Evaluating university performance using reference point based composite indicators.

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Abstract

In this paper, we propose the application of a novel methodology to build composite indicators, in order to evaluate university performance. We analyse separately the three basic dimensions of our university system (*research*, *teaching* and *technology transfer*), because we are interested in getting a more accurate vision of each of them. In order to build the composite indicators, we use a multi-criteria analysis technique, based on the double reference point method. One advantage of this technique is the possibility to use reference levels, in such a way that the results obtained are easily interpreted in terms of the performance of the university with respect to these levels. Besides, aggregations for different compensation degrees are provided. In order to illustrate the advantages of this method, it has been applied to evaluate the performance of the public universities of the Spanish region of Andalucía, for year 2008. The results show that the performance of the Andalusian public universities in the *teaching* block is better than in the *research* and *technology transfer* blocks. The application lets us conclude that the methodology offers a warning system to assist in strategic decision making, and the values of the indicators allow us to find fields of improvement in all areas.

Keywords Higher education. Multi-criteria analysis. Composite indicators. Reference point method. Universities Ranking.

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1 Introduction

There is a growing recognition about the role that Higher Education Institutions (HEIs) play towards economic growth and social development in the current "knowledge society" (OECD, 2015). According to Hazelkorn (2013) and Berbegal-Mirabent *et al.* (2015), HEIs are important factors of growth and competitiveness, as they are key players as knowledge and innovation sources.

However, in an increasingly global competitive environment, HEIs are undergoing considerable changes worlwide (De Filippo *et al.*, 2016; Berbegal-Mirabent and Solé-Parellada, 2012) and facing new challenges, as they have been forced to redefine themselves to adapt to market forces without compromising quality (Heitor and Horta, 2013).

According to Mägi and Beerkens (2016), nowadays a learning society and knowledge economy require specific competences, so changes are needed in the field of HE (Enders and De Boer, 2009). In this context, HE rankings, an outcome of the competitiveness boosted by globalization, have put pressure on HEIs to implement internationalisation strategies, opposedly to their former nationally-oriented focus (Huisman and Van der Wende, 2004).

Since the publication of the first edition of the *Academic Ranking of World Universities (ARWU)* in 2003 and the successive league tables, like the *Times Higher Education World University Ranking (THE)* or the *QS World University Ranking (QS)*, the comparative evaluation of the quality and the excellence of HEIs has been brought into the focus of public and policy interest (see Gómez-Sancho and Pérez-Esparrells (2012), who examine these major global rankings and other international rankings specialized in assessing research undertaken by HEIs). There is no doubt that rankings will continue to dominate headlines in the field of HE (Frenken *et al.*, 2017; Collins and Park, 2016; Tan and Goh, 2014; Marope *et al.*, 2013; Marginson and Van der Wende, 2007; Altbach-Phillip, 2006).

According to Rauhvargers (2011), rankings were established to create transparency about the HE system in a competitive world market. However, there is no single model of universities ranking, varying in their aims and target groups as well as in terms of what they measure, how they measure it and how they implicitly define quality and excellence (Aguillo *et al.*, 2010; Cheng and Liu, 2008; Usher and Savino, 2006).

Despite their popularity, rankings have come under some criticism for using poor research methods, emphasizing science, medicine and technology over arts and humanities, being biased towards english speaking universities, and engendering inequality and exclusion (Barron, 2016; Stolz *et al.*, 2010; West, 2009; Gómez-Sancho and Pérez-Esparrells, 2012). Furthermore, according to Abramo and D'Angelo (2015) and Dill and Soo (2005), rankings seem to homogenize HE by promoting one university archetype, where research intensity has become the key indicator of quality and excellence.

Moreover, the literature notes that many HE rankings produce single scores, making it "difficult for users to distinguish among institutions based on the characteristics they find most important" (Bonaccorsi and Cicero, 2016; IHEP, 2007). Besides, Dehon *et al.* (2009) and IREG (2006) ask for the recognition of the diversity of institutions and of their missions and goals.

According to Finch *et al.* (2016) and Dehon *et al.* (2009), HEIs fulfil different functions, such as the construction of knowledge (*research*), the diffusion of

knowledge (*teaching*), and the valorisation and use of knowledge (service to society, *technology transfer*; some authors refer to this function as the "third stream" or "third mission" of universities, such as Laredo, 2007). To these ends, they use various inputs and have a large variety of outputs. So, given this multidimensional nature, it seems reasonable to develop composite indicators for each of the three main missions of universities. Anyway, even if a single composite indicator comprising the three missions is desired, these three mission composite indicators should be built at a first step, and synthesized at a second step.

There have been a few attempts to evaluate university performance without using composite indicators, such as the U-Multirank and its Spanish version, CYD Ranking, which consider the scores of universities on individual indicators and place these in five performance groups ("very good" through to "weak"). Opposedly, most of the rankings existing nowadays have developed and used composite indicators to provide rankings of HEIs or countries (ARWU[1], THE, QS, Alasehir *et al.*, 2014; Torres-Salinas *et al.*, 2011; Giannoulis and Ishizaka, 2010; Aguillo *et al.*, 2008). Other papers adopt composite indicators in order to analyse the quality of universities, such as Murias *et al.* (2008), who estimate a composite indicator for quality assessment in the Spanish public university system.

As defined by Nardo *et al.* (2008), *a composite indicator is an aggregate of all dimensions, objectives, individual indicators and variables used. This implies that what formally defines a composite indicator is the set of properties underlying its aggregation convention.* In this context, the composite indicator should ideally measure multidimensional concepts which cannot be captured by a single indicator. Composite indicators are increasingly recognised as useful tools in policy analysis and public communication, because they provide simple comparisons that can be used to illustrate complex and sometimes elusive issues in wide-ranging fields, such as performance of HEIs.

The literature on composite indicators is vast and provides a wide range of methodological approaches (the common practice in constructing composite indicators is well synthesized in El Gibari *et al.*, 2018; Gana *et al.*, 2017; Nardo *et al.*, 2008; Saisana and Tarantola, 2002). However, the quality of a composite indicator as well as the soundness of the messages it conveys depend not only on the methodology used in its construction, but primarily on the quality of the framework and the data used.

In this paper, we propose the application of a recently developed methodology, based on the multicriteria double reference point method (Cabello *et al.*, 2014), to the calculation of composite indicators of university performance, given a set of individual indicators. To our knowledge, this (or similar) methodology has not yet been adapted to obtain composite indicators of university performance. The main advantage of this method is twofold. First, reference levels are used for each indicator and thus, the scores are easily interpreted as the current position of the university with respect to these levels. Second, composite indicators for different compensation degrees can be derived in such a way that the scores, apart from giving an overall performance measure of the universities, also provide warning signals that let the user detect improvement

[1]See Billaut *et al.* (2010), who propose a critical analysis of ARWU from the point of view of the proposed aggregation method, using Multiple Criteria Decision Making tools.

areas. In summary, the aim of this paper is to develop and use composite indicators jointly with individual indicators of university performance, taking into account all HEIs missions, in order to carry out a wide analysis of the HEIs, make comparative judgements among them, and identify their weaknesses and strengths (not just to rank them). As an example to show the potential benefits of this method, it has been applied to public universities of the Spanish region of Andalucía.

To this end, we have used an existing set of indicators that is frequently used by several Spanish institutions to analyse the performance of the Spanish universities (the database from the Spanish University Rectors' Conference (CRUE) and the IUNE Observatory). Although we center our attention in the Andalusian HEI system in this study, we have used data of all the Spanish public universities to derive the reference levels. This way, we will find out the position of the Andalusian public universities in the Spanish global framework. The weights have been assessed by stakeholders (postgraduate students from different schools and researchers from different fields) of the university community.

Following this introduction, Section 2 gives a short overview of the Spanish HE system, Section 3 discusses the methodology for this research work. The empirical results are presented in Section 4, and finally, Section 5 draws some conclusions.

2 Institutional context

The Spanish HE system is considered among the largest HE systems in Europe, the fifth one in terms of students; it comprises 84 universities, out of which 50 are public and 34 are private, and it has approximately 1.5 million students and 115 thousand academic staff (MECD[2]).

The Spanish HE system has been seriously affected by the economic recession since 2010. The investment in knowledge in Spain is not comparable to the gross investment of other countries. In fact, the Government Budget Appropriations or Outlays for R&D (GBOARD) of Spain decreased almost 20% from 2009 to 2013 (Heitor *et al.*, 2016). However, according to European Commission (2014), Spain increased its international scientific co-publications by 16% over the period 2000-2011, due to the higher research requirements set by the academic authorities for staff hiring and promotion purposes. Nevertheless, the level of Spain's international co-publication (29.1%) is still below other comparable European countries (France 35.2% or Portugal 41%). Moreover, scientific quality, measured by the 10% most-cited publications, has grown by 3.6 % over the period 2007-2012.

Traditionally, Spanish universities focused their efforts on professional training and teaching, neglecting scientific research. However, the Government of Spain introduced "LOMLOU" (the Organic Law 4/2007 on universities), in order to redefine Spanish universities in the European Higher Education Area (EHEA).

Since 2006, Spain has implemented structural changes in its HE system according to the Bologna Process, which ensures comparability in standards

[2]Spanish Ministry of Education, Culture and Sports. Information for 2014-2015 academic year.

with the EHEA. In this regard, official university programmes are adapted to the EHEA, and structured into three cycles leading to undergraduate, master and PhD degrees, noticing a huge increase in the number of bilingual programmes and in the international student mobility.

However, despite the Spanish Government attempts to adapt to change in times of crisis and to align with "the Modernisation Agenda for Universities" introduced by the European Commission (European Commission, 2006), a lot still needs to be done. In the 2017 edition of ARWU, only 11 Spanish universities are positioned among the top 500 institutions in the world, and all of them are beneath the 200th place.

Andalucía is a region located in southern Spain, traditionally considered a less-developed region, but it has experienced a process of rapid change and now it has practically similar average in several socio-economic indicators to the rest of the Spanish regions (Fernández-Esquinas *et al.*, 2016). Regarding HE system, Andalucía has 11 universities, out of which 9 are public, with approximately 246 thousand students and 17 thousand academic staff (MECD). Still, the University of Granada is the only Andalusian university listed in the 2017 ARWU. As in other Spanish regions, the Andalusian universities are regulated by the National Government, which exercises the competencies that ensure the consistency and uniformity of the HE system, and also by the Regional Government, which has competencies for the creation, modification and elimination university programmes, and also for the core funding of public universities.

As mentioned before, the main objectives of HE are *research*, *teaching* and *technology transfer*, and this is why we decided to consider these three blocks to evaluate the performance of the Andalusian public university system. In addition, the first two ones are further broken down into four sub-blocks that capture several issues of *research* and *teaching*. It must be pointed out that, in some cases, the election of the indicators (into sub-blocks and technology block) is highly conditioned by the availability of uniform data for all the universities. A final set of 33 indicators was selected considering a balance between the relevance of the indicators and their availability. Nevertheless, this study can be easily adapted to use other indicators, should they become available. It is notable that, as other relevant Spanish rankings, such as U-Ranking[3], our system of indicators is designed to assess the performance of the four main areas (access to funding, quality and excellence, internationalisation and results) in each of the three dimensions considered (*research*, *teaching* and *technology transfer*).

Furthermore, it must be pointed out that most of the indicators adopted in well-known Spanish university rankings are used in this research work (our system of indicators covers 33 indicators, the same as the CYD Ranking, while the U-Ranking covers 31 of the indicators used here). Anyway, here, we do not make any judgement about the suitability of this set of indicators. They have been used for this study because of their availability, and their use by the Spanish Education authorities to assess the performance of the universities. In fact, the (in our opinion) most adequate indicators to measure a given effect sometimes just did not exist. For example, the percentage of students that pass their exams has been used as a proxy for measuring the teaching results of a university, which can be arguable, but other more adequate indicators (like

[3]See Pérez and Aldás (2016), who analyse the performance of the Spanish public university system, synthesizing the universities' achievements in the three dimensions considered in a single index.

opinions of employers or external evaluations) simply do no exist.

According to Rauhvargers (2011), indicators used by rankings may use absolute values (number of publications, citations, students, staff members, etc.) or relative values (publications per staff member, citations per publication, funding per student, etc.). Then, if a ranking predominantly uses absolute values, its scores are size-dependent, which favour large universities. In opposition to this, if relative values prevail, universities which are more efficient and not necessarily large, will score more highly. This simple aspect should be taken into account when analysing ranking results. In this study, the 9 public universities considered are comparable in terms of their aims (they can be regarded as generalist universities), and therefore their specific research fields are similar, but they are quite different in terms of size. Consequently, in this research work we have decided to adopt a size-independent nature (relative values) because it enables comparisons between smaller and larger universities.

The data were collected from two sources: the Spanish University Rectors' Conference[4] of 2008, and the IUNE Observatory[5]. The source data used in this paper are available from the authors upon request (see Tables 9-11 in the Appendix for a full description of the indicators considered). Our analysis covers the academic year 2008 for two reasons: first, it coincides with the starting point of the economic recession, which has been seriously affected the Spanish higher education, in general, and the Andalusian one in particular; and second, it also coincides with the structural changes made by the Government of Spain in order to redefine Spanish universities in the European Higher Education Area.

3 Methodology

The approach applied to construct the composite indicators is based on a multicriteria method known as the double reference point method (Wierzbicki, 1980; Wierzbicki *et al.*, 2000), which was adapted later on to build composite indicators (Ruiz *et al.*, 2011). The procedure to obtain the composite indicators, given a set of individual indicators, has the following steps:

1. For each indicator j, we establish a reservation level r_j (which is a level regarded as acceptable, that is, values worse than r_j are regarded as unacceptable), and an aspiration level a_j (level regarded as desirable, that is, values better than a_j are regarded as good or desirable).

2. A so-called achievement function measures, for each indicator, the position of each unit with respect to the corresponding reference levels. This function also covers the purpose of bringing all the individual indicators down to a same scale (normalisation).

3. We establish the weights representing the relative importance of each individual indicator. This issue is controversial as it always involves subjectivity (Rauhvargers, 2011). Nardo *et al.* (2005) recommend that the weighting technique must be in accordance with the objectives pursued by the composite indicator, and it must always be explicit and transparent.

[4]http://www.crue.org/Publicaciones/Paginas/UEC.aspx?Mobile=0
[5]http://www.iune.es

4. We obtain two composite indicators. The so called weak composite indicator (WCI) allows full compensation among the different components, that is, a bad performance in one (or several) individual indicators can be compensated by a good performance in another one(s). This measure gives an idea of the overall performance of each unit. On the other hand, the so called unweighted strong composite indicator ($USCI$) does not allow for any compensation, and thus, it is used to point out bad performances in certain individual indicators.

Next, we specify how these steps have been carried out for the application to the assessment of the Andalusian public universities performance.

3.1 Normalisation

With respect to the reference levels, in principle they can be set in two ways. First, they can be given by one or a group of experts or decision makers, who can establish what is acceptable and desirable for each indicator. In this case, the final composite indicator obtained gives us an absolute measure of performance, with respect to these values. Second, they can be set statistically, given a data set. In this case, the composite indicator measures the relative position of the universities with respect to those belonging to the data set. In our case, given that we did not have experts available to set the reference levels, we have used the statistical option, using the set of all the Spanish public universities as the data set. This way, we will obtain a measure of the relative positions of the Andalusian public universities with respect to all the Spanish public universities. Namely, when indicator j is of kind "the more, the better", r_j has been set the average value between the mean $\bar{I}_j$ and the minimum $I_j^{\min}$ values of each indicator for all Spanish public universities, while a_j is the average value of $\bar{I}_j$ and the maximum $I_j^{\max}$ value. Other statistical measures (like for example, 25 and 75 percentiles) could have been used as well.

As for the achievement functions, for a "the more, the better" indicator, we have used the following one:

$$S_j(I_j^u, a_j, r_j) = \begin{cases} 1 + \frac{I_j^u - a_j}{I_j^{\max} - a_j}, & \text{if } a_j \leq I_j^u \leq I_j^{\max}, \\ \frac{I_j^u - r_j}{a_j - r_j}, & \text{if } r_j \leq I_j^u \leq a_j, \\ \frac{I_j^u - r_j}{r_j - I_j^{\min}}, & \text{if } I_j^{\min} \leq I_j^u \leq r_j, \end{cases} \tag{1}$$

where I_j^u is the value of indicator j for university u. S_j transforms the values of the indicator I_j^u into a dimensionless scale with values between -1 and 2, that takes values between -1 and 0 if the university u performs worse than the corresponding reservation level (weakness), values between 0 and 1 if it performs better than the reservation level, but worse than the aspiration level (admissible), and values between 1 and 2 if it performs better than the corresponding aspiration level (strength) (Figure 1). In particular, it gets the value -1 if the university u has the worst value of all Spanish public universities for the indicator, and value 2 if is has the best value. This way, apart from normalising the indicators, the achievement function provides us with valuable information about the performance of each university.

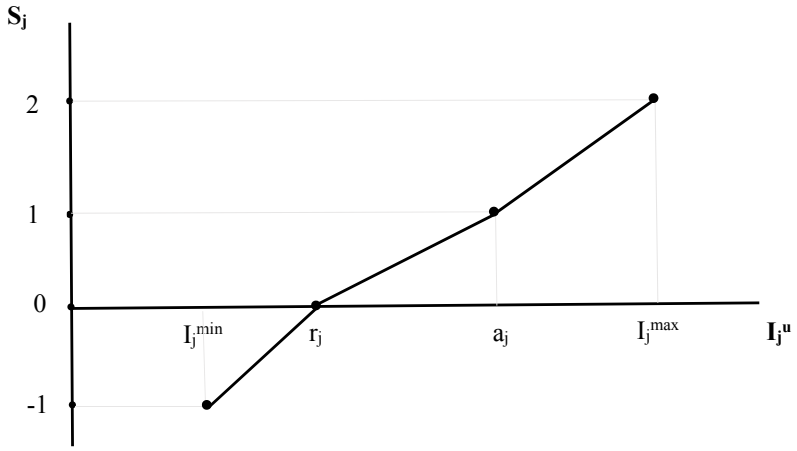

Figure 1: Graphical representation of S_j. Case "the more, the better".

For the "the less, the better" type indicators, the corresponding reference levels and achievement scalarizing function are illustrated in Figure 2.

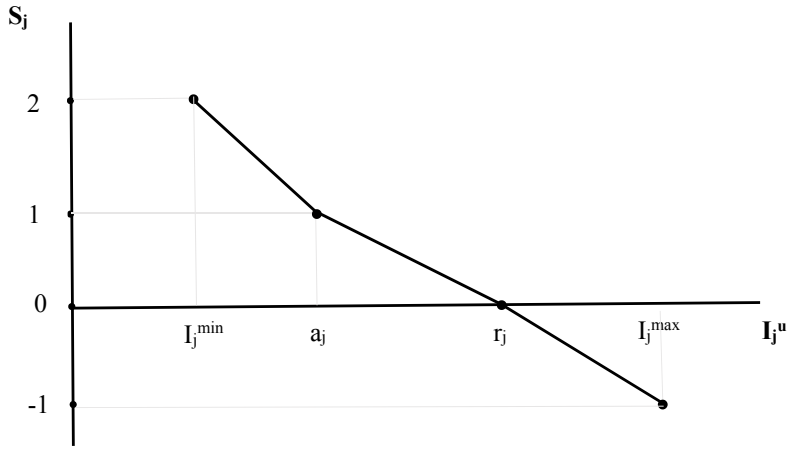

Figure 2: Graphical representation of S_j. Case "the less, the better".

In Table 1 we can see a hypothetical example with 5 indicators. For simplicity, we assume that the minimum and maximum values for all of them are 0 and 100, respectively. In the first row, we see the indicator type ("More" or "Less"). The hypothetical average values of the indicators are displayed in the next row. Then, the reservation and aspiration levels are calculated as previously described. The following row contains the value of the indicator for a given unit (university) and finally, the values of the achievement functions are calculated in the last row. Indicators 1 and 3 have negative achievement function values, because the unit performs worse than the corresponding reservation levels, while indicators 2 and 4 get values between 0 and 1, meaning that the unit

	I_1	I_2	I_3	I_4	I_5
Type	More	Less	Less	More	More
Average	55.0	60.0	45.0	40.0	50.0
Reservation	27.5	80.0	72.5	20.0	25.0
Aspiration	77.5	30.0	22.5	70.0	75.0
Value	21.0	37.0	76.0	32.0	84.0
Ach. Fun.	-0.236	0.860	-0.127	0.240	1.360

Table 1: Achievement functions for a hypothetical example

	I_1	I_2	I_3	I_4	I_5
StH1	3	4	5	3	4
StH2	2	4	5	4	4
StH3	3	4	4	3	3
$m\omega$	2.667	4.000	4.667	3.333	3.667
$a\omega$	1.966	3.375	4.423	2.576	2.948
μ^w	0.129	0.221	0.289	0.168	0.193

Table 2: Calculation of the weights

performs better than the reservation levels, but worse than the aspiration levels. Finally, indicator 5 is greater than one because the unit performs better than the aspiration level.

3.2 Weighting

The next step is to establish the weights representing the relative importance of each aspect. In our case, we have considered the opinion of different interest groups from the University of Málaga community (3 researchers from different fields and 50 postgraduate students from different schools at the University of Málaga). Postgraduate students have set the weights of the *teaching* block, while researchers have set the weights for the *research* and *technology transfer* blocks. They have assessed the importance of the indicators using a Likert scale (1-5).

Following with the example shown in Table 1, the weights assigned by three stakeholders to the 5 indicators are displayed in the first three rows in Table 2. Then, the arithmetical means of these judgements are calculated, obtaining a weight ($m\omega_j$, row 4) for each indicator. Row 5 shows the adjusted weights defined as $a\omega_j = 1.5^{m\omega_j - 1}$ to be applied in a multiplicative environment. This has been done because, when used to calculate the composite indicators, the weights have a ratio meaning, that is, an indicator weighed 2 is twice as important as an indicator weighed 1. Therefore, $a\omega_j$ have been defined so that the ratio between two consecutive elements of the original Likert scale is constant (equal to 1.5). The last row contains the normalised weights for the WCI, adding up 1 (μ^w).

3.3 Aggregation

Finally, the composite indicators are calculated. In our case, the aggregation is carried out in two stages, as illustrated in Figure 3. First, we get the composite indicator of each sub-block of the *research* and the *teaching* blocks, and the composite indicators of the *technology transfer* block (which has no sub-blocks). Second, we aggregate the sub-blocks to get the composite indicators of the *research* and the *teaching* blocks.

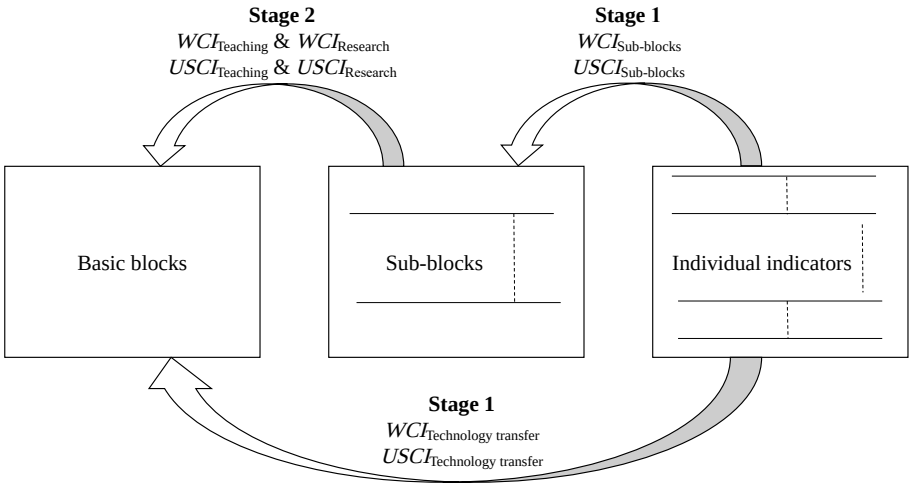

Figure 3: Stages for obtaining WCI and $USCI$.

In the first stage, the WCI of university u is calculated by:

$$WCI_t^u = \sum_{j=1}^{n_t} \mu_j^w S_j(I_j^u, r_j, a_j), \tag{2}$$

where n_t is the number of indicators in sub-block t.

On the other hand, the $USCI$, not allowing for compensation, is a measure of the worst performance of university u. So, the $USCI$ does not consider weights, and just takes the minimum value of the achievement functions for university u. This would inform us about the value of the worst achievement. Therefore, the $USCI$ is built following expression (3).

$$USCI_t^u = \min_{j=1,\ldots,n_t} \left\{ S_j(I_j^u, r_j, a_j) \right\} \tag{3}$$

Note that WCI and $USCI$ take values between -1 and 2 and they indicate better performance for higher values. Therefore, they can be interpreted as the position of the university with respect to hypothetical global reference levels. Also, given that the composite indicators have values lying in the same intervals as the achievement functions, they can be used as achievement functions in the second stage of the aggregation process.

Finally, the WCI and the $USCI$ of each university can be combined to get a mixed indicator (MCI) which allows us to rank the Andalusian public universities:

$$MCI = \lambda WCI + (1 - \lambda)USCI, \tag{4}$$

where $\lambda \in [0, 1]$ is the compensation coefficient between both composite indicators. If $\lambda = 0$, then no compensation is allowed ($MCI = USCI$), and if $\lambda = 1$, full compensation is allowed ($MCI = WCI$). λ could be set according to the user's opinion, or we can see the values of MCI for different λ and extract some consequences from this information.

4 Results

In this section, we show and discuss the results obtained. First, the methodology developed in Section 3 was applied to the data of the Andalusian public universities to obtain a WCI and a $USCI$ for each university and for each basic block (*research*, *teaching* and *technology transfer*). We present these results, and discuss them while highlighting the major strengths and weaknesses of the universities. Second, we rank the Andalusian public universities by means of the MCI (4), for different compensation degrees. Due to space limitations, we will discuss the results of the *research* block in detail, while we will just show the final results of the other two blocks.

4.1 Strengths and weaknesses

Next, we discuss the performance of the Andalusian public universities, using a graph like Figure 4, where each point represents a university, and the values of WCI and $USCI$ are, respectively, in the horizontal and vertical axis. We also analyse the scores of the indicators (using the corresponding achievement functions), with the aim of identifying the main strengths and weaknesses of the Andalusian public university system. For space reasons, we present a more in depth analysis only for the *research* block.

1. Research.

   In Figure 4, three groups of universities can be identified (named as $G1$, $G2$ and $G3$). All the universities of groups $G1$ and $G2$ (except the University of Málaga) are located in the the third quadrant, that is, despite having a negative $USCI$, the unfavourable indicators are compensated, resulting in a positive WCI. The universities of group $G3$ and the University of Málaga are placed in the worst quadrant, that is, universities which perform worse than the reservation level for at least one individual indicator (negative $USCI$), and for which these unfavourable indicators are not compensated (negative WCI).

   $G1$ is formed by the best positioned universities, Córdoba and Granada, with the highest values of the WCI (0.46 and 0.42, respectively) and of the $USCI$ (-0.24 and -0.32, respectively), locating themselves further right and on the top in the third quadrant. The reasons of this behaviour will be explained later.

   All the scores for the $USCI$ are negative and for the WCI, they are below 1. However, the $USCI$ ranges from -0.24 to -1, that is, a wider range than this of the WCI, which varies between 0.46 and -0.18. This

shows significant differences in the *research* block among the Andalusian public universities, as will be seen later.

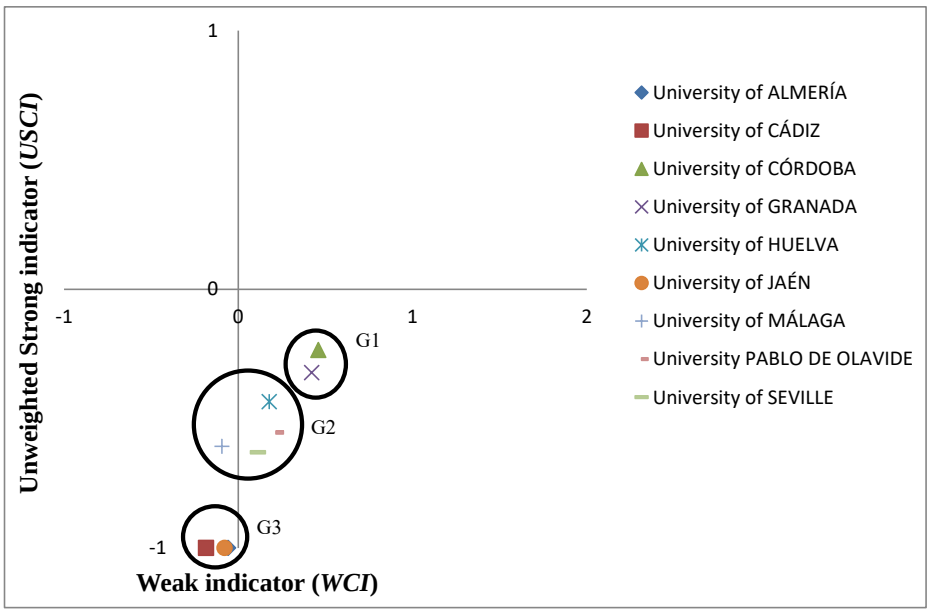

Figure 4: Positions of the universities for the *research* block.

The University Pablo de Olavide, from group $G2$, is the third one with respect to the WCI (0.22), but it is the fourth one for the $USCI$ (-0.55); that is, its poor performance in certain individual indicators is compensated by acceptable results in others. On the other hand, the University of Seville is the worst positioned one in group $G2$ for the $USCI$ (-0.63), while the University of Málaga is the worst positioned one for the WCI (-0.1), and this is why it is in the worst quadrant.

The University of Almería has the best value for the WCI in group $G3$ (-0.06), but together with the universities of Cádiz and Jaén, they have the worst score for the $USCI$ (-1), when no compensation is allowed.

Tables 3-5 present the values of the achievement functions of the individual indicators for each *research* sub-block. The scores below 0 appear in red (values worse than the reservation level, weaknesses); the scores between 0 and 1 are in yellow (values better than the reservation level, but worse than the aspiration level, admissible); and the scores over 1 are highlighted in green (values better than the aspiration level, strengths). An in-depth analysis of the information contained in these tables will help us to justify the previously commented results about the positions of the Andalusian public universities in the *research* block with respect to all the Spanish public universities.

In general, the University of Córdoba performs differently from the others, having admissible or strong values in all the indicators, with the exception of "*participation in projects*", the lowest weighted individual indicator, with a score -0.23 (which is the value of the $USCI$). The case of Granada

Group	University	Publications (Weight = 0.38)		
		Publications per doctor (0.32)	Citations per doctor (0.32)	Q1 publications per doctor (0.36)
1	University of Córdoba	0.38	0.26	0.64
	University of Granada	0.12	0.20	-0.13
2	University of Huelva	0.22	0.28	0.19
	University of Pablo de Olavide	-0.14	0.08	-0.11
	University of Seville	-0.32	-0.26	-0.20
	University of Málaga	-0.61	-0.51	-0.53
3	Universidad de Almería	-0.01	0.04	-0.36
	Universidad de Cádiz	-0.47	-0.66	-0.40
	Universidad de Jaén	0.04	-0.15	-0.25

Table 3: Achievement functions of the universities for the *publications* sub-block.

Group	University	Other research activity (Weight = 0.33)				
		Research projects applied (0.13)	International collaboration per doctor (0.26)	Theses defended per doctor (0.17)	Participation in projects (0.17)	Official recognition research (0.27)
1	University of Córdoba	0.20	0.33	0.85	-0.24	1.10
	University of Granada	0.04	0.64	0.78	0.77	2.00
2	University of Huelva	0.21	0.66	0.22	0.46	-0.23
	University of Pablo de Olavide	0.03	0.45	0.40	1.48	0.55
	University of Seville	-0.13	0.50	0.63	0.34	0.96
	University of Málaga	-0.23	-0.21	0.03	0.80	0.30
3	Universidad de Almería	0.32	0.10	0.12	0.53	-1.00
	Universidad de Cádiz	0.26	0.63	-0.30	0.08	0.33
	Universidad de Jaén	0.88	0.44	0.04	-1.00	0.30

Table 4: Achievement functions of the universities for the *other research activity* sub-block.

is slightly different. It has two individual indicators with negative values ("*Q1 publications per doctor*", -0.13 and "*amounts of the National Plan projects per doctor*", -0.32). In contrast, it achieves the maximum value in the indicator "*official recognition research*" (in fact, it is the best value on this individual indicator across all the Spanish public universities). This explains that when compensation is allowed (WCI), this university has a good result (0.42), very close to the University of Córdoba (0.46), which is the best one. However, when such compensation is not allowed ($USCI$), the performance of the University of Granada (-0.32) is further from the University of Córdoba (-0.24).

The universities of Almería, Cádiz and Jaén have, in general, the worst results, with individual indicators way worse than their reservation levels (red color values in Tables 3-5). They achieve the worst possible value for the $USCI$ (-1), which means that they all have the worst performance of

Group	University	Projects & funds (weight = 0.29)				
		FPU grants and contracts per doctor (0.18)	Projects am. (National Plan (0.22)	Assignment of national projects (0.17)	National / Europ. Projects per doctor (0.19)	Research R&D funds per teacher (0.24)
1	University of Córdoba	0.57	0.15	0.64	0.27	0.51
	University of Granada	0.89	-0.32	0.65	0.16	0.16
2	University of Huelva	0.18	-0.43	0.52	0.21	-0.15
	University of Pablo de Olavide	-0.55	0.04	0.63	0.25	0.41
	University of Seville	0.31	-0.63	0.68	-0.04	0.39
	University of Málaga	0.33	-0.13	0.97	-0.02	0.23
3	Universidad de Almería	0.26	0.02	-0.37	0.13	0.23
	Universidad de Cádiz	0.23	-0.58	-1.00	-0.20	0.19
	Universidad de Jaén	-0.10	0.21	-0.23	-1.00	-0.31

Table 5: Achievement functions of the universities for the *projects* & *funds* sub-block.

all Spanish universities for at least one indicator, and this is why they are at the bottom in the worst quadrant (group $G3$). However, the University of Almería nearly compensates its weaknesses and reaches a negative WCI close to 0 (-0.06). In contrast, the University of Cádiz has the poorest score on the WCI (-0.18), that is, its strengths are not enough to compensate its weaknesses (mostly placed in the *Publications* sub-block).

It is worthy to point out the case of the University of Málaga, from $G2$. It is positioned in the worst quadrant with a negative WCI (-0.1). However, regarding the $USCI$, it is better positioned than the University of Seville (-0.61 and -0.63, respectively). This means that its weaknesses are not as bad as those of the universities from group $G3$, but the overall performance, when compensation is allowed, is similar (in some cases, worse) to those of group $G3$.

2. *Teaching.*

   All the Andalusian public universities are positioned in an intermediate situation in the *teaching* block, with a negative $USCI$ and a positive WCI (Figure 5). In addition, the scores for the WCI are way below 1, which reveals that there are not many important indicators for which the universities have a good performance (better than the aspiration level, set by all Spanish public universities), and if any, they are offset by poor performances in other indicators. The negative values of the $USCI$ mean that every university has at least one indicator that performs worse than the corresponding reservation level.

   In Figure 5, we can observe three different groups ($G1$, $G2$ and $G3$). Once again, the universities of Granada and Córdoba are the best positioned ones for the $USCI$ (-0.29 and -0.34, respectively). These two universities form group $G1$. The universities of Córdoba, Cádiz and Almería show the best performance for the WCI (0.42, 0.41 and 0.41, respectively). The universities in $G2$ have similar values for both indicators, with the exception of the universities of Seville and Jaén, which reach a value on the $USCI$ similar to this obtained by the University of Almería (-0.75,

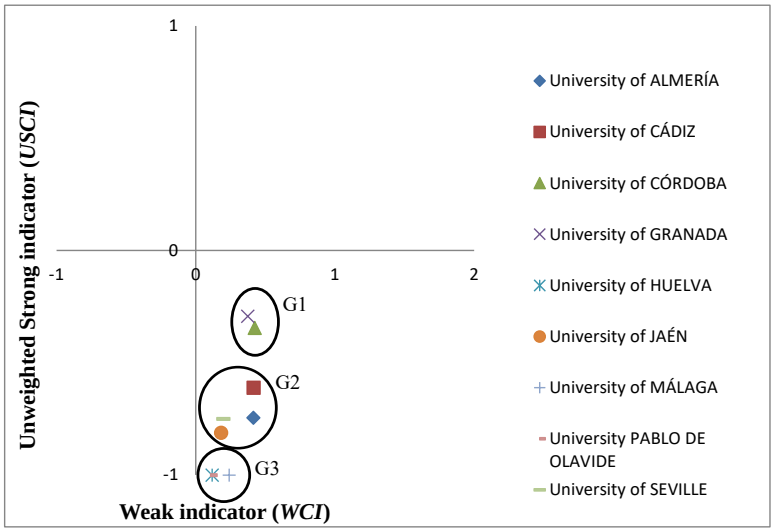

Figure 5: Positions of the universities for the *teaching* block.

-0.81 and -0.74, respectively), but with worse values for the WCI. This means that the University of Almería achieves an admissible score on some important indicators and thus, it compensates the low performance on others. Moreover, all the universities in $G3$ have worse values for both indicators than the universities in groups $G1$ and $G2$, with the exception of the University of Málaga. This university has a better value for the WCI than the universities of Seville and Jaén, from $G2$ (0.24, 0.2 and 0.18, respectively); however, it reaches the worst possible value for the $USCI$ (-1), indicating again that it has the worst performance of all the Spanish universities for some indicator. This analysis shows the added value of the joint visualization of WCI and $USCI$, which allows us to detect weaknesses that would be hidden by a traditional compensatory measure.

3. *Technology transfer.*

   With respect to the *technology transfer* block, once again, all the universities have negative scores on the $USCI$ and values below 1 on the WCI (Figure 6). The former ranges from -0.44 (University of Seville) to -1, and the latter ranges from 0.43 (University of Almería) to -0.66 (University of Córdoba). But now, the differences in the values of the weak indicator are much greater than in the two previous blocks. These data show that, in general, the Andalusian public universities are worse positioned in *technology transfer* than in the other blocks. There are four universities with positive WCI, which are placed in the third quadrant and have, consequently, an intermediate situation on this block. Two of them have very similar scores on the WCI close to cero, and thus, we have considered two groups for these four universities, $G1$ (Almería and Seville) and $G2$ (Granada and Málaga), according to this. The other five universities are located in the worst position, the third quadrant, with negative results on

both indicators. They form group $G3$.

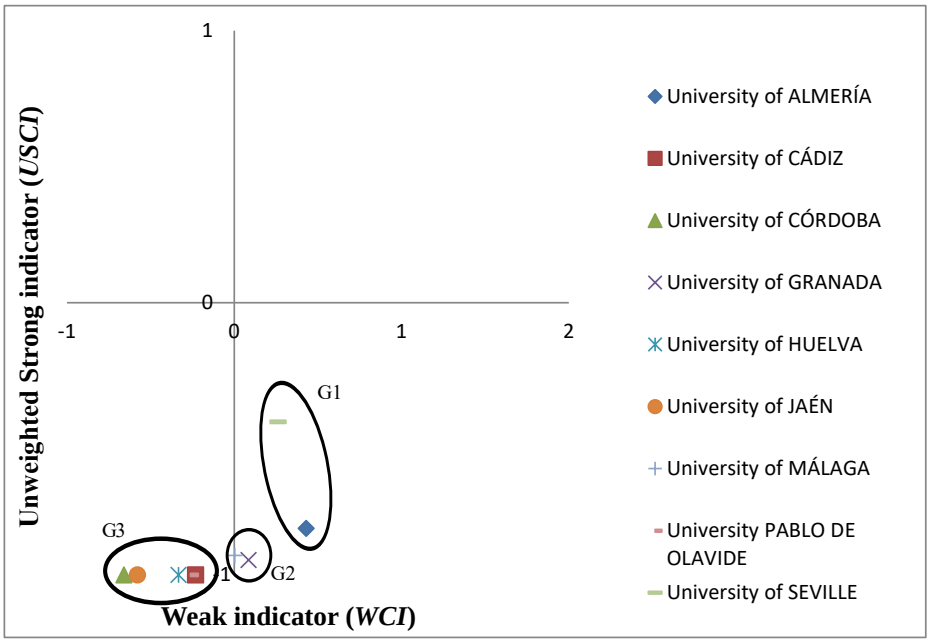

Figure 6: Positions of the universities for the *technology transfer* block.

In general, it can be affirmed that the performance of the Andalusian public universities in the *teaching* block is better than in the *research* and *technology transfer* blocks, although the values of the indicators suggest that all the universities have still much room for improvement. Analysing WCI and $USCI$, simultaneously, is very useful to obtain a complete photography of the universities performance and can help the decision maker(s) in deciding which aspects must be corrected.

4.2 Rankings

As seen in section 4.1, the joint consideration of WCI and $USCI$ provides us with valuable information about the performance of the universities. But if we still want to get a ranking, a single composite indicator must be used. In this subsection, WCI and $USCI$ will be combined to obtain MCI, according to expression (4). For each value of the compensation degree λ, a MCI is generated, which allows us to rank the Universities. Also, by varying this degree from 0 to 1 (with 0.1 steps), we will analyse how the scores range from the no compensation ($USCI$) to the compensation situation (WCI).

1. *Research.*

   Table 6 shows the positions in the ranking of the *research* block of each university, for each value of the compensation degree from 0 to 1, taking 0.1 steps. Since the WCI ($\lambda = 1$) and the $USCI$ ($\lambda = 0$) are two extreme situations, from full compensation among indicators to no compensation

allowed, we have decided to focus on intermediate degrees of compensation, from 0.30 to 0.70 (highlighted in purple in the table), to determine a rank of the Andalusian public universities regarding the *research* block. There are no changes in the coloured area. It is worthy to point out the case of the University Pablo de Olavide, which overtakes the University of Huelva, occupying the third position when the compensation is very high ($\lambda = 0.8$). Therefore, the ranking is very stable with respect to changes of the compensation degree (excluding the extreme values) in the *research* block.

		USCI	*MCI*									*WCI*
Rank	**Compensation degree**	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	University of CÓRDOBA	1	1	1	1	1	1	1	1	1	1	1
2	University of GRANADA	2	2	2	2	2	2	2	2	2	2	2
3	University of HUELVA	3	3	3	3	3	3	3	3	4	4	4
4	University PABLO DE O	4	4	4	4	4	4	4	4	3	3	3
5	University of SEVILLE	6	5	5	5	5	5	5	5	5	5	5
6	University of MÁLAGA	5	6	6	6	6	6	6	6	6	6	8
7	University of ALMERÍA	7	7	7	7	7	7	7	7	7	7	6
8	University of JAÉN	7	8	8	8	8	8	8	8	8	8	7
9	University of CÁDIZ	7	9	9	9	9	9	9	9	9	9	9

Table 6: Ranking of the *research* block.

Figure 7 depicts the values of the MCI reached by the Andalusian public universities in the *research* block, as the compensation degree between WCI and $USCI$ is increased. The Universities of Córdoba and Granada maintain their good scores in the MCI away from the rest. The universities of Almería and Jaén improve their scores as the compensation coefficient is increased, although they do not reach positive values. The reasons of this behaviour have been explained in Section 4.1.

2. *Teaching.*

   In table 7, it can be observed that the universities of Granada, Córdoba and Cádiz stay at the top, and the University of Córdoba overtakes the University of Granada when the compensation degree is high ($\lambda \geq 0.6$). The University Pablo de Olavide is always at the bottom. Therefore, the ranking is not very sensitive to changes of the compensation degree (excluding the extreme values). The variations in the positions of the universities are few (in the colored area), only changing in some cases in one position.

		USCI	*MCI*									*WCI*
Rank	**Compensation degree**	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	University of GRANADA	1	1	1	1	1	1	2	2	2	3	4
2	University of CÓRDOBA	2	2	2	2	2	2	1	1	1	1	1
3	University of CÁDIZ	3	3	3	3	3	3	3	3	3	2	2
4	University of ALMERÍA	4	4	4	4	4	4	4	4	4	4	3
5	University of SEVILLE	5	5	5	5	5	5	5	5	5	6	6
6	University of JAÉN	6	6	6	6	6	6	6	6	7	7	7
7	University of MÁLAGA	7	7	7	7	7	7	7	7	6	5	5
8	University of HUELVA	7	8	8	8	8	8	8	8	8	8	8
9	University PABLO DE O	7	9	9	9	9	9	9	9	9	9	9

Table 7: Ranking of the *teaching* block.

3. *Technology transfer.*

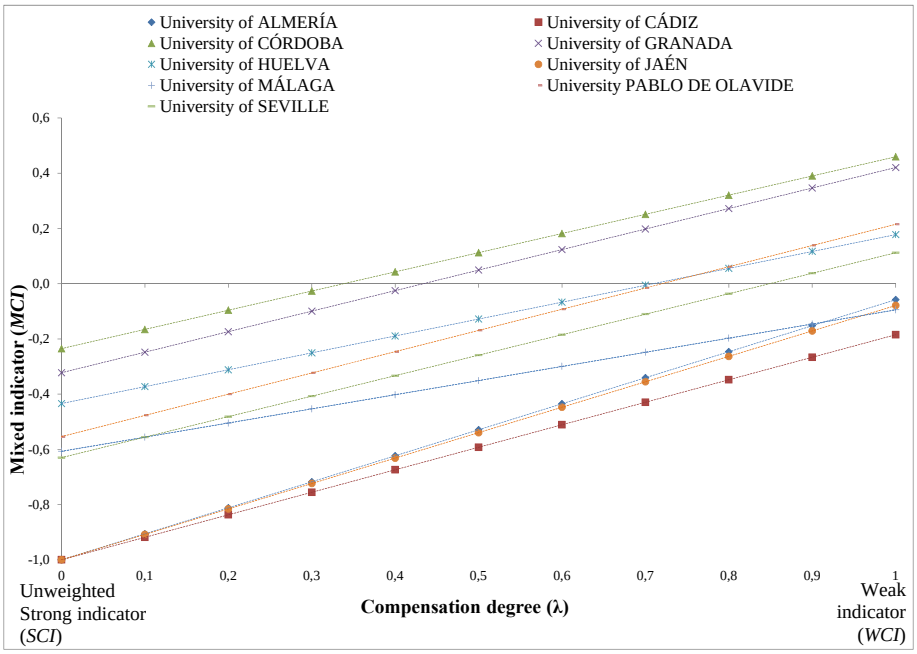

Figure 7: MCI of the *research* block for different compensation degrees.

With regard to the *technology transfer* block, the universities of Almería, Seville and Granada are the best ranked ones, with a positive MCI as the compensation degree grows (Table 8).

		USCI	*MCI*									*WCI*
Rank	**Compensation degree**	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	University of SEVILLE	1	1	1	1	1	1	1	2	2	2	2
2	University of ALMERÍA	2	2	2	2	2	2	2	1	1	1	1
3	University of GRANADA	4	4	3	3	3	3	3	3	3	3	3
4	University of MÁLAGA	3	3	4	4	4	4	4	4	4	4	4
5	University of CÁDIZ	5	5	5	5	5	5	5	5	5	5	5
6	University PABLO DE O	5	6	6	6	6	6	6	6	6	6	6
7	University of HUELVA	5	7	7	7	7	7	7	7	7	7	7
8	University of JAÉN	5	8	8	8	8	8	8	8	8	8	8
9	University of CÓRDOBA	5	9	9	9	9	9	9	9	9	9	9

Table 8: Ranking of the *technology transfer* block.

Thus, we can affirm that the ranking for the *research* Block is more stable than the other ones, and the rankings are not very affected by slight changes in the compensation allowed. Even comparing extreme situations, there are only minor changes in the positions of the Andalusian universities.

5 Conclusions

According to Gleich *et al.* (2008), a better performance and commitment to achieve a competitive advantage is essential for HEIs in today's knowledge based environment, since it seems clear that in the future they will have an even

more vital contribution in our society. In this context, we have applied the double reference point method in order to evaluate the performance of HEIs. First, in opposition to the well-known university rankings, the main advantage of our research is the possibility to analyse HEIs from different perspectives simultaneously by developing and using composite indicators jointly with individual indicators of university performance. On the one side, we evaluate university performance without using composite indicators in such a way that reference levels are used for each indicator and thus, the scores are easily interpreted as the current position of the university with respect to these levels (it has been used in the U-Multirank and its Spanish version, CYD Ranking). Moreover, from the aggregation point of view, most of the rankings existing nowadays have developed and used composite indicators to provide rankings of HEIs (ARWU, THE, QS and the Spanish U-Ranking). However, to our knowledge, composite indicators for different compensation degrees has not yet been adopted to evaluate university performance. In this regard, we have developed composite indicators for different compensation degrees for each of the three main missions of universities, in such a way that the scores, apart from giving an overall performance measure of the universities, also provide warning signals that let the user assist in strategic decision making for policy purposes, by identifying the weaknesses and strengths of each university. It should be pointed out that we analyse separately the three basic dimensions of our university system (*research*, *teaching* and *technology transfer*), because we are interested in getting a more accurate vision of each of them. Anyway, the double reference point method adopted in this research work allows us to build a single composite indicator comprising the three missions if is desired. First, these three mission composite indicators should be built at a first step, and synthesized at a second step.

Considering the case of the Andalusian public HEIs, we can conclude that there is a quite remarkable variety across results within HEIs missions. The relative performance of the Andalusian public universities with respect to all Spanish public universities in the *teaching* block is better than in the *research* and *technology transfer* ones, although the values of the indicators suggest that all the universities have still much room for improvement in all areas. Regarding the *teaching* block, OECD (2012) comments that the internationalisation of HEIs features among the sector's key transformations, specially in the European context. However, our results show that the "*international attractiveness*" and "*internships*" (External Projection) are weaknesses for most of the Andalusian public HEIs. Thus, the Regional Government authorities should pay greater attention to them in order to meet these new demands. With respect to the *research* block, a large number of weaknesses takes place in the "*publications*" and in the "*amounts of the National Plan projects per doctor*". This is not surprising, given that in 2008 (the year considered), as mentioned in Section 2, the Andalusian public HEIs, as other Spanish universities, neglected scientific research, and the public investment in R&D was critically low. This should encourage the Andalusian public HEIs to adapt to the HE global competition, which has led to define research intensity as the key indicator of the quality of universities (Mägi and Beerkens, 2016). Moreover, as Heitor *et al.* (2016) mentioned, the investment in R&D and in education needs to be constantly supported, since it will greatly help the HEIs to improve their economic growth and social development. Finally, the Andalusian public HEIs and the authorities should not neglect any of the HE missions, and pay special attention to the

technology transfer block, since, as mentioned by Caldera and Debande (2010), university policies are important determinants of university technology transfer performance, and nowadays it has a vital role in the valorisation and use of knowledge. Our results reveal that some universities have a good performance and they are better ranked in the *teaching* and *research* blocks, but they perform poorly and are worse positioned in the *technology transfer* one.

Future research can extend this study. It is important to point out that the main emphasis of this paper is on the methodological contribution, while the evaluation of the nine public universities of the Andalucía region serves as an illustration of the methodology proposed. Therefore, the attention has been centered in stating the potential advantages of the methodology as compared to the ones traditionally used. The application is also devoted to this aim. Of course, an in depth study of the Andalusian (or Spanish) public university system needs more attention so some practical aspects. In fact, we are working on a comparison among all Spanish public HEIs (accross several years), where the weights are assessed by a group of experts in the field of the Spanish universities, integrated by researchers and professionals from different fields of research and different Spanish public universities. Furthermore, a wider comparison among HEIs from different European countries could be useful for the Spanish Government purposes in order to get the most out of the Bologna Process. Finally, it must be pointed out that this analysis can also be embedded in a dynamic scheme, in order to study the evolution of the HEIs along a given period, either by using fixed reference levels for the whole period, or even changing these levels according to new requirements established by the academic authorities.

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Appendix: System of Indicators

Sub-blocks	Indicators	Description
Resources	Ratio students per faculty member (*)	Total number of students / Full-time equivalent (FTE) faculty members
	Ratio of faculty members with PhD	Number of FTE faculty members holding a PhD / Number of FTE faculty members
	Availability of libraries (*)	Total number of students / Number of reading posts available
	Satisfaction of the demand	Number of new students enrolled in the degree as their first option / Number of new students enrolled
	Ratio of postgraduated students	Number of postgraduated students / Total number of students
Results	Success rate	Number of course credits passed per student / Number of course credits assessed per student
	Assessment rate	Number of course credits assessed per student / Number of course credits enrolled per student
	Graduation rate	(Number of students, among those newly enrolled in a cohort, who pass, in the expected time or in one more year, the credits needed to obtain the degree / Total number of new students of the same cohort of the corresponding university degree) * 100
	Drop-out rate (*)	(Number of students belonging to the entry cohort that first enrolled, in the first course, in the academic year 2006-2007 and who left without academic accreditation, not enrolling in the courses 2007-2008 and 2008-2009 / Number of students in the cohort who first enrolled in the academic year 2006-2007) * 100
External projection	National students	Number of undergraduate students coming from other Spanish regions / Total number of students
	International attractiveness	Number of undergraduate students coming from other countries / Total number of students
	Internships	Number of undergraduate students who carry out internships / Total number of undergraduate students
	National students in an Erasmus program	Number of Spanish undergraduate students who participate in Erasmus / Total number of students
	Foreign students in an Erasmus program	Number of students coming from other countries participating in Erasmus / Total number of students

Table 9: System of indicators in the *teaching* block. The indicators (*) are of kind *"the less, the better"*.

Sub-blocks	Indicators	Description
Publications	Publications per doctor	Universities' yearly scientific output / Number of FTE faculty members holding a PhD
	Citations per doctor	Total citations received / Number of FTE faculty members holding a PhD
	Q1 publications per doctor	Total papers in first quartile / Number of FTE faculty members holding a PhD
Other research activity	Research projects applied	Number of national research projects applied / Number of FTE faculty members holding a PhD
	International collaboration	Papers involving international collaboration / Universities' yearly scientific output
	Theses defended per doctor	Total dissertations defended / Number of FTE faculty members holding a PhD
	Participation in projects	(Number of faculty members who participate in European and national competitive scientific projects / Total number of faculty members) * 100
	Official recognition research	(Number of six-year merits awarded to the university / Number of possible six-year merits) * 100
Projecs & Funds	Training grants and contracts per doctor	Number of training grants and contracts (including all national plans) / Number of FTE faculty members holding a PhD
	Amounts of the National Plan Projects per doctor	Budgety received from national research projects / Number of FTE faculty members holding a PhD (€ per doctor)
	Success rate in National Plan Projects	Number of national research projects granted / Number of national research projects applied
	National and European projects assigned per doctor	Number of national and European projects awarded / Number of FTE faculty members holding a PhD
	R&D funds per faculty member	Budgety received from R&D / Number of FTE faculty members (€ per faculty members)

Table 10: System of indicators in the *research* block.

Indicators	Description
National patents per doctor	Number of national patents registered / Number of FTE faculty members holding a PhD
R&D contracts per doctor	Value of R&D and consultancy agreements / Number of FTE faculty members holding a PhD (thousand € per doctor)
Provision of services per doctor	Amount billed for services rendered / Number of FTE faculty members holding a PhD (thousand € per doctor)
Licenses per doctor	Patent licence revenues / Number of FTE faculty members holding a PhD (thousand € per doctor)
International patents (PCT) extensions per doctor	Number of international patents (PCT) extensions / Number of FTE faculty members holding a PhD
Spin-Off per doctor	Number of spin-offs / Number of FTE faculty members holding a PhD

Table 11: System of indicators in the *technology transfer* block. The patents granted to the Andalusian public universities in the Spanish Patent and Trademark Office are taken into account.