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A comparison of top economics departments in the US and EU on the basis of the multidimensional prestige of influential articles in 2010

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Abstract Here we show a comparison of top economics departments in the US and EU based on a summary measure of the multidimensional prestige of influential papers in 2010. The multidimensional prestige takes into account that several indicators should be used for a distinct analysis of structural changes at the score distribution of paper prestige. We argue that the prestige of influential articles should not only consider one indicator as a single dimension, but in addition take into account further dimensions, since several different indicators have been developed to evaluate the impact of academic papers. After having identified the multidimensionally influential articles from an economics department, their prestige scores can be aggregated to produce a summary measure of the multidimensional prestige of research output of this department, which satisfies numerous properties.

Keywords Publication-based ranking · Economics department · Multidimensional prestige · Influential articles · ISI Impact Factor · Citation impact · Princeton University · MIT · Oxford University

Introduction

In this paper we provide an objective ranking of top economics departments in the European Union (EU) and an assessment of how EU departments compare to the top economics departments in the United States.

To this aim, a select group of eight economics departments in the US and EU are considered: (1) Department of Economics, Harvard University; (2) Department of Economics, Massachusetts Institute of Technology (MIT); (3) Department of Economics,

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But, what is the interest in the ranking of economics departments? It stems from the need to evaluate research output using to this aim some kind of objective metrics, such as citation impact and journal ranking models. For example, it may guide student choice of a university and department to pursue a graduate degree (Dridi et al. 2010).

The number of academic papers produced in a year by each member of staff in a department particularly in the EU and US is regarded as an indication of their career success. Rankings of graduate programs based on publication in peer-reviewed journals are objective, and many faculty believe academic journals remain the fairest measure of the quality of our research (Dusansky and Vernon 1998). Since publication-based performance evaluations underlie the faculty promotions process, there are already mechanisms to ensure high levels of accuracy of these data (Dusansky and Vernon 1998).

Economists have been conducting research about department rankings at geographical scales (Davies et al. 2008; Lubrano et al. 2003; Kalaitzidakis et al. 2003). Ranking of departments by specializations in economics exist as well (Rousseau et al. 2008; Laband et al. 2006; Kinnucan et al. 1994). However formal rankings of economics departments are often based on one metric only (Dridi et al. 2010).

Each academic paper from an economics department may be graded on the basis of the prestige accorded to the journal in which it appears as well as how often it was cited. The analysis of the prestige distribution can be concerned with only one dimension, e.g., the ISI Impact Factor. Nevertheless, the ISI Impact Factor does not capture every single component that arguably might influence journal prestige (Garcia et al. 2011c).

In this study we fill a gap in the literature and provide a publication-based ranking of economics departments in a multidimensional setting, in which prestige relates to the recognition of the originality of research and its impact on the development of the same or related discipline areas from the viewpoint of several indicators. That is, the perception of prestige is not only restricted to the analysis of ISI Impact Factor distribution, but different models, e.g., H-index, Article Influence Score (AIS) or citation impact, play an important role in the measurement of prestige.

Journal coverage of the SCI and Scopus is based on different principles, and this—possibly the different national perspectives of the producers—influences the different prestige indicators given above. The former coverage is based on sociometric, elitist principles, whereas the latter aims to be more comprehensive. That is why the multidimensional measurement of prestige can be of interest for researchers.

In this paper, we extend the one-dimensional measure developed by Garcia et al. (2011a, b) to a multidimensional case following Peichl and Pestel (2010) who proposes a class of economic measures of richness in Germany. Thus our approach identifies those articles from an economics department that are considered to be multidimensionally influential. Furthermore, the multidimensional prestige of influential articles is to be sensitive to changes in the score distribution of each dimension, which allows us to investigate inequality among multidimensionally influential articles.

The setup of the paper is organized as follows: "Multidimensional prestige of influential papers" section introduces a summary measure of multidimensional prestige of influential papers, which satisfies numerous properties. "Dimensions of the multivariate indicator space" section discusses the definition of a multivariate indicator space in which multidimensional prestige of influential articles is to be calculated. The data we employ are from

Web of Knowledge in 2010. Then in "Ranking of top economics departments in the US and EU in 2010" section we shall apply our approach to a select group of eight economics departments in the US and UE in order to analyse the comparative multidimensional prestige of influential articles in 2010. "A summary measure of multidimensional prestige" section concludes.

Multidimensional prestige of influential papers

Let $U = \{s_1, s_2, \ldots, s_n\}$ be the set of academic papers (published in JCR journals) from an economics department.

Each paper may be graded on the basis of the prestige accorded to the JCR journal in which it appears as well as how often it was cited. Regarding the number of dimensions (prestige indicators) to be used in a multidimensional setting in order to measure prestige of influential papers, we may consider several indicators with different degrees of correlation among them, but which should be used for a distinct analysis of structural changes at the score distribution of paper prestige: e.g., Scimago Journal Ranking (SJR); H-Index (H); ISI Impact Factor (IF); 5-Year Impact Factor (5IF); Immediacy Index (II); Eigenfactor Score (ES); AIS; and citation impact.

Then, a paper s_i is considered as having dimension-specific prestige when its score based on a given ranking model (e.g., citation impact or ISI Impact Factor accorded to the journal in which it appears) exceeds a threshold value.

Next, we define which academic papers from an economics department are considered to be prestigious using a multivariate indicator space. In a multidimensional setting "Prestige" relates to the recognition of the originality of research and its impact on the development of the same or related discipline areas from the viewpoint of several dimensions. That is, the perception of the recognition of the originality of research and its impact is not only restricted to the analysis of ISI Impact Factor distribution, but different models, e.g., H-index, AIS or citation impact, play an important role in the measurement of prestige. Thus, a paper has multidimensional prestige only if it is a prestigious article with respect to a number of dimensions.

Finally, after having identified the multidimensionally influential papers from an economics department, their prestige scores are aggregated to a summary measure of multidimensional prestige. The summary measure is not only sensitive to the number of dimensions but also takes into account changes in the ranking scores of prestigious articles from this department.

Multidimensionally influential papers

The number of papers (published in JCR journals) from an economics department is denoted with n as given above, and let $d \geq 2$ be the number of dimensions in the multivariate indicator space.

Let $\mathbf{X}$ be the matrix of dimension-specific scores x_{ij} which denote the ranking score of paper s_i, with $1 \leq i \leq n$, in ranking model corresponding to dimension j, with $1 \leq j \leq d$:

$$\mathbf{X} = \left[x_{ij}\right]_{n \times d} \tag{1}$$

For each dimension j, there is a threshold z_j such that papers s_i with ranking score x_{ij} above threshold z_j are to be considered dimension-specific prestigious articles.

Let $\mathbf{z}$ be the $1 \times d$ vector of dimension-specific thresholds. Using this vector it is possible identify whether paper s_i is prestigious with respect to dimension j or not. Let θ_{ij} be a function defined as:

$$\theta_{ij} = \begin{cases} 1 & \text{if } x_{ij} > z_j \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Using function θ_{ij} it is possible to construct a matrix Θ^{0-1} which provides information about whether a paper s_i is prestigious with respect to dimension j or not:

$$\Theta^{0-1} = \left[\theta_{ij}\right]_{n \times d} \tag{3}$$

where each row vector θ_i of Θ^{0-1} gives us a vector of prestige counts which can be denoted as $\mathbf{c} = (c_1, \ldots, c_n)'$ whose elements $c_i = \sum_{j=1}^{d} \theta_{ij}$ are equal to the number of dimensions in which paper s_i is found to be prestigious.

We can now define which academic papers from a given department are considered to be prestigious in a multidimensional sense: An article s_i is a multidimensionally influential paper if it is prestigious for a number of dimensions which is greater than or equal to a certain integer k, with $1 \leq k \leq d$.

That is, a paper s_i is multidimensionally influential if $c_i \geq k$, with c_i being the number of dimensions in which paper s_i was found to be prestigious.

For a given integer k, we can define a function ϕ_i ($\mathbf{z}$; k) which equals to one if article s_i is multidimensionally influential, and is zero otherwise:

$$\phi_i(\mathbf{z}; k) = \begin{cases} 1 & \text{if } c_i \geq k \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

with $\mathbf{z}$ being the $1 \times d$ vector of dimension-specific thresholds.

Therefore the subset of academic papers from an economics department which are multidimensionally influential is given by:

$$\Phi(\mathbf{z}; k) = \{s_i, 1 \leq i \leq n | \phi_i(\mathbf{z}; k) = 1\} \tag{5}$$

For a given integer k, let $w(k)$ be the number of multidimensionally influential articles from an economics department. From Eq. (5) it follows that $w(k)$ is given by the cardinal of the subset $\Phi(\mathbf{z}; k)$:

$$w(k) = |\Phi(\mathbf{z}; k)| \tag{6}$$

where $| \cdot |$ is the cardinality (size) of a set.

In case of $k = 1$, paper s_i is multidimensionally influential when it is considered prestigious in only one single dimension (e.g., citation impact) under consideration. But paper prestige in one single dimension may be something dangerous (Garcia et al. 2011c).

Second, in case of $k = d$, it is only considered as multidimensionally influential if it is prestigious for all dimensions under consideration. But this is a demanding requirement, especially if the number of dimensions d of the multivariate indicator space is large, which often identifies a very narrow slice of papers from an economics department.

In case of $1 < k < d$ we have an intermediate approach as proposed in Alkire and Foster (2008).

A summary measure of multidimensional prestige

Recall that the vector of prestige counts denoted as $\mathbf{c}$ was defined such that $\mathbf{c} = (c_1, \ldots, c_n)'$, where $c_i = \sum_{j=1}^{d} \theta_{ij}$ is the number of dimensions in which paper s_i is found to be prestigious, with θ_{ij} being equal to one if paper s_i is prestigious with respect to dimension j and zero otherwise as given in Eq. (2). Since a summary measure of the multidimensional prestige of influential papers must take into account information on multidimensionally influential articles only, we must replace the elements of $\mathbf{c}$ as follows:

$$c_i^k = \begin{cases} c_i & \text{if } c_i \geq k \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

From Eq. (7), we have that $\mathbf{c^k} = (c_1^k, \ldots, c_i^k, \ldots, c_n^k)'$ contains zeros for articles s_i not considered to be multidimensionally prestigious, that is, when a paper s_i is not multidimensionally influential, $c_i < k$, its entry in $\mathbf{c^k}$ is zero.

For a given integer k, let W_1 (k) be the proportion of multidimensionally influential papers from an economics department as follows:

$$W_1(k) = \frac{w(k)}{n} \tag{8}$$

with $w(k)$ being the number of multidimensionally influential papers as given in Eq. (6).

Also let W_2 (k) be the ratio between the number of prestige counts among the multidimensionally influential papers and the maximum number of prestige counts that would be observed when all multidimensionally influential papers were prestigious in all the dimensions:

$$W_2(k) = \frac{|\mathbf{c^k}|}{w(k) \times d} \tag{9}$$

with $\mathbf{c^k} = (c_1^k, \ldots, c_i^k, \ldots, c_n^k)'$ and c_i^k being defined as given in Eq. (7); and thus, **|c^{k|** $= \sum_{i=1}^{n} c_i^k$ denotes the number of prestige counts of multidimensionally influential papers.

From Eqs. (8) and (9), it follows a first measure of multidimensional prestige of influential papers by multiplying W_1 and W_2:

$$W_1(k) \times W_2(k) = \frac{|\mathbf{c^k}|}{n \times d} \tag{10}$$

which is equal to the proportion of the total number of prestige counts to the maximum number of prestige counts that one would observe when every academic paper from a given department would be influential with respect to every single dimension. But this simple measure does not necessarily increase when some dimension-specific score (above a given threshold z_j) rises for a multidimensionally influential paper. Hence, $W_1 \times W_2$ does not reveal information about the depth of paper prestige.

To overcome this drawback and others, in the following we propose a number of constraints which an axiomatic measure of the multidimensional prestige of influential papers must satisfy. But first, following the approach given in Garcia et al. (2011a), we define a summary measure MW of the multidimensional prestige of influential papers as the normalized weighted sum of the article contribution to the overall prestige as follows:

Definition 1 Given a configuration $\mathbf{X} = \left[x_{ij}\right]_{n \times d}$ of dimension-specific scores of size $n \times d$, and a $1 \times d$ vector $\mathbf{z} = (z_1, \ldots, z_j, \ldots, z_d)$ of dimension-specific thresholds, a summary measure of the overall prestige MW of multidimensionally influential papers from an economics department is defined by a normalized weighted sum of article contributions to the overall prestige using weighting function f, as follows:

$$MW = \frac{1}{n \times d} \sum_{i=1}^{n} \sum_{j=1}^{d} f\left(\frac{x_{ij}}{z_j}\right), \tag{11}$$

where the mathematical form of f depends on a set of axioms to be proposed.

We now present a set of axioms in order to define the exact form of a summary measure as that given in Definition 1 which shall have some desirable properties. To this aim we reformulate to the study of the multidimensional prestige of influential papers a number of constraints which were first used in an axiomatic approach to economic poverty measurement (Sen 1976; Takayama 1979; Peichl et al. 2008).

Thus, a first axiom states that a paper which is not multidimensionally prestigious should not influence the overall prestige of multidimensionally influential papers.

Axiom 1 Given two configurations of dimension-specific scores $\mathbf{X}$ and $\mathbf{X}'$ of the same size $n \times d$ where the scores of multidimensionally influential papers are the same in both cases, the summary measure of the multidimensional prestige of influential articles measured on either configuration should give the same value.

Now, a second axiom can be justified on the idea that small changes in the configuration of dimension-specific scores for multidimensionally influential papers shall not lead to discontinuously large changes in the summary measure of multidimensional prestige.

Axiom 2 The summary measure of the multidimensional prestige of influential papers should be a continuous function of dimension-specific scores for multidimensionally influential papers.

In the following, a third axiom states than an increment in some dimension-specific score (above the corresponding threshold z_j) for a multidimensionally influential paper shall increase the summary measure.

Axiom 3 An index of multidimensional prestige of influential papers should increase whenever some dimension-specific score (above threshold z_j corresponding to that dimension) rises for a multidimensionally influential paper.

Next an axiom states a property of subgroup decomposability. That is, the index has to be additively decomposable, i.e., the index of overall prestige is a weighted sum over several subgroups of papers in which the complete set U can be partitioned.

Axiom 4 The overall prestige of multidimensionally influential papers can be decomposed into the weighted sum of subgroup-prestige indices.

And the following axiom requires that the summary measure of multidimensional prestige of influential papers shall increase after a progressive transfer (from a more influential paper to a less prestigious one) of domain-specific scores above the corresponding threshold z_j between two multidimensionally influential papers.

Axiom 5 An overall prestige index should increase when a rank-preserving progressive transfer (above the corresponding domain-specific threshold) between two multidimensionally influential papers takes place.

Next, following Garcia et al. (2011c), a theorem states that these five axioms determine an axiomatic measure of multidimensional prestige of influential papers for a given domain-specific score configuration.

Theorem 1 *Let k be such that paper s_i is multidimensionally influential if $c_i \geq k$, with c_i being the number of dimensions in which paper s_i was found to be influential. Then, a summary measure of the multidimensional prestige of influential papers, given by a normalized weighted sum of domain-specific scores in the configuration* $\mathbf{X}$ *of size $n \times d$, using a weighting function f as follows:*

$$\frac{1}{n \times d} \sum_{i=1}^{n} \sum_{j=1}^{d} f\left(\frac{x_{ij}}{z_j}\right) \tag{12}$$

and such that satisfies Axioms 1–5, it can be defined as:

$$MW(k) = \frac{1}{n \times d} \sum_{i=1}^{n} \sum_{j=1}^{d} \left(1 - \left(\frac{z_j}{x_{ij}}\right)^{\beta}\right)_{+} \cdot \phi_i(\mathbf{z}; k) \tag{13}$$

with $\beta > 0$ being a sensitivity parameter for the intensity of paper prestige (for smaller values of β more weight is put on more intense prestige); $(y)_{+} = \max(y, 0)$; and where function ϕ_i ($\mathbf{z}$; k) *equals to one if article s_i is multidimensionally influential, and is zero otherwise*.

Proof Given a configuration $\mathbf{X}$, let MW be a normalized weighted sum of the dimension-specific scores in $\mathbf{X}$ using weighting function f

$$MW = \frac{1}{n \times d} \sum_{i=1}^{n} \sum_{j=1}^{d} f\left(\frac{x_{ij}}{z_j}\right) \tag{14}$$

where we have that f should be a continuous function for multidimensionally influential papers in order to satisfy Axiom 2, i.e., to verify that small changes in the configuration of dimension-specific scores (for multidimensionally influential papers) shall not lead to discontinuously large changes in the summary measure MW.

But also it follows that weighting function f should be a strictly increasing function for multidimensionally influential papers, since Axiom 3 states that an increment in some dimension-specific score (above the corresponding threshold z_j) for a multidimensionally influential paper shall increase the summary measure of multidimensional prestige MW.

From Axiom 1, a paper which is not multidimensionally prestigious should not influence the overall prestige MW, i.e., MW is independent of the dimension-specific scores for papers which are not multidimensionally influential. Hence to fulfill Axiom 1 we have that

$$f\left(\frac{x_{ij}}{z_j}\right) = 0 \tag{15}$$

for all i such that ϕ_i ($\mathbf{z}$; k) $= 0$; where ϕ_i ($\mathbf{z}$; k) equals to one if paper s_i is multidimensionally prestigious and zero otherwise, as given in Eq. (4).

Now, from Axiom 4, the summary measure MW can be decomposed into the weighted sum of subgroup prestige indices. Thus it follows that the measure MW has to be additively decomposable.

Finally, following Axiom 5, the summary measure of multidimensional prestige MW should increase after a progressive transfer (from a more influential paper to a less prestigious one) of domain-specific scores above the corresponding threshold z_j between two multidimensionally influential papers. Hence we have that weighting function f has to be concave for multidimensionally influential papers, and thus, the relative dimension-specific scores $\frac{x_{ij}}{z_j}$ then have to be transformed by a function that is concave on $(1, \infty)$ for multidimensionally influential papers.

For example, given a multidimensionally influential paper s_i, we have that

$$f\left(\frac{x_{ij}}{z_j}\right) = \left(1 - \left(\frac{z_j}{x_{ij}}\right)^{\beta}\right) \cdot \phi_i(\mathbf{z}; k)$$

is concave for $x_{ij} > z_j$ and $\beta > 0$.

To sum up, following Axioms 1–5, the summary measure MW

$$MW = \frac{1}{n \times d} \sum_{i=1}^{n} \sum_{j=1}^{d} f\left(\frac{x_{ij}}{z_j}\right) \tag{16}$$

shall satisfy that $f : R_+ \to [0, 1]$ is a strictly increasing and concave function on $(1, \infty)$ for multidimensionally influential papers s_i.

Following Peichl and Pestel (2010), if we define weighting function f as:

$$f\left(\frac{x_{ij}}{z_j}\right) = \left(1 - \left(\frac{z_j}{x_{ij}}\right)^{\beta}\right)_+ \cdot \phi_i(\mathbf{z}; k) \tag{17}$$

where $(v)_+ = \max(v, 0)$, we obtain a summary measure of the multidimensional prestige of influential journals, that resembles equation (13) satisfying Axioms 1–5, since f being defined as given in Eq. (17) it is a strictly increasing and concave function $f : R_+ \to [0, 1]$ on $(1, \infty)$ for multidimensionally influential journals s_i. $\square$

Ranking of top economics departments in the US and EU in 2010

Here we show, as an example of application, the ranking of eight economics departments in the US and EU in 2010. To this aim we compute the multidimensional prestige of influential papers for each institution using a multivariate indicator space.

Dimensions of the multivariate indicator space

Eight variables are candidates to be used in this analysis (see Appendix 1 for further details): (1) SJR; (2) H-Index (H); (3) ISI Impact Factor (IF); (4) 5-Year Impact Factor (5IF); (5) II; (6) ES; (7) AIS; and (8) Citation Impact. Part of the datasets (SJR and H scores) was retrieved from the website SCImago Journal and Country Rank (SCImago portal 2011). The rest of the data was retrieved from the websites Journal Citation Reports Thomson Reuters (Journal Citation Reports 2011) and Scopus (2011). The data were downloaded in November 2011.

Given that to this study in addition to ISI Impact Factor we incorporate a number of journal prestige indicators as further dimensions of journal prestige, we have to analyse the rank correlation coefficients between these candidate journal ranking models. Thus, we compute Spearman's rank correlation coefficients of seven score distributions (i.e., SJR, H, IF, 5IF, II, ES, and AIS distributions) over all scientific subject categories of Web of Knowledge in 2010. It allows us to study whether journal ranking models are strongly correlated or not.

Table 1 Spearman's rank coefficients of seven journal ranking models over all scientific subject categories of Web of Knowledge in 2010

Spearman's correlation between journal rankings							
	IF	5IF	II	ES	AIS	SJR	H
IF	1						
5IF	0.97	1					
II	0.81	0.79	1				
ES	0.78	0.75	0.68	1			
AIS	0.87	0.91	0.72	0.74	1		
SJR	0.90	0.87	0.71	0.74	0.79	1	
H	0.75	0.75	0.64	0.89	0.69	0.74	1

Table 1 shows Spearman's rank coefficients of seven journal ranking models over all scientific subject categories. In general, it turns out that journal ranking models are positively correlated as expected. But there exist some models which are more strongly correlated since the corresponding rank-correlation coefficients are greater than or equal to 0.9, as it happens for rank-correlation coefficients corresponding to 5IF and IF ($\rho = 0.97$), 5IF and AIS ($\rho = 0.91$), SJR and IF ($\rho = 0.9$), and to a lesser extent for H and ES ($\rho = 0.89$). As it has been mentioned before, the rank-correlations between the other journal ranking models (i.e., IF, ES, II, and AIS) are positive as well, but far from perfect.

From these results, we define the five dimensions of the multivariate indicator space as follows: ($j = 1$) ISI Impact Factor distribution; ($j = 2$) Immediacy Index distribution; ($j = 3$) Eigenfactor Score distribution; ($j = 4$) AIS distribution; and ($j = 5$) Citation Impact.

For each dimension of the multivariate indicator space we must define a threshold such that papers with ranking score above this threshold are to be considered dimension-specific prestigious papers. More precisely, given a dimension-specific threshold z_j as well as scores x_{ij} which denote the ranking score of paper s_i corresponding to dimension j, we have that papers s_i with ranking score x_{ij} above threshold z_j are dimension-specific influential articles.

For example, thresholds z_j, with $j = 1, 2, 3, 4$, can be defined such that the top 20 % of the score distribution given by the corresponding ranking model (over all scientific subject categories of Web of Knowledge in 2010) are dimension-specific influential. In this case we have that $z_1 = 2.8210$; $z_2 = 0.5520$; $z_3 = 0.0117$; and $z_4 = 0.9750$. And threshold z_j with $j = 5$ may be defined such that $z_5 = 3$; that is, the number of citations received by a dimension-specific influential paper is above 3.

Recall that a paper s_i from an economics department is defined multidimensionally influential if it is prestigious with respect to a number of dimensions which is greater than or equal to a certain integer k, with $1 \leq k \leq 5$. But in case of $k = 1$, s_i is multidimensionally prestigious when it is considered prestigious in only one dimension which can be something dangerous, Garcia et al. (2011c). On the other hand, in case of $k = 5$, it is only considered as multidimensionally influential if it is prestigious in all dimensions under consideration which is a demanding requirement and often identifies a very narrow slice of papers.

If we choose larger values for thresholds z_j and integer k (e.g., $k = 4$ and thresholds z_j are such that the top 10 % of the score distribution given by the corresponding ranking model are prestigious), we have that the ranking of economics departments will be based on more elitist principles. By the contrary if the values of thresholds z_j and k decrease (e.g., $k = 2$ and the top 40 % of the score distribution), it follows a more comprehensive analysis.

An intermediate approach corresponds to the situation in which, for example, $k = 2$ and thresholds z_j are such that the top 20 % of the score distribution given by the corresponding ranking model are dimension-specific influential.

Multidimensional prestige of influential papers for Harvard Economics Department

In this section, we illustrate the measurement of the multidimensional prestige of influential papers $MW(k)$ for an economics department of example (i.e., Harvard Economics Department).

Table 6 in Online Resource lists journals in which academic papers from this economics department appeared (in 2010). In parentheses, the number of articles appeared in each journal in the same year. To get a better insight into the measurement, Table 2 illustrates the total number of JCR papers for each Economics Department in 2010.

Table 7 in Online Resource provides information on the one-dimensional score distributions of the five dimensions under consideration: (IF) Impact Factor distribution ($j = 1$); (II) Immediacy Index distribution ($j = 2$); ES distribution ($j = 3$); AIS distribution ($j = 4$); and (# Cites) Citation Impact ($j = 5$). Table 7 (first column) in Online Resource lists papers ordered by ISI Impact Factor.

The multidimensional prestige $MW(k)$ was computed for $k = 2$ and thresholds z_j, with $j = 1, 2, 3, 4$, defined such that the top 20 % of the score distribution given by the corresponding ranking model (over all scientific subject categories of Web of Knowledge in 2010) are dimension-specific influential (i.e., $z_1 = 2.8210$; $z_2 = 0.5520$; $z_3 = 0.0117$; $z_4 = 0.9750$). The number of citations received by a dimension-specific influential paper is above 3, that is $z_5 = 3$. The value of β in Eq. (13) is $\beta = 3$ following the results presented in Garcia et al. (2011a, b).

For this same economics department, Table 7 (Online Resource) lists prestige counts $c_i = \sum_{j=1}^{d} \theta_{ij}$ which represent the number of dimensions in which paper s_i is found to be influential, with θ_{ij} being equal to one if paper s_i is prestigious with respect to dimension j and zero otherwise as given in Eq. (2) (see Table 7 in Online Resource).

Table 7 (Online Resource) shows ϕ_i ($\mathbf{z}$; k) values which equal to one if paper s_i is multidimensionally influential and is zero otherwise, as given in Eq. (4). Recall that we select $k = 2$.

From Table 7 (Online Resource) it can be derived the overlap between individual dimensions for one-dimensional influential papers, once these are defined by choosing a threshold in that dimension (i.e., $z_1 = 2.8210$; $z_2 = 0.5520$; $z_3 = 0.0117$; $z_4 = 0.9750$; and $z_5 = 3$). To this aim, Table 3 shows the percentage of prestigious papers for each dimension i (i.e., *IF*, *II*, *ES*, *AIS* and *#Cites*) that are also prestigious for each dimension j. This is not a symmetric matrix, and gives a different perspective than the correlation Table 1.

Table 2 Number of JCR papers in the year 2010

Total number of JCR papers for each Economics Department in 2010							
Berkeley	Harvard	MIT	Oxford	Pompeu Fabra	Princeton	UCL	Warwick
27	42	24	37	35	30	24	29

Table 3 Percentage of overlap between individual dimensions for one-dimensional influential papers, once these are defined by choosing a threshold in that dimension (i.e., $z_1 = 2.8210$; $z_2 = 0.5520$; $z_3 = 0.0117$; $z_4 = 0.9750$; and $z_5 = 3$)

	IF (%)	II (%)	ES (%)	AIS (%)	# Cites (%)
IF	100	66	83	100	50
II	72	100	63	72	54
ES	50	35	100	90	35
AIS	46	30	69	100	30
# Cites	60	60	70	80	100

In this example for the Harvard Economics Department, from Table 3 we have that the highest overlap (a percentage of the 100 %) is given between *IF* and *AIS*, in the sense that when a paper is prestigious for *IF* then it is influential for *AIS* as well. By the contrary, the overlap between *AIS* and *IF* is much lesser (a percentage of the 46 %). The lowest overlap is given between *AIS* and *II* as well as between *AIS* and #*Cites* with a percentage of the 30 %.

Table 8 in Online Resource lists the elements $\theta_{ij}^{\beta}(k)$ defined as:

$$\theta_{ij}^{\beta}(k) = \left(1 - \left(\frac{z_j}{x_{ij}}\right)^{\beta}\right)_{+} \cdot \phi_i(\mathbf{z}; k) \tag{18}$$

Since, from Eq. (13), the summary measure $MW(k)$ of multidimensional prestige of influential papers for a given department is equal to the sum of elements $\theta_{ij}^{\beta}(k)$ divided by the value $n \times d$, it follows that $MW(k) = 0.2545$ for Harvard Economics Department. Again, Table 8 (first column) in Online Resource lists papers ordered by ISI Impact Factor.

In addition to looking at the overall value of multidimensional prestige of influential papers for an economics department we can provide information on how different dimensions of the multivariate indicator space contribute to the measure $MW(k)$ of multidimensional prestige. Thus, we rewrite Eq. (13) as follows:

$$MW(k) = \frac{1}{d}\sum_{j=1}^{d}\frac{\sum_{i=1}^{n}\theta_{ij}^{\beta}(k)}{n} = \frac{1}{d}\sum_{j=1}^{d}\Pi_j^{\beta}(k) \tag{19}$$

where $\Pi_j^{\beta}(k) = \frac{1}{n}\sum_{i=1}^{n}\theta_{ij}^{\beta}(k)$ represents the contribution of each dimension j (multiplied by the number d of dimensions) to the measurement of multidimensional prestige of influential papers.

To Harvard Economics Department, from Table 8 (bottom) in Online Resource, we have that the contribution $\Pi_j^{\beta}(k)$ of the AIS dimension ($j = 4$) is about 36.58 % of the multidimensional prestige, and taken together, the ES and AIS dimensions make up about 66 % of the multidimensional prestige of influential papers for this department. Hence, the AIS and ES dimensions play a dominant role to the measurement of the multidimensional prestige $MW(k)$ for Harvard Economics Department.

Ranking of top economics departments in the US and EU

In this section, we use the summary measure of multidimensional prestige $MW(k)$ to assess the comparative performance of top economics departments in the US and EU in 2010.

Four main economics departments from the EU are considered—UCL, UWarwick, UOxford, and UPompeu Fabra.

The departments from the U.S. are included to provide a comparison and a broader perspective on the EU rankings. We selected four departments from the United States—University of Princeton, University of California-Berkeley, MIT, and Harvard University. They are top economics departments in the world and provide a comparison between EU departments and the best in the world.

Table 4 shows the ranking of the eight economics departments according to the multidimensional prestige $MW(k)$ of influential papers, for different selections of k and thresholds z_j with $j = 1, \ldots, 4$. For our analysis the economics department with the best value of the multidimensional prestige of influential papers is assigned the rank # 1, the second best # 2, and so.

In order to produce the results given in Table 4, thresholds z_j with $j = 1, 2, 3, 4$ were defined such that the top 10 % (or alternatively 20, 30, and 40 %) of the score distribution given by the corresponding journal ranking model (over all scientific subject categories of Web of Knowledge in 2010) are dimension-specific influential. For example, in case of the top 20 % we have that $z_1 = 2.8210$; $z_2 = 0.5520$; $z_3 = 0.0117$; and $z_4 = 0.9750$. In this

Table 4 Ranking of eight economics departments in the US and EU (at the 2010) according to the multidimensional prestige $MW(k)$ of influential papers, for different selections of k and thresholds z_j

	10th percentile		20th percentile		30th percentile		40th percentile	
$k = 2$	Princeton	0.233	Princeton	0.325	Princeton	0.395	Princeton	0.445
	Berkeley	0.209	MIT	0.311	MIT	0.375	MIT	0.444
	MIT	0.174	Berkeley	0.279	Berkeley	0.338	Berkeley	0.422
	Harvard	0.144	Harvard	0.254	Harvard	0.326	Harvard	0.395
	UCL	0.120	UCL	0.238	UCL	0.303	UCL	0.362
	Warwick	0.104	Warwick	0.178	Warwick	0.260	Pompeu Fabra	0.321
	Oxford	0.088	Oxford	0.168	Pompeu Fabra	0.227	Warwick	0.317
	Pompeu Fabra	0.071	Pompeu Fabra	0.141	Oxford	0.213	Oxford	0.256
$k = 3$	MIT	0.110	Princeton	0.277	Princeton	0.349	Princeton	0.408
	Princeton	0.106	MIT	0.244	MIT	0.288	MIT	0.370
	Berkeley	0.103	Berkeley	0.212	Harvard	0.283	Berkeley	0.341
	Harvard	0.090	Harvard	0.171	Berkeley	0.262	Harvard	0.329
	Warwick	0.053	Warwick	0.120	Warwick	0.178	Pompeu Fabra	0.232
	UCL	0.040	UCL	0.104	Pompeu Fabra	0.159	Warwick	0.205
	Oxford	0.037	Oxford	0.086	UCL	0.127	UCL	0.201
	Pompeu Fabra	0.012	Pompeu Fabra	0.086	Oxford	0.114	Oxford	0.152
$k = 4$	Princeton	0.063	MIT	0.194	Princeton	0.245	Princeton	0.330
	MIT	0.040	Princeton	0.164	MIT	0.223	Berkeley	0.288
	Harvard	0.030	Harvard	0.145	Berkeley	0.180	MIT	0.286
	Warwick	0.034	Berkeley	0.145	Harvard	0.182	Harvard	0.256
	Berkeley	0.028	Warwick	0.060	UCL	0.083	UCL	0.177
	Oxford	0.020	UCL	0.051	Pompeu Fabra	0.070	Oxford	0.129
	UCL	0.000	Oxford	0.043	Warwick	0.061	Pompeu Fabra	0.117
	Pompeu Fabra	0.000	Pompeu Fabra	0.000	Oxford	0.059	Warwick	0.085

analysis, threshold z_j with $j = 5$ is defined such that $z_5 = 3$; that is, the number of citations received by a dimension-specific influential paper is above 3.

Regarding the value of k, here we follow an intermediate approach, and thus, a paper s_i from an economics department is defined multidimensionally influential if it is prestigious with respect to a number of dimensions which is greater than or equal to a certain integer k with $1 < k < 5$. Thus the multidimensional prestige $MW(k)$ was computed for different values of k, with $k = 2$, 3, and 4. For each one of the selections, Fig. 1 illustrates the multidimensional prestige $MW(k)$ of the eight economics departments in 2010.

The results reveal that Princeton Economics Department has the best overall behaviour for the considered test problems, followed by MIT, Berkeley and Harvard Econs Departments. That is, the four best institutions in the study were US economics departments.

Recall that if we choose larger values for thresholds z_j (e.g., only the top 20 % of the score distribution are dimension-specific influential), we have that the ranking of economics departments will be based on more elitist principles. In this case, it follows that the best EU economics departments are Warwick and UCL Econs Departments (see Table 4).

By the contrary if the values of thresholds z_j decrease (e.g., the top 30 % of the score distribution are dimension-specific influential), it follows a more comprehensive analysis. In this case, we have that the best EU economics departments are UCL, Pompeu Fabra, and Warwick Econs Departments.

From these results, we have that the best overall behaviour (of selected EU departments) is given by UCL Economics Department, closely followed by Warwick Economics Department.

Looking for a general pattern of rankings across all the above selections for k and thresholds z_j, Table 4 and Fig. 1 show persistence in the rankings of UPrinceton as first, MIT as second, UCBerkeley as third, UHarvard as fourth. UCL for most selections appears either fifth or sixth. UWarwick seems to be competing for the fifth position with UCL. For most selections UOxford and UPompeu Fabra rank last among competitor economics departments in this study.

Table 5 shows Spearman's correlation coefficients between a reference rank order—(1) UPrinceton, (2) MIT, (3) UCBerkeley, (4) UHarvard, (5) UCL, (6) UWarwick, (7) UPompeu Fabra, (8) UOxford—and 12 department rankings for different selections of k and thresholds z_j. The reference rank order is similar to the department ranking for values of $k = 2$ and thresholds z_j corresponding to the top 30 % of the marginal score distribution.

In general, it turns out that rankings for different selections are very strongly correlated with reference rank order since the corresponding rank-correlation coefficients are about 0.9 or >0.9.

Conclusions

Each academic paper might be graded on the basis of the prestige accorded to the journal in which it appears, where the analysis of the prestige distribution can be concerned with only one dimension, e.g., the ISI Impact Factor. Nevertheless, the ISI Impact Factor (or any other indicator) does not capture every single component that arguably might influence journal prestige. Hence, we have proposed a publication-based ranking of economics departments in a multidimensional setting, in which prestige relates to the recognition of the originality of research and its impact on the development of the same or related discipline areas from the viewpoint of several indicators. That is, the perception of prestige

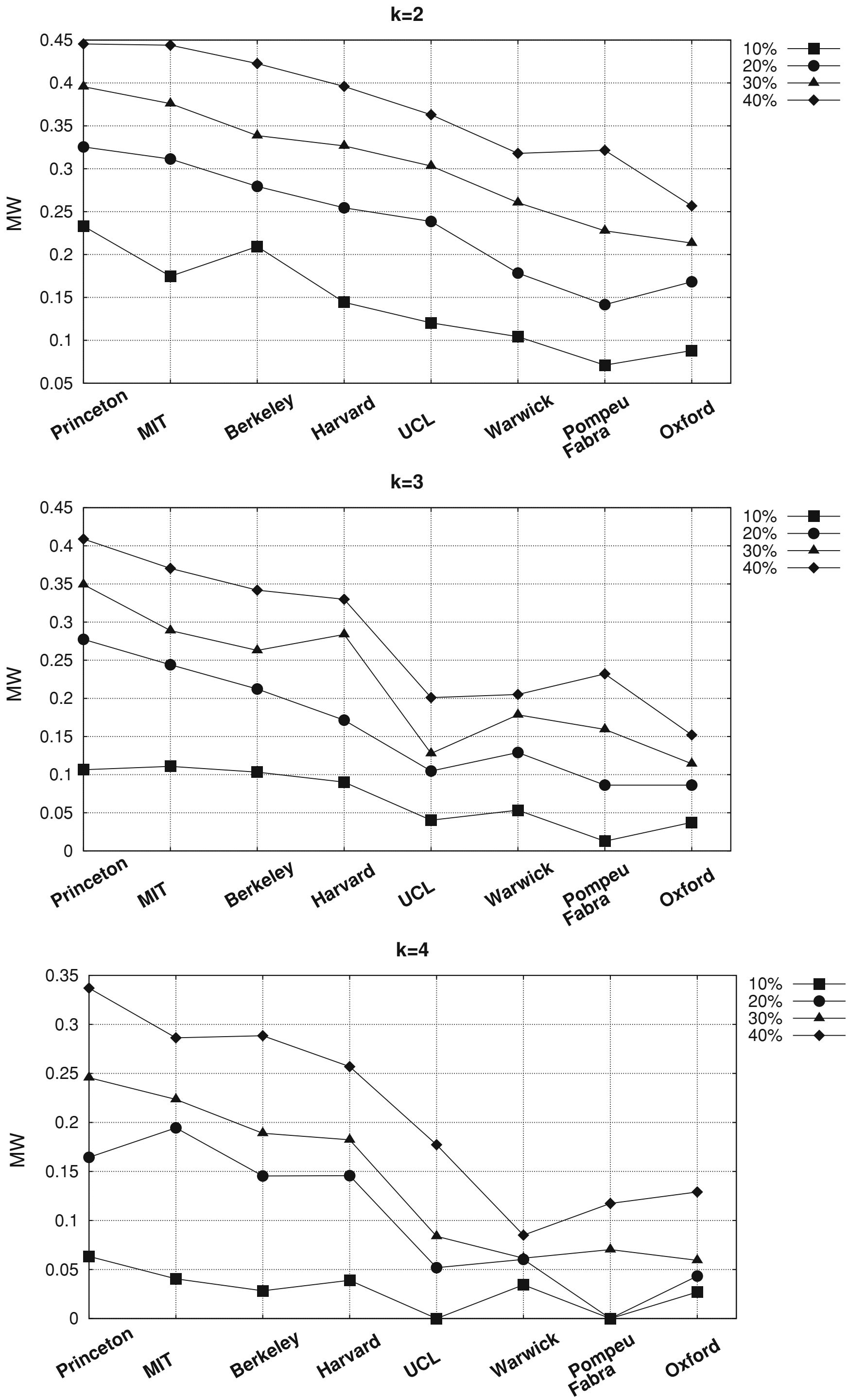

Fig. 1 Ranking of economics departments in 2010

Table 5 Spearman's coefficients between a reference rank order and department rankings for different selections of k and thresholds z_j

Econs dept	Rank	Rankings for $k = 2$				Rankings for $k = 3$				Rankings for $k = 4$			
		10 %	20 %	30 %	40 %	10 %	20 %	30 %	40 %	10 %	20 %	30 %	40 %
Princeton	1	1	1	1	1	2	1	1	1	1	2	1	1
MIT	2	3	2	2	2	1	2	2	2	2	1	2	3
Berkeley	3	2	3	3	3	3	3	4	3	5	4	3	2
Harvard	4	4	4	4	4	4	4	3	4	3	3	4	4
UCL	5	5	5	5	5	6	6	7	7	7	6	5	5
Warwick	6	6	6	6	7	5	5	5	6	4	5	7	8
Pompeu Fabra	7	8	8	7	6	8	7	6	5	8	8	6	7
Oxford	8	7	7	8	8	7	8	8	8	6	7	8	6
Spearman's correlation coefficient	1	0.95	0.97	1	0.97	0.92	0.97	0.90	0.90	0.78	0.90	0.97	0.88

is not only restricted to the analysis of ISI Impact Factor distribution, but different models, e.g., H-index, Article Influence Score or citation impact, may play an important role in the measurement of prestige.

In the proposed approach, a paper has multidimensional prestige only if it is a prestigious article with respect to a number of dimensions. And after having identified the multidimensionally influential papers from an economics department, their prestige scores are aggregated to a summary measure of multidimensional prestige. The summary measure is not only sensitive to the number of dimensions but also takes into account changes in the ranking scores of prestigious articles from this department. Here we demonstrated that this summary measure satisfies numerous properties following an axiomatic approach. But, what does this mean? An axiomatic derivation consists of some terms, a number of axioms referring to those terms and partially describing their properties, and a rule or rules for deriving new propositions from already existing propositions. There are several reasons why axiomatic systems are useful: They provide compact descriptions of the whole field of propositions derivable from the axioms, so large bodies of math can be compressed down into a very small compass; and because they are so abstract, these systems let us derive all, and only, the results that follow from things having the formal properties specified by the axioms.

What are the limitations of the proposed approach? It is not rare that one would like to impose more axioms that are jointly compatible. It may also happen that the summary measure resulting from the original list of axioms is found to react very bad to some economics department. One must then formalize the characteristics of the particular institution and state an additional axiom that specifies how the criterion should behave in this situation, and finally determine the greatest subset of axioms from the original list that are compatible with the new axiom. Of course, compatibility may hold for several distinct such subsets.

As a case of study, in this paper we have presented a comparison of top economics departments in the US and EU based on the measurement of multidimensional prestige of influential papers in 2010.

From the results showed in this paper, the top four economics departments (in 2010) were US economics departments: (1) Department of Economics, Princeton University; (2)

Department of Economics, Massachusetts Institute of Technology (MIT); (3) Department of Economics, University of California-Berkeley; and (4) Department of Economics, Harvard University.

From these results, it also follows that the best overall behaviour of selected EU departments is given by UCL Economics Department, closely followed by Warwick Economics Department. Departament d'Economia i Empresa, Universitat Pompeu Fabra, and Oxford Economics Department have the worst overall behaviour among competitor departments in this study.

In this paper we argue that this type of analysis, for example, may be relevant to the evaluation of research output using objective metrics in several dimensions such as citation impact and journal ranking models, which may guide student choice of a university and department to pursue a graduate degree.

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Appendix 1: dimensions of the multivariate indicator space

The impact factor, often abbreviated IF, is a measure reflecting the average number of citations to articles published in science and social science journals. It is frequently used as a proxy for the relative importance of a journal within its field, with journals with higher impact factors deemed to be more important than those with lower ones. The impact factor was devised by Eugene Garfield (Garfield 2006), the founder of the Institute for Scientific Information (ISI), now part of Thomson Reuters. Impact factors are calculated yearly for those journals that are indexed in Thomson Reuter's Journal Citation Reports.

The SCImago Journal Rank (SJR) (González-Pereira et al. 2010), presents an indicator of "journal prestige" (Bollen et al. 2006), that belongs to a new family of indicators based on eigenvector centrality. The SJR indicator is a size-independent metric aimed at measuring the current "average prestige per paper" of journals for use in research evaluation processes. It has already been studied as a tool for evaluating the journals in Scopus, compared with the Thomson Scientific Impact Factor and shown to constitute a good alternative for journal evaluation, (Leydesdorff et al. 2010).

The ES calculation is based on the number of times articles from the journal published in the past 5 years have been cited in the JCR year, but it also considers which journals have contributed these citations so that highly cited journals will influence the network more than lesser cited journals, (Journal Citation Reports 2011). References from one article in a journal to another article from the same journal are removed, so that ESs are not influenced by journal self-citation.

The Article Influence determines the average influence of articles in a journal over the first 5 years after publication, (Journal Citation Reports 2011). It is calculated by dividing a journal's ES by the number of articles in the journal, normalized as a fraction of all articles in all publications. This measure is roughly analogous to the 5-Year Journal Impact Factor in that it is a ratio of a journal's citation influence to the size of the journal's article contribution over a period of 5 years.

The H-index attempts to measure both the productivity and impact of the published work of a scientist or scholar. The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other publications. The index can also be applied to the productivity and impact of a department or university or country or journal. The index was suggested by Jorge E. Hirsch, a physicist at UCSD, as a tool for determining theoretical physicists' relative quality, (Hirsch 2005), and is sometimes called the Hirsch index or Hirsch number. In our analysis, the H-index expresses the journal's number of articles (h) that have received at least h citations over the whole period. The H-index for each journal in a subject category was computed as given in the SCImago Journal and Country Rank portal (available at: http://www.scimagojr.com).

An II is a measure of how topical and urgent work published in a scientific journal is. Along with the better known impact factor measure, it is calculated each year by the Institute for Scientific Information for those journals which it indexes; both impact factors and immediacy indices are published annually in the Journal Citation Reports, (Journal Citation Reports 2011).

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