49

Fuzzy cluster analysis on Spanish public universities

Davinia Palomares-Montero

Adela García-Aracil

INGENIO (CSIC-UPV), Spanish Council for Scientific Research

dpalomares@ingenio.upv.es

agarcia@ingenio.upv.es

Fuzzy cluster analysis on Spanish public universities

Davinia Palomares-Montero

Adela García-Aracil

INGENIO (CSIC-UPV), Spanish Council for Scientific Research

dpalomares@ingenio.upv.es

agarcia@ingenio.upv.es

The present study tries to provide an alternative approach, by grouping Spanish public universities for the academic year 2006, into clusters that are statistically similar across all criteria, without making any assumptions about the relative importance of each criterion. When using (non fuzzy) clustering techniques, universities can only belong to a group, having a particular performance. But, actually, the same university could be important from different perspectives at the same time, to a different degree. In this sense, a fuzzy clustering approach is applied. With the results, it is possible to know the situation of each Spanish public university at the national context.

1 Introduction

Higher Education Institutions (HEIs) around the world are undergoing important changes. Experts in the field of higher education (HE) affirm that the 21st century will be the period of the highest growth in HE in the history of education, with qualitative changes in the system such that HEIs will be forced to make important readjustments in order to fit with public sector financial management systems (Rodriguez Vargas, 2005; Leydesdorff, 2006; Bonaccorsi and Daraio, 2007).

According to the OECD (1999), universities are developing new roles and missions that have serious implications for their structures. At the same time, universities are carrying out processes of costs rationalization due, among others things, to the decrease in public R&D funding and the increase in private funding. For example, in Germany Spain and Portugal, between 1997 and 2005 public R&D funding decreased by 1.0%, 0.5% and 10.6% respectively, while private financing of universities increased by 2.4%, 5.6% and 13.7%, respectively (Eurostat, 2007; INE, 2007).

To cope with these changes, governments and HE agencies are implementing strategies to improve HE efficiency and ensure optimal utilization of resources. Spanish universities have undergone a complete legal and structural transformation over the last few decades, which have resulted in major reforms to their systems. Governments are establishing new management forms for public institutions, the most important of which is greater autonomy, which demands greater

efficiency, efficacy and responsibility from these organizations (LOU, 2001, 2007). In this context, many theoreticians think it is vital that universities are evaluated (Keller, 1999; Villarreal, 1999; Pla and Villarreal, 2001; García-Aracil et al., 2006).

Evaluation of universities is a relatively recent phenomenon in Spain compared to other western countries; North America can be taken as the reference case (Blank, 1993; De Miguel, 2007). HE assessment is a complex process that requires previously agreed reliable and appropriate standards (Miguel Díaz, 1999). Rather surprisingly, in a world where information plays an important role in the creation of new knowledge, we do not have information about how to develop such indicators (Bonaccorsi and Daraio, 2007). Thus, there has been an upsurge in studies on the evaluation of universities using different indicators systems (Douglas Williams, 1995; García-Aracil et al., 2006; Aghion et al., 2007; García-Aracil and Villarreal, 2009), which has resulted in a multiplicity of indicators in the literature that are addressed to teaching, research activities, the transfer of research results or evaluation of several of these factors simultaneously. There is also a lack of adequate disaggregated data. Therefore, it is necessary to systematize the existing indicators to facilitate the establishment of criteria for decision making and classification of the factors related to evaluation (Oakes, 1989; Consejo de Universidades, 1999; Westerheijden, 1999; García-Aracil, 2007; MEC, 2007).

In this paper we present some indicators from different aspects of the universities performance according to their three main missions: teaching, research and knowledge transfer. In Section 2 those indicators are presented like academic rankings approaches in each university mission and a global ranking is obtained. Section 3 describes the fuzzy cluster methodology. Section 4 shows the results, and Section 5 offers some concluding remarks.

2 Descriptive data

Spanish Higher Education is provided almost entirely within the framework of the universities. The Spanish Constitution of 1978 provides for the existence of both public and private universities. In 2009, there are 50 public (one of which, UNED – National Open University – which operates throughout the whole Spain; and another two, UNIA – Internacional de Andalucía – and UIMP – Internacional Menéndez Pelayo- that offer only unofficial degrees) and 27 private universities (four of which, UDIMA- Universidad a Distancia de Madrid, UOC – Universitat Oberta de Catalunya, VIR – Universidad Internacional Valenciana; UNIR – Universidad Internacional de la Rioja, are open private universities operating throughout the whole of Spain). There are also several foreign universities that offer studies based on the education systems in their countries of origin.

Within the university system, public and private universities differ in terms of their structural and main output features. Public universities are older than private ones and are larger in size

measured by number of students and professors. In terms of number of professors with a PhD degree in total university tenured professors, there are no significant differences between the two types of universities. Private universities are associated with higher regional GDP, since most are in the richer regions of the country, while public ones are widely distributed geographically.

Public universities are more research-oriented: their publications are mainly international (ISI vs Spanish databases), they show higher productivity per professor in ISI publications and number of successful PhD graduates. The younger age of private universities might be an explanatory factor, since some have not had time to develop PhD programmes. On the other hand, private universities tend to be more teaching-oriented. Teaching predominates over research in private universities because many of these institutions are oriented principally to providing training in professional areas of interest to society. Furthermore, private universities usually obtain good results when teaching is assessed in relation to productivity, measured by the rate of graduate students, unemployment rates among graduates and type of job obtained.

Therefore, the analysis of this paper is limited to the 47 face-to-face public universities, due to the different structure of the distance universities and the low scientific output of most private universities, which can in part be explained by their short history.

Table 1 presents the classification of the Spanish public universities according to the teaching indicators: performance rate (rate between the number of credits passed with respect to the number of credits enrolled); student-teacher ratio; and running expenses per student Scores on indicators are ranked from highest to lowest. Then, universities are classified with number: 1 (the top), 2, 3, …., 47 (the bottom). Focusing on the successful performance rate, the University Pompeu Fabra rated the highest in this ratio, followed by the Autonoma of Barcelona, Carlos III of Madrid, Public University of Navarra and University of Lleida. For the case of the student-teacher ratio, the values ranged from less than 11 students per teacher, as the Public University of Navarra (10.44) and the Basque Country University (10.75), to more than 16 students per teacher such as the University of Malaga (17.63). Regarding the indicator of running expenses per student, the leader was the Public University of Navarra with more than 8,000 euros per student, followed by the Technical University of Madrid (between 7,000 euros and 8,000 euros). Finally, the last two columns in Table 1 show the classification of the Spanish public universities after calculating an index made up of the previous three teaching-indicators as we called the global ranking. It is observed that the five best public universities in Spain were the Public University of Navarra, University of Lleida, Pompeu Fabra, Carlos III of Madrid and the Basque Country University.

In general, looking at the teaching performance rankings, we can conclude that Pompeu Fabra University, University of Barcelona, University of Cantabria, Technical University of Catalonia, Basque Country University, Public University of Navarra, Carlos III University, Technical University of Madrid and University of Lleida are the best universities in terms of

performance on teaching activities because they appear in the first five in the teaching ranking. It is curious that only one of them is a "historical university", that is, the University of Barcelona. The others were established in the 1970s (four of them) and the late 1980s and early 1990s (four of them). Thus, in contrast to established thinking "historical universities" are not always the best universities for teaching, and new institutions established since the 1960s are among the best performing for teaching.

Table 2 presents the classification of the Spanish public universities according to the research indicators: thesis awarded by professor holding a PhD degree; ISI publication-tenured professor ratio; sexenio-tenured professor ratio (sexenios – for each period of six years, a tenured professor can present his/her most relevant scientific contribution to a national committee of experts in his/her particular discipline in the hope of receiving a positive assessment of individual research activity – the so-called sexenios, which implies a salary increase). Again, universities are classified with number: 1 (the top), 2, 3, …., 47 (the bottom). The universities that obtained a high rate in the number of thesis awarded by professor holding a PhD degree were the University of Miguel Hernandez, Autonoma of Barcelona, Complutense of Madrid and Autonoma of Madrid, which got more than 18 thesis per each 100 professor. Regarding the number of ISI publications per tenured professor, the leader university was the University of Burgos for the academic year 2006/2007. Focusing on the ratio of sexenios by tenured professor, we found at the top the Autonoma of Madrid (2.31) followed by the Pompeu Fabra (1.95) and the Autonoma of Barcelona (1.94). Finally, the last two columns in Table 2 show the classification of the universities after calculating an index made up of the previous three research-indicators as we called the global ranking. It is observed that the five best public universities were the Autonoma of Madrid, Pompeu Fabra, Cordoba, Santiago of Compostela and Rovira Virgili. Thus, one of the "historical universities" as the University of Santiago de Compostela is among the best research institutions. Maybe, it could not be concluded that new universities perform better than older universities for research activities.

Table 3 shows the classification of the Spanish public universities according to the knowledge transfer indicators: patent-teacher ratio; contracts-teacher ratio; grants income by full-time teacher. Universities are classified with number: 1 (the top), 2, 3, …., 47 (the bottom). With respect to the proportion of patents applied by full-time teacher, we observe that the Technical University of Catalunya rated the highest. On the other hand, the universities that got more money from R&D contracts were the Technical University of Valencia, Cantabria, Technical University of Catalunya and Autonoma of Madrid with more than 10,000 euros per full-time teacher. However, the universities that got more money from R&D grants were the Rovira Virgili, Santiago of Compostela and Technical University of Catalunya with more than 17,000 euros per full-time teacher. Finally, the last two columns in Table 3 present the global ranking after taking into account

the three previous knowledge transfer- rankings. The five best public universities were: Technical University of Catalunya, Cantabria, Technical University of Valencia, Technical University of Madrid and Autonoma of Madrid. It seems that university's age could be an indicator of university's performance in this area.

Table 1. Teaching performance rankings for the Spanish public universities. Academic year 2006/2007.

R	University	Performance Rate	R	University	Students/ Teacher Staff (FTE)	R	University	Running expenses / Students (€)	Global R	University
1	pompeu_fabra	81.70	1	publica_navarra	10.44	1	publica_navarra	8,323.53	1	publica_navarra
2	autonoma_barcelona	70.38	2	pais_vasco	10.75	2	poli_madrid	7,122.61	2	lleida
3	carlosIII_madrid	69.36	3	lleida	11.05	3	poli_catalunya	6,795.56	3	pompeu_fabra
4	publica_navarra	69.36	4	zaragoza	11.24	4	lleida	6,713.32	4	carlosIII_madrid
5	lleida	69.02	5	poli_madrid	11.80	5	pais_vasco	6,595.75	5	pais_vasco
6	girona	68.85	6	cantabria	11.90	6	cantabria	6,521.25	6	poli_catalunya
7	roviraivirg	68.21	7	pompeu_fabra	11.90	7	pompeu_fabra	6,406.07	7	barcelona
8	poli_catalunya	67.70	8	carlosIII_madrid	11.95	8	carlosIII_madrid	6,303.43	8	cantabria
9	autonoma_madrid	66.98	9	valladolid	12.20	9	alcala	6,247.02	9	zaragoza
10	barcelona	66.71	10	poli_cartagena	12.38	10	barcelona	6,202.16	10	autonoma_barcelona
11	pablo_olavide	65.95	11	salamanca	12.90	11	roviraivirg	6,075.02	11	salamanca
12	huelva	65.36	12	barcelona	12.98	12	zaragoza	6,013.66	12	autonoma_madrid
13	castilla_mancha	65.36	13	huelva	13.11	13	autonoma_barcelona	5,964.58	13	huelva
14	salamanca	65.14	14	alcala	13.16	14	poli_valencia	5,816.52	14	roviraivirg
15	pais_vasco	64.98	15	poli_valencia	13.20	15	complutense_madrid	5,814.44	15	alcala
16	zaragoza	64.70	16	poli_catalunya	13.22	16	jaume	5,727.62	16	girona
17	complutense_madrid	64.03	17	autonoma_madrid	13.27	17	salamanca	5,702.48	17	poli_madrid
18	santiago_compostela	63.34	18	burgos	13.31	18	castilla_mancha	5,673.45	18	poli_valencia
19	leon	63.22	19	la_laguna	13.50	19	autonoma_madrid	5,639.38	19	valladolid
20	cantabria	62.87	20	girona	13.69	20	poli_cartagena	5,579.59	20	castilla_mancha
21	valencia	62.69	21	jaume	13.83	21	la_laguna	5,565.51	21	complutense_madrid
22	valladolid	62.66	22	miguel_hernandez	14.18	22	santiago_compostela	5,541.42	22	santiago_compostela
23	cadiz	61.72	23	santiago_compostela	14.25	23	miguel_hernandez	5,452.93	23	miguel_hernandez
24	cordoba	60.77	24	autonoma_barcelona	14.29	24	huelva	5,410.31	24	jaume
25	poli_valencia	60.12	25	extremadura	14.40	25	valencia	5,263.30	25	pablo_olavide
26	malaga	59.96	26	alicante	14.43	26	valladolid	5,235.92	26	poli_cartagena

27	oviedo	59.90	27	oviedo	14.51	27	girona	5,199.26	27	valencia
28	alcala	59.67	28	castilla_mancha	14.62	28	cordoba	5,174.40	28	la_laguna
29	is_baleares	59.65	29	complutense_madrid	14.65	29	oviedo	5,122.66	29	oviedo
30	miguel_hernandez	59.58	30	pablo_olavide	14.67	30	la_rioja	4,989.41	30	leon
31	la_rioja	59.55	31	cadiz	14.69	31	las_palmas_gran_canaria	4,982.85	31	burgos
32	granada	59.43	32	roviraivirg	14.73	32	burgos	4,937.57	32	cadiz
33	jaen	59.33	33	valencia	14.83	33	leon	4,906.13	33	cordoba
34	sevilla	58.48	34	murcia	14.89	34	almeria	4,855.43	34	alicante
35	rey_jc	58.34	35	leon	14.94	35	pablo_olavide	4,854.67	35	la_rioja
36	almeria	57.51	36	is_baleares	15.03	36	alicante	4,810.37	36	almeria
37	vigo	57.19	37	almeria	15.23	37	cadiz	4,793.49	37	sevilla
38	burgos	57.17	38	sevilla	15.38	38	sevilla	4,651.48	38	is_baleares
39	jaume	56.76	39	las_palmas_gran_canaria	15.44	39	granada	4,596.67	39	extremadura
40	la_laguna	55.42	40	vigo	15.61	40	murcia	4,594.07	40	las_palmas_gran_canaria
41	alicante	54.88	41	jaen	16.00	41	malaga	4,485.53	41	malaga
42	murcia	54.66	42	a_corunya	16.08	42	vigo	4,407.93	42	granada
43	a_corunya	54.52	43	la_rioja	16.09	43	jaen	4,299.41	43	murcia
44	las_palmas_gran_canaria	54.10	44	granada	16.34	44	extremadura	4,177.62	44	jaen
45	extremadura	53.60	45	rey_jc	16.67	45	a_corunya	4,176.07	45	vigo
46	poli_madrid	52.03	46	cordoba	16.89	46	rey_jc	4,171.95	46	rey_jc
47	poli_cartagena	51.25	47	malaga	17.63	47	is_baleares	4,168.86	47	a_corunya

Table 2. Research performance rankings for the Spanish public universities. Academic year 2006/2007.

R	University	Thesis awarded/ 10 Professor holding PhD	R	University	ISI publications/ Total tenured professor	R	University	*Sexenios*/ Total tenured professor	Global R	University
1	miguel_hernandez	6.19	1	burgos	3.89	1	autonoma_madrid	2.31	1	autonoma_madrid
2	autonoma_barcelona	2.02	2	roviraivirg	0.96	2	pompeu_fabra	1.95	2	pompeu_fabra
3	complutense_madrid	1.90	3	alicante	0.91	3	autonoma_barcelona	1.94	3	cordoba
4	autonoma_madrid	1.83	4	castilla_mancha	0.79	4	carlosIII_madrid	1.78	4	santiago_compostela
5	barcelona	1.60	5	lleida	0.71	5	complutense_madrid	1.70	5	roviraivirg
6	poli_catalunya	1.55	6	autonoma_madrid	0.63	6	barcelona	1.66	6	alicante
7	valencia	1.47	7	girona	0.56	7	santiago_compostela	1.65	7	complutense_madrid
8	pompeu_fabra	1.46	8	santiago_compostela	0.55	8	valencia	1.62	8	granada
9	cordoba	1.42	9	cantabria	0.45	9	cantabria	1.59	9	cantabria
10	alcala	1.41	10	cordoba	0.44	10	pablo_olavide	1.56	10	alcala
11	alicante	1.39	11	valladolid	0.44	11	granada	1.54	11	autonoma_barcelona
12	rey_jc	1.34	12	vigo	0.43	12	cordoba	1.53	12	miguel_hernandez
13	roviraivirg	1.30	13	oviedo	0.41	13	murcia	1.46	13	oviedo
14	salamanca	1.28	14	granada	0.37	14	salamanca	1.45	14	barcelona
15	leon	1.27	15	jaen	0.34	15	alcala	1.44	15	valencia
16	granada	1.19	16	pompeu_fabra	0.33	16	oviedo	1.36	16	leon
17	jaume	1.19	17	almeria	0.32	17	sevilla	1.35	17	murcia
18	santiago_compostela	1.17	18	zaragoza	0.32	18	zaragoza	1.34	18	zaragoza
19	almeria	1.15	19	leon	0.32	19	miguel_hernandez	1.27	19	carlosIII_madrid
20	oviedo	1.14	20	carlosIII_madrid	0.32	20	is_baleares	1.24	20	sevilla
21	poli_valencia	1.10	21	murcia	0.32	21	roviraivirg	1.19	21	almeria
22	sevilla	1.07	22	alcala	0.31	22	publica_navarra	1.19	22	lleida
23	vigo	1.07	23	is_baleares	0.29	23	poli_catalunya	1.16	23	is_baleares
24	poli_cartagena	1.06	24	la_laguna	0.29	24	alicante	1.14	24	poli_catalunya
25	zaragoza	0.95	25	malaga	0.28	25	leon	1.13	25	vigo

26	murcia	0.94	26	publica_navarra	0.28	26	valladolid	1.11	26	salamanca
27	cantabria	0.93	27	sevilla	0.27	27	jaume	1.09	27	publica_navarra
28	publica_navarra	0.93	28	poli_cartagena	0.27	28	malaga	1.08	28	girona
29	is_baleares	0.88	29	miguel_hernandez	0.26	29	extremadura	1.07	29	castilla_mancha
30	extremadura	0.87	30	poli_valencia	0.26	30	lleida	1.03	30	valladolid
31	a_corunya	0.87	31	extremadura	0.26	31	la_laguna	1.01	31	pablo_olavide
32	pais_vasco	0.85	32	complutense_madrid	0.25	32	pais_vasco	0.99	32	malaga
33	malaga	0.82	33	a_corunya	0.23	33	girona	0.95	33	rey_jc
34	poli_madrid	0.81	34	poli_madrid	0.23	34	almeria	0.89	34	burgos
35	pablo_olavide	0.80	35	rey_jc	0.23	35	la_rioja	0.87	35	extremadura
36	lleida	0.80	36	la_rioja	0.23	36	castilla_mancha	0.86	36	jaume
37	cadiz	0.77	37	cadiz	0.20	37	vigo	0.86	37	poli_valencia
38	girona	0.77	38	pais_vasco	0.20	38	cadiz	0.83	38	la_laguna
39	castilla_mancha	0.75	39	huelva	0.17	39	rey_jc	0.83	39	poli_cartagena
40	burgos	0.75	40	pablo_olavide	0.17	40	jaen	0.82	40	jaen
41	carlosIII_madrid	0.74	41	las_palmas_gran_canaria	0.17	41	a_corunya	0.77	41	pais_vasco
42	las_palmas_gran_canaria	0.73	42	valencia	0.16	42	poli_madrid	0.77	42	a_corunya
43	la_laguna	0.72	43	poli_catalunya	0.13	43	poli_valencia	0.64	43	poli_madrid
44	valladolid	0.69	44	autonoma_barcelona	0.11	44	huelva	0.61	44	cadiz
45	jaen	0.64	45	barcelona	0.11	45	las_palmas_gran_canaria	0.61	45	la_rioja
46	la_rioja	0.60	46	salamanca	0.10	46	poli_cartagena	0.60	46	las_palmas_gran_canaria
47	huelva	0.54	47	jaume	0.09	47	burgos	0.59	47	huelva

Table 3. Knowledge-transfer performance rankings for the Spanish public universities. Academic year 2006/2007.

R	University	(%) Patent applied per Teacher Staff (FTE)	R	University	Contracts income/Teacher Staff (FTE)	R	University	Grants income/ Teacher Staff (FTE)	Global R	University
1	poli_catalunya	1.17	1	poli_valencia	18.194,64	1	roviraivirg	19.086,22	1	poli_catalunya
2	alcala	0.91	2	cantabria	13.027,82	2	santiago_compostela	17.191,75	2	cantabria
3	cadiz	0.90	3	poli_catalunya	12.282,57	3	poli_catalunya	17.167,04	3	poli_valencia
4	poli_valencia	0.87	4	autonoma_madrid	10.108,11	4	pompeu_fabra	16.973,66	4	poli_madrid
5	almeria	0.80	5	roviraivirg	9.737,44	5	cantabria	16.174,14	5	autonoma_madrid
6	vigo	0.64	6	poli_madrid	8.508,77	6	autonoma_madrid	13.351,17	6	sevilla
7	poli_cartagena	0.63	7	santiago_compostela	7.569,99	7	almeria	12.876,17	7	publica_navarra
8	poli_madrid	0.62	8	carlosIII_madrid	6.205,59	8	cordoba	12.724,78	8	almeria
9	cantabria	0.55	9	autonoma_barcelona	6.035,96	9	sevilla	12.166,14	9	cordoba
10	burgos	0.49	10	barcelona	5.730,56	10	pablo_olavide	11.684,91	10	roviraivirg
11	sevilla	0.48	11	poli_cartagena	5.639,60	11	poli_valencia	10.872,12	11	santiago_compostela
12	cordoba	0.47	12	publica_navarra	5.373,72	12	cadiz	10.844,45	12	barcelona
13	publica_navarra	0.43	13	zaragoza	5.344,54	13	granada	10.724,67	13	cadiz
14	leon	0.43	14	girona	5.017,49	14	publica_navarra	10.481,99	14	pompeu_fabra
15	malaga	0.42	15	miguel_hernandez	4.921,00	15	barcelona	10.354,15	15	miguel_hernandez
16	miguel_hernandez	0.40	16	extremadura	4.898,06	16	poli_madrid	9.849,82	16	alcala
17	granada	0.36	17	valencia	4.359,03	17	girona	9.630,28	17	carlosIII_madrid
18	is_baleares	0.34	18	sevilla	3.938,14	18	castilla_mancha	8.923,81	18	poli_cartagena
19	alicante	0.33	19	pompeu_fabra	3.900,37	19	carlosIII_madrid	8.882,52	19	girona
20	oviedo	0.31	20	castilla_mancha	3.899,74	20	extremadura	8.845,81	20	zaragoza
21	salamanca	0.29	21	a_corunya	3.852,28	21	is_baleares	8.712,62	21	autonoma_barcelona
22	zaragoza	0.29	22	cordoba	3.666,11	22	lleida	8.712,21	22	extremadura
23	murcia	0.28	23	alcala	3.483,33	23	autonoma_barcelona	8.667,20	23	lleida
24	autonoma_madrid	0.28	24	lleida	3.454,51	24	miguel_hernandez	8.585,45	24	leon
25	jaen	0.22	25	las_palmas_gran_canaria	3.312,88	25	pais_vasco	8.379,65	25	granada
26	barcelona	0.21	26	oviedo	3.217,74	26	valladolid	7.671,90	26	is_baleares
27	complutense_madrid	0.19	27	pais_vasco	3.118,00	27	leon	7.591,73	27	vigo
28	lleida	0.15	28	huelva	3.103,00	28	vigo	7.393,20	28	castilla_mancha
29	huelva	0.13	29	almeria	3.018,03	29	zaragoza	7.298,09	29	pablo_olavide
30	pompeu_fabra	0.12	30	pablo_olavide	2.877,76	30	murcia	6.866,44	30	oviedo
31	girona	0.12	31	jaume	2.856,56	31	jaen	6.853,42	31	pais_vasco

32	rey_jc	0.09	32	alicante	2.816,88	32	huelva	6.765,82	32	murcia
33	carlosIII_madrid	0.07	33	rey_jc	2.812,03	33	jaume	6.275,02	33	valencia
34	las_palmas_gran_canaria	0.07	34	leon	2.765,19	34	alcala	6.262,09	34	huelva
35	pais_vasco	0.07	35	murcia	2.603,14	35	valencia	6.077,58	35	alicante
36	valencia	0.07	36	complutense_madrid	2.540,36	36	rey_jc	6.063,78	36	jaen
37	extremadura	0.06	37	cadiz	2.428,63	37	la_rioja	5.968,08	37	malaga
38	la_laguna	0.06	38	is_baleares	2.306,23	38	complutense_madrid	5.830,97	38	complutense_madrid
39	santiago_compostela	0.05	39	malaga	2.281,29	39	alicante	5.258,03	39	rey_jc
40	autonoma_barcelona	0.04	40	jaen	1.887,81	40	a_corunya	5.018,42	40	burgos
41	pablo_olavide	0.00	41	la_rioja	1.780,14	41	oviedo	4.331,44	41	las_palmas_gran_canaria
42	roviraivirg	0.00	42	salamanca	1.745,29	42	poli_cartagena	4.297,57	42	a_corunya
43	castilla_mancha	0.00	43	vigo	1.528,39	43	la_laguna	3.908,68	43	jaume
44	jaume	0.00	44	valladolid	1.410,71	44	las_palmas_gran_canaria	3.877,49	44	salamanca
45	valladolid	0.00	45	la_laguna	1.222,32	45	malaga	3.771,36	45	valladolid
46	a_corunya	0.00	46	granada	810,74	46	burgos	3.571,30	46	la_rioja
47	la_rioja	0.00	47	burgos	642,59	47	salamanca	2.713,74	47	la_laguna

3 Methodology

Clustering involves the task of dividing data points into homogeneous classes or clusters so that items in the same class are as similar as possible and items in different classes are as dissimilar as possible. Clustering can also be thought of as a form of data compression, where a large number of samples are converted into a small number of representative prototypes or clusters. Depending on the data and the application, different types of similarity measures may be used to identify classes, where the similarity measure controls how the clusters are formed.

In non-fuzzy or hard clustering, data is divided into crisp clusters, where each data point belongs to exactly one cluster. In fuzzy clustering, the data points can belong to more than one cluster, and associated with each of the points are membership grades which indicate the degree to which the data points belong to the different clusters. In real applications there is very often no sharp boundary between clusters so that fuzzy clustering is often better suited for the data. Membership degrees between zero and one are used in fuzzy clustering instead of crisp assignments of the data to clusters. The most prominent fuzzy clustering algorithm is the fuzzy c-means, a fuzzification of k-Means or ISODATA.

The family of objective function-based fuzzy clustering algorithms includes, amongst others, the fuzzy c-means algorithm (FCM): spherical clusters of approximately the same size; the Gustafson-Kessel algorithm (GK): ellipsoidal clusters with approx. the same size; there are also axis-parallel variants of this algorithm; can also be used to detect lines (to some extent); the Gath-Geva algorithm (GG) / Gaussian mixture decomposition (GMD): ellipsoidal clusters with varying size; there are also axis-parallel variants of this algorithm; can also be used to detect lines (to some extent); the fuzzy c-varieties algorithm (FCV): detection of linear manifolds (infinite lines in 2D); the adaptive fuzzy c-varieties algorithm (AFC): detection of line segments in 2D data; the fuzzy c-shells algorithm (FCS): detection of circles (no closed form solution for prototypes); the fuzzy c-spherical shells algorithm (FCSS): detection of circles; the fuzzy c-rings algorithm (FCR): detection of circles; the fuzzy c-quadric shells algorithm (FCQS): detection of ellipsoids; the fuzzy c-rectangular shells algorithm (FCRS): detection of rectangles (and variants thereof), among others (see for a more detail Höppner et al., 1999). In this study we applied the fuzzy c-means clustering algorithm (FCM).

FCM is a method of clustering which allows one piece of data to belong to two or more clusters. This method (developed by Dunn in 1973and improved by Bezdek in 1981 is frequently used in pattern recognition. It is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2 , \quad 1 \le m < \infty$$

where *m* is any real number greater than 1, *uij* is the degree of membership of *xi* in the cluster *j*, *xi* is the *i*th of d-dimensional measured data, *cj* is the d-dimension center of the cluster, and ||*|| is any norm expressing the similarity between any measured data and the center.

Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership *uij* and the cluster centers *cj* by:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{2}{m-1}}}, \qquad c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \cdot x_i}{\sum_{i=1}^{N} u_{ij}^{m}}$$

This iteration will stop when $\max_{ij}\left\{\left|u_{ij}^{(k+1)} - u_{ij}^{(k)}\right|\right\} < \varepsilon$, where ε is a termination criterion between 0 and 1, whereas *k* are the iteration steps. This procedure converges to a local minimum or a saddle point of *Jm*. The algorithm is composed of the following steps:

Initialize $U=[u_{ij}]$ *matrix,* $U^{(0)}$

At k-step: calculate the centers vectors $C^{(k)}=[c_j]$ *with* $U^{(k)}$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \cdot x_i}{\sum_{i=1}^{N} u_{ij}^{m}}$$

Update $U^{(k)}$, $U^{(k+1)}$

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{2}{m-1}}}$$

If $|| U^{(k+1)} - U^{(k)}|| < \varepsilon$ *then STOP; otherwise return to step 2.*

4 Results

After applying the fuzzy clustering approach, three main clusters are found: Two of them completely independent, containing one of them the teaching mission and the other factor the research and knowledge transfer missions; and the third one which refers to all the three main missions altogether: teacher, research and knowledge transfer.

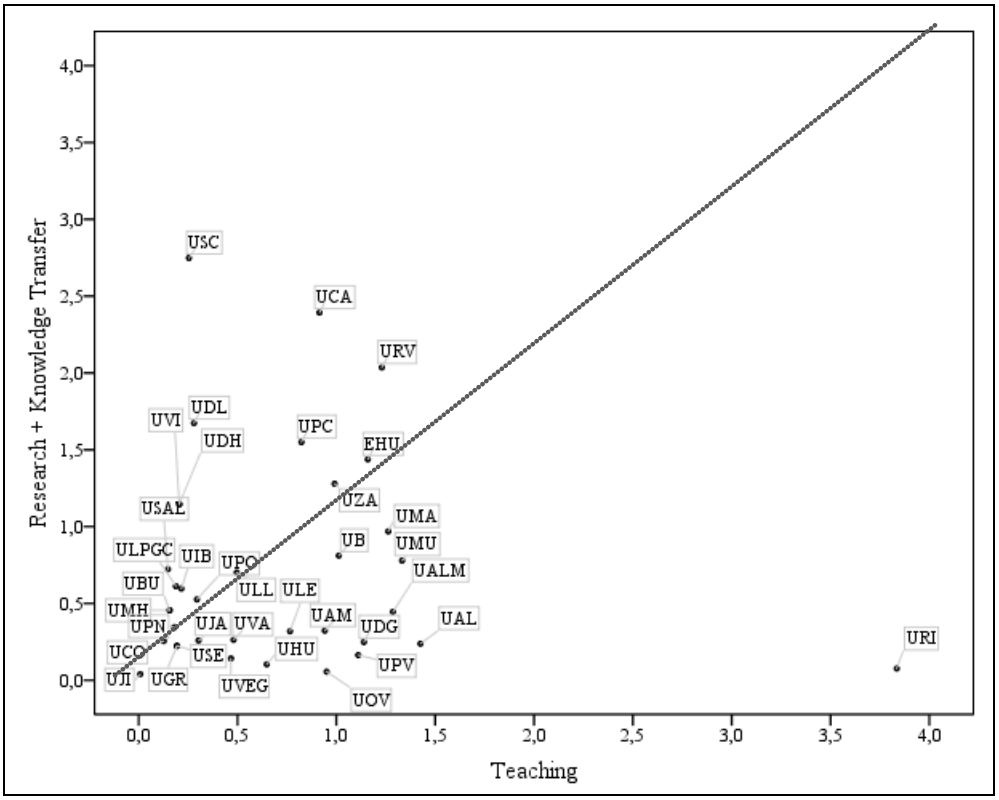
Figure 1 shows the university groups depending on their scores in each factor. It gives us an idea of the possible orientation of universities missions based on their indicators selected in this paper. Thus, universities under the diagonal are universities more guided to "Teaching". In this group we find 14 universities where it highlights mainly the University of Rioja, but also

University of Alicante, Techincal University of Valencia, University of Oviedo, University of Girona, Autonomous University of Madrid, University of Huelva, University of Valencia and University of Valladolid, which obtain high punctuations at teaching factor and low punctuations at research and knowledge transfer factors. In this group are also included University of Leon, University of Barcelona, University of Murcia, University of Malaga and University of Almeria that, in spite of being mainly guided to teaching, they obtain bigger punctuations in the other two missions compared with the previous ones.

At the top of the diagonal we find the universities guided to "Research" and "Knowledge Transfer". In this group we identify 18 institutions being the most outstanding the Santiago of Compostela University, the University of Cadiz and the Rovira i Virgili University. University of Salamanca, University of Leon, University of Vigo and University of Corunya among other also obtain high punctuations in these two missions and low scores in teaching.

Finally, there are four institutions near the diagonal, which are associated mainly with the third cluster. These are the University of Jaen, University of Seville, University of Granada and Jaume I University. We could say that these universities develop the three missions in a well balance.

Figure 1. Grouping universities depending on their orientation to teaching or to research and the knowledge transfer.



5 Conclusions

Generally, universities positioned in the first five places in the rankings in any one of the three missions, do not appear in the top five in one of the other areas. Thus, we can conclude that universities tend to focus on one particular area which means that university mission could be a good discriminatory variable on which to base a university typology.

This is not a straightforward exercise: it is sometimes difficult to decide to which group a university belongs. Depending on the indicator applied, university rankings can change. This limitation has been used by some to delegitimize the ranking approach instead of using it to improve ranking analysis through self-criticism. Establishing rankings entails making decisions that sometimes are based on suppositions and subjective decisions to legitimate the rankings. In our view, the objectivity of this evaluation processes depends on the vision and purpose of these processes. We believe, therefore, that before delegitimizing the ranking approach we should state its purpose and motivations to justify this methodology and validate the results.

In this context, we go a step further. We applied a more accurate classification using two multivariate methods, the partitioning k-means algorithm to find out whether SPU can be classified into three clusters, related to the missions, and *fuzzy cluster* analysis to find whether universities can be in different clusters at the same time depending on their degree of belonging to each cluster. This last method provides the conventional cluster approach with more flexibility.

The *fuzzy cluster* results that SPU is a flexible system which develops the three main university missions at different levels. Policy makers and stakeholders should take these results into account to implement evaluations at HEI. Not all universities plan their strategies in the same way and evaluations have to be conscious of these differences.

To conclude, we consider that university evaluation is important to improve the efficiency of the system, to compare institutions and, overall, to know how public institutions, such as SPU, manage public funding for example. What this study has revealed is that universities plan their activities following their own strategy. Thus, evaluation processes must consider these differences in order to obtain valid and comparable results among universities. In this context, it is important to get a consensus among the indicators we should apply to evaluate HEI in order to select those most appropriate for evaluation purposes.

6 References

Aghion, P., Dewatripont, M., Hoxby, C., Mas-Colell, A., Sapir, A. (2007). Why Reform Europe's Universities? *Bruegel Policy Brief,* 4, 1-8.

Bezdek, J.C. (1981). *Pattern Recognition with Fuzzy Objective Function Algoritms*. New York: Plenum Press.

Blank, R.K. (1993). Developing a System of Education Indicators: Selecting, Implementing and Reporting Indicators. *Educational Evaluation and Policy Analysis,* 15(1), 65-80.

Bonaccorsi, A., Daraio, C. (2007). Universities as strategic knowledge creators: some preliminary evidence. In A. Bonaccorsi, C. Daraio (Eds.), *Universities and Strategic Knowledge Creation* (pp. 31-81). Northampton: Edward Elgar.

Consejo de Universidades (1999). *Indicadores en la Universidad: Información y decisiones*. Madrid: MEC.

De Miguel, M. (2007). *Acreditación de educación superior*. Madrid: CIS.

Douglas Williams, J. (1995). The Challenge of Developing New Educational Indicators. *Educational Evaluation and Policy Analysis,* 17(1), 113-131.

Dunn, J.C. (1973). A Fuzzy Relative of the ISODATA Process and Its Use in Detecting Compact Well-Separated Clusters. *Journal of Cybernetics,* 3: 32-57.

Eurostat (2007). *Total intramural RandD expenditure (GERD) by source of funds*. Luxembourg: Eurostat.

García-Aracil, A. (2007). Expansion and reorganization in the Spanish higher education system. In A. Bonaccorsi, C. Daraio (Eds.), *Universities and Strategic Knowledge Creation* (pp. 376-401). Northampton: Edward Elgar.

García-Aracil, A., Gutiérrez-Gracia, A., Pérez-Marín, M. (2006). Analysis of the evaluation process of the research performance: an empirical case. *Scientometrics*, 67(2), 213 – 230.

García-Aracil, A., Villarreal, E. (2009). Some indicators to measure regional impact of entrepreneurial universities. *Management Science,* forthcoming.

Höppner, F., Klawonn, F., Kruse, R., Runkler, T. (1999). *Fuzzy Cluster Analysis.* Chichester: Wiley.

INE (2007). *Estadística sobre desarrollo de I+D. 2007*. Madrid: INE.

Keller, G. (1999). The New Importance of Strategic Management at Universities. *Universitat: Estratègies per avançar*, UPC, Barcelona.

Leydesdorff, L. (2006). *The Knowledge-based economy: modeled, measured, simulated.* USA: Universal Publisher Boca Raton.

LOU (2001). BOE n. 307 de 24/12/2001.

LOU (2007). BOE n. 89 de 13/04/2007.

MEC (2007). Borrador del catálogo de indicadores del sistema universitario público español. Madrid: MEC.

Miguel Díaz, M. (1999). La evaluación de la enseñanza. Propuesta de indicadores para las titulaciones. In Consejo de Universidades (Ed.), *Indicadores en la Universidad: Información y decisiones* (pp. 413-430). Madrid: MEC.

Oakes, J. (1989). What Education Indicators? The Case for Assessing the School Context. *Educational Evaluation and Policy Analysis,* 11(2), 182-199.

OECD (1999). *University research in transition*. Paris: OECD.

Pla, A., Villarreal, E. (2001). Measuring the Internal Efficiency of Universities: Social Demand, Diversity and Rising Costs. Paper presented at the *XXIII Annual EAIR Forum*. University of Porto, Porto.

Rodríguez Vargas, J.J. (2005). *La Nueva Fase de Desarrollo Económico y Social del Capitalismo Mundial*. http://www.eumed.net/tesis/jjrv/

Villarreal, E. (1999). La utilización de indicadores de rendimiento en la financiación de la educación superior. In Consejo de Universidades (Ed.), *Indicadores en la Universidad: Información y decisiones* (pp. 65-80). Madrid: MEC.

Westerheijden, D.F. (1999). Innovations indicators in science and technology: comments from a higher education point of view. *Scientometrics,* 45(3), 445-453.