919	0.05360705	1

Efficiency correlations	Technical efficiency score(CRS)	Pure technical efficiency score(VRS)	Scale efficiency score
Technical efficiency score	1		
Pure technical efficiency score (VRS)	0.40531	1	
Scale efficiency score (EE)	0.91575	0.0056	1

three periods analyzed and suggests the effect of political, macroeconomic or market variables.

Regarding the standard deviation of the efficiencies that indicates the degree of dispersion among the DMUs analyzed in Table 4, it can be seen how there is an increase for each type efficiency between 2012 and 2013, which makes 2013 more efficient. For the year 2014, it decreases, to maintain now values below the year 2012, which makes the analyzed incubators more heterogeneous with respect to their management in those two years (2012, 2014).

To give support to the above, the comparison is made by quadrants in dispersion charts of the positioning of the units (Graph 1), where it can be seen that the most efficient year is 2013, reaching 20 DMUs in the first quadrant, compared with the 17 of 2012 and 19 of 2014, and although the difference between 2014 and 2013 is of only one DMU, the dispersion in the second quadrant in 2014 is greater, which makes the difference in efficiency.

Another priority task was to identify the behaviour of the efficiency in the three years (Table 5), identifying seven main groups on the GTE level, highlighting the following:

Groups 1 and 2, each composed of nine incubators, the first with a positive trend, that is, they maintained efficiency during the three years. The second, with a negative trend, remained inefficient in the three years. From this analysis, the micro and small Types 3 and 4 incubators are the ones that best manage their resources to maximize their production.

Table 4.
Summary of DEA model results

	2012			2013			2014		
	GTE	ETP	EE	GTE	ETP	EE	GTE	ETP	EE
Min.	0.6508	0.8	0.6653	0.5531	0.6861	0.5724	0.6461	0.8289	0.6461
Max.	1	1	1	1	1	1	1	1	1
Mean	0.8826	0.0975	0.9047	0.8712	0.9791	0.8898	0.9072	0.9685	0.9365
St. Dev	0.1331	0.0507	0.1256	0.1622	0.0645	0.1525	0.1167	0.0588	0.1017
DMUs (incubators)	25	25	25	25	25	25	25	25	25
DMUs efficient	12	18	14	13	19	14			
% DMUs efficient	48	72	56	52	76	56	48	72	56
DMUs IRS		0			1			0	
DMUs		11			10			11	

Notes: DMUs: decision making units. IRS: increasing scale returns. DRS: decreasing scale yields

Table 5.
Incubator groups by efficiency ratio

Group by efficiency	DMU	2012–2013–2014	DMU (incubators)	Type (1 micro, 2 small, 3 medium and 4 large)
1	9	E-E-E	A, B, F, I, J, K, M, N, X	3,2,3,3,4,3,4,4,4
2	9	I-I-I	C, E, H, O, R, T, U, V, W	1,1,3,2,2,1,2,1,1
3	2	I-E-E	D, L	2,3
4	1	I-I-E	S	3
5	2	E-E-I	G	3
6	1	E-I-I	P, Y	2,3
7	1	I-E-I	Q	4

Group 3, with two incubators of Type 2 and group four with an incubator of Type 3, have the characteristic of having been inefficient in 2012 and ending 2014 as efficient, regardless of the result of 2013.

On the contrary, Group 5 with an incubator of Type 3 and Group 6 with two, have the characteristic of having been efficient during 2012 and having finished 2014 as inefficient, DMUs, regardless of the result of the 2013 period.

Finally, Group 7 whose characteristic is that both 2012 and 2014 remained inefficient, under these returns. The foregoing is contrary to the results with decreasing and constant return me efficient, but it did not remain constant.

To deepen the differences in operating efficiency between the business incubators analyzed, a K-means grouping analysis is was prepared on the results of 2013, where there is the largest number of efficient incubators. The model decomposes efficiency into general, pure technique and scale. The overall efficiency is equal to the product of pure technical efficiency and scale efficiency, and there is no direct correlation between both measures. This research paper selects pure, and there is no direct correlation between both measures. This research selects pure and there is no direct correlation between both measures, also choose pure technical efficiency and scale efficiency as grouping variables and establish K = 4 for the analysis, as can be seen in Table 6, the pure technical efficiency and scale efficiency of the Class I business incubators maintained at a high level, there are the Type 4 and 3 incubators, which is still consistent with the results obtained where, micro and small incubators, are the most efficient in the analyzed years. In contrast, the overall efficiency of Classes III and IV incubators needs to improve.

Similarly, Table 7 shows that the level of significance of the grouping variables (0.000). The grouping variables pass the significance test; therefore, the results of the previous grouping can be the basis of the clustering analysis of the efficiency differences of the business incubators.

Finally, the main utility of the DEA technique lies in its ability to determine the reference units of each inefficient subject, facilitating benchmarking processes and making future improvement decisions. Hence, the model makes a projection of the variations that the DMU should make if it wishes to be in an efficiency position. The main finding highlights micro and small incubators as the most efficient of the time frame.

Based on the results of the most efficient year (2013), a benchmarking analysis is carried out for the 12 incubators identified as inefficient. The study focusses on the efficiency of DMU incubators; therefore, the analysis focusses on this and, secondly, to identify the most efficient type of incubators. The main references have been identified, as well as the necessary levels of inputs and outputs, to be efficient as shown in Table 8.

	Initial cluster center				Initial cluster center			
PTE	1.00000	0.09183	0.96639	0.68618	0.9987	0.9695	0.9888	0.6862
EE	EE 1.00000	0.07744	0.57243	1	0.983	0.7532	0.5838	1

Table 6. Relationship of cluster centres

	Cluster mean quadratic	gl.	Error mean quadratic	gl.	F	Sig.
PTE	0.03	3	0	21	86.76	0

Table 7. Level of significance of the grouping variables (ANOVA)

Table 8. Benchmarking analysis (2013)

	EGT score	Benchmark score	X1 resources	X2: Square meters	X3: People involved	X4: Financial guarantees	X5: Investment available	Y1: Annual rate of graduates	Y2: Survival annual rate	Y3: Annual employment growth rate
DMU C	0.5532	G (1.230769); J(0.769231)	−17.6923	0.0000	−9.6923	0.0000	−1807692.3000	67.6923	64.6154	93.0769
E	0.5833	I (0.714286); J (0.571429); Q (0.714286)	−5.7143	25.7143	−2.1429	0.0000	−2364285.7000	64.2857	50.0000	57.1429
H	0.9057	G (0.303857); J (0.169332); Q (0.164628); X (0.574788)	0.0000	0.0000	−15.7197	0.0000	−3336829.7000	6.2465	9.3697	64.6943
O	0.8841	D (0.366120); G (0.84699); K (1.049180)	−5.4235	−289.3443	−10.0000	0.0000	0.0000	40.4918	6.5574	10.4918
P	0.8333	I (0.300000); J (1.200000)	−14.5000	−554.0000	0.0000	0.0000	525000.0000	18.0000	14.0000	99.0000
R	0.5958	G (1.553571); J (0.285714); X (0.107143)	−5.8036	−12.8571	0.0000	0.0000	−633928.5700	47.5000	61.0714	103.2143
S	0.6862	I (0.208191); J (0.116041); N (0.324232); X (0.351536)	−19.6758	−419.0444	0.0000	0.0000	0.0000	19.2935	22.8669	18.5324
T	0.7500	I (1.500000)	−12.5000	−250.0000	−5.0000	0.0000	−3725000.0000	30.0000	30.0000	45.0000
U	0.7222	G (0.346154); J (1.153846)	−14.0385	0.0000	−21.5385	0.0000	−461538.4600	41.5385	26.9231	34.6154
V	0.7111	I (0.750000); J (0.750000)	0.0000	−165.0000	−20.0000	0.0000	−2687500.0000	32.5000	35.0000	60.0000
W	0.6377	I (0.477273);	−22.7273	−479.5455	0.0000	0.0000	−1601136.4000	39.7727	30.4545	45.4545
Y	0.9192	G (0.489740); I (0.225948); J (0.025486); X (0.172551)	0.0000	−339.3779	−15.9654	0.0000	0.0000	16.1463	5.2758	4396536.0000

In the benchmark column, the incubators that obtained efficiency values equal to 1 are considered as a reference in higher efficiency for non-efficient ones, frequently, the fact that a DMU appears repeatedly in this column can be considered as an indicator that the DMU in question can be used as a model to be imitated by the other DMUs. The model incubators would be the "J" being reference for ten incubators, and the "I", which is reference for seven incubators, to a lesser extent, but also important are the "G" and the "X" with six and four, respectively.

Each of the inefficient incubators in the GTE column shows weightings in percentage terms that indicate the score obtained, and consequently, the percentage of savings that should be made with respect to the inputs used to achieve efficiency. For example, the results in the case of the less efficient incubator called by the letter "C", has a score of 55.31%, so if efficiency is sought, you must reduce your inputs by 45.69%.

A factor of interest for the efficiency analysis is the benchmark for inefficient incubators, which is shown in the benchmark column, which aims to center the model with orientation towards managerial efficiency. For the case of the less efficient "C", they are considered as models to follow, to the incubator "G" with one 123.0% and to the incubator "J" with one 76.92%. The projection analysis highlights all the indicators, the levels of the incubators (Y3) with the greatest need and proportion of adjustment and the graduation levels must be increased.

For the input indicators, the search for financial resources by the incubators and entrepreneurs (X5) must also adjust to reduce the available square metres (*X*2) owing to better management at the required levels of efficiency.

Before presenting the distances between the efficiency indices, we resume the procedure followed to validate the incubator's efficiency model. It starts with a filter to evaluate the viability of the model by comparing the sample size with the sum of inputs and outputs. Next, the degree of linear association between each pair of variables in the 2012–2014 period is collected, which is valid in the analysis of efficiencies by running correlation tests between the CRS indices vs efficiency; RSV (0.405); CRS vs EE (0.915) and VRS vs EE (0.0056).

Subsequently, a radar analysis is carried out (Figure 2) to establish the efficiency of the seven types of incubator incubators (large, medium, small and micro) over the ETG level of the seven main DMU groups. The VRS index only measures pure technical efficiency; however, for comparative purposes, constant scale rate rates can be calculated, which comprise a non-additive combination of pure and scale technical efficiencies.

The relationship between the CSR efficiency index and the VRS pure technical efficiency index provides a measure of the efficiency of the EE scale.

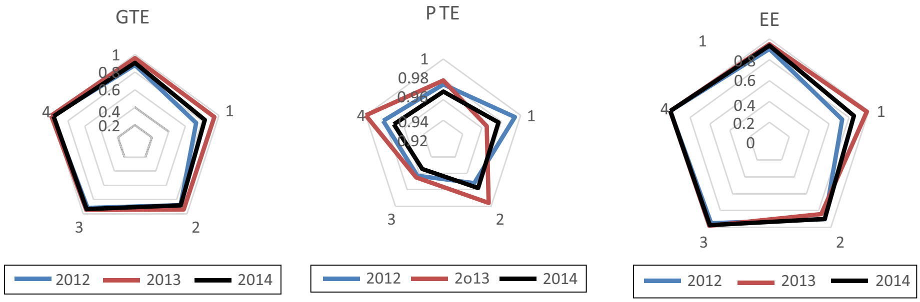


Figure 2.
Efficiency index of the seven incubators types (large, medium, small and micro)

5. Conclusions and discussion

The estimated model in the context of Mexico confirms that high efficiency appears to be associated with the minimum use of resources to provide a specific volume of result. The overall performance of business incubators has a medium-low level, considering survival levels, employment growth, these being its contribution to economic growth. For this reason, the methodology of DEA was applied to understand the efficiency indicators in Mexican incubators, which allowed us to respond to the three areas of research, which will guide this discussion:

(1) size;
(2) efficiency factors; and
(3) entrepreneurship and academic attributes.

Regarding the first, incubators oriented to businesses in the technology sector were classified by their size (number of students) and the economic role of the geographical location. This approach allowed focussing those that have better efficiency, and with this, to establish that the efficiency represented in the resulting model is integrated by the incubators of type micro and small, finding that these sizes of incubators are predictive of an efficient incubator. This finding could be affected because such incubators are born with a more limited structure in each of the services offered, that is, fewer physical spaces, human resources, technological resources and network levels. Despite this, the core of incubation is carried out in an environment of institutional efficiency and deploys professional competence to lead innovative projects that are inserted into an intermediate technology market.

Some universities have technology parks and business accelerators, which signal their magnitude; they focus on companies also larger, but less efficient, so it could be said that the optimization of the resources of the incubators is not a premise of limiting operation, as is the case with micro and small business. The analyzed model of efficiency of incubators, measured by:

- the number of new business in progress;
- the survival in the first year of having concluded the incubation process; and
- the growth in the number of employees with higher efficiency rates for micro and small incubators vs to medium and large incubators, which represents a contrast in the level of service provision estimated owing to greater control and interest in their resources.

The second research position refers to factors that lead the Mexican incubators to the efficiency frontier:

- physical resources;
- technological resources;
- human resources; and
- income to finance companies.

Financing for the creation of new businesses has been found relevant although the findings are contradictory, as it is not the number of financial institutions associated with the incubator that makes the difference but rather the administration and availability of access to resources or through financing to incubated people who start a new business.

Notwithstanding the physical and technological resources where incubation activities are conducted market, the knowledge, skills and experience of the founders and others interested in the innovation process within the incubators underpin the competitive advantage of the institution that generates successful spin-offs for the employment generated in their context.

Scale returns, this model of projective efficiency suggests taking into account the size to create a new incubator reducing resources and supported by the survival of the newly generated companies a truly significant growth in employment would be stimulated, with the economic growth of the region where the firm was installed.

To conclude, this analysis recognizes the size and restriction of resources coupled with academic and business talent would be determinants in the efficiency of incubators. However, an obvious limitation is the non-standardized sample of 25 incubators does not allow generalizing the results. Additionally, the implication highlights the special support received by start-ups linked to a university with strong financial and non-financial support.

Derived from this study, it is appreciated as a future research line longitudinal studies of the growth of incubated companies, as well as the effect of financing on incubated companies as an element that stimulates their star-up, performing and growth market.

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