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The Impacts of Covid-19 on Postgraduate Courses at the Federal University of Ceará (UFC, Brazil)

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Abstract

With the aim of identifying the impact of the Covid-19 pandemic on postgraduate courses (stricto sensu) at the Federal University of Ceará (UFC), the Data Envelopment Analysis (DEA) multi-criteria methodology was adopted, using the BCC modeling oriented to the outputs (BCC-O), proposed by Banker et al. [1]. This methodology was used to carry out a longitudinal analysis of the period leading up to the pandemic (2018 and 2019) and the pandemic period (2020 and 2021). An ex-ante and ex-post-facto study was carried out, taking postgraduate courses as the scenario, specifically the academic and professional master's courses at the UFC. One could see that although the Covid-19 pandemic had an impact on the performance of this university's master's courses, in general, their relative efficiency did not fall so significantly, as it varied from an efficiency score of 0.808 in 2018 and 0.8009 in 2019, to 0.7685 in 2020 and 0.7401 in 2021. In addition, some master's courses succeeded in maintaining their relative efficiency, remaining as efficient units (score 01) over the four years, while others, such as the Master's in Public Policy Evaluation - Professional, and the Master's in Public Policies and Management of Higher Education-Professional (POLEDUC), boosted their indexes. One concludes that the DEA methodology, besides identifying the best practices during the pandemic period, can guide managers in monitoring the courses portrayed as inefficient.

Keywords: Covid-19 pandemic, Data envelopment analysis, Postgraduate studies (stricto sensu).

1 | Introduction

This research lies in the field of Brazilian higher education and takes a quantitative approach to measuring the relative efficiency of stricto sensu postgraduate courses at the Federal University of Ceará (UFC) during the Covid-19 pandemic, from a longitudinal monitoring perspective. The Covid-19 virus emerged in the city

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of Wuhan, China, with its first cases dating back to December 2019 [2], [3]. Given the high rate of spread and contagion of the disease, in March 2020, the World Health Organization (WHO) gave it pandemic status.

According to Rodrigues et al. [4], it is a "disease caused by the severe acute respiratory syndrome coronavirus 2 (Sars-CoV-2), a coronavirus disease (Covid-19)", which requires special attention, the mobilization of several combat fronts, adaptations and a high cost of investments and changes in the organic way in which society behaved until then. For example, it was necessary to adopt the use of masks, social isolation, quarantine, lockdown, vaccines, and many other measures in this regard, guided by the health authorities.

According to Rodrigues et al. [4], this scenario of uncertainty and great complexity arose because the "high virulence of the new coronavirus, associated with the lack of an effective treatment for the disease, led to the adoption of preventive emergency measures capable of protecting health and saving lives around the world, such as quarantine and social isolation". Therefore, Covid-19 came to place its name in history as the gravest public calamity of the 21st century, generating an unprecedented health crisis [3], which impacted various segments of society, with Education being one of those most affected.

Having emerged in December 2019, by January 2020, the pandemic began to affect university activities in China. "In March, there were already cases of suspension of face-to-face activities at higher education institutions on all continents" [5], with the "unheard of situation of 90% of the student population being isolated around the world".

In this context, Brazil began to adopt a legislative framework to guide its educational institutions on how to deal with the new scenario that the pandemic had created. Considering that the Ministry of Education (MEC) is the body responsible for education in the country, it began to issue ordinances and regulations to meet the demands of the atypical moment. One example is MEC Ordinance n. 343, which "provides for the replacement of face-to-face classes by classes in virtual formats for as long as the new Coronavirus - COVID-19 pandemic lasts", with classes migrating from face-to-face teaching to remote teaching, with neither the students nor the teachers being prepared to deal with the technology needed to operate remote teaching, which may have compromised these students' training process.

Regarding higher education, the federal government launched Provisional Measure n. 934 (2020), which "established exceptional rules on the school year of basic education and higher education resulting from measures to deal with the public health emergency". This law, also in its article 2, states that "higher education institutions are exempt, on an exceptional basis, from the obligation to observe the minimum number of days of effective academic work", in the context of dealing with the emergency situation that Covid-19 has created.

In this scenario, we need to better understand whether the changes resulting from the Covid-19 pandemic have influenced the performance of higher education institutions in the country. This aspect deserves special attention because higher education is a key marker of a nation's development. With this in mind, this research aimed to identify the impacts of the Covid-19 pandemic on the academic and professional master's courses at the UFC.

It is worth noting that from the point of view of the systematic monitoring of national higher education institutions, since 2004 Brazil has had a National Higher Education Evaluation System, SINAES, created through Law No. 10,861, of April 14, 2004, with the aim of "ensuring a national process for evaluating higher education institutions, undergraduate courses and the academic performance of their students". Therefore, there are already regulations that guarantee the monitoring of higher education in the country [6]. Thus, with this research, one intends to add information to the monitoring systems that already exist.

2 | Methodology

The methodology used in this study is Data Envelopment Analysis (DEA), known as DEA. It is a quantitative methodology for evaluating the relative efficiency of production units. Some of its potential features include: a ranking of units according to their efficiency; the identification of reference units (benchmarks or lambdas) for inefficient Decision Making Units (DMUs); score tables, which show the score achieved by each unit;

efficiency frontier charts, among other possibilities. The methodology also makes projections, in which managers can visualize what the units would look like if they made the changes suggested by the model.

The DEA methodology is a computational tool to support decision-making. Through the analysis made, it allows managers to orient themselves in terms of the most effective way for the units portrayed as inefficient to improve their indexes. Furthermore, the DEA methodology is one of the best mathematical techniques for calculating the overall performance of the units under analysis, considering, of course, the input and output factors used [7].

This methodology was adopted in this study so that a longitudinal analysis could be carried out, looking at the period leading up to the pandemic (2018 and 2019) and the pandemic period (2020 and 2021). Longitudinal research of an ex-ante and ex-post-facto nature was carried out, taking postgraduate courses as the scenario, specifically the academic and professional master's courses at the UFC. This choice was intentional, as this university is part of the research project Covid-19 Pandemic and Higher Education: evaluation of the impacts on the mental health of students and workers, as well as on the performance of Higher Education Institutions (HEIs), under the coordination of Prof. Dr. Wagner Bandeira Andriola.

Thus, the performance indicators of these courses were used, namely: the number of places on offer; the number of students entering, enrolling, and graduating; the total number of scholarships awarded; and the Capes Concept for each of the master's courses analyzed. Andriola [8] emphasizes the importance of using indicators, since "[...] in the educational field, an indicator is an artifice that provides relevant information about significant aspects of reality", to which he adds two intrinsic characteristics, namely: a synthetic character and the ability to guide decision-making.

So, the data were collected from the Statistical Yearbooks of the UFC. Data analysis using the DEA methodology was carried out using the DEA-Solver software, from the multinational company Saitech, in professional version 7.0.

3 | Theoretical Framework

According to Souza Júnior and Gasparini [9], the theoretical principles for frontiers and efficiency measures originated from the work of Farrell [10] and, later, Charnes et al. [11], who generalized the study, extending the model to multiple resources and results in obtaining an indicator that met Koopmans'[1] [12] concept of efficiency". Muñiz [13], Muniz et al. [14], in turn, explain that the origins of the theoretical framework that enabled the development of the DEA methodology come from the work of Debreu [15], whose improvement of his ideas was carried out by Charnes et al. [11], scientists who extended the non-parametric method introduced by Farrell [10] to measure DMUs with multiple inputs and outputs.

It is a methodology that identifies the best practices within the set of units evaluated. These units, which can be of different types, such as schools, universities, industries, hospitals, hotel chains, factories, among others, are the DMUs. These must keep the input information, which are also the inputs used by the DMUs, with the output information, which are the results obtained in order to carry out the DEA, consisting of the evaluation of the relative efficiency of these units, namely the productive units [16].

In this sense, efficiency would be the optimum combination of the necessary supplies and methods (inputs) in the production process, in such a way that they generate the maximum product (output) [17]. Thus, the DMUs, which must be homogeneous, are compared among themselves and those ones that obtain the highest productivity according to the resources at their disposal are considered efficient units. These units achieve a

[1] Souza Júnior and Gasparini (2006, p. 806) elucidate that efficiency in the Pareto-Koopmans sense exists when an operating plan satisfies the following conditions: 1) a product cannot be generated in greater quantity without decreasing the quantity generated of some other product or without increasing the quantity consumed of at least one input; 2) an input cannot be consumed in less quantity without increasing the quantity consumed of some other input or without decreasing the generation of at least one product.

score of 01 (one), i.e., they reach 100% efficiency and start to act as peers or benchmarks, which are the partners of excellence for the inefficient units, those productive units that have not achieved a score of 01 and therefore have not reached the efficiency frontier and consequently need to "mirror" their benchmarks and review their factors (inputs and/or outputs) with the aim of improving their productivity [14], [18], [19].

Moradi and Maghbouli [20] point out that the efficiency of a DMU is obtained by maximizing the ratio between the weighted sum of its outputs and the weighted sum of its inputs. Thus, this relation cannot exceed a score of 01 (one) for any unit and those that reach this value are the efficient units. It is imperative that the DMUs under analysis are homogeneous and therefore perform the same functions, i.e., that they are similar to each other and belong to the same group. In this article, the productive units are the academic and professional master's courses at the UFC.

As for the input and output factors used, they consist of the performance indicators adopted by the universities, namely: the number of places on offer, the number of students entering, enrolling, and graduating, the number of scholarships awarded, as well as the Capes Concept for each of the master's courses analyzed. It should be clarified that there is no rule regarding either the number of production units or the number of inputs and outputs used in an analysis, but Nunamaker [21] advises that the number of DMUs should be at least three times greater than the sum of products and supplies included in the specification, in other words, it is suggested that the sum of inputs and outputs should not exceed one third of the number of DMUs.

The next step after choosing the production units under analysis and the inputs and outputs factors to be used in the research consists of choosing the DEA modelling to be adopted. There is a considerable variety of DEA models. Among them, one can highlight the Constant Returns to Scale (CCR) model, idealized by Charnes et al. [11], which took the initials of their names and consists of CCR, implying that variations in inputs induce proportional variations in outputs and vice versa. Another widely referenced model is the BCC model, also known as Variable Returns to Scale (VRS), proposed by Banker et al. [1], which also took the initials of the names of the idealizers and consists of VRS, i.e., they can grow, decrease, or remain constant, varying according to the scale of production [17].

Given the objectives of this study, which are to determine the maximum productivity (output) of postgraduate courses (academic and professional master's courses at the UFC) during the pandemic period, one chose output-oriented BCC modeling (BCC-O), since it considers VRS.

4 | Results and Discussion

For this study, all the professional and academic master's courses at the UFC relating to the years 2018, 2019, 2020 and 2021 were evaluated, representing a total of eighty-three master's courses. However, the courses that did not have all the information for the aforementioned years were removed from the analysis: systematics, use and conservation of biodiversity, teaching of history – Profhistória, psychology and public policies, management of water resources - professional; family health - network professional, cardiovascular sciences, physiotherapy and functionality, translational medicine, gastronomy, educational technology, computing, and finally, the master's degree in logistics and operational research. As such, the final analysis using the DEA methodology in the BCC-O modeling, using the DEA-solver software, was carried out with the other 71 courses. For this, one considered as input factors: the number of places on offer, the number of students entering, the total number of students enrolled, and the number of scholarships awarded. As for the outputs, we considered the total number of graduating students and the Capes Concept for each of the master's courses analyzed.

An overview of the relative efficiency of the UFC's academic and professional master's courses during the pre-pandemic period (2018-2019) and pandemic period (2020-2021) will be presented below, in order to illustrate how the university's master's courses have behaved over the time.

Table 1. Longitudinal performance of the UFC's academic and professional master's programs.

N°	DMU	Score_2018	Score_2019	Score_2020	Score_2021
1	Biochemistry	1	0.881	0.9517	0.8571
2	Computer science	0.7537	0.7789	0.7143	0.7218
3	Ecologyand natural resources	0.8039	0.6582	0.7305	0.6419
4	Teaching of science and mathematics-professional	1	0.9509	1	0.8828
5	Teaching of physics-professional in a national network	0.6708	0.451	0	0.6809
6	Physics	1	1	1	1
7	Geography	0.8679	0.8571	0.9038	0.8571
8	Geology	0.6555	0.6165	0.6918	0.6233
9	Mathematics	1	1	1	1
10	Mathematics-national professional network (PROFMAT)	0.7891	0.3246	0.4639	0.6331
11	Modelingand quantitative methods	0.5608	0.5897	0.4736	0.4566
12	Chemistry	0.944	1	1	0.9327
13	Agronomy-phytotechnics	0.8177	0.8545	0.8427	0.8209
14	agronomy-soil science and plant Nutrition	0.5995	0.9591	0.6529	0.6374
15	Public policy evaluation-PPGAPP	0.4962	0.4742	0.6341	0.4396
16	Public policy evaluation-professional	0.6667	0.6	1	1
17	Natural resources biotechnology	1	1	1	0.8865
18	Food science and technology	0.7149	1	0.6371	0.6658
19	Rural economics	0.9265	0.6088	0.7062	0.5961
20	Agricultural engineering	0.7169	0.8265	0.7196	0.7614
21	Fisheries engineering	0.6726	0.6919	0.7854	0.6435
22	Zootechnics-inter-institutional	0.7792	1	1	0.7791
23	Anthropology (associationwith UNILAB)	1	1	0.5495	1
24	Information science	1	0.7291	0.5249	0.506
25	Translation studies	0.6667	0.6133	0.6759	0.5726
26	History	0.7938	0.7754	0.7544	0.7506
27	Languagesand literature	0.7243	0.8154	0.7143	0.8315
28	Languages and literature-national professional network (PROFLETRAS)	0.9953	0.6305	0	0.5569
29	Linguistics	0.7557	0.7143	0.8507	0.7143
30	Psychology	0.6457	0.866	0.9063	0.6043
31	Sociology	0.7419	0.7143	0.7143	0.745
32	Sociology-national professional network (PROFSOCIO)	1	1	0.8	0.8385
33	Architecture and urbanism and design	0.8113	0.7535	0.6385	0.628
34	Civil engineering-water resources and environmental sanitation	1	1	1	1
35	Civil engineering-structures and civil construction	0.791	0.5802	0.5972	0.598
36	Teleinformatics engineering	1	0.8637	0.9115	0.9182
37	Transportation engineering	0.8571	0.8571	0.8571	0.8571
38	Materials science and engineering	0.798	1	0.8456	0.7414
39	Electrical engineering	0.6543	0.5714	0.6176	0.6412
40	Mechanical engineering	0.708	0.7334	0.7301	0.5845
41	Chemical engineering	1	1	1	1
42	Education	1	0.9692	1	0.5887
43	Law	0.9914	0.9399	0.8746	0.7561

Table 1. Continued.

N°	DMU	Score_2018	Score_2019	Score_2020	Score_2021
44	Administrationand controllership	0.6154	0.7262	0.937	0.6082
45	Administrationand controllership-professional	1	0.9211	0.8418	1
46	Economics-professional	1	1	1	1
47	Economics	0.8026	0.8417	0.7607	0.7642
48	Pharmaceutical sciences	0.5999	0.8721	0.6228	0.63
49	Nursing	1	1	1	1
50	Dentistry	0.8054	0.7545	0.7759	0.7874
51	Medical sciences	0.861	0.8571	0.8719	0.8792
52	Morphofunctional sciences	0.8032	0.8827	0.7433	0.6711
53	Medical and surgical sciences	0.8414	0.7143	0.7175	0.8447
54	Pharmacology	1	1	1	1
55	Clinical pharmacology-professional	1	1	1	1
56	Medical microbiology	1	1	0.9997	0.8882
57	Pathology	0.7893	0.7473	0.6949	0.5933
58	Women's and children's health-professional	0.8138	0.6636	0.6289	0.9536
59	Public health	0.7791	1	0.9173	0.737
60	Arts	0.7128	0.6933	0.7727	0.5714
61	ArtsProfArtes-professional (networked)	1	1	1	0.384
62	Communication	0.65	0.8268	0.817	0.6259
63	Philosophy-professional (interinstitutional)	0	0.8958	0.3876	0.6757
64	Philosophy	0.6385	0.6426	0.7768	0.6412
65	Tropical marine sciences	0.9449	0.9075	0.9662	0.9164
66	Biotechnology	0.9061	0.6153	0.5183	0.507
67	Health science	0.8684	0.5309	0.5319	0.4286
68	Electricaland computer engineering	0.4585	0.4949	0.5779	0.4427
69	Family health	0.6367	0.6351	0.4876	0.5083
70	Developmentand environment	0.7891	0.7235	0.7449	0.7738
71	Public policies and management of higher education-professional (POLEDUC)	0.6786	0.6693	1	0.7651

* Source: The authors, with results obtained from the DEA-Solver software (2023).

With regard to the maximum efficiency that can be obtained, this value is represented by the score 01 (one) and indicates that this course achieved 100% (one hundred percent) efficiency, i.e., it achieved the best possible result using the resources at its disposal it should be noted that this refers to a relative efficiency, so the best productivity takes into account only the DMUs under analysis, according to the methodology adopted.

For understanding the longitudinal performance of these DMUs, the Likert scale was used to group the values into four categories: very low (efficiency ≤ 50%); low (50% < efficiency ≤80%); medium (80% < efficiency ≤ 90%) and high (efficiency > 90%), in agreement with Cavalvante et al. [16]. Thus, the units (DMUs) that show the best productivity and achieve a score of 01 (one) fall into the highest category. They are therefore the efficient units and act as benchmarks, as reference units for inefficient units to mirror and thus improve their efficiency [14], [17], [19].

As can be seen, several courses succeeded in remaining on the efficiency frontier, as shown by score 01, such as: master's in physics, master's in mathematics, civil engineering - water resources and environmental sanitation, chemical engineering, economics-professional, nursing, pharmacology, clinical pharmacology - professional. This means that these courses achieved the best possible productivity. In other words, even during the pandemic, these master's degrees have succeeded in managing their resources in such a way as to maintain the best possible productive efficiency.

Given the limitations of this article, it is not possible to explore each of the courses individually. However, it is worth highlighting the DMUs for the masters in public policy evaluation - professional, and the masters in public policies and management of higher education - professional (POLEDUC). Both achieved a great feat: they increased their efficiency during the pandemic period. Even at a time considered tenebrous in our history,

when thousands of lives were taken and students had to adapt to social distancing and remote classes, these two courses became examples of excellence in their management.

The master's degree in public policy evaluation-Professional, during the pre-pandemic period, had a score of 0.6667 in 2018 and a score of 0.6 in 2019. In the year the pandemic is declared (2020), this master's degree reaches 100% efficiency, maintaining this score the following year. Meanwhile, the master's degree in public policies and management of higher education - Professional (POLEDUC) was also in the category considered low (50% < efficiency ≤ 80%), with a score of 0.6786 and 0.6693 in the period preceding the pandemic. Like the master's program previously described, POLEDUC also reached the efficiency frontier in 2020 and this is a considerable achievement, as it reflects good management. In other words, it can be inferred that resources, whether material or human, were used in the best possible way in such an atypical context as the pandemic.

For a more comprehensive view of the university's behavior in the pre-pandemic and pandemic periods, below is a graph of the longitudinal efficiency curve of the UFC's master's degree courses in the time frame portrayed in this study.

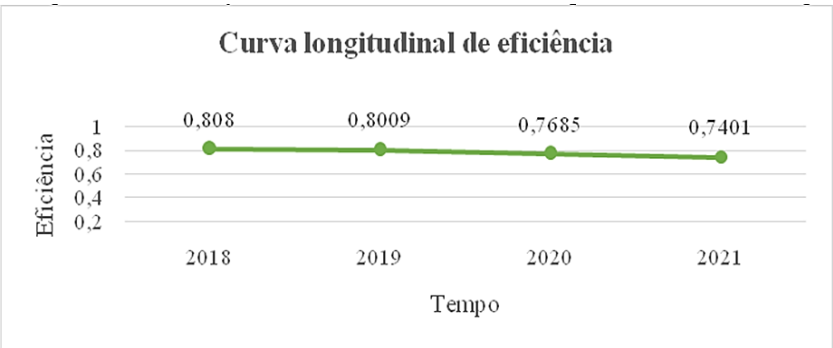

Fig. 1. Longitudinal efficiency curve of the UFC's academic and professional master's degree courses (source: the authors, with data generated by DEA-solver (2023)).

As can be seen, the efficiency of the master's courses at the UFC was impacted during the pandemic, since it varied from an overall efficiency score of 0.808 in 2018 and 0.8009 in 2019, to 0.7685 in 2020 and 0.7401 in 2021. On the other hand, this drop was not so significant considering that it was a period of pandemic in which teaching and learning methodologies were reframed, imposed by this pandemic. In theory, this subtle drop represents that the people responsible have respected the decrees and ordinances (ordinance No. 343, of March 17, 2020) established, guaranteeing all master's students the offer of subjects and the appropriate follow-up in a virtual way.

5 | Final Considerations

A longitudinal study was carried out to identify the impact of Covid-19 on the UFC's master's degree courses. Contrary to common belief, the impacts on their efficiency were not as alarming as expected. In fact, although negative, as the productive efficiency of master's degrees stood at 0.808 in 2018 and 0.8009 in 2019, it fell to 0.7685 in 2020 and 0.7401 in 2021, this drop was not so significant, given that this was a period permeated by a series of restrictions imposed by the Coronavirus.

It's worth noting that during the pandemic, some master's degrees succeeded in maintaining their relative efficiency, remaining efficient units (score 01) throughout the four years, while others, such as the master's degree in public policy evaluation - Professional, and the master's degree in public policies and management of higher education - Professional (POLEDUC), catapulted their indexes. They both started from what was considered low efficiency (efficiency greater than 50% and less than 80%) and reached high efficiency (efficiency greater than 90%), reaching 100% efficiency in the year in which the pandemic was declared.

Regarding the courses portrayed as inefficient, or whose productive efficiency declined in the pandemic period referring to the years 2020 and 2021, it is advisable for managers to analyze the indicators to identify which factors they shouldconcentrate their efforts on in order to increase their efficiency, according to the DEA methodology. A management tool was used, a technological artifact to support managers' decision-making, which is also one of the methods used in various countries to evaluate the efficiency of production units.

Finally, the objectives set out in this study have been met, as in addition to determining the maximum productivity (output) of postgraduate courses (academic and professional master's courses) at the UFC during the pandemic period, an overview of this university was presented during this interlude of time, presenting the impacts of the pandemic on the UFC's master's courses. As it is a tool to support the management of the institutions being analyzed, it is recommended that those responsible take up such methodologies in order to add information to existing evaluation methodologies.

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