

The impact of the economic crisis on the (in)efficiency of public Higher Education institutions in Southern Europe: The case of Spanish universities

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ABSTRACT

The evaluation of university efficiency in Europe began timidly when the European Higher Education Area (EHEA) was created. However, this issue is currently becoming increasingly important in Southern European countries, where the limitation of public funding following the economic crisis in 2008 has put greater pressure on their public universities to achieve excellence and improve competitiveness. In this context, the goals of this paper are: first, to measure the relative technical (in)efficiency of Spanish public Higher Education Institutions in the period 2002–03 to 2012–13, comparing the situation before and during the last economic crisis; and, second, to analyze the determinants of university (in)efficiency and, especially, the direct impact of the crisis. After applying the two-stage double bootstrap DEA methodology, the results show that Spanish public universities have become more efficient during the crisis than before it. In fact, the regression analysis confirms that the “crisis” variable has had a statistically significant positive impact on university efficiency. We also find that age has favorably influenced how these institutions utilize their resources to produce teaching and research outputs, but technical specialization has had a negative effect. Moreover, the regional location of public universities has been also a crucial determinant of their efficiency level. Our findings are therefore relevant for political and academic decision-makers in order to know if public universities have been adequately managed in the crisis period and to identify factors that could improve their efficiency, and hence to help them to enhance their international competitiveness in the future.

1. Introduction

The Bologna Declaration signed in 1999, which promoted the European Higher Education Area (EHEA), introduced for the first time the efficiency criterion in university management to improve the performance of Higher Education Institutions (HEIs) in Europe and make them more competitive internationally [1,2]. This efficiency objective is particularly important for the subsector consisting of public HEIs, especially in an austerity context that requires them to be more productive in the utilization of public resources and to have an unavoidable duty to render accounts to society of their actions [3]. Because most European public universities are likely to produce their outputs using their inputs in a sub-optimal way, a great deal of attention is currently being paid to the evaluation of their performance [4]. Specifically, knowledge of both their efficiency level and the variables that can affect it is very useful to know how well European HEIs have used public funding in their teaching and research activities and to adopt measures to improve their management [5].

Within Europe, the evaluation of public universities' efficiency is becoming increasingly important in Southern countries, whose Higher Education sectors have traditionally been weaker and less developed than those in the rest of the continent [6], and where the recent economic crisis of 2008 is leading to more drastic budget cuts in their university systems, stimulating greater competition for increasingly scarce public funds [7]. All this is putting great pressure on their public HEIs to achieve excellence and improve competitiveness. In a scenario like this, one of the main concerns of political and academic decision-makers is to attain a more efficient and rational management of available resources to guarantee the sustainability of these institutions [8,9]. However, current research assessing the efficiency of public HEIs in Southern European countries is limited, despite the weaknesses of their Higher Education systems and that the vast majority of their universities are publicly financed [9]. In addition, although knowing the factors that might improve the efficiency of public universities is especially relevant for managing them and making them more competitive in the current scenario of globalization of Higher Education, to date, there

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is no prior study focused exclusively on Southern European countries. Furthermore, to our knowledge, only the possible effect of the 2008 crisis on the efficiency of Italian public HEIs has been previously analyzed [10].

In Spain, the evaluation of efficiency in public HEIs first became relevant with the two last legislative reforms in 2001 and 2007, both of which aimed to adapt the national university system to the EHEA [11]. Given that traditionally the inputs used by Spanish universities have increased more than their teaching and research outputs [12], a key challenge of this new regulatory framework was to achieve more efficient use of public resources to increase their competitiveness [13]. In addition, the budgetary restrictions following the 2008 economic crisis have also required Spanish public HEIs to reach higher efficiency levels, all of which has resulted in greater competition among them. Consequently, knowing both the evolution of their efficiency throughout this period characterized by an increasingly competitive environment and the factors that may promote a better adjustment between their inputs and their outputs is becoming a matter of increasing importance for political and university authorities, as well as for society in general. However, to date no research has been conducted in Spain on these two topics. After reviewing the main international databases of peer-reviewed scientific literature, only three studies were found that evaluated the efficiency of Spanish public HEIs, two of them in pre-crisis periods [11,14] and the other during the crisis period [15], although none of them examined the determinants of university efficiency. Our paper aims to fill these research gaps by pursuing a twofold goal: first, to assess the relative technical (in)efficiency of Spanish public universities during the whole period between the 2002–03 and 2012–13 academic years in order to compare the levels achieved before and during the last economic crisis; and, second, to identify the factors behind their (in) efficiency, with special emphasis on the possible impact of the crisis. To achieve these goals, we apply the two-stage double bootstrap Data Envelopment Analysis (DEA) methodology, as recent studies recommend applying bootstrapping techniques to evaluate efficiency in the context of public Education [16].

This research contributes to the literature in several ways: First, given the great interest that both governments and universities currently have in evaluating university efficiency in Southern Europe, we provide new data on the efficiency of its public HEIs, adding empirical evidence to the limited research carried out to date. In particular, this paper focuses on Spain, which is a good study reference for Southern European countries because the characteristics of its Higher Education system and the impact of the crisis on it resonate with those of Italy, Portugal and Greece [7]. Second, our study covers a fairly long period and, with a longitudinal approach, it compares for the first time university efficiency in Spain in two periods: pre-crisis and crisis. Third, in view of the lack of empirical evidence for Southern Europe, we analyze the main determinants of efficiency in Spanish public HEIs and, especially, the direct impact of the crisis. Fourth, from a methodological perspective, we apply the two-stage double bootstrap DEA methodology, which allow us to reach more robust and generalizable results than the methods traditionally used in this research area.

2. Literature review

2.1. Public Higher Education systems in Southern Europe: an overview

All Southern European countries (Portugal, Italy, Greece and Spain) have shared similar attributes regarding their public university systems, which have been weaker than those in Northern and Central Europe for decades, and they are still developing today due to they have not rapidly adapted to the global context of Higher Education and the changes it entails [7]. In particular, their main weaknesses have traditionally been the following [6,17]: (a) the lack of competition among HEIs increasing the role of government in funding them; (b) poor teaching and research performance, since the public funds each university receives are based

on input measures (for example, number of students) without any reliable evaluation of their outputs; (c) the underfunding by government; (d) an excessive control by government implying low levels of financial and organisational autonomy for HEIs, and limited strategic capacity; (e) the problems of inbreeding, lack of meritocracy, nepotism, etc. that may be related to poorly qualified staffs; and (f) the mismatch between Higher Education and labour market requirements.

The last economic crisis has amplified the chronic crisis of public Higher Education systems in Southern Europe because these countries have been hit by the crisis harder than other European countries, and the negative impact of austerity policies on their university sectors has been more severe due to they were poorly equipped to adapt to the new environment of shrinking resources [18]. Specifically, in Greece, the external interference of international creditors represented by a troika forced the dismissal of thousands of university professors and researchers, and a contingency budget that eliminated most of the elementary services of public universities. In Italy, Portugal and Spain, the radical cuts in Higher Education budgets have jeopardized their basic functioning in last years. On average, a decrease by more than 10% in the public expenditure on Higher Education, as a percentage of Gross Domestic Product (GDP), can be perceived in Southern European countries between 2008 and 2013 [17].

The limitation of public funding following the crisis together with the challenges of globalization, demographic change and technological innovation have placed even greater emphasis on increasing the quality of public Higher Education systems in Southern Europe. In this context, one of the main concerns of political and academic decision-makers has been the need to achieve a more efficient management of public HEIs through policy interventions aimed at stimulating competition among them to improve their competitiveness [8,9]. Despite this, there are hardly any previous studies that have analyzed the impact of the 2008 crisis on university efficiency in Southern European countries. Our study addresses this issue by focusing on the Spanish Higher Education system.

2.1.1. The Spanish case

Up to the 1970s, the Higher Education sector in Spain was homogeneous, elitist, focused on teaching and detached from the country's needs. But, during the following decade, a number of factors brought an important process of change to the Spanish university system [19]: (a) the rise in the population; (b) economic growth; (c) a more qualified workforce motivated by growing unemployment; (d) private profitability of university studies for graduates in terms of higher remuneration; (e) the rise in compulsory schooling; (f) the increase in public investment in Higher Education; and (g) the creation of new universities. This situation facilitated access to university education, boosting the number of students in Higher Education. In addition, research activity was also stepped up and new competencies, such as the transfer of knowledge to society, were attributed to universities. Thus, legislative reform became necessary.

In the 1980s, the *Organic Law 11/1983, dated 25 August, on University Reform (LRU)*, was passed, triggering political and administrative decentralization of Higher Education from the central government to the regions. Since then, the financing and management of Spanish universities depends on the policies and strategies adopted by regional governments, which have full authority to decide the level of public direct funding, the tuition fees that residents in the regions should pay, if they set up additional regional R&D funding strategies, etc.

After the Bologna Declaration in 1999, which lays the foundations for the creation of the EHEA, the Spanish Higher Education system had to adapt to European requirements. The two last legislative reforms, the *Organic Law on Universities 6/2001, dated 20 December (LOU)*, subsequently amended by the *Reform of the Organic Law on Universities 4/2007, dated 12 April (RLOU)*, created a new legal context aiming to improve the performance in the Spanish university system [13]. Shortcomings in the quality and international relevance of the educational services provided by public HEIs in Spain and their inadequate

management of the resources available had traditionally given rise to problems regarding their efficiency and international competitiveness. In general, the university resources used had increased more than the teaching and research outputs generated, and there had been doubts about the economic and social contribution of public Spanish universities because the return on the investments made over many years had been limited by the inefficiencies of the institutions themselves and by the characteristics of the country's production fabric [12]. In this context, both the *LOU* and the *RLOU* introduced certain technical measures aimed at promoting university efficiency [11]: (a) restructuring of Higher Education into three cycles – bachelor's degree, master's degree and doctorate – to endorse the role of students and improve their training and employability; (b) introduction of a new promotion and accreditation system for academic staff based on reliable evaluations of teaching and research activities; (c) improvement of relations between universities and firms; and, finally, (d) promotion of international mobility of students and academic/administrative staffs, as well as collaboration between Spanish and foreign universities.

However, several difficulties arose in the execution of these measures, coinciding with the decline in government spending on Higher Education that occurred after 2008 as a consequence of the crisis. On the basis that the bulk of the income of Spanish public universities is the block grant assigned by their respective regional governments (80% approximately), their funding as a percentage of GDP decreased by 16.2% between 2008 and 2013 [17]. More specifically, expenditure per university student as a proportion GDP per capita dropped by 15% in Spain. This reduction in public funding, together with the greater concern for increasing the Higher Education performance, led to the implementation of pro-competitive policies in the Spanish university sector – for example, the growing link between government economic support and outstanding results, or the stricter requirements from the public quality assurance agencies for both the evaluation of research activity and the promotion of teaching staff –, which has resulted in greater competition among HEIs. All this have exerted even more pressure on public Spanish universities to achieve excellence and improve international competitiveness, so that knowledge of the evolution of their efficiency, comparing the situation before and during the crisis, has become a matter of increasing importance for political and university authorities.

During the period between the implantation of the *LOU* in 2002 and the end of the last economic crisis in 2013, the Spanish Higher Education system was comprised of 77 HEIs of which 50 were public universities (approximately 65% of the total). Of the public HEIs, 47 were campus-based institutions, one was for distance learning, and the other two only taught specialist postgraduate programmes. In Spain, public and private universities are embedded within the same regulatory framework, which assigns them the same basic activities – teaching and research –. However, public universities are constrained by greater regulation and control mechanisms than private universities. These differences regarding autonomy with their different nature entail distinct internal organisational structures for the development of the same activities, that is, different managerial procedures for consumption of the same inputs to produce the same outputs [15].

2.2. Evaluation and determinants of efficiency of public Higher Education systems in Southern Europe

The efficiency of an organization can be analyzed from two different points of view [20]: *technical efficiency*, which refers to the best possible relation between the amounts of inputs used and of outputs obtained, and *allocative efficiency*, which refers to whether the best possible combination of inputs is being used at current market prices. The concept that best adapts to evaluate whether public universities are performing efficiently is that of technical efficiency, which ranges from 0% – *fully inefficient* – (when HEIs have obtained 100% less than the maximum level of outputs that might be expected if they have used their inputs

better) to 100% – *fully efficient* – (when HEIs have obtained the maximum level of outputs that might be expected from their inputs), because it is more related to the assessment of the efficiency on the public service provision whereas the allocative efficiency is more related to market criteria [4].

Over the last few years, renowned academics in the field of the Economics of Education have considered it relevant to evaluate the efficiency of the public HEIs, especially because of the need for them to be accountable for the way the resources provided by citizens are used, and to assess the excellence of such institutions in a highly competitive environment [3,5,21]. Empirical research on this topic is therefore becoming increasingly important at an international level in recent years [4].

Within Europe, country-specific research has been mainly focused on the United Kingdom. While some prior studies [22–25] showed good values for average technical efficiency (around 90%) in British public universities in some academic year before the last crisis, the recent study by Ref. [26] found that their mean efficiency decreased over a 17-year period (between 1996–97 and 2012–13 academic years), obtaining a value close to 70% during the crisis period.

In Southern Europe, there has been limited research on the technical efficiency of public HEIs, which has been mostly carried out in Italy and Spain. Among the country-specific studies for Italy [27], considered a sample from 58 HEIs in the 2002–2003 academic year, showing an acceptable average efficiency value (85%). More recently, both [8,9] examined 53 universities over the 4-year period 2008–2011 and found that Italian public HEIs increased their efficiency as the crisis progressed, obtaining mean scores of around 89%. For Spain [15], compared the efficiency of 47 public HEIs in the 2009–10 and 2013–14 academic years, showing an increase of 70%–79%. With a longitudinal approach [11], evaluated 39 universities over a 7-year period (between the 2002–03 and 2008–09 academic years), obtaining an average level of efficiency of 86.1%, whereas [14] reported a mean value of 88.4% in a sample of 44 institutions over a 3-year period (between the 2006–07 and 2008–09 academic years).

Previous research has also evaluated the efficiency of European public HEIs from a cross-country perspective: first, the study by Ref. [28] compared the university efficiency levels in two Southern European countries, Italy and Spain, in the 2000–01 and 2004–05 academic years, finding that the efficiency of Italian and Spanish HEIs was similar in 2000–01, while the former were more efficient than the latter in 2004–05. Second, other studies compared the efficiency of public HEIs in a Southern European country, Italy, to that of universities in other European countries such as the United Kingdom [29], Germany [30], and Netherlands [21], before the recent crisis. All of them found that Italian institutions underperformed their European counterparts. Third, only one study compared the efficiency of Italian public HEIs to that of institutions in another European country – Poland – before and during the crisis [31]. The findings showed that, on average, Italian universities turned out to be less efficient than Polish ones over the whole period 2001–11. Moreover, the public HEIs of both countries improved their average efficiency during the crisis period compared to the previous academic years. Lastly, two studies assessed university efficiency in several European countries. While [32] focused on seven European countries (only Italy from Southern Europe) in the period 2001–05, finding that, on average, Swiss universities were the most efficient [2], examined a sample of HEIs from ten European countries (Italy and Spain from Southern Europe) during the whole period 2000–10, showing that, on average, English and Polish universities performed more efficiently than those from the rest of Europe.

After reviewing the literature on the factors that explain how well European public HEIs have used their resources to produce their outputs [2,30–32], five potential determinants of university efficiency can be highlighted: *Size*, *Age*, *Specialization in technical fields*, *Degree programs in Medicine and/or Pharmacy*, and *Regional location*. Table 1 gives an overview of the empirical studies on each determining factor,

Table 1
Efficiency determinants in European public universities.

Variables	Authors and samples	Theoretical arguments	Findings
Size	[32] HEIs from 7 European countries (only Italy from Southern Europe) [31] HEIs from Italy and Poland [2] HEIs from 10 European countries (only Italy and Spain from Southern Europe)	<u>Positive effect:</u> The largest universities can benefit from the achievement of economies of scale, which may lead to more efficient management. <u>Negative effect:</u> The largest universities tend to be slower and less flexible in organisational terms, which may lead to possible waste of resources and hence to less efficient management.	A positive and statistically significant effect on university efficiency
Age	[32] [2]	<u>Positive effect:</u> The experience, know-how and lower operating costs associated with the more mature universities, as well as the privileges provided by their reputation, may help to improve their efficiency. <u>Negative effect:</u> Younger universities can benefit from both their greater flexibility and adaptability to changes in their environment and their greater possibilities of having more modern structures that allow them to manage their resources better, all of which may improve their efficiency.	A positive and statistically significant effect on university efficiency
Specialization in technical fields	[2]	<u>Positive effect:</u> The teaching and research specialization of technical universities can be seen as a differentiation strategy that seeks to position their activities in relation to their generalist competitors, in addition to implying the need to invest only in specific resources for specialized services they offer, all of which may increase their efficiency. <u>Negative effect:</u> The offer of a more limited range of academic degrees, the higher dropout rate, the need for greater amounts of highly specialized resources and the lower scientific production of technical universities compared to their generalist counterparts may reduce their efficiency.	A negative and statistically significant effect on university efficiency
Degree programs in Medicine and/or Pharmacy	[30] HEIs from Italy and German [32] [2]	<u>Positive effect:</u> Offering degree programs in Medicine and/or Pharmacy brings more prestige to universities and this can attract the best students and teachers, which may lead to a more efficient management. <u>Negative effect:</u> Universities with degree programs in Medicine and/or Pharmacy need more human, physical and financial resources than those without them, which may reduce their efficiency.	A positive and statistically significant effect on university efficiency A negative and statistically significant effect on university efficiency
Regional location	[30] [31] [2]	The heterogeneity existing among the different regions of a country –especially in terms of government policies, regulation, and macroeconomic conditions– may help to explain the differences in efficiency of their public universities.	There is a statistically significant regional effect on university efficiency

Source: Compiled by authors.

summarizing both the theoretical arguments offered by them to explain the possible effects on university efficiency and their main findings. As shown, to date, there is no previous research focused exclusively on Southern European countries.

In addition, given that the 2008 economic crisis has led to a reduction in public expenditure on Higher Education in all Southern European countries, it is also interesting to analyze its possible impact on the efficiency of public universities in Spain:

- **Crisis:** On the one hand, the decline in government spending on Higher Education could make it difficult for public HEIs to carry out their teaching and research activities because, in general, public funding is their main source of revenue, so their level of efficiency would be reduced. On the other hand, in an austerity scenario like this, political and university authorities could react by setting up initiatives to increase teaching and research outputs through pressure on competitive resources, thus improving university efficiency [18]. From the empirical point of view [10], conclude that the last crisis has had a positive impact on university efficiency in Italy, but the opposite effect in Germany.

3. Research design

3.1. Methods

We apply the two-stage double bootstrap DEA methodology, Algorithm 2, proposed by Ref. [33]. In the first stage, efficiency scores are calculated combining the DEA model with the bootstrap procedure. In the second stage, efficiency estimates are regressed on a set of exogenous variables using the truncated regression with bootstrap. This procedure

is performed using *FEAR*® (Frontier Efficiency Analysis with R) software [34].

3.1.1. First stage: bootstrap DEA efficiency estimates

Efficiency is analyzed by means of Data Envelopment Analysis (DEA), which is the most international accepted estimator for evaluating organisational efficiency [35]. Specifically, it is a deterministic and non-parametric method based on a linear programming model that calculates the relative efficiency score of a given organization (Decision Making Unit – *DMU*, in this case, a public HEI) in comparison with the performance of other homogeneous organizations by constructing an efficient frontier where the best practices are situated. Therefore, an inefficient behavior is determined by the radial distance between the *DMU* under analysis and the boundary where the efficient entities are located.

This methodology has been applied successfully in different management contexts. We consider that it is appropriate for measuring efficiency in public HEIs for the following reasons: first, it allows employing multiple outputs and multiple inputs at the same time, regardless of the different measurement units, and this feature is particularly important for settings such as Higher Education; second, it does not need information about input or output prices, which is relevant in the field of public University, where prices are usually unknown or established by the Administration; third, each *DMU* is assigned a single efficiency score that allows ranking amongst the *DMUs* in the sample; fourth, this method provides information about the areas of improvement for each single *DMU*; and finally, it does not require a preconceived functional form of the production function.

The initial DEA model was developed by Ref. [36] and assumed constant returns to scale (CRS). It was based on the concept of efficiency

originally proposed by Ref. [20]. Later [37], extended this to variable returns to scale (VRS). In the present study, following other researches on the efficiency of public HEIs [2,23,31], we use a DEA model under variable returns to scale (VRS) because CRS DEA model is only appropriate when all organizations operate at an optimal level of scale, and the existence of technological advances, imperfect competition, government regulation changes and budgetary constraints, as well as regulatory constraints on entry, mergers and exits may have different impacts across HEIs of different size. Additionally, given that the institutional managers cannot control the inputs, at least in the short run, we implemented an output-oriented DEA model, which tries to maximize outputs while using no more than a given inputs level. Accordingly, the *conventional efficiency* estimator for the DMU_i ($\hat{\delta}_i$) is obtained by solving the following linear programming problem (Eq. (1)), which must be resolved n times, one for each DMU in the sample,

$$\hat{\delta}_i = \max_{\delta, \lambda} \left\{ \delta > 0 \mid \hat{\delta}_i y_i \leq \sum_{j=1}^n y_j \lambda_j; x_i \geq \sum_{j=1}^n x_j \lambda_j; \sum_{j=1}^n \lambda_j = 1; \lambda \geq 0 \right\}; \quad i = 1, \dots, n \text{ DMUs} \quad (1)$$

where x_i is the vector of inputs; y_i is the vector of outputs; λ is an $n \times 1$ vector of constants which represent the weights used to calculate the location of an inefficient DMU in order to become efficient; and $\hat{\delta}_i$ is the efficiency score for the i th DMU under the VRS assumption. Thus, each DMU is assigned an efficiency indicator between 0 and 1, so that if $\hat{\delta}_i = 1$, the DMU_i can be considered fully efficient, whereas if $\hat{\delta}_i < 1$, the DMU_i will be relatively inefficient.

However, despite its advantages, the conventional DEA model also suffers from some limitations such as high sensitivity to the presence of outliers and, above all, the absence of statistical properties due to its deterministic nature, which generates biased efficiency estimates [38]. To mitigate this last drawback, as in the recent study by Ref. [16]; we calculated a statistically-modified version of conventional DEA scores, based on the bootstrap procedure by Ref. [39]. These authors proposed a smooth bootstrap on DEA estimates by drawing with replacement from the original estimates, which involves the generation of pseudo-data and the approximation of the unknown distribution of efficiency scores using the distribution of bootstrap values. As a result, a set of *bias-corrected efficiency* scores is obtained (denoted by $\hat{\hat{\delta}}$). Nevertheless [39], advise that bias-corrected efficiency scores should only be used when the following ratio r_i is well above unity (Eq. (2)),

$$r_i = \frac{1}{3} \left(\widehat{\text{bias}}_B^2[\hat{\delta}(x, y)] / \hat{\sigma}^2 \right) \quad (2)$$

where r_i is a statistical test value, which allows us to assess whether the bias correction might increase mean square error; $\hat{\sigma}^2$ is the variance of the bootstrap values; B is the number of replications and $\hat{\delta}$ is the original efficiency estimate. This issue is also considered in our empirical study, so the resulting *useful efficiency* indices are denoted by $\hat{\delta}$.

Although many studies have applied the conventional DEA method to cross-sectional data in the context of public Higher Education, the most recent literature deals with panel data, which allow to obtain more reliable evidence of the management carried out by the universities, since the performance of each DMU can be analyzed over time. Therefore, following [40]; we develop a dynamic DEA model and define an inter-temporal reference technology constructed by pooling the data from all years and DMUs. Specifically, this study applies a bootstrapped VRS and output-oriented DEA model in which each DMU is treated as if it were a different observation in each period in order to evaluate the dynamic management of the different DMUs, to know their trend and to show the stability of the efficiency results.

3.1.2. Second stage: bootstrap truncated regression

The two-stage DEA analysis is applied to examine the determinants of university efficiency. A common practice in the DEA literature in the field of Higher Education is to use different regression models, such as Ordinary Least Square (OLS) or censored (Tobit) regression, to carry out the second stage. However, these regression models were criticized by Refs. [33,41]; who point out that they may produce biased and inconsistent parameter estimates due to correlation and dependency problems of the efficiency scores that may violate the regression assumptions, thus invalidating the results of statistical inference. Furthermore, these authors suggest that truncated regression adjusts better to provide evidence about the potential determinants of efficiency scores. Indeed [41], demonstrated that the two-step bias-corrected estimator proposed by Ref. [33] is the only known method that ensures a feasible and consistent inference on the second stage regression.

Therefore, as in some recent studies evaluating efficiency in Higher Education [2,31], we follow the bootstrapping truncated regression procedure included in the second stage of Algorithm 2 introduced by Ref. [33]; where the useful efficiency scores ($\hat{\delta}_i$) yielded in the first stage of the analysis are regressed on a set of exogenous factors, specified as follows (Eq. (3)):

$$\tilde{\delta}_i = \alpha + \beta z_i + \varepsilon_i, \quad i = 1, \dots, n \quad (3)$$

where α is a constant term; β is a vector of the parameters to be estimated; z_i is a vector of exogenous variables that are expected to affect the efficiency of the i th DMU (they must meet the requirement established by Ref. [33] of not affecting universities' production processes but of being able to affect their performance); and ε_i is an error term assumed to be $N(0, \sigma_\varepsilon^2)$ distributed with right truncation at $(1 - \alpha - \beta z_i)$.

3.2. Population and sample

Our population comprises the 47 campus-based public HEIs existing in Spain between the implantation of the LOU in 2002 and the end of the last economic crisis in 2013. As data on the Spanish Higher Education system are published every two years, the period of study covers the six alternating academic years between 2002/03 and 2012/13. The initial sample therefore consists of 282 DMUs or observations.

The presence of outliers is a serious limitation for the DEA methodology, because they may increase sample noise and distort the results. Therefore, before calculating efficiency, they must be detected and eliminated from the sample. We used the methodology devised for this purpose by Ref. [42]. After removing the three identified outliers, the resulting final sample comprises a total of 264 DMUs or observations (44 public HEIs x 6 academic years).

3.3. Variables

One of the critical points to measure efficiency in the Higher Education sector is to select the input and output variables that determine its complex production function, for which data availability, which has traditionally been a restriction in Spain, is essential. We follow the studies by Refs. [2,32] who, focusing on European public HEIs and covering the two main university activities – teaching and research –, consider three inputs and two outputs. Specifically, the input variables include the main human and financial resources used by public universities to achieve their outputs: *Enrolled students*, *Academic staff* and *Total revenues*. The output variables refer to the universities' main teaching and research results generated from resources at their disposal: *Graduates* and *Publications*.

Regarding the determinants of university efficiency, the five exogenous factors considered are [2]: *Size*, *Age*, *Specialization in technical fields*, *Degree programs in Medicine and/or Pharmacy*, and *Regional location*. In addition, since one of the main goals of this study is to analyze the possible impact of the 2008 crisis on the efficiency of Spanish public

universities, an additional explanatory variable was included in our model (*Crisis*).

Definitions and descriptive statistics of input and output variables and of those that measure the efficiency determinants are shown in Table 2. Analysis of the variance inflation factor (VIF) of the latter shows that all the values are below 5, indicating that there are no multicollinearity problems [43].

The data about all these variables were collected from the websites of the Council of Rectors of Spanish Universities (CRUE) (www.crue.org), of the Ministry of Education, Culture and Sports (www.mecd.gob.es), of the National Statistics Institute of Spain (www.ine.es), and of each of the universities analyzed, as well as from the Web of Science (www.webofknowledge.com). Data expressed in monetary units were deflated at constant prices for 2002 by using the GDP deflator (www.bde.es).

4. Results and discussion

4.1. First stage: university efficiency scores

In the first stage of the methodology proposed by Ref. [33], the DEA model was applied together with the bootstrap technique (with 2.000 repetitions and a confidence level of 95%) to estimate the values of relative technical efficiency in Spanish public HEIs from a complete data panel made up of 264 DMUs or observations. Table 3 shows mean and standard deviation values of the conventional ($\hat{\delta}$), bias-corrected ($\hat{\delta}^*$) and useful ($\hat{\delta}^u$) efficiency indices, for both the total period (2002–03 to 2012–13) and each sub-period: pre-crisis (2002–03 to 2006–07) and crisis (2008–09 to 2012–13). It also reports the number and percentage of fully efficient observations in each case. The values considered to interpret the results are those referring to useful efficiency, which ranges from 0% ($\hat{\delta} = 0$: fully inefficient) to 100% ($\hat{\delta} = 1$: fully efficient). These efficiency scores must be interpreted cautiously as they are relative to best observed practices within our particular sample.

The estimates show that the mean value of university efficiency for the overall period was 58.38% – only slightly above 50%, which is the minimum tolerable value for estimates of technical efficiency [40]. This suggests that Spanish public HEIs generated on average 41.62% less than the maximum level of university outputs that might be expected if they had used their human and financial resources better. In other words, they should have increased their teaching and research outputs

by 41.62% from the available inputs to be fully efficient and thus reach the efficiency frontier where the best practices are located. Specifically, only 5 of the 264 observations were totally efficient, meaning that the most technically efficient HEIs, which should work as ideal benchmarks in the sector, only represented 2.27% of the total observations. This shows that a great portion of public universities in Spain were working inefficiently between the 2002–03 and 2012–13 academic years, contributing to a significant waste of resources. It can therefore be concluded that during this period there was a clear sub-optimal allocation of human and financial inputs in the Spanish Higher Education system, to the detriment of teaching and research outcomes. This efficiency gap requires some explanation that can be useful for defining consistent policies that may lead to a more rational management of resources in public HEIs in Spain, following the example of the more successful peers in the sector.

Analysis by sub-periods points to a considerable increase by almost 27% in the average efficiency of Spanish public universities during the crisis period in comparison with the previous academic years, from 51.51% to 65.25%. Moreover, only one observation was totally efficient before the crisis, increasing to four during it. This means that, in spite of budgetary restrictions and the consequent reduction in some university resources, public HEIs in Spain generated higher levels of teaching and research outputs during the last economic crisis than before it. According to our data set, between the two sub-periods, their number of graduates and high-quality publications increased on average by 29.2% and 63.7% respectively, given the inputs at their disposal. This better management of the human and financial resources used by Spanish public HEIs during the crisis period contributed to greater homogeneity among them, bringing their efficiency levels closer to the frontier where the best practices in the sector are found. Our findings, therefore, coincide with those found for Italian public HEIs, which also improved their average efficiency in the crisis period compared to the pre-crisis period [31].

Fig. 1 represents, through a black dotted line, the position taken by the 132 DMUs or observations analyzed in each sub-period (pre-crisis and crisis) regarding the university efficiency scores, sorted from lowest to highest value. As shown, while 47.73% (63 out of 132) of the observations show efficiency scores below 50% before the crisis ($\hat{\delta} < 0.5$), so that they can be considered technically very inefficient, this percentage drops to only 12.88% (17 out of 132) during the crisis.

Another interesting insight of this Figure is about the different

Table 2
Definitions and descriptive statistics of variables.

	Definition	Mean	SD	Minimum	Maximum
Input variables					
Students (ST)	Number of students enrolled in official teaching, at all university levels, in one academic year	22842.94	13360.03	4419	67175
Academic staff (AS)	Number of teaching and research staff, in one academic year	1786.44	978.30	419	4472
Total revenues (TR)	Total amount of university revenues, in thousands of euros, in one year	168706.10	107394.07	30613.54	609789.85
Output variables					
Graduates (GRAD)	Number of graduates from official teaching, at all university levels, in one academic year	3478.49	2012.93	512	10103
Publications (PUB)	Number of scientific articles published and indexed in the ISI Web of Science, in one year	584.53	449.38	45	2269
Determining factors					
Size (SIZE)	Number of academic degrees offered by universities	46.90	20.47	11	113
Age (AGE)	Number of years since the creation of universities	132.48	218.80	4	794
Specialization in technical fields (TECH)	1 in those universities with a teaching and research specialization of a technical nature, and 0 otherwise	0.20	0.40	0	1
Degree programs in Medicine and/or Pharmacy (M&P)	1 when universities offer degree programs in Medicine and/or Pharmacy, and 0 otherwise	0.57	0.49	0	1
Regional location (REG)	Universities' location within Spain (16 regional dummy variables ^a)	–	–	–	–
Crisis (CRISIS)	1 in the three academic years corresponding to the crisis period (2008–09, 2010–11 and 2012–13), and 0 otherwise	0.50	0.50	0	1

n = 264 observations.

^a In geographic terms, Spain is divided into 17 Autonomous Communities (regions), with different regional governments financing and managing public universities, and with different macroeconomic characteristics.

Table 3
University efficiency estimates.

Period	Conventional efficiency ($\hat{\delta}$)	Corrected efficiency ($\hat{\hat{\delta}}$)	Useful efficiency ($\hat{\delta}$)
Total: 2002–03/2012–13 ($n = 264$)			
Mean	0.6446	0.5685	0.5838
SD	0.1702	0.1438	0.1562
Fully efficient observations	16	0	5
Fully efficient observations (%)	6.06%	0.00%	2.27%
Pre-crisis: 2002–03/2006–07 ($n = 132$)			
Mean	0.5656	0.5016	0.5151
SD	0.1457	0.1273	0.1427
Fully efficient observations	3	0	1
Fully efficient observations (%)	1.14%	0.00%	0.38%
Crisis: 2008–09/2012–13 ($n = 132$)			
Mean	0.7236	0.6354	0.6525
SD	0.1561	0.1277	0.1381
Fully efficient observations	13	0	4
Fully efficient observations (%)	4.92%	0.00%	1.52%

Note: The percentage (%) is based on the 264 observations in the sample.

positions taken by the blue contour lines. Although in the pre-crisis period we can observe two peaks, above and below the 50% efficiency level in which most universities are concentrated, during the crisis period there is a lower dispersion of the efficiency levels and a closer approach of them to best practices located on the frontier. This confirms that, to improve the quality and performance of the public Higher Education system and guarantee its sustainability, Spanish HEIs achieved a better use of public funds during the last crisis than before it, since they produced a greater number of graduates and quality academic publications despite the limitations in their human and financial resources.

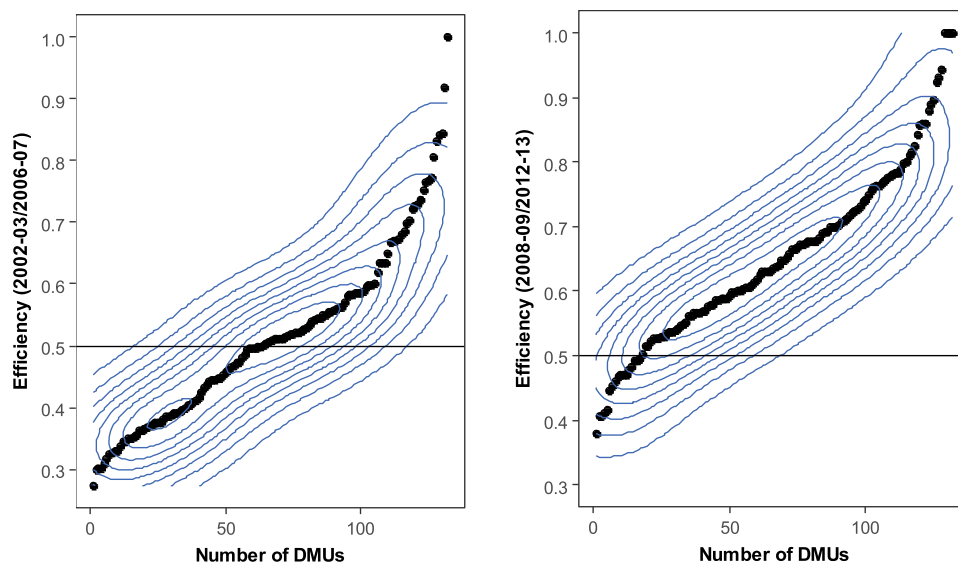
Fig. 2 displays a graphical representation of the evolution of average

efficiency in Spanish public universities over the six alternate academic years between the implantation of the LOU in 2002 and the end of the last economic crisis in 2013. As shown, after a continuous drop in efficiency levels during the three academic years corresponding to the pre-crisis period due to the weaknesses of the Higher Education system in Spain, strong and constant growth began in 2008–09 year, reaching maximum efficiency in 2010–12 and remaining practically stable in 2012–13. Therefore, although the economic crisis had begun, university performance showed a clear recovery after the 2008–09 academic year, that is, after both the first steps towards adaptation of the Spanish university system to the EHEA and the implementation of the first austerity measures by government. On a policy ground it is interesting to notice that, according to the studies by Ref. [15] for Spanish public HEIs and by Refs. [8,9] for Italian institutions, our findings also show a marked improvement in university efficiency in Spain as the crisis period progresses.

4.2. Second stage: determinants of university efficiency

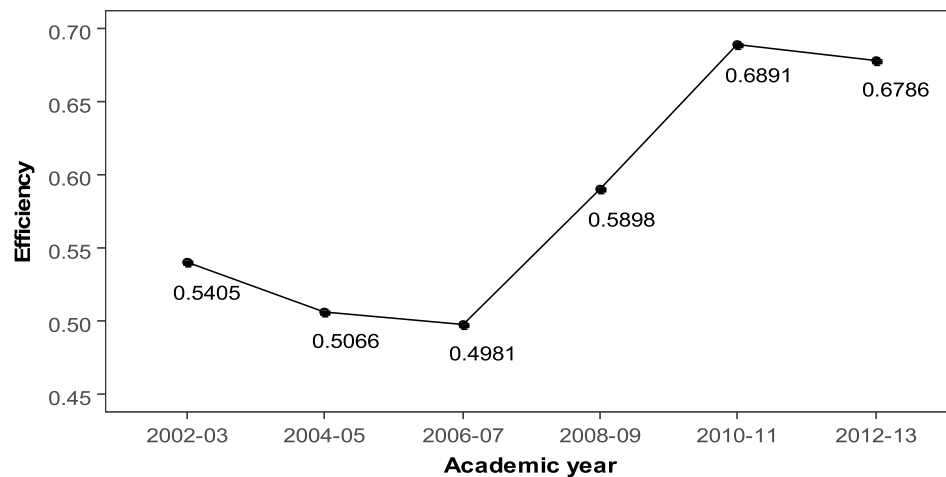
Table 4 presents the results obtained after applying bootstrap truncated regression (with 2000 repetitions and a confidence level of 95%), corresponding to the second stage of the [33] estimator. In particular, they allow us to know what the determinants of the Spanish public HEIs' performance are and, consequently, what could be done to improve their efficiency.

Firstly, our findings show that the age of these institutions (AGE) has a positive and statistically significant impact on university efficiency ($p < 0.01$). Therefore, the older the HEIs, the greater their efficiency, which suggests that the experience, maturity and reputation gained over the years benefit them in the form of better resource management, thus increasing their performance. This result is therefore in line with the findings of [2,32] for a sample of European public universities. Conversely, technical specialization of teaching and research (TECH) has a negative and statistically significant effect on the efficiency of Spanish public universities ($p < 0.05$). This points out that, even if their differentiation strategy brings them competitive advantages over generalist universities, specialized HEIs achieve a less rational use of resources because they have a higher dropout rate and a lower scientific production than their generalist counterparts. This finding thus



Source: Drawn up by the authors.

Fig. 1. Sample observations sorted by university efficiency (pre-crisis and crisis)
Source: Drawn up by the authors.



Source: Drawn up by the authors.

Fig. 2. Evolution of university efficiency by academic year
Source: Drawn up by the authors.

corroborates results in the study by Ref. [2]. In addition, the regional location of Spanish universities (REG) is also an important determinant of their performance such that those territories with a greater degree of economic and technological development (for example, Madrid, Catalonia and the Basque Country) and/or with governments more active in setting up policies to stimulate teaching and research outcomes in an austerity context have a statistically significant positive impact on efficiency, and vice versa. Previous studies have also shown that there is a regional effect in the Higher Education sector, suggesting that university efficiency varies according to the region in which HEIs are located within a specific country [2,30,31]. In summary, according to our findings, the profile of the most efficient public universities in Spain corresponds to mature institutions that provide generalist training and are located in regions with a thriving economy and/or with a government policy that stimulates university competition. This profile is therefore in line with that observed in the study by Ref. [2] for a sample of European public universities.

Finally, the results show that, in comparison with the pre-crisis period, the stage corresponding to the last economic crisis (CRISIS)

had a direct, positive and statistically significant impact on university efficiency in Spain ($p < 0.01$), confirming the findings derived from the descriptive analysis presented previously in section 4.1. Therefore, Spanish public HEIs were significantly more efficient in the crisis period (2008–2013) than before it (2002–2007), so this stage of uncertainty had a beneficial effect on their capacity to optimize the teaching and research outputs obtained from their human and financial resources. Although the recent economic crisis led to a reduction in government funding for the Spanish Higher Education system, public universities performed better during this period because their outputs increased mainly due to greater competition for increasingly scarce public funding. Our result is therefore in line with that of [10] from a sample of Italian public HEIs, but contrasts with that observed by them for German universities.

5. Conclusions

This study aimed to achieve two goals: first, to evaluate the relative technical (in)efficiency of Spanish public universities between the 2002–03 and 2012–13 academic years, comparing the situation before and during the last economic crisis; and, second, to analyze the determinants of university (in)efficiency, with a special emphasis on the possible impact of the crisis. We can draw some interesting conclusions from our findings, which should be contextualized in the geographical area of Southern Europe, whose Higher Education systems are weaker and less developed than those in the rest of Europe and therefore most affected by the austerity measures derived from the crisis.

First, the Spanish public HEIs showed a limited average efficiency of 58.38% between the 2002–03 and 2012–13 academic years, suggesting that their resources should have been better managed to produce 41.62% more outputs. During this period, therefore, there was considerable inefficiency in the Higher Education sector in Spain. By sub-periods, the low average efficiency in the pre-crisis period (51.51%) points to important weaknesses in the Spanish university system at that time, most of which stemmed from poor adaptation to an increasingly competitive and globalized context. After adoption of the LOU in 2001 and, especially, of the RLOU in 2007, both of which aimed to adapt the Spanish university sector to the EHEA, HEIs were restructured to boost their efficiency and competitiveness. The beginning of these legal reforms and the consequent greater need for resources coincided with the start of the last economic crisis, which led to serious cutbacks in public spending on Higher Education in Spain. We can conclude that despite

Table 4
Determinants of university efficiency.

Variables	β coefficients	Bootstrap standard error
Constant (α)	0.3724***	0.9426
SIZE	−0.0109	0.0289
AGE	0.0471***	0.0087
TECH	−0.0665**	0.0149
M&P	0.0250	0.0143
REG	Yes ^a	
CRISIS	0.1192***	0.0136
Sigma	0.0926***	0.0049
Log likelihood	250.2286	
Wald χ^2 (21)	444.19***	
n = 264 observations Bootstrap repetitions = 2000 $\alpha = 95\%$		

SIZE: Academic degrees (total number); AGE: Age of university (number of years); TECH: Specialization in technical fields (dummy: 1 yes/0 = no); M&P: Universities with Medicine and/or Pharmacy degrees (dummy: 1 = yes/0 = no); REG: Regional location (16 regional dummy variables); CRISIS: Crisis (dummy: 1 = academic years 2008–09, 2010–11 and 2012–13).

***p < 0.01; **p < 0.05.

^a Six of the 16 regional dummy variables are statistically significant at the 0.05 level.

these restrictions and the consequent decrease in the main university inputs, Spanish public HEIs were able to obtain higher levels of outputs during the crisis than before it, increasing their efficiency to 65.25%.

Second, when the efficiency dynamics during the period 2002–2013 are analyzed, the results show a continuous improvement in university efficiency as the crisis period progresses, indicating that the years of the crisis period benefited the Spanish public universities' performance. Specifically, the growth in the number of graduates and high-quality publications from the available resources seems to have been mainly motivated by different policy interventions that encouraged competition among universities for increasingly scarce public funds. The little empirical evidence existing for Southern Europe also provides a clue towards the expansion of pro-competitive policies in the public Higher Education sector during periods of budget constraint, suggesting that when market forces operate, there are benefits for university efficiency. Accordingly, it is possible to conclude that the public university systems in Southern European countries met the goal of improving their efficiency during the last crisis, achieving a better adjustment of inputs to teaching and research outputs, in the face of greater competitive pressure due to the need to adapt to the EHEA in an austerity context.

Third, regarding the factors crucial in promoting efficiency gains in the context of Spanish public Higher Education, we can conclude that the oldest public HEIs were able to take advantage of their greater experience, status and prestige to better manage their resources when producing their educational services. In contrast, despite the competitive advantages in differentiation of technical universities compared to their generalist counterparts, their more limited range of academic degrees, their higher dropout rate, their greater need for highly specialized resources, and their lower scientific production led to lower efficiency. In addition, our findings reveal that variables related to regional aspects can also explain the performance of Spanish public HEIs. The different strategies to deal with the crisis that regional governments have adopted when managing and financing public universities, and the presence of specific regional characteristics have played a key role, suggesting that efficiency differences may also be due to the fact that public universities are somewhat embedded in their corresponding regional context.

Finally, our study also provides the first results on whether the last economic crisis influenced the efficiency of public HEIs in Spain. Specifically, this stage of uncertainty exerted a significant positive influence on how these institutions utilized their human and financial resources to produce university outputs. In a scenario of declining public spending on Higher Education, this better performance of Spanish HEIs during the crisis period was stimulated mainly by some measures taken by governments and universities to increase teaching and research outputs through greater pressure on competitive resources, which seem to have encouraged universities to be more rational in the use of existing inputs to increase their competitiveness. This positive impact of the 2008 crisis on university efficiency has been also observed in Italian public HEIs. Consequently, despite the fact that the recent crisis led to drastic budgetary restrictions in university systems in Southern Europe, we can conclude that it also led to a more efficient management of the production processes of their public universities.

5.1. Policy implications

This paper should spark a debate among the political decision-makers, university authorities and society in Southern European countries, which have undergone similar shocks due to the 2008 crisis, on whether, how and why efficiency should play a key role in the public university sector. For *political decision-makers*, our results suggest that, in an adverse external situation requiring budgetary cuts, policy interventions that encourage competition among public HEIs may be particularly important to improve their efficiency. Indeed, in an austerity context, policymakers can only either risk worsening the functioning of existing production processes in public universities due to a reduction in their teaching and research outputs, since public funding is

their main source of revenue, or they can try to incentivize public HEIs to change their processes to generate more outputs – for example, by supporting excellence, innovation, internationalization, and institutional cooperation, and/or by setting up result-based incentive programs to allocate public funding to universities or for hiring policies –. In addition, since according to our findings, the profile of efficient Spanish public HEIs combines experience and generalist training, governments should manage in a more rational way the implementation of new and/or specialized HEIs within the public university system to make it more competitive in the current scenario of globalization of Higher Education. Finally, the application of the same policy to enhance universities' performance in different territories, without proper adaptation to the specific characteristics of each region, may not contribute to improving university efficiency. In short, political will is required to replace Higher Education systems that are costly and inefficient with others that offer high added value and competitiveness, the latter being an essential requirement for the necessary change of the production model in Southern Europe in general, and in Spain in particular.

For *university authorities*, the findings obtained suggest that they need to understand that, although public HEIs fall under the aegis of the government, their management largely depends on them. Indeed, a great deal of Spanish HEIs' inefficiency may be attributable to deficient governance. In this regard, there is scope for improvement in performance due to better governance mechanisms. Although the low flexibility of public universities limits the definition of institutional policies, academic decision-makers should try to improve their strategic behavior – for example, by working towards greater autonomy, promoting intra-university competition, fostering meritocracy among students and staffs, promoting the institutional conditions that stimulate creativity and productivity, changing their decision-making processes or modernizing their information, organization and management systems – in order to reduce their considerable technical inefficiency and raise the performance of Higher Education in Spain. In addition, public universities should adopt strategic planning measures in response to increasing concerns about attracting students and funding – for example, the growing social demand for better quality, the need to provide value-added services to the society, and the need to extend and improve links with the economic and social environment –. All these university policies are likely to enhance teaching and research efficiency as they set out an overall agenda for the departments and the University as a whole.

5.2. Limitations and future research

This study does not come without limitations. The generalizability of our results is limited since our sampling is restricted with regards to institutions (public universities), geography (a Southern European country, Spain) and time period (before and during the recent crisis). Moreover, this study focuses on the short term effect of the crisis on university efficiency and it does not reflect the time-lag between inputs and outputs in the Higher Education production process. Other limitation is the choice and measurement of input and output variables because of the complexity of quantifying university performance and the shortage of data at institutional level in Southern European countries. Our findings should therefore be interpreted with caution, particularly outside this geographical area.

Future research might carry out a cross-country analysis to find out the effect of the last crisis on university efficiency in different kinds of Higher Education systems across the world. In addition, it could be also interesting to examine the long term effect of the crisis on university efficiency due to time is needed for teaching and research outputs levels to reflect the input cut downs. Finally, the output variables could be improved, referring to the quality of teaching and research. If we assume that, in spite of the difficulty inherent in quantifying university efficiency, quality is a multifaceted and much-debated topic, a study on the relation between quantity and quality, especially with a view to defining future university funding, could be of great practical use worldwide.

Author contributions

The two authors have materially participated in the research and article preparation. Almudena Martínez-Campillo worked on the conceptualization and theoretical framework of the paper. Yolanda Fernández-Santos built up the databases. Both authors carried out the statistical analyses and wrote the empirical section (Research design and Results and discussion). Almudena Martínez-Campillo wrote the conclusions and finally supervised the full article. Both authors have approved the final version of the article.

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Declaration of competing interest

The authors declare no conflict of interest.

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