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Is it worth it? Using DEA to analyze the efficiency gains and costs of merging university departments: a case study of the Complutense University of Madrid

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Abstract

The aim of this paper is to analyze the benefits of the university department merger undertaken by the Complutense University of Madrid (UCM) in 2017. The merger led to a new structure in which the original 184 departments were reduced to 97. To do this, we use the data envelopment analysis (DEA) to evaluate the efficiency gains of a merger process decomposing efficiency into three savings effects: learning, harmony, and scale effects. They decomposed efficiency into three savings effects: learning, harmony, and scale effects. Additionally, we introduce a new regulatory effect, which accounts for other potential recursive savings not included in the DEA analysis. Our results suggest that the merger process undertaken by the UCM achieved savings of around 20.5 million euros, approximately 6.6 million euros, which is accounted for by the regulatory effect. These savings will reproduce and accumulate annually over time. The results also show that, as a result of the intense negotiations, academic staff based at faculties engaged in the merger process may have taken more days of sick leave than academics from unmerged faculties in 2017, although the increase is not significant at standard levels.

Keywords: DEA; mergers; efficiency; university; departments

1. Introduction

In the wake of the global financial crisis, public universities in many countries came under increasing pressure to improve budget sustainability. The aim was to continue delivering high-quality education and research with fewer available resources in the face of increasing and open worldwide competition. In the specific case of Spain, public spending on higher education as a percentage of

GDP fell from 1.031% in 2010 to 0.817% in 2016 (OECD, 2023). This was a direct consequence of budget cuts, a generalized reduction of civil service salaries, and a turnover hiring freeze policy designed to reduce the high levels of public debt during this period.

One approach to this problem was to merge universities (Estermann and Pruvot, 2015; Pruvot et al., 2015; Pinheiro et al., 2016). In some cases, like France, this reversed a previous split strategy (Ripoll-Soler and Miguel-Molina, 2019). A well-known methodology for assessing the gains of university merging is data envelopment analysis (DEA). Introduced by Charnes et al. (1978) and Banker et al. (1984), DEA is a non-parametric method for measuring the relative efficiency of decision-making units (DMUs) based on their input and output data.

DEA has been widely used in the literature to evaluate the efficiency of various organizations, industries, and public services (Emrouznejad and Yang, 2018). Regarding education, there is a vast literature evaluating the efficiency of universities and higher education institutions (HEIs) within a country or across countries (for a review, see Johnes, 2015; De Witte and López-Torres, 2017; Agasisti et al., 2024). Other studies have evaluated the efficiency of similar university departments across different universities. For example, Tomkins and Green (1988) analyze the technical efficiency of 20 accounting departments at English universities; Johnes and Johnes (1993) measure the research performance of 36 U.K. economics departments; and Madden et al. (1997) compare the research and teaching performance of 29 economics departments at Australian universities.

Another avenue explored by some universities in order to deal with budget constraints is to merge departments within the same university. In this paper, "merger" is construed as being the combination of resources belonging to two or more university departments to create a single department with a new name, structure, and legal status that automatically replaces the departments that existed before the fusion. Departmental mergers can lead to cost savings, improved resource allocation, and greater collaboration between faculty members in order to enhance teaching and boost research groups capable of attracting more research funding. However, it is important to carefully assess the potential benefits and drawbacks of departmental mergers before they are implemented.

Since Sinuany-Stern's seminal work (Sinuany-Stern et al., 1994) analyzing the performance of 21 departments at the Ben-Gurion University (Israel), some researchers have used DEA to evaluate the technical efficiency of university departments within the same university (e.g., see, Fernando and Cabanda, 2007; Kao and Hung, 2008; Tyagi et al., 2009; Agha et al., 2011; Kounetas et al., 2011; Abd-Aziz et al., 2013; Saniee et al., 2013; Gökşen et al., 2015; Abing et al., 2018). In Spain, Giménez and Martínez (2006) analyzed the cost efficiency of 42 departments at the Autonomous University of Barcelona, whereas Martín (2006) estimated the teaching and research performance of 52 departments at the University of Zaragoza.

However, to the best of our knowledge, no previous studies have conducted an in-depth analysis of the economic gains to be made from a real-world university department merger process within a single university. Therefore, this paper is the first empirical attempt to use the DEA methodology introduced by Bogetoft and Wang (2005) and Bogetoft and Otto (2011) to quantify the benefits of merging university departments. This methodology identifies three primary sources of improvements: learning effect, harmony or scope effect, and scale effect.

To do this, we use administrative data to analyze the merger process undertaken by the Complutense University of Madrid (UCM) in November of 2017. The UCM managed to create a new structure that reduced the former 184 departments and 36 departmental sections to 97 departments and 20 departmental sections. On top of the above three gains, we propose the use of a new "regulatory effect" to account for how the equally distributed fixed budget amounts and administrative staff numbers defined by law for any existing DMU change after a merger.

Our ultimate aim is to quantify the potential efficiency gains and pinpoint the relative qualitative benefits to be made from the merger process in order to support future decision making by university boards on resource allocation. We also explore whether mergers may have detrimental effects on staff wellbeing and morale. To do this, we run a difference-in-differences (DiD) model to causally determine whether the merger process had a significant effect on the number of days of sick leave taken during the 2017 merger process. The treated group was the set of 18 faculties whose departments underwent mergers, while the control group were the remaining eight faculties whose departments were unaffected.

The paper is structured as follows. Section 2 provides an overview of the literature on the efficiency gains from mergers in different sectors and countries analyzed using DEA. Section 3 gives a broad description of the context of departmental mergers at UCM. Section 4 introduces the methodology for analyzing a merger process. Section 5 describes the data and defines the inputs and outputs used in the analysis. Section 6 reports the efficiency and economic results of the new departmental structure and explores the impact that the merger process had on academic staff wellbeing. Finally, Section 7 outlines the conclusions.

2. Literature review

Existing studies (e.g., Harman and Harman, 2008; Green and Johnes, 2009; Ripoll-Soler and De Miguel-Molina, 2014; Ylijoki, 2014; Nasiri et al., 2023) report theoretical grounds, empirical studies, and case analyses providing insights into the pros and cons of university, and specifically departmental, mergers. The merger of production units has been a common strategy implemented by organizations aiming to achieve any number of objectives, including market expansion, internationalization, economies of scale, economies of scope, synergies in research, visibility, cost reduction, and increased efficiency and productivity. Some of the reported disadvantages of departmental mergers are cultural clashes, loss of autonomy, disruption and uncertainty, increased bureaucracy, and the risk of mission drift. For this reason, any merger process should seek to enhance the theoretical benefits and mitigate the potential drawbacks.

The analysis of efficiency gains from mergers using DEA and related approaches spans different industries and countries, examining the theoretical or empirical impact of merger processes on productivity, operational performance, and overall organizational efficiency. The following comprehensive literature review on this research line provides a better understanding of DEA's usefulness for this purpose.

Table 1 shows an overview of 54 earlier papers written in English and published in journals applying DEA and related non-parametric frontier methods to examine the efficiency gains of merger processes. Studies are categorized by applied methodology, sector, merged organizations, country or countries, analysis period, and the number of DMUs before and after the mergers. First, there is abundant literature (17 out of the 54 studies) on DEA in the banking and financial services sector. These studies aim to assess the impact of mergers and acquisitions on bank performance and operational efficiency, most (11 out of 17) of which focused on the Persian Gulf region, China, and other Asian and African countries.

Table 1
Studies on efficiency gains from mergers calculated using data envelopment analysis (DEA) and related methods

Studies	Technique	Sector	Decision-making units (DMUs)	Country	Years	DMUs b. m.	DMUs a. m.
Abbot and Doucouliagos (2001)	Malmquist	Education	Colleges of adv. education	Australia	1984–1987	31	25
Bogetoft et al. (2003)	DEA	Forestry	Forestry extension service	Denmark	1997–1999	14	10
Ferrier and Valdmanis (2004)	DEA and Malmquist	Health	Non-profit hospitals	United States	1996–1998	38	19
Bogetoft and Wang (2005)	DEA	Agriculture	Agricultural advisory services	Denmark	1994/1995	71	25
Sherman and Rupert (2006)	DEA	Banking	Bank branches	United States	-	217	-
Bagdadioglu et al. (2007)	DEA	Electricity	Distribution utilities	Turkey	1999–2003	82	18
Kjekshus and Hagen (2007)	DEA+OLS	Health	Hospitals	Norway	1992–2000	53	43
Hu and Liang (2008)	Malmquist	Education	Higher education institutions (HEIs)	China	1999–2002	25 mergers	
Simper and Weyman-Jones (2008)	DEA	Police	Police service	England and Wales	2001–2004	41	-
De Witte and Dijkgraaf (2010)	Conditional DEA	Water	Drinking water companies	Netherlands	1992–2006	20	10
Kristensen et al. (2010)	DEA	Health	Public hospitals	Denmark	2004	36	26
Kwoka and Pollitt (2010)	DEA+OLS	Electricity	Distribution companies	United States	1994–2003	73	53
Blancard et al. (2011)	FDH-DDF	Agriculture	Farms	France	2003	609	-
Wu et al. (2011)	DEA and SFA	Banking	Bank branches	Canada	1999–2000	30	27
Peyrache (2013)	DEA-DDF	Health	Public hospitals	Australia	1996–2004	116	-
Halkos and Tzeremes (2013)	DEA (bootstrap)	Banking	Banks	Greece	2007–2011	18	-
Gattoufi et al. (2014)	Inverse DEA	Banking	Commercial banks	Persian Gulf Countries	2006	42	-
Johnes (2014)	DEA and SFA-DF	Education	HEIs	England	1996–2010	142	133
Zschille (2015)	Conditional DEA	Water	Water utilities	Germany	2006	364	224
Blancard et al. (2016)	FDH-DDF	Agriculture	Farms	Ethiopia	2003	608	-
Peyrache and Zago (2016)	DEA-DDF	Justice	Courts of justice	Italy	2003–2008	165	-
Halkos et al. (2016)	DEA (bootstrap)	Banking	Regional banks	Japan	2000–2008	97	-
Amin et al. (2017)	G. Inverse DEA	Banking	Commercial banks	Persian Gulf Countries	2006	42	-
Drew et al. (2017)	DEA	Municipalities	Councils	Australia	2011	152	112
Flokou et al. (2017)	DEA (bootstrap)	Health	Public hospitals	Greece	2009	71	55
Saastamoinen et al. (2017)	DEA-STONED	Electricity	Distribution system operators	Norway	2004–2012	123	-
Shi et al. (2017)	DEA-two stages	Banking	City commercial banks	China	2012	20	19

Continued

Table 1
(Continued)

Studies	Technique	Sector	Decision-making units (DMUs)	Country	Years	DMUs b. m.	DMUs a. m.
Studies	Technique	Sector	DMUs	Country	Years	DMUs b. m.	DMUs a. m.
Wanke et al. (2017)	Network DEA	Banking	Banks	South Africa	2003–2012	90	-
Li et al. (2018)	DEA	Banking	City commercial banks	China	2012	20	19
Castro and Guccio (2018)	DEA	Justice	First instance courts	Italy	2011	165	135
McQuestin et al. (2018)	Inter-temp. DEA	Municipalities	Councils	Australia	2003–2013	157	73
Amin et al. (2019)	Inverse DEA	Banking	Commercial banks	Persian Gulf Countries	2006	42	-
Bai et al. (2019)	DEA (bootstrap)	Railway	Local railway bureaus	China	2011–2015	18	10
Johnes and Tsionas (2019)	SFA-DF	Education	HEIs	England	1996–2009	25 mergers	
Mattsson and Tidanå (2019)	DEA	Justice	District courts	Sweden	2000–2009	95	48
Papadimitriou and Johnes (2019)	DEA+OLS	Education	HEIs	England	1996–2013	138	125
Amin and Ibn Boamah (2020)	Inverse DEA	Banking	Banks	Canada	2017	28	-
Arocena et al. (2020)	Malmquist	Water	Water supply systems	Japan	2003–2009	762	561
Guijarro et al. (2020)	Inverse DEA	Education	Public universities	Colombia	2018	32	20
Mydland (2020)	DEA	Electricity	Distribution utilities	Norway	2004–2014	55	27
Nguyen and Pham (2020)	DEA	Banking	Banks	Vietnam	2010–2016	13	6
Xie et al. (2020)	Network DEA	Banking	Commercial banking	China	2014	134	-
Agasisti et al. (2021)	Malmquist + OLS	Education	Universities	Russia	2013–2017	38	24
Amin and Ibn Boamah (2021)	Inverse DEA	Banking	Banks	United States	2016–2018	50	-
Al Tamimi et al. (2022)	DEA-DDF	Banking	Conventional and Islamic banks	Mid-East and North Africa	2014–2016	107	-
Ray and Sethia (2022)	DEA	Banking	Domestic banks	India	2000–2019	59	43
Contreras and Lozano (2022)	DEA	Education	Public universities	Spain	2016	47	33
Oukil et al. (2022)	Inverse DEA	Agriculture	Tomato farms	Algeria	2014–2015	51	-
Pyra and Siedlecka (2022)	DEA	Education	Universities	Poland	2018	32	-
Wanke et al. (2022)	DEA + Tobit	Airlines	Airlines	Latin America	2010–2014	19	-
Adler et al. (2024)	DEA-DDF	Air Traffic	Air traffic control	Europe	2010–2014	29	4
Oukil et al. (2024a)	Inverse DEA	Hospitality	Hotels	Oman	2021	58	47
Oukil et al. (2024b)	Inverse DEA	Agriculture	Tomato farms	Algeria	2017–2018	43	33
Soltanifar et al. (2024)	Inverse DEA	Banking	Commercial banks	Persian Gulf Countries	2006	42	-

Note: DMUs b. m.: number of DMUs before the merger process. DMUs a. m.: number of DMUs after the merger process. -: not available.

Second, a number of studies, such as Ferrier and Valdmanis (2004), Kjekshus and Hagen (2007), Kristensen et al. (2010), Peyrache (2013), and Flokou et al. (2017), delve into the healthcare sector, particularly hospitals, to investigate whether mergers lead to increased productivity and technical and scale efficiency improvements. This literature states that merged hospitals may be able to increase productivity by reducing the overuse of inputs caused by operating at non-decreasing returns to scale (NDRS) to improve their scale efficiency. While Ferrier and Valdmanis (2004) and Flokou et al. (2017) find that mergers have positive effects on hospital technical and scale efficiency and productivity, Kjekshus and Hagen (2007) and Kristensen et al. (2010) provide evidence suggesting mixed outcomes, pointing out that efficiency gains are not universally guaranteed across all merged units. Moreover, Peyrache (2013) found that very large hospital break-ups are the most effective policy for dealing with productivity improvements in Australian hospitals.

Third, some works on the electric power sector (Bagdadioglu et al., 2007; Kwoka and Pollitt, 2010; Saastamoinen et al., 2017; Mydland, 2020) examine the impact of mergers on operational efficiency. In this sector, the incentive to merge is often dictated by economies of scope, which implies cost subadditivity in the multiproduct case (Saastamoinen et al., 2017). Bagdadioglu et al. (2007) analyze electricity distribution companies in Turkey and note the high potential gains from mergers. Kwoka and Pollitt (2010) focus on the restructuring of the U.S. electric power sector and find no evidence of efficiency improvements following merger activities. Saastamoinen et al. (2017) demonstrate that efficiency gains from the mergers in Norway may vary depending on the assumptions of the regulatory model about the production technology. Finally, Mydland (2020) shows evidence of potential merger gains for some of the Norwegian electricity distribution companies. Interestingly, this work reports that, as a result of the strict separation of all generation and distribution companies within the electricity industry in Norway as of 2021, the losses from not using economies of scope will lead to a cost increase in this industry.

Fourth, the impact of mergers on public service efficiency is investigated in studies like Simper and Weyman-Jones (2008) focusing on police services; Drew et al. (2017) examining the case of municipal mergers in Australia; and Peyrache and Zago (2016) analyzing the efficiency of Italian courts and concluding that the most promising way of boosting the performance of justice is to break up large courts to combat inefficiency. These studies shed light on the potential benefits and challenges associated with consolidating production units within public services. Additionally, research extends to other sectors, such as forestry (Bogetoft et al., 2003), water supply systems (De Witte and Dijkgraaf, 2010; Zschille, 2015), agriculture (Oukil et al., 2024b), hospitality (Oukil et al., 2024a), and transportation (Bai et al., 2019; Wanke et al., 2022), providing a comprehensive understanding of the efficiency implications of mergers across diverse industries.

Finally, merger gains in the education sector have been analyzed at the level of universities and HEIs with diverse results. Abbott and Doucouliagos (2001) and Hu and Liang (2008) were the first to analyze the productivity gains from merging universities using the Malmquist Index. While Abbot and Doucouliagos concluded that the merged Australian colleges of advanced education attained better technical and scale efficiency levels, Hu and Liang found that the short-term effects on these two components in HEI mergers in China were negligible. Additionally, Guijarro et al. (2020), Contreras and Lozano (2022), and Pyra and Siedlecka (2022) simulated the theoretical efficiency gains of merging universities in Colombia, Spain, and Poland, respectively, whereas Agasisti et al. (2021) used the Malmquist Index and a fuzzy regression discontinuity design to conclude that mergers had a statistically positive significance on Russian universities' efficiency over the 2013–2017 period.

Worthy of note are the valuable contributions by Johnes (2014), Johnes and Tsionas (2019), and Papadimitriou and Johnes (2019), each using different methods to analyze the efficiency of merged and non-merged HEIs in England over a period of 17 years. Johnes (2014) used parametric distance functions and DEA to show that merged HEIs achieved significant efficiency gains, compared with non-merged HEIs, regardless of the estimation method used. These results were revisited by Johnes and Tsionas (2019) using a Bayesian dynamic stochastic frontier analysis. They concluded that the efficiency gains delivered in the first instance by the merger soon plateau out. In the same vein, Papadimitriou and Johnes (2019) followed up DEA with a second stage where efficiency scores were regressed against a set of covariates including merger dates as dummies. Their results confirm that the significantly higher post-merger efficiency scores of merged over non-merged HEIs peter out after the first year.

All in all, the problem of calculating merger efficiency gains has been analyzed across different countries and sectors, including education, using different frontier techniques. To the best of our knowledge, however, this paper is the first to examine these effects for university departments within a single university.

3. Case study: UCM

The UCM is a public university in the Autonomous Community of Madrid (Spain). By total number of students, it is Spain's largest university offering on-campus education (MU, 2023). In 2015, UCM had an extremely complex structure made up of 26 faculties, nine affiliated centers, 37 university institutes and research centers, seven professional specialization schools, 184 departments, 36 departmental sections, 14 university clinics and hospitals, 14 research support centers and unique scientific and technological installations, five colleges, two centers abroad, and 32 libraries, apart from other structures not listed here.

Due to its size and history, the UCM is organized around its 26 faculties, which are the academic structures responsible for managing the degree programs and respective administrative infrastructures in their area. This means that the different departments are attached to or based at a single faculty. If a department has a number of lecturers, typically at least 10 academics, attached to a faculty other than the one where it is based, it may be set up as a departmental section. A departmental section is part of the department but has a high degree of organizational autonomy and separate representation on the board of the faculty where it is based.

Looking back through history, Spain's modern-day university departments evolved from the previous university chairs after the 1983 University Reform Act. Academically, they were generally constituted according to the definition of 190 "areas of knowledge." Every academic staff member had to be ascribed to one and only one such area. The sheer number and disparity of these areas of knowledge, some of which were very large and others very small, led to a very fragmented and heterogeneous structure of many small departments being set up at the UCM. Despite the democratization of the departmental decision-making bodies, there was, in practice, a dynamic of fragmentation that often inherited the culture and methods of production of the old university chairs.

Table 2
Descriptive statistics of the previous departmental structure in 2016

Statistics	TAS	PAS	AAT	FTEAS	PB	AB	ECTS
Mean	14	18	31	26	42	11	18,381
Std. dev.	7	9	25	14	30	7	12,079
Median	13	17	26	23	33	9	15,202
Min.	3	3	6	6	2	0	1591
Max.	40	50	281	131	179	38	84,254

Note: See Section 5.1 for an explanation of the last three variables. As a general rule, each department had one administrative officer, regardless of its size.
Abbreviations: AB, active productivity bonuses; AAT, academic staff (All); CSAS, tenured academic staff; ECTS, enrolled European Credit Transfer System; FTEAS, full-time equivalent academic staff; PAS, permanent academic staff; PB, productivity bonuses.

This trend led to the appearance of new departments belonging to the same area of knowledge that were distinguished by a numeral.

Rather than providing an in-depth explanation of the former UCM structure, this paper aims to highlight the complexity of its past departmental organization. For example, Applied Economics is one area of knowledge that was divided, before the mergers, into six departments called Applied Economics I, II, III, IV, V, and VI. These departments were either located at different faculties (in this case, Applied Economics IV and V were based at the Faculties of Law and Politics, respectively) or taught sub-areas of Applied Economics within the Faculty of Economics (I, II, III, and VI). Another example is the Statistics and Operational Research area of knowledge, divided into three departments with the same name and distinguished by the numerals I, II, and III, teaching and researching mainly at the Faculties of Mathematics, Economics, and Statistics, respectively. The last example is the department of Constitutional Law, located at the Faculty of Law, which, because of its teaching workload, also possesses a departmental section based at the Faculty of Media and Communication Science. The descriptive statistics for the departments, including their departmental sections, are shown in Table 2, which highlights the huge interdepartmental disparity.

Against this backdrop, the UCM set out to continue offering a high-quality public service in teaching, research, and knowledge transfer to society, albeit subject to increasing budget constraints due to the global financial crisis. To do this, the UCM embarked upon a process of structural reorganization with the objective of emerging strengthened after the 2015–2019 period. This reorganization was essential to deal with a situation of economic cutbacks, including a policy of very low staff replacement rates, which had hit the university particularly hard due to the high average age of its staff who were not replaced upon retirement.

The principles defining and guiding the reorganization process were written into a master plan (readers interested in more detail and in the disaggregated data of the departments are referred to UCM, 2016). This plan did not merely target cutbacks or savings, which, as a concept, does not make sense for a public service that should, however, try to optimize the efficiency of the resources that society invests in its public universities. For this reason, the plan aimed to free up financial resources, as well as teaching and administrative and service staff, by streamlining the former structure. Some examples of potential savings derived from merging departments are: (a) some academic positions will no longer be needed, (b) purchasing power will be increased as larger material orders could result in more competitive prices or fixed capital investment in equipment will be shared by a bigger group, (c) administrative support staff may also be reallocated and specialize in other functions, for example, teaching or research support. All these freed-up resources can be invested in enhancing teaching and research activities in order to improve the efficiency and competitiveness of the public service that the university provides to the society. Second, the plan aimed to consolidate, modernize, and expand the UCM's offer of degree programs while at the same time increasing teaching and student support quality. The third objective was to strengthen the UCM's internationalization and sustainability by providing more intensive support for teaching and research staff activities. The integration of departments sharing common teaching and research areas should create a new, larger, more diverse, and multidisciplinary structure able to generate virtuous synergies among academics with different successful teaching and research ideas and methodologies. A larger department has the potential to develop competitive research teams able to attract more international research project funding and with greater prospects of transferring technology and knowledge to the productive sector. In addition, the university's internationality should be enhanced as the new departments would have greater visibility and appeal in terms of attracting global talent.

Last but not least, the reorganization of the departments was expected to open up better prospects, both educationally and professionally, for young people looking to begin their research career within a competitive environment. A small department with few or no research groups cannot offer the same opportunities as a strong, multidisciplinary department with greater research diversity that frequently offers scientific seminars, intergroup meetings, and so forth.

4. Methodology

In this section, we develop the methodology for assessing the potential gains from merging university departments. This methodology consists of the following steps and assumptions. Let us assume that we are observing the production of a set of N initially observed DMUs, $i = 1, 2, \ldots, N$ that employ a vector of K inputs $x^i = (x_1^i, \ldots, x_K^i) \in R_+^K$ to obtain a vector of Q outputs $y^i = (y_1^i, \ldots, y_Q^i) \in R_+^Q$. In order to boost the efficiency of this sector, we are interested in implementing a merger process in order to transform the initial N DMUs into a new set of M DMUs, where $M < N$.

To measure the efficiency of each considered DMU, we need to consider a benchmark technology defined by $T = \{(x, y) \in R_+^Q \times R_+^K / x \text{ can produce } y\}$. The production frontier of the estimated technology is given by the set of feasible points $(x, y) \in T$ such that there is no $(x', y') \in T$ where $x' < x, y' > y$, that is, there is no other feasible production plan that produces more with less.

In general, the benchmark technology is unknown, and it has to be estimated from the observed DMUs assuming some additional hypotheses. There are different methods in the literature for estimating the technology T defined above. In this paper, we use non-parametric DEA. This technique was introduced by Charnes et al. (1978) and applies linear optimization programming to obtain a piecewise linear frontier that includes all the efficient units and their possible linear combinations. In what follows, we shall consider that the benchmark technology verifies $\{(x^i, y^i), i = 1, \mathrm{K}, N\} \subset T$, as well as the properties of free disposability, NDRS, convexity, and additivity:

Free disposability: For all $(x, y) \in T$, if (x', y') is such that $x \leq x', y \geq y'$ then $(x', y') \in T$.

Non-decreasing returns to scale: If$(x, y) \in T$ and $\lambda \geq 1 \Rightarrow \lambda(x, y) \in T$.
Convexity: If $(x, y), (x', y') \in T$ and $\lambda \in [0, 1] \Rightarrow \lambda(x, y) + (1 - \lambda)(x', y') \in T$.
Additivity: If $(x, y), (x', y') \in T \Rightarrow (x + x', y + y') \in T$.

The above properties are justified in the context of the case study. To measure the efficiency of a given DMU (x^i, y^i), we use the Farrell input efficiency (Farrell, 1957) given by $E_I(x^i, y^i) = \theta^i = \min_{\theta}\{\theta > 0 : (\theta x^i, y^i) \in T\}$. Farrell input efficiency is an easy representation of a multiple-input multiple-output technology that assumes that outputs are given and calculates the largest equiproportional input vector contraction that the analyzed DMU can carry out in order to reach the benchmark technology production frontier.

DEA yields estimates of the technical efficiency of the set of DMUs included in the analysis. Under an input orientation, the relative technical efficiency of each DMU depends on its ability to reduce the consumption of its inputs without changing its current outputs taking into account the inputs and outputs of the other DMUs. According to Banker et al. (1984), the formulation of the input-oriented DEA linear programming to calculate the Farrell input efficiency of each analyzed DMU (x^0, y^0) against the estimated benchmark technology is given by:

$$
\begin{aligned}
&\theta^0 = \underset{\theta,\lambda}{\text{Min}}\, \theta \\
\text{s.t. } &\sum_{i=1}^{N} \lambda_i y_r^i \geq y_r^0 \qquad r = 1, \ldots, Q \\
&\sum_{i=1}^{N} \lambda_i x_k^i \leq \theta x_k^0 \qquad k = 1, \ldots, K \\
&\sum_{i=1}^{N} \lambda_i \geq 1.
\end{aligned}
\tag{1}
$$

The input efficiency, θ^0, may be interpreted as technical efficiency in an input-oriented framework. Therefore, if $\theta^0 < 1$, then, even though (x^0, y^0) belongs to the technology T, the DMU under evaluation is inefficient as the sample contains other DMUs or linear combinations of DMUs that perform better. When $\theta^0 = 1$, the evaluated DMU is located on the production frontier and is considered efficient and is a benchmark for other inefficient DMUs. Note that the production frontier in (1) exhibits NDRS property because a percentage increase in inputs brings about an equal or more than proportionate increase in the outputs.

DEA has been widely used for benchmarking public service production units due to its well-known advantages. First, DEA is a non-parametric approach, which means that it does not require the specification of a parametric functional form, like the Cobb–Douglas, quadratic or translog production functions, in order to draw the production frontier to measure technical efficiency. Therefore, DEA identifies the most efficient DMUs, allowing managers to emulate the internal management of the best practices, and yields meaningful targets for improvement among inefficient DMUs. Second, DEA can simultaneously analyze multiple inputs and outputs, making it suitable for evaluating the efficiency of organizations not subject to profit maximization. Finally, DEA can account for the potential economies of scale, identifying opportunities for possible scale efficiency improvements in pursuit of the optimal size.

On the other hand, DEA also has some drawbacks (Dyson et al., 2001), especially its sensitivity to input and output selection or input and output data measurement errors that can lead to inconsistent efficiency assessments (Holland and Lee, 2002). Furthermore, unlike parametric methods, DEA cannot be used to calculate output–input elasticities, although it is possible to calculate confidence intervals for the estimated technical efficiency scores (for a review, see Kneip et al., 2008; Moradi-Motlagh and Emrouznejad, 2022).

4.1. Potential gains from merging

Theoretically, when a merger is planned, the expected potential gain of merging two similar units is that, once the process is complete, the new unit will be more productive than the previous two units in terms of the considered outputs given a set of inputs or, alternatively, will, from an input-oriented viewpoint, produce the same with fewer resources. According to Bogetoft and Otto (2011), we can distinguish three primary sources of improvements when merging DMUs referred to as learning effect, harmony or scope effect, and scale effect.

Let us assume an organization composed of N units. All these units define the reference technology T or, in our context, the "pre-merger technology." Let us also assume that the organization is considering merging a subset P of units into one new unit F. Every initial unit uses a production plan (x^p, y^p) for all $p \in P$, and the result will be a new unit F that, immediately after the merger, will produce the sum of the outputs with the sum of the inputs of previous units $(x^F, y^F) = (\sum_{p \in P} x^p, \sum_{p \in P} y^p)$.

Following Bogetoft and Wang (2005) and Bogetoft and Otto (2011), the calculation of the overall potential gain of merging P units into a new unit F includes the following components and necessary steps. First, before the merger process, we have to calculate the technical efficiency of the individual units that are to be merged against the technology set composed of all units T within the organization. This implies calculating the technical efficiency θ^p for all $p \in P$, using the DEA programming in (1) as the individual technical efficiency gains or *learning* gains that could be achieved by each unit before the merger.

Second, we have to calculate the technical efficiency θ^F for the new post-merger unit F with respect to the pre-merger technology using the DEA programming in (1). From this analysis, we obtain θ^F representing the potential overall efficiency gains after the merger. The aim now is to decompose this overall gain into its three main components. To do this, we use the efficient projected input quantities and the outputs of the original units in P, $(\theta^p x^p, y^p), \forall p \in P$, to calculate a new DMU F^* with production plan $(x^{F^*}, y^{F^*}) = (\sum_{p \in P} \theta^p x^p, \sum_{p \in P} y^p)$ obtained by merging the corresponding efficient units of P. The so-called adjusted overall gains from the mergers are calculated as θ^{F*} with respect to the pre-merger technology again using the DEA programming in (1). An adjusted overall gain of less than one, $\theta^{F*} < 1$, suggests that it is possible to obtain more gains on top of the potential individual pre-merger learning or efficiency gains. Note, however, that if $\theta^{F*} > 1$, the merger will generate more costs than gains.

Now, using θ^F and θ^{F*}, it is easy to derive the learning effect of merging the initial DMUs in P into the new unit F as $\mathrm{LE}^F = \frac{\theta^F}{\theta^{F*}}$.

Note that learning effects cannot be directly attributed to the merger process because these potential technical efficiency gains were also present before the merger. Although a merger is an opportunity to boost these savings that would not be available under business-as-usual conditions, we will omit the learning effect from the total sum of savings. Consequently, $1-\theta^{F*}$ indicates the true savings of the merger process through the scale and the harmony effects.

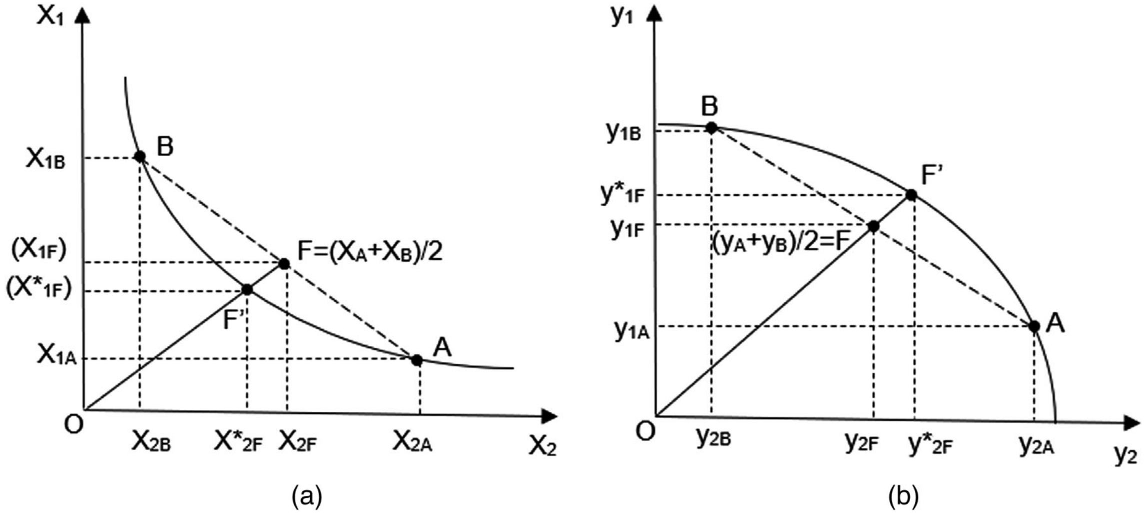

Fig. 1. Harmony effect from the input and output sides. (a) Harmony effect. Input side. (b) Harmony effect. Output side.

The third task is to disentangle harmony and scale effects. The harmony effect, also called the scope effect (Mydland, 2020), is related to the gains that DMUs that are highly specialized in the production of some outputs or, alternatively, make intensive use of some inputs can experience by averaging out their production and/or input use with other DMUs specialized in other outputs or inputs. The harmony effect of the P DMUs in our example can be measured directly as the technical efficiency of a synthetic average unit $\bar{F}$ with respect to the pre-merger technology. To do this, consider a new unit $\bar{F}$ with an average production plan $(x^{\bar{F}}, y^{\bar{F}}) = (\frac{\sum_{p\in P}\theta^p x^p}{P}, \frac{\sum_{p\in P} y^p}{P})$ and then use the DEA programming in (1) to obtain $\text{HE}^F=\theta^{\bar{F}}$. Note that $\text{HE}^F < 1$ indicates potential gains due to the harmony effect, while $\text{HE}^F > 1$ indicates a loss for harmonizing inputs and/or outputs.

Figure 1 summarizes the idea of the gains that can be achieved through the merging of two DMUs developing their production activity with two inputs (outputs) and one equal output (input). In Fig. 1a (1b), we observe two fully efficient production units A and B that are highly specialized in using (producing) inputs X_2 and X_1 (Y_2 and Y_1), respectively. The merged production unit F shows average input (output) values, leaving room $\text{HE}^{AB}=\frac{OF'}{OF}$ for new efficiency improvements. All in all, harmony gains quantify by how much the average input (output) in the production (use) of the average output (input) can be reduced (increased).

Finally, we calculate the size effect of the upscaled average efficient unit. This means first obtaining the new DMU $\tilde{F}$ operating efficiently at full scale as $(x^{\tilde{F}}, y^{\tilde{F}}) = (HE^F \sum_{p\in P}\theta^p x^p, \sum_{p\in P} y^p)$. The size effect is measured using the DEA in (1) as $\text{SE}^F = \theta^{\tilde{F}}$. Note also that the size effect can be calculated even more simply as a residual, $\text{SE}^F = \frac{\theta^{F*}}{HE^F}$. As above, if $\text{SE}^F < 1$, there are economies of scale and the merger is advisable, whereas $\text{SE}^F > 1$ indicates that the new larger DMU is more costly than the previous ones. Using the above calculations, the final decomposition is:

$$\theta^F = LE^F \cdot HE^F \cdot SE^F. \tag{2}$$

4.2. Additional cost savings through regulatory effects

On top of learning, harmony, and scale effects, a merger process can be also useful for automatically reducing the current administrative and managerial costs of the merged units. This occurs when the regulation governing the organization allocates, by law, a fixed budget and set number of administrative staff to each existing unit, regardless of its performance. For example, a unit might necessarily include, by law, a head of the unit to lead, manage, and develop the unit and ensure that it achieves the necessary output standards defined by the organization. The organization's regulations may also define other positions, such as unit deputy head, secretary, administrative staff, and so on.

For this reason, we define a new regulatory effect as the cost savings that automatically ensue by law from the merger. For example, if a unit employs a fixed number of managerial and administrative staff, the merger of two units could mean that the associated costs are reduced by half. In other cases, savings ratios could be less than half or vary depending on the number of units to be merged and the applicable labor regulation.

The general rule for considering regulatory effects as separate from the inputs included in the DEA analysis is that all the DMUs have the same amount of these other inputs. In our empirical case, this includes the current fixed budget for academic and administrative departmental positions, which cannot be arbitrarily increased or decreased depending on performance because there are a set number of positions per department. In this case, it makes no sense to include a new input with the same value for all DMUs in the NDRS DEA analysis defined in (1) because this would lead to the conclusion that all DMUs are efficient. On these grounds, we compute the savings-related gains ensuing from internal regulations separately.

5. Merging departments at the UCM: data, variables, and a numerical example

In this study, we use UCM administrative data from just before and immediately after the merger process that took place on 7 November 2017. After the publication and presentation of the UCM's preliminary Master Plan for Structural Reorganization, different agents within the university engaged in an internal bargaining process. Finally, the UCM's Governing Board (composed of the rector, vice-rectors, deans, and other university representatives) decided that, based on size, 31 departments employing more than 24 full-time equivalent academic staff (FTEAS) would be omitted from the merger process. Accordingly, the merger reduced 153 departments to 66 departments. This is the final result analyzed in this paper.

Regardless of the scientific field that they serve, all departments may be seen as production units whose inputs are academics and whose outputs are teaching and research activities. Variables were selected in order to homogeneously measure the performance of all departments. All information was gathered on 1 January 2017, the year in which the merger took place.

Note that, like any other potential merger process, not all the departments in this real university department merger will merge either because they are already large enough, as mentioned above, or because there are no other departments specializing in a similar knowledge area with which they can merge. However, the observed pre-merger production technology is defined based on all the departments belonging to the same university.

5.1. Inputs and outputs

Abing et al. (2018) provide a comprehensive summary of different approaches for assessing university departmental efficiency. In general, the works considered propose three to eight inputs, including academic and non-academic staff, departmental operating costs, floor space, and budget. Except for the cost associated with the number of academic staff, most of these variables were not relevant to the merger process in this case because they were, in practice, identical across departments. The reason is that all departments had one non-academic staff member for administrative tasks, the same managerial positions (director and academic secretary), and a similar budget covering current expenses. As it does not make sense to introduce input variables that are equally distributed among all DMUs, the respective cost reduction after the merger process is discussed as a regulatory effect in Section 6.3. Another reason for proposing FTEAS as the only input and accounting for other inputs as part of the regulatory effect is to make the main economic outcomes of the merger process plain for managers.

We also considered three output variables. To measure the accumulated amount of research activity, we used the total number of research productivity bonuses (*sexenios* in Spanish) of the academic members of the department. A research productivity bonus or *sexenio* is a six-year period of high-quality research activity recognized by the Spanish National Commission for Assessment of Research Activity. A *sexenio* is granted to researchers who have managed to publish at least five papers in good-quality research journals indexed in well-recognized databases like the Web of Science. Researchers who are awarded a *sexenio* automatically get a salary increase. The criteria for receiving a *sexenio* differ from one research field to another because they are adjusted to what is considered high-quality research in each field. However, the effort required to earn this recognition is similar across all research fields. A department whose members hold more *sexenios* is perceived as being a more prestigious department with greater research experience within the academic profession.

The second output is the number of academics with "*active sexenios*." A researcher with an active *sexenio* is an academic who has received his/her last *sexenio* in the last seven years and is considered to be an active high-quality researcher. A seven-year period is considered for the active *sexenio* because the application for the next productivity bonus is filed at the end of the sixth year or at the beginning of the seventh year, and it takes about six to seven months to get the results, plus the time taken to appeal against a negative decision, if applicable. Although the process might take longer in the event of rejection, the current *sexenio* is considered to be no longer active at the end of the seventh year. Another reason for including active *sexenios* was not to penalize departments composed of on average slightly younger academics, which, by construction, may accumulate fewer productivity bonuses than departments composed of more veteran researchers.

The third output measures teaching workload as the total number of credits in which students taught by academics who are members of a department are enrolled. The European Credit Transfer System (ECTS) is a well-known method for measuring the teaching workload of an academic department and is more accurate than the number of students. Table 3 reports the main descriptive statistics of the outputs and inputs included in the efficiency analysis.

The aim of this input and output selection is to guarantee that UCM departments across different areas and disciplines are treated as homogenous DMUs that are comparable. This sought-after homogeneity is offset by the omission of other dimensions for accounting for research quality beyond the bar defined by the research productivity bonus. First, Spain awards a *sexenio* to researchers

Table 3
Descriptive statistics of variables included in the analysis of the 153 departments considered in the merger process

Variable	Brief description	Mean	Std. dev	Min	Max
Outputs					
ECTS	Number of enrolled European Credit Transfer System (ECTS) credits of subjects in which students are enrolled that are taught by a department	16,279	10,046	1870	57,677
SEXENIOS	Number of research productivity bonuses awarded to academic staff belonging to a department after assessment by the CNEAI	37	23.36	3	168
ACTIVE SEXENIOS	Number of academic staff belonging to a department with an active *sexenio*, that is, earned in the last seven years	9.77	5.28	0	31
Input					
FTEAS	Full-time equivalent academic staff belonging to a department	21.68	8.46	5.38	54.88

Abbreviation: CNEAI, Spanish National Commission for Assessment of Research Activity.

whose publications meet a minimum quality level. However, the quality of two productivity bonuses earned by two researchers in the same field might vary substantially taking into account the number of citations or the impact factor of the journals in which the two academics published their papers.

Second, we decided not to include revenues earned from international, national, and regional research projects (Agasisti et al., 2012), patents (Chen and Chang, 2021), or contracts (Kao and Hung, 2008) as an output. Again, the reason for the omission of this output is to ensure departmental homogeneity for comparability purposes. In this sense, a possible alternative would have been to add this output and carry out the analysis of departments grouped by branches of knowledge (humanities, physical science, social science, life science, and engineering) to take into account that some research fields are able to attract more funding than others.

5.2. Technology and efficiency measure

As mentioned above, the technology considered for this case study is assumed to verify the properties of free disposability, convexity, NDRS, and additivity. Free disposability and convexity are very common properties that are easy to justify in empirical production processes.

Under the assumption of NDRS, constant and increasing returns to scale are possible, whereas decreasing returns of scale are not allowed. This assumption relies on the fact that, in the worst-case scenario, the academics who are members of a newly merged department could refuse to work together. They should, however, be potentially able to at least deliver the same research effort and handle the same teaching workload as before the merger. In most cases, however, some, if not all, of the academics in the new department will be able to interact with each other in order to enhance their teaching, develop their research groups, and collaborate on the preparation of new research projects to apply for broader research calls with more funding than before. Additionally, a larger department will encourage more internal competition for promotion to higher-category positions,

Table 4
A real numerical example of four merged departments before and after their merger

Departments	FTEAS	*Sexenios*	*Active sexenios*	ECTS	TE[a]
Department A	16.750	11	5	10,868	$\theta^A = 0.4464$
Department B	20.500	19	3	19,631	$\theta^B = 0.4751$
Department C	16.250	11	2	13,029	$\theta^C = 0.4861$
Department D	18.375	39	9	11,055	$\theta^D = 0.6226$
Merged department	71.875	80	19	54,583	$\theta^F = 0.3949$
Efficient merged dept.	36.556	80	19	54,583	$\theta^{F*} = 0.7670$
Mean eff. department	9.139	20	4.75	13,646	$\theta^{\bar{F}} = 0.9457$
Merger gains					
Saving effects	Overall θ^F	LE^F	HE^F	SE^F	FTEAS (HE, SE)
Potential gains	0.3949	0.5149	0.9457	0.8110	16.75

[a] Where $\theta^A, \theta^B, \theta^C, \theta^D$ are the technical efficiencies of individual departments A, B, C, and D before the merger; θ^F is the technical efficiency for the potential new department *F* after the merger; $\theta^{\bar{F}}$ is the technical efficiency for the hypothetical average efficient department; and θ^{F*} are the adjusted overall gains from the mergers, using the efficient projected input quantities and the sum of outputs of the original departments. FTEAS (HE, SE) represent the savings in FTEAS as a direct consequence of the harmony and size effects of the merger. All technical efficiency measures are calculated against the technology set T defined by the 184 Complutense University of Madrid (UCM) departments before the merger process.
Abbreviations: HE, harmony effect; SE, scale effect.

thereby boosting the teaching and research efforts of all department staff. Finally, an internationally better-known and more competitive department will also be able to attract more proficient young researchers that will sustain this virtuous circle in the long run.

Table 3 shows that the average department size was just 23 FTEAS, ranging from a minimum of 5.38 to a maximum of 54.88 FTEAS. Given that the average size of an international department is larger than the average size of a UCM department, we assume that UCM departments operate under NDRS. Finally, additivity, which is an essential property for merging units, implies that the sum of the FTEAS of two departments can produce at least the same amount of research and can undertake the same teaching activities.

With respect to the efficiency measure, we chose to use the input orientation. Under this approach, the technical efficiency of each department depends on its ability to reduce the number of FTEAS while maintaining its current research and teaching output, thereby achieving the savings that we seek to measure.

5.3. A numerical example

Before reporting the empirical results for the whole merger process, let us introduce a real numerical example to illustrate all the necessary calculations. We use the case of four UCM departments belonging to the same area of knowledge that were merged into one department. Table 4 shows the real input and output data and the different technical efficiency scores against the reference technology needed to calculate the learning effect, the harmony effect, and the size effect.

Looking at the pre-merger figures, we find that Department D develops more research than its counterparts and is the most efficient department before the merger ($\theta^D = 0.6226$). By FTEAS, Department B is the largest unit and is also responsible for a sizeable teaching workload. Departments A and C are of similar size, although Department A (C) outperforms Department C (A) in terms of the number of academics with active *sexenios* (ECTS). The merger will result in an even more inefficient department $\theta^F = 0.3949$, where this value represents the potential room for gains after the merger. Additionally, $\theta^{F^*} = 0.7670$ measures the adjusted overall gains from the mergers, calculating this efficiency score based on the efficient projected input quantities and the sum of outputs of the original departments.

The aim now is to decompose this overall gain θ^F into its three main components: the learning effects, the harmony effects, and the scale effects. Using θ^F and θ^{F*}, we can derive the learning effect of merging the original four departments into a new one taking the ratio $\text{LE}^F = \frac{\theta^F}{\theta^{F*}} = 0.5149$. In this case, this value represents the distance with respect to the production frontier. Although, as mentioned in Section 4, this technical efficiency effect existed before the merger and cannot be fully attributed to this process.

Therefore, the harmony and the size-saving effects are embedded inside $1-\theta^{F*}$. The harmony effect is $\text{HE}^F = \theta^{\bar{F}} = 0.9457$, suggesting that the available input levels after the merger could lead to more research and teaching. For example, the merged department could offset teaching staff shortages in one of the former departments with surplus teaching capacity from one of the other former departments instead of asking the Rectorate to employ new academics. Finally, the scale effect can be directly calculated as a residual $\text{SE}^F = \frac{\theta^{F*}}{HE^F} = 0.811$.

Multiplying the harmony and size effects $1-\theta^{F*} = 0.2330$, which are fully attributed to the merger, by the sum of FTEAS of the previous four departments (71.875), which now constitutes the new merged department, we find that there is room for a saving of 16.75 academics without any change to the sum of output levels.

6. Results

In this section, we report the empirical results of the case study. First, we estimate all the analyzed effects, interpret the results, and convert them into monetary terms. Second, we examine whether the merger process had an impact on the wellbeing of the academics involved in this process.

6.1. *Efficiency effects, harmony effects, and size effects*

Note that although DEA measures technical efficiency, the proposed input orientation can be used to evaluate the savings made in monetary terms. So, we first calculate the harmony and scale effects on input reductions, which we then convert into euros to be added to the analyzed regulatory savings.

Table 5 shows that the merger process savings are estimated at 289.56 FTEAS, taking into account the harmony and the scale effects, which are accounted for entirely by the mergers. Although we discovered three departments where the merger process resulted in the need for more FTEAS

Table 5
Total savings in FTEAS made through the merger process

	Overall θ^F	Adjusted gains θ^{F*}	Learning effect (LE)	Harmony effect (HE)	Scale effect (SE)	FTEAS (HE, SE)
Mean	0.5574	0.9158	0.6049	0.9587	0.9546	4.3873
Std. dev.	0.1679	0.0839	0.1660	0.0527	0.0620	4.7705
1st quartile	0.4498	0.8992	0.4751	0.9330	0.9419	1.2690
Median	0.5453	0.9366	0.6100	0.9726	0.9802	2.9547
3rd quartile	0.6728	0.9708	0.7296	0.9957	0.9976	6.1702
Min	0.1905	0.6696	0.2588	0.7627	0.7336	−1.5998
Max	0.8917	1.0375	0.9768	1.0375	1.0000	21.1427
Sum	-	-	-	-	-	**289.5648**
N	66	66	66	66	66	66

(−0.18, −1.30, and −1.60) due to harmony effects that were greater than one, the result generally led to a more efficient structure.

To calculate the potential monetary value of the 289.56 FTEAS, we divided the UCM's total budget earmarked for academic staff in 2018 (226,710,358.31 euros) by the FTEAS as of 1 January 2018 (4728 FTEAS) resulting in an average cost of 47,949.42 euros per FTEAS. This means that the potential savings linked to FTEAS, primarily accounted for by academics who do not need to be hired because the current academic staff are able to cover the post-merger teaching and research needs, equals 13,884,463 euros.

6.2. Regulatory effects and total savings

In our case study, a regulatory saving effect occurs when the regulation governing the university allocates, by law, a fixed budget amount to the department. For example, by law, a department might necessarily include a departmental head to lead, manage, and develop the department in order to ensure that it achieves the necessary teaching and research standards defined by the university. University regulations could also include other academic positions, such as departmental deputy head, academic secretary, departmental section head, and so on. Furthermore, internal university regulations also usually define the administrative staff employed at the department to deal with the workload associated with teaching and research activities. As a general rule, all departments have an associated fixed budget.

In our empirical analysis, the input is expressed in units other than cost (FTEAS). Neither does it include all the costs because they are equal for all departments or because they are difficult to divide. For this reason, we prefer to separate the regulatory effect from the other savings effects calculated in Section 6.1.

The merger of departments approved by the UCM's Governing Council on 7 November 2017 led to an internal reorganization of academic, research, and management activity. In the new structure, there were 97 departments and 20 departmental sections, compared to the 184 departments and 36 departmental sections before the mergers. Therefore, academic positions associated with the former departments (director, deputy director, academic secretary, etc.) disappeared, whereas new

Table 6
Economic impact of the merger process at UCM during the 2017/2018 academic year

Regulatory effects	Total (€)
Supplemental pay for academic positions	474,388
Release of teaching and research staff	3,247,614
Reallocation of administrative staff	2,878,700
Sum of savings due to regulatory effects	**6,600,702**
Harmony and size effects	
Savings due to harmony and size effects	13,884,463
Total savings	**20,485,165**

positions were created within the new departments with their respective remuneration and teaching dispensations.

The ensuing savings are based on three types of freed-up resources, which are valued in 2017/2018 academic year euros. First, we computed the salary savings through the reduction of academic positions within the new structure. The annual cost of academic positions before the mergers was 1,342,262 euros, which fell to 867,874 euros with the departmental structure established after the merger process. This implies an annual savings of 474,388 euros.

Second, we estimated the release of teaching and research staff previously employed in management tasks. This figure was calculated as the number of teaching staff equivalent to the hours freed up by management posts that no longer had to be covered by academics who could now concentrate on teaching and research tasks. In this case, the pre-merger teaching dispensations amounted to 48,100 hours, whereas, after the mergers, they accounted for 31,845 hours, yielding a difference of 16,255 hours. A theoretical FTEAS represents a teaching workload of 240 hours per academic year. Therefore, if we divide 16,255 hours by 240, we get savings equivalent to 67.73 FTEAS. If we multiply the cost of an FTEAS (47,949.42 euros) by 67.73, we get annual savings equivalent to 3,247,614 euros.

Finally, we need to sum the release of administrative and service staff previously employed as administrative secretaries of the former departments. The new structure made it possible to remove jobs from the UCM's list of positions, redistribute staff to cover other administrative positions, many of which were vacant because of the recent global economic crisis that hit Spain and many other countries worldwide, and fill the newly created posts in the new departments. This redistribution was carried out without dismissing any employees. All in all, the cost of administrative staff before the merger was 8,463,000 euros, which was reduced to 5,584,300 euros after the merger process, implying savings equivalent to 2,878,700 euros. Table 6 summarizes the list of savings and provides an estimation of the amount saved in euros.

Summing all the concepts, the impact of reorganizing the UCM's departmental structure during the 2017/2018 academic year can be quantified as a saving of approximately 20.5 million euros, which can be employed for other purposes. Note that although Johnes and Tsionas (2019) found that the benefits of mergers for universities were potentially short-lived, this is not the case here. On the one hand, the traditional harmony and scale effects are not straightforward cost savings, as they only represent the space created by the mergers to generate new savings. On the other hand, the sum of approximately 6.6 million euros represented by the regulatory effects (Table 6) is real savings that reproduce and accumulate every year. Therefore, in 10 years' time, say, they will add up to 60.6 million euros in 2017/2018 academic year euros without accounting for a discount rate or any other financial complexity.

6.3. The effects of mergers on the well-being of academic staff

The mergers may well have had detrimental effects on the well-being and morale of academics who were exogenously thrown into what could have been a very stressful process. The merger process as a whole involved a huge effort in terms of meetings and negotiations to reach agreements about which departments would finally be merged. This process was particularly intense throughout 2017, as the mergers finally materialized in November of that year. One way to test this hypothesis is by answering the following questions: Did academics take more sick leave in the merger year or in post-merger years? If sick leave did increase, this could lead to increased staff turnover where the negative impact on teaching quality would also affect student well-being.

To explore the variation in sick leave across faculties, we use a DiD approach, capable of detecting whether the merger process had a significant effect on the number of days of sick leave taken during and after the mergers. Within this framework, our identification strategy uses the set of eight out of the 26 faculties whose departments were not affected by the merger process as the control group, whereas the treatment group are the 18 faculties that were involved in the mergers. Our baseline regression model can be defined as

$$Y_{it} = \alpha + \beta_1 T17_{it} + \beta_1 T18_{it} + \beta_1 T19_{it} + \gamma_t + \gamma_i + \varepsilon_{it}, \tag{3}$$

where Y_{ist} stands for the number of days of sick leave taken in faculty i in year t. $T17_{it}$ is the treatment whose value is one when the departments belonging to a faculty are treated by the 2017 mergers and zero otherwise. Finally, we also include the dummies $T18_{it}$ and $T19_{it}$ to analyze whether the process of integration into the new department as a consequence of the mergers significantly increased the number of days of sick leave taken in 2018 and 2019, respectively. We limit the post-merger analysis to 2018 and 2019 because the COVID-19 pandemic dramatically changed the sick leave patterns at all faculties. Finally, γ_t is a time dummy for every year over the 2014–2019 period, and γ_i includes a set of faculty dummies to take out other intrinsic individual fixed effects. Finally, ε_{it} represents the error term.

Equation (3) accounts for the assumption of common trends, according to which all faculties follow a fixed parallel trend in the absence of mergers. In our case, this is probably not a valid assumption. To deal with this problem, we also relaxed the common trends assumption as follows:

$$Y_{it} = \alpha + \beta_1 T17_{it} + \beta_1 T18_{it} + \beta_1 T19_{it} + \gamma_t + \gamma_i + \sum_{i=1}^{26} \delta_k \left(F_i \cdot \tau\right) + \varepsilon_{it}, \tag{4}$$

In Equation (4), we add a set of interaction terms between the faculty i denoted as F_i and a time trend variable (τ), creating a set of faculty-specific time trends with different slopes for each faculty. In this manner, the estimation can control for unobserved but fixed heterogeneity across faculties

Table 7
The effect of mergers on sick days

	Unweighted regressions			Regressions weighted by faculty size		
	(1)	(2)	(3)	(4)	(5)	(6)
Merger year (2017)	251.7*	173.9	278.2	452.9*	120.8	215.9
	(147.5)	(268.7)	(534.1)	(221.5)	(382.1)	(721.8)
One year after (2018)	30.4	−86.1	174.5	327.6	−170.7	67.1
	(274.6)	(439.4)	(1064.0)	(499.4)	(598.2)	(1404.4)
Two years after (2019)	−37.8	−193.3	286.3	139.7	−524.7	−87.1
	(314.1)	(580.8)	(1849.3)	(458.9)	(851.6)	(2512.1)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Faculty trend	No	Yes	Yes	No	Yes	Yes
Faculty trend squared	No	No	Yes	No	No	Yes
N	156	156	156	156	156	156
R^2	0.156	0.816	0.626	0.155	0.813	0.622

Note: All models include a set of year and faculty dummies. Robust standard errors clustered at the faculty level are shown in parentheses.
*Below the 10% statistical significance threshold.

over time by following the linear trend captured by the coefficient δ_k. Moreover, we assume that other factors that are intrinsic to each faculty, for example, the average age of academics or the percentage of men and women, can change over time in complex and non-linear ways. For this reason, we also relax individual linear trends and introduce a squared term to account for individual non-linear trends. Therefore, the resulting regression can be written as

$$Y_{it} = \alpha + \beta_1 T17_{it} + \beta_1 T18_{it} + \beta_1 T19_{it} + \gamma_t + \gamma_i + \sum_{i=1}^{26} \delta_k \left(F_i \cdot \tau\right) + \sum_{i=1}^{26} \varphi_k \left(F_i \cdot \tau^2\right) + \varepsilon_{it}, \quad (5)$$

where δ_k and φ_k simultaneously capture the individual non-linear trend of each faculty for the number of days of sick leave. Finally, we obtain the parameters of regressions (3), (4), and (5) unweighted and weighted by faculty size measured by the number of academics in 2017.

Table 7 reports the regression results for the six models built from Equations (3), (4), and (5) using a sample of faculties for the 2014–2019 period. We report the results of the unweighted (columns 1–3 in Table 5), and the weighted (columns 4–6 in Table 7) estimations considering faculty size by number of academics.

Baseline models (1) and (4) suggest that the faculties that seriously engaged in the merger process experienced a significant increase in the number of days of sick leave taken by academics in 2017 but not in the following two years. However, when the common trends assumption is relaxed in models (2) and (5), the originally significant effect of participating in the merger process disappears. Coefficients remain positive but are not significantly different from zero. Finally, we introduce specific non-linear faculty trends in models (3) and (6) according to Equation (5). The results show that the coefficients associated with participating in the 2017 mergers are positive but are no longer significant in these specifications either.

In summary, the results show that the intense level of meetings and bargaining during 2017 may have increased the number of days of sick leave taken by academics in 2017, although this increase does not appear to be significant at standard levels. Moreover, this negative effect seems to be limited to the year in which the mergers took place. None of the econometric specifications in Table 6 show significant results for the two years following the mergers.

7. Conclusion

This paper demonstrates the potential usefulness of DEA for evaluating the technical and economic consequences of a merger process. Note, however, that the analysis focuses on the economic evaluation of the merger of departments within a university, which is only one of the dimensions to be considered in a merger process. The estimation of savings is based on the methodology introduced by Bogetoft and Wang (2005). It was decided not to take learning effects into account, even though this might imply an underestimation of the savings made. On the other hand, a regulatory effect was introduced to account for DMU fixed inputs stipulated by law.

The mergers performed by the UCM in 2017 took one year and set up in a new structure consisting of 97 departments and 20 departmental sections with potential savings of around 20.5 million euros. Although this does not constitute a very big percentage of the UCM's budget, whose current expenditure budget was 453.5 million euros in 2018, these savings do in fact account for a sizable increase with respect to the university's free disposal budget, that is, the budget that is not previously committed. Note also that this consolidation process was not just a simple reduction in size but generally led to a more academically coherent outcome.

Moreover, our results suggest that the number of days of sick leave at faculties whose departments participated in the 2017 mergers increased, although not at significant levels. Finally, the mergers had no effect on the number of days of sick leave in the two years following the mergers. We think that this exploratory analysis about the impact of the merger process on the number of days of sick leave warrants more detailed examination in future research, taking into account quarterly data and analyzing by gender, average age, scientific field, or the different merger process intensity levels within each faculty.

Furthermore, we should acknowledge that it may be challenging to effectively explain these methodologies to stakeholders. This is even more important when the democratic decision-making process for merger approval involves multiple stakeholders, like students, academics, staff, and policymakers, with diverse interests in the process. This underlines the fact that the economic perspective should not be the sole factor considered when evaluating a merger. Other aspects, such as rationalizing the offer of university degrees, as well as the well-being of academics and the potential for increasing outputs, must take precedence and be managed through policy.

Looking ahead, it is advisable to conduct a follow-up study to examine the evolution of the new departmental structure after a few years. Key performance indicators include publications, research grants, student applications, program innovations, interdisciplinary efforts, and post-merger staff integration and satisfaction. The timing of measurement is crucial. So far, seven years on, UCM has moved from 226th place in the 2012 QS World University Rankings and 239th place in 2017 to 171st place in 2024. Moreover, the new structure has proven to be stable, as there have been only minor readjustments by the new Executive Board at UCM seven years after the mergers.

Finally, note that, in 2023, the Spanish Government proposed a draft version of a law to define a minimum number of academic staff per department at Spanish public universities, ranging from 35 to 50 academics, to boost the Spanish higher education system. In this sense, this research is a guideline for assessing the economic impact of the forthcoming mergers of departments in Spain and other countries to meet new regulatory requirements. To do this, the UCM's experience provides added value and some practical recommendations for future merger processes. First, it is advisable to start the merger plan with a preliminary proposal following a top-down design, with a strong justification strictly based on academic criteria. Second, the university should provide a time window in which to explain and debate the plan with the higher education community in order to enhance the preliminary proposal. To overcome inertial resistance to change, it is necessary to draw up a final proposal according to which a significant part of the savings made as a result of the merger process is invested to strengthen departments and which includes convincing arguments about the future benefits for all university stakeholders. The objective of this strengthening plan is to enhance the department's economic resources and increase the quality and quantity of administrative staff with a particular focus on the recruitment process. This will support the management of research and teaching activities, thereby enhancing both core missions.

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