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A multidimensional approach to academic productivity

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Abstract This study represents one of the first attempts to use empirical analysis to estimate academic productivity complex and proves the thesis that academic productivity is a function of multidimensional combination of the work of academic researchers: the scientific work, education, and external relationships. Given the complexity of academic productivity, it is necessary to clarify that it is divided into scientific productivity of the first type (scientific publications); scientific productivity of the second type (awards and academic positions); productivity in terms of external relationships (or external advice); and educational productivity. This objective of this paper is achieved through a sample survey (2,738 academics responded) conducted by Italian researchers from the PIR research project. The results obtained, however (as a case of estimates obtained using the results of a sample survey), are the result of a working reality that Italian academics are flooded by a myriad of activities that are not always consistent with the primary aims of the work of a researcher with an organisational and environmental well-being at the limit of iper productivity (or hyper productivity). The overall productivity (academic productivity) is significantly correlated with the four dimensions: average annual scientific productivity of the first type, average annual scientific productivity of the second type, the productivity external advice and, lastly, teaching productivity. The estimate of the sizes for the four indicators of productivity are the result of a literature search of the primary techniques used to assess productivity in academia. By comparing the most significant indicators, we managed to select all of the technical aspects missing in the Italian system of evaluation. This process allowed for us to add additional variables characterising the various aspects of

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productivity and prove the validity of our theory about the multidimensionality of academic productivity.

Keywords Academic productivity complex · Scientific productivity · Assignments and awards · Patents and service productivity · Didactics productivity

JEL Classification I23 · J24 · O15

Introduction

The scientific community defines productivity in the academic world in terms of scientific publications, patents and scientific awards.

In this study, we will attempt to reformulate a definition of academic productivity.

It is important to measure productivity, understood as a performance measure, because productivity is a stimulating factor for competitiveness in the work process that defines organizational strategies. Measuring the scientific output of a researcher means stopping to analyse only one dimension of what a researcher is invited to produce. In reality, an Italian scientific university researcher performs several tasks during the working year. This researcher performs scientific research, receives awards, teaches and conducts external activities relating to both products (patents) and knowledge. In this scenario, it becomes necessary to ask a question: is scientific and academic productivity only one-dimensional or is it a combination of multidimensional activities?

We will attempt to demonstrate that productivity, understood as the output of work produced by an academic researcher, is the result of a combination of different activities performed by the university researcher. In particular, our vision of academic productivity should be understood as a combination of the output of scientific work, education, and external relationships.

This study represents one of the first attempts to use empirical analysis to estimate productivity measures in academia. The methodology of the estimators used is a combination of various bibliographic sources: the MIUR (Italian Scientific Research Ministry), the Higher Education and Accreditation Council of Taiwan and the ARWU Shanghai (Academic Ranking of World Universities).

Given the complexity of academic productivity, it is necessary to clarify that it is divided into scientific productivity of the first type (scientific publications); scientific productivity of the second type (awards and academic positions); productivity in terms of external relationships (or external advice); and educational productivity.

The complexity of academic productivity can be attributed to the different areas of scientific disciplines (SDA) in Italy, reclassified in relation to the European Research Council (ERC) panel. The SDA and the ERC are associated with different outputs for the dimensions mentioned above, implying that the standardised estimates of productivity can not be one-dimensional but multidimensional.

This objective of this paper is achieved through a sample survey conducted by Italian researchers from the PIR research project; The most Italian public universities have joined in PIR project.

These researchers have administered an online questionnaire (in accordance with the laws on anonymity), from which we obtained satisfactory results.

Theoretical analysis

There are many studies that provide estimates and methodological criticisms regarding the measurements of academic productivity (Van Raan 2005; Markusova et al. 2009; Abramo et al. 2008; Bonaccorsi et al. 2006; Gilli 2010).

In addition, there are studies on the determinants of scientific productivity, such as the following: family and children (Stack 2004; Sax et al. 2002), networks of researchers, gender differences and satisfaction in the working environment (Corley 2005; Gulbrandsen and Smeby 2005), the university location (Bozeman and Corley 2004), the researchers' level of satisfaction (Hermanowicz 2003), the social context (Salaran 2010), women's scientific productivity (Tower 2006), the perceived satisfaction in the work environment of certain U.S. universities, which are more attractive to PhD students (Corley and Sabharwal 2007), and the organisational atmosphere and work environment (Fox and Mohapatra 2007). This study reveals the subjective determinants that can affect the productivity, performance and the quality of life of human capital in the field of scientific research. The micro-data obtained (the lowest level of information is the interviewees perceptions) represent a further deepening of the understanding of the determinants of brain drain from the Italian Academy (Monteleone and Torrisi 2012a, b; Skonieczny and Torrisi 2009, 2011).

The scientific community has developed many contributions toward developing indicators and methods for a quantitative evaluation of the productivity of university researchers. Most of these indicators and methods have focused more on the quantification of the total scientific output, which is similar to our approach (Torrisi 2012a, b). In this section, we analyse the contributions of different approaches to measuring academic productivity.

First type of scientific productivity (publications)

The primary activity of university researchers is the contribution that they provide, through their studies, in relation to their field of specialisation (Italian Council of State with the sentence[1] n. 2364 22 April 2004). To measure the ability to produce scientific output, two dimensions must be taken into account: the *quantitative dimension*, expressed on the basis of numerical characteristics, such as the number of publications attributable to each individual actor; and the *qualitative dimension*, expressed in terms of the prominence and importance of the publication compared to other publications.

The methods developed to measure publications include the bibliometric approach, the peer review approach and the mixed approach.

The bibliometric approach is the one most commonly utilised by both the scientific community and by the evaluation committee to measure the productivity of a scientific researcher.

The indicators from a bibliometric analysis are based on the number of publications (i.e., are oriented toward the quantitative dimension), on the count of citations received by individual researchers, or on the prestige of the journals in which the studies are published (which is oriented toward the qualitative dimension).

While this method of measurement is well suited for large-scale evaluation and international evaluation, it also has limits (Van Raan 2005).

Apart from the fact that there is, as mentioned, a comprehensive collection of data on a global scale, it is universally acknowledged that scientific journals collect publications at the international level in priority subject areas. These priority areas are those with the

[1] http://www.altalex.com/index.php?idnot=7243.

greatest impact (areas of so-called "hard science"), and this priority comes at the expense of the more humanistic disciplines, such as the arts or humanities, where there are typically a smaller number of publications.

Certain issues related to the count are not limited to publications, but they become even more important in the estimation and allocation of citations, a parameter that is used to estimate the importance of the publication or to assess its quality.

Despite the weaknesses stated, a bibliometric analysis presents certain arguments in weight compared to other methods. These arguments consist of the reduced cost to conduct investigations and the speed and ability to easily update data over time, a feature that allows for continuous and dynamic feedback.

Because of these characteristics, in conclusion, we can say that the methods based on bibliometric analysis primarily lend themselves to quantitative evaluations, but they can also be used to assess the qualitative dimension based on certain assumptions (such as the weighing of the SDA, the number of authors and coauthors).

In the bibliometric approach (in the *Journal of Citation Reports* (JCR), analysis edited by *ISI Web of Knowledge*)**,** three indices measuring two dimensions (quantitative and qualitative) were constructed: (1) the impact factor (IF) is calculated by dividing the number of citations of articles published by a given journal to the total number of articles published during the same period; (2) the immediacy index measures the success of a particular scientific journals on the basis of quotations obtained from the same year of publication; (3) the cited half-life measures the impact in time of the articles cited, indicating the number of years, measured backward from the year in question, that represents 50 % of the citations of the articles in the journal in question.

To these indicators, the scientific community has added others:

The *Eigenfactor* calculates the impact of scientific journals based on different standards. The Eigenfactor was developed by Jevin West and Carl Bergstrom (University of Washington) and estimates the prestige of the scientific journals on the basis of a weighting conducted on both the number of citations and, unlike the IF, based on the type of quotation.

The Hirsch index or H-index was proposed and developed by Jorge E. Hirsh (University of California, San Diego) in 2005. The H-index calculates the impact of not only a magazine, such as the previous indices, but also of a single researcher. This index is suitable for estimating the productivity of a researcher's career.

The H-index is the number of papers that have received at least the same number of citations:

"A university has index h if h of its Np papers has at least h citations each, and the rest (Np—h) papers have fewer than h citations each" (Hirsch 2005).

Even using these measures, there is the problem of heterogeneity across scientific disciplinary areas (SDA).

Therefore, the H-index index is not valid if it is used to classify the productivity of researchers in the same subject areas (SDA).

The *SCImago Journal Rank* (SJR) is an indicator that measures the influence of academic journals; it was inspired by Google's PageRank algorithm developed by Brin and Page (1998). The SCImago Journal Rank presents itself as an alternative to the IF and uses an algorithm that, beginning from an initial condition of equality for all of the journals analysed, redistributes the value based on quotations from the publications appearing in different journals over a period of 3 years.

There is a high degree of similarity between all of these indicators (see Table 1), which has been studied in some contributions (Rousseau and STIMULATE 8 Group 2009).

Table 1 Relation between the impact factor, the Eigenfactor, the SCImago Journal Rank, the Article Influence Score and H-index—year 2008

Indicators	IF	SJR	Eigenfactor	A.I. score	H
IF	1	0.915	0.827	0.918	0.898
SJR		1	0.731	0.813	0.76
Eigenfactor			1	0.827	0.951
A.I. score				1	0.855
H					1

Second type of scientific productivity (assignments and awards variables layout)

Another dimension of the scientific maturity of a researcher is the number of awards and the number of assignments as a referee, editor, chairman, member of a management board, management of a research institution or the coordinator of research projects.

All of these activities can be conducted by university researchers and represent an additional element that adds value to scientific productivity. Within this area, the bibliographic analysis cannot effectively measure contributions. This aspect will be the subject of our analysis. Scientific awards or chief editor or referee or member of editorial board for scientific journals is synonymous of scientific maturity of researchers. For this reason proposes to these aspects integrated into the scientific productivity and not in the service productivity.

Patents and service productivity

Patents and service productivity represent the technology transfer output and the transfer of knowledge outside of the university through collaboration or consultation between the public and the private sector.

More attention has recently been reserved for patent activity as a measure of product or service productivity.

The research that produces more patents or external relationships also helps to transfer knowledge (the output of products and services).

In the U.S., interest is increasing in this dimension of academic productivity (Trajtenberg et al. 1997 has launched a series of analyses in the U.S. at Stanford University, Columbia University and University of California system).

Researchers display a high interest in this second dimension of productivity, but the public institutions in Europe do not appear to share this interest.

The research into how to measure this second dimension, with the particular calculation of patent activities or product output, can be attributed to Fontes in 2001, who analysed the Portuguese case, Wallmark in 1997, who focused on the case of the University of Chalmers, and Azagra Caro and Dolado in 2001, who provided an analysis of patenting activity in Spanish universities.

While the different contributions of the patenting activities of Italians in public research organisations such as the National Research Council, CNR (National Research Center) (Abramo 1998; Abramo and Lucantoni 2003; Abramo and D'Angelo 2004), the Enea group (Piccaluga and Patrono 2001) and the universities (Balconi et al. 2003; Campo Dall'Orto and Conti 2002; Baldini et al. 2003; and Abramo and Pugini 2004) provide us with a fairly exhaustive list in terms of patent production, including in relation to other countries (Cesaroni and Piccaluga 2003).

A growing diffusion of research results can be observed, including both traditional channels characterised by their publications and new forms that provide direct monetisation and therefore an increase in resources for the university and the researchers.

Focusing attention on this second dimension of productivity produces governance policies for the scientific research funds that are located in the SDA and proportional to the increased production capacity.

The interest of researchers in patent productivity has generated the development of new contributions that demonstrate that a high level of patent activities results from a level of high scientific productivity. Adams and Griliches (1998) and Lach and Schankerman (2003) demonstrate that there is a strong positive correlation between scientific productivity and patent productivity (Breschi et al. 2008; Calderini and Franzoni 2004).

Abramo and Pugini (2004) demonstrated that in Italy, there is no such correlation because the production of patents is still modest.

Thus, in relation to these studies, until recently, Italian publications were considered to be a strong indicator for estimating scientific productivity at the aggregate level. Today, with this study, we add other elements to the study of productivity. In fact, we will show that the thesis of Adams and Griliches (1998), and Lach and Shankerman (2003), is also valid for the academic Italian context, contrary to the statement of Abramo and Pugini (2004).

Didactics productivity

The final dimension of a researcher's academic productivity is teaching and service to students.

While researchers produce scientific research, they are also constantly engaged in teaching activities that take different forms: lectures, seminars, exams, and work with undergraduates in preparation.

The theoretical and empirical studies do not appear to have any special concern for this dimension of productivity. In fact, there are no studies that analyse only the educational commitment of researchers, although there are a few studies that include this dimension of scientific activity.

Our contribution will be to demonstrate in the Italian case the weight of academic productivity compared to the overall productivity of the researcher; the overall productivity of the researcher represents for us the academic productivity of a researcher.

Teaching requires significant effort by the teachers and varies considerably in length (hours of lectures, hours tutoring students, time allocated for the examinations and the number of subjects taught by each teacher). The estimate for this form of productivity is very complex and suffers from a number of issues.

Teaching activity also appears to have a negative influence on other forms of scientific productivity (see "Results"). Experts such as Graves et al. (1982) have reported a negative trade-off between the two forms of activity (research and teaching activity).

While the commitment of teaching hours specified in the plan of study can vary, the hours are the same as they are for those to whom this activity is directed, namely, the students. Particular evaluation rankings adopt a methodology based on the value of these assets or take into account the students' performance (assessing different aspects, such as the rate of students regularly over the years and the rate of graduate students in good standing during the year period covered by the course or the number of students regularly attending over the years). The theme could be deepened to emphasise the qualitative rather than the quantitative aspect, conducting investigations on the reputation of teachers or evaluating aspects such as the level of internationalisation.

In the quantitative view of productivity didactics, an interesting indicator is the number of students who consistently attend classes. This factor can also be a qualitative element measuring the ability of the teacher. If a teacher is educationally poor (unproductive), there is a lower presence in the classroom. To identify the number of students taking the course as a quantitative indicator of the teaching workload appears to be a viable path.

Sampling and data

The survey instrument

We use a questionnaire as the instrument of our investigation. The questionnaire was constructed to achieve the goals proposed by the project PIR: "The Productivity of Italian Researchers" and "Potential Academic Italian Brain Drain". The goal of PIR is to understand and evaluate the "academic productivity correlated with wellbeing at work and propensity and motivation to emigrate or remain in Italy." The questionnaire is divided into section: *A*—Family and academic context (to discover the relationship between academic productivity and family influence); *B*—Academic work times and network relationships; *C*—Scientific production; *D*—Teaching productivity; *E*—Work environment satisfaction; *F*—Work and Well-being Survey (UWES—Utrecht Work Engagement Scale).

Sampling and the data set model

A statistical sampling model cannot be adopted because there is no a data set of direct contacts for the academic population in Italy (71,000) academics between full professor, associate, researchers, PhDs, and post-docs). Conversely, the existence of a structured database of contacts for stages of the population (Universities Scientific-Disciplinary Areas-academic roles) would lead to a three-stage random sampling.

Therefore the survey scheme was as follows:

- In 2011, we invited all of the Rectors of Italian public universities to authorise the online distribution of the questionnaire to the mailing list of their university.
- Of 83 Italian universities, 26 supported the initiative (and authorised the online distribution of the questionnaire), 6 universities declined to distribute the questionnaire, while the remainder did not respond. A total of 31 % of the Italian universities therefore acceded to the research project.
- Over 3 months in 2012, we received responses from 2,738 academics who were anonymous members of those universities that disseminated the questionnaire. The questionnaires were sent by computer systems of universities participating in the project, its researchers. These researchers were invited to participate in the compilation of the questionnaire. The anonymity and free participation of researchers has guaranteed the random sample.

There was no selection sampling, but the anonymity of the questionnaire assured that the participation of the interviewees was random, which overcomes the problems of self selection.

Out of 71,808 in the academic Italian population (see Table 2) (including PhD students, contractors, researchers, and ordinary members) 2,738 academics responded. Missing or inconsistent responses reduced the sample to 1,474 units (see Table 2). We based our elaboration on this sample.

The sample size was determined by the level of adherence to the questionnaire. Despite this, the results of the Chi squared test run for the difference between two or more proportions (sample and population, SDA and academic role) were satisfactory. In Table2 there are the p value of the Chi square run test to see if there is difference between the proportion between respondents and population for SDA and academic role (see Table 2; not significantly are p value < 0.01). This test proved that most of of the differences are not significantly. This means that the results of the sample are representative of the population ($1 - \alpha = 99\ \%$).

It has also been developed non-parametric test run between more than two proportions. The results of the test is not significant. This confirms that there is no significant difference between the proportions of respondents championships and those of the population (see Table 2; critical value = 69.83. Chi square test statistic = 3.91, p value = 0.9878).

Materials and methods

The variables that we used from the questionnaire are as follows:

Italian scientific disciplinary areas classification (SDA) = Area 01—Mathematical and Computer Sciences; Area 02—Physical Sciences; Area 03—Chemical Sciences; Area 04—Earth Sciences; Area 05—Biological Sciences; Area 06—Medical Sciences; Area 07—Agricultural and Veterinary Sciences; Area 08—Civil Engineering and Architecture; Area 09—Industrial and Computer Engineering; Area 10—Antiquities, philological, literary, historical and artistic studies; Area 11—Historical, philosophical, pedagogical and psychological studies; Area 12—Legal Studies; Area 13—Economics and statistics; Area 14—Political and Social Sciences.

To construct the overall productivity, which was defined as the academic productivity, we took the following steps:

a. Developed all of the answers for the variables VAR-C_4 to VAR-C_{19} *(*see Table 3*)* where each respondent provided the amount of scientific output produced during the last 5 years = X_{ik} for each k = VAR-C_4 to VAR-C_{19} and $i = 1$ to 1,474 surveyed respondents.
b. Every type of scientific output has a different weight. Because of these differences, it was necessary to weight the scientific products using a policy already adopted at the University of Catania by the committee for the evaluation of scientific research operations. These weights are different for each SDA = P_k for each k = VAR-C_4 to VAR-C_{19}.
c. Each type of scientific output is produced by the contribution of either individual researchers or groups of co-authors. It was necessary to estimate the weight attributed to each scientific output in relation to the number of authors = $Q_{\rm i}$ for each $i = 1$ to 1,474 surveyed respondents as the converted VAR-C_{20} variable;
With n indicating the number of authors declared by each respondent, different functions for the estimation of the weighting Q_i were tested with the VAR-C_{20} variable until the function that interpolates the best number of authors for a scientific product was reached. These functions have been adopted in the following:

Table 2 Academic Italian population (*N*) in different roles

Italian SDA classification	*N* (population) *n* (sample) *p* (run test)	Total	Full professor	Associate professor	Researcher confirmed and not	Researcher a term	Post doc
Area 01—Mathematical and Computer Sciences	*N*=	3,680	882	945	1254	80	519
	n=	165	22	22	52	1	68
	p value=	0.000	0.002	0.000	**0.497***	**0.170***	0.000
Area 02—Physical Sciences	*N*=	3020	517	746	868	95	794
	n=	64	11	13	22	0	18
	p value=	**0.796***	**0.989***	**0.420***	**0.325***	**0.150***	**0.742***
Area 03—Chemical Sciences	*N*=	3880	624	889	1,308	87	972
	n=	111	24	20	36	2	29
	p value=	0.000	**0.119***	**0.225***	**0.779***	**0.757***	**0.797***
Area 04—Earth Sciences	*N*=	1404	228	337	455	34	350
	n=	33	6	9	9	0	9
	p value=	**0.437***	**0.765***	**0.664***	**0.533***	**0.366***	**0.759***
Area 05—Biological Sciences	*N*=	6546	1095	1,289	2,279	176	1707
	n=	171	27	22	48	0	74
	p value=	0.001	**0.745***	**0.026***	**0.067***	**0.030***	0.000
Area 06—Medical Sciences	*N*=	11,951	2031	2,755	4,777	271	2117
	n=	170	13	35	69	0	53
	p value=	0.000	0.001	**0.449***	**0.871***	**0.047***	0.000
Area 07—Agricultural and Veterinary Sciences	*N*=	4119	745	868	1,330	81	1095
	n=	74	18	14	29	0	13
	p value=	**0.242***	**0.168***	**0.652***	**0.209***	**0.223***	**0.081***
Area 08—Civil Engineering and Architecture	*N*=	4623	885	1,051	1,475	146	1066
	n=	67	7	11	22	1	26
	p value=	0.003	**0.072***	**0.220***	**0.871***	**0.437***	0.002
Area 09—Industrial and Computer Engineering	*N*=	8245	1493	1,515	1,951	322	2964
	n=	189	27	31	57	2	72
	p value=	**0.110***	**0.176***	**0.488***	**0.038***	**0.044***	**0.543***
Area 10—Antiquities philological literary historical and artistic	*N*=	5907	1306	1,508	2,180	178	735
	n=	108	11	25	28	0	44
	p value=	**0.213***	0.003	**0.574***	**0.019***	**0.067***	0.000
Area 11—Historical philosophical pedagogical and psychological	*N*=	5605	1308	1,321	1,935	194	847
	n=	74	12	15	27	0	20
	p value=	0.000	**0.150***	**0.506***	**0.724***	**0.103***	0.005
Area 12—Legal Studies	*N*=	5303	1532	1118	1966	160	527
	n=	58	15	12	18	0	13
	p value=	0.000	**0.613***	**0.942***	**0.343***	**0.179***	0.002
Area 13—Economics and statistics	*N*=	5449	1466	1,314	1,729	259	681
	n=	148	32	22	58	1	35
	p value=	0.000	**0.152***	**0.01***	**0.055***	0.020*	0.000

Table 2 continued

Italian SDA classification	*N* (population) *n* (sample) *p* (run test)	Total	Full professor	Associate professor	Researcher confirmed and not	Researcher a term	Post doc
Area 14—Political and Social Sciences	*N*=	2076	405	465	763	90	353
	n=	42	1	8	14	0	19
	p value=	**0.925***	0.005	**0.606***	**0.649**	**0.168**	0.000
Total	*N*=	71,808	14,517	16,121	24,270	2173	14,727
	n=	1474	226	259	489	7	493
	p value=	0.000	0.000	0.000	**0.616***	0.000	0.000

Respondents who answered completely (n) and p value results by run difference proportion test

Source MIUR CINECA al 31.12.2011; p value results by run difference propotion test (*$p < 0.01$ is not significant difference between the proportions of respondents championships and those of the population—H_0: $\pi_N = \pi_n$ H_1: $\pi_N \neq \pi_n$)

$$Q_i = {}^{1}\!/_{\sqrt{n}} \tag{1}$$

$$Q_i = n^{\mathrm{p}} \quad \text{where p} = 0.10 \tag{2}$$

$$Q_i = 1 - 0.87 \times \log(n) \tag{3}$$

$$Q_i = {}^{1}\!/_{n} \tag{4}$$

$$Q_i = 1.02 - 0.02 \times n \text{ linear regression model} \tag{5}$$

$$Q_i = n^{-0.5} + 0.15 \text{ exponential regression model} \tag{6}$$

$$Q_i = 1 - 0.212 \times \ln(n) \text{ log normal regression model} \tag{7}$$

With respect to the estimation of the functions, Q_i has been selected (7) for mediation due to the overestimation of certain functions (2, 5, and 6) and the underestimation of others (1, 3 and 4). Therefore, all of the following elaborations have adopted the weighting of Q_{i} calculated using (7) (see Fig. 1). Moreover, this choice also arises from the evaluation of the weight lost based on the number of authors participating (see Fig. 2). That is, the best approximation of Q_{i} aims at determining a weight that grows more than proportionally to the increase in the number of participating authors and that has a mean variability of the maximum weight ($Q_{\mathrm{i}} = 1$ if there are no coauthors) that it overestimates or underestimates, then the next 0.50 ($\Delta\ Q_{\mathrm{i}}$ (7)) (see Fig. 1).

d. Studies on the evaluation of scientific productivity use the h index as the score. In Italy, the different classifications for the SDA implies the estimation of indicators of scientific productivity that exceed the estimated H_i index and achieve a greater accuracy in the measurement of productivity. For this reason, 2 scores for scientific productivity were built and compared to the results obtained from the index. These scoring systems are a bibliometric indicator $= B_i$ (adopted by the University of Catania for the operations of its researchers) and the cograduazione index of scientific productivity $= C_i$, for each $i = 1$ to 1474 interviewees.

$$B_i = \left(\sum_{k=\mathrm{var-c4}}^{\mathrm{var-c19}} X_{ik} P_k \right) \times Q_i \tag{8}$$

Table 3 Scientific productivity variables layout (I° type) + scientific productivity for assignments and awards variables layout (II° type)

Type		Questions
I°	VAR-C1	1. How many papers in national journals have you published in the last 5 years?
	VAR-C2	2. How many papers in international journals (but without an impact factor) have you published in the last 5 years?
	VAR-C3	3. How many papers in international journals (with an impact factor) have you published in the last 5 years?
	VAR-C4	4.1—How many books or collections of national or international research (as author or co-author) have you produced in the last 5 years?
	VAR-C5	4.2—How many articles on ISI (as author or co-author) have you produced in the last 5 years?
	VAR-C6	4.3— How many articles in journals with a scientific committee and an editorial board process of selection (not ISI) have you produced in the last 5 years?
	VAR-C7	4.4—How many articles or books full of acts of international events (congresses. conferences. seminars. workshops) of international scientific institutions have you produced in the last 5 years?
	VAR-C8	4.5—How many articles or books full of acts of national events (congresses. conferences. seminars. workshops) have you produced in the last 5 years?
	VAR-C9	4.6—How many thematic maps or monographs have you produced in journals or volumes in the last 5 years?
	VAR-C10	4.7—How many patents have you produced in the last 5 years?
	VAR-C11	5.1—How many highly popular educational books (author or co-author) have you produced in the last 5 years?
	VAR-C12	5.2—How many scientific books or conference proceedings under your "responsibility" have you produced in the last 5 years?
	VAR-C13	5.3—How many contributions in encyclopaedias or dictionaries etc. or translations of unpublished texts in source language have you produced in the last 5 years?
	VAR-C14	How many papers in other scientific journals have you produced in the last 5 years?
	VAR-C15	How many notes and reviews published in scientific journals. translation of texts already published in the language version have you produced in the last 5 years?
	VAR-C16	5.4—How many abstracts or posters have you presented at international conferences in the last 5 years?
	VAR-C17	5.5—How many abstracts or posters have you presented at national conferences in the last 5 years?
	VAR-C18	5.6—How many multimedia products with scientific content have you produced in the last 5 years?
	VAR-C19	5.7—How many other documents. research reports or preprints. etc. have you produced in the last 5 years?
	VAR-C20	How many number of co-authors do you produce with (on average) in a year?
	VAR-C21	7—Please indicate how you classify your area of scientific publication?

Table 3 continued

Type		Questions
II°	VAR-C22	8—What is your h index?
	VAR-C23	9—How many journals (with ISI) do you review for or have you reviewed for?
	VAR-C24	10—How many journals (without ISI) do you review for or have you reviewed for?
	VAR-C25	11—Have you been given any responsibilities for the Studies and Research Centres Directorate? How many?
	VAR-C26	12—Have you been assigned responsibilities with the management boards of any scientific journals?
	VAR-C27	13—Have you received any international awards?
	VAR-C28	14—Have you received any national awards?
	VAR-C29	15—Have you been the coordinator or principal supervisor for any international research projects?
	VAR-C30	16—Have you been the coordinator or principal supervisor for any national research projects?
	VAR-C31	17—Have you taken part in any international research projects as a partner?
	VAR-C32	18—Have you taken part in any national research projects as a partner?
	VAR-C33	19—Have you been a speaker at any international congresses?
	VAR-C34	20—Have you been a speaker at any national congresses?

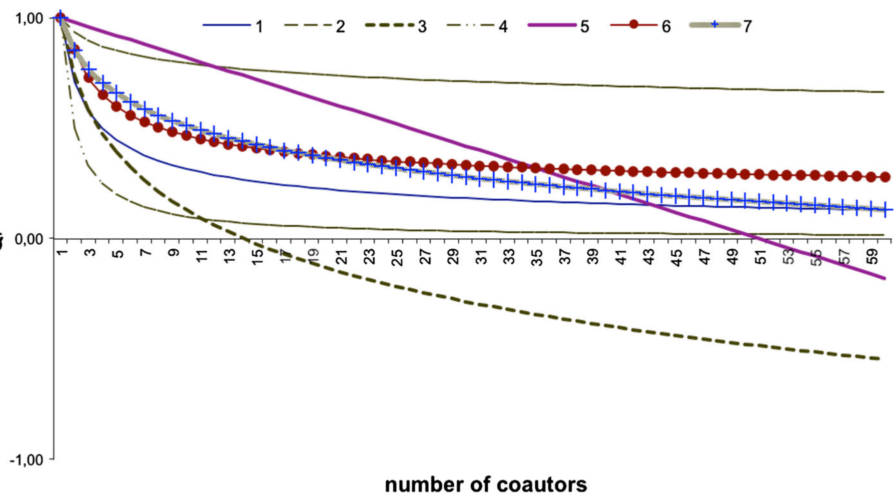

Fig. 1 Different functions for the estimation of the weighing Q_i with functions from (*1*) to (*7*). Elab. StatEcon Area—year 2012

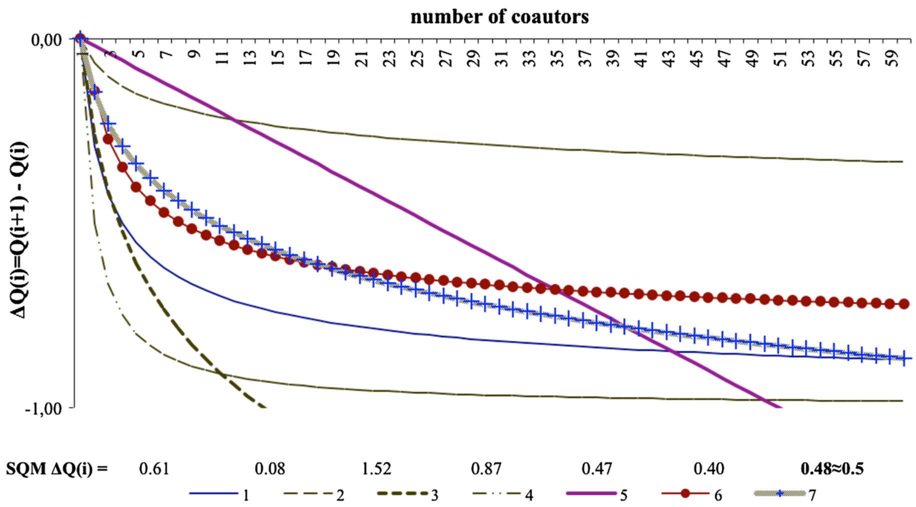

Fig. 2 Different evaluation functions from (*1*) to (*7*) of the weight loss ($\Delta\ Q_i$) based on the number of authors participants. Elab. StatEcon Area—year 2012

$$C_i = \left(\sum_{k=\mathrm{var-c1}}^{\mathrm{var-c3}} X_{\mathrm{ik}} P_{\mathrm{k}} \right) \times Q_{\mathrm{i}} \quad \text{where} \quad P_{\mathrm{var-c1}} = 0.25;\ P_{\mathrm{var-c2}} = 0.30;\ P_{\mathrm{var-c3}} = 0.45 \tag{9}$$

$$H_i = h\ x\ Q_i, \ \text{where } h \text{ is the index declared from the respondents} \tag{10}$$

The selection of P_k in (8) depends on the importance assumed by the scientific outputs in all of the SDA (for $K =$ from var-c_4 to var-c_{19}. The weights in (9) depend on the importance assigned to the national scientific outputs ($P_{\text{var-c1}} = 0.25$), the international outputs without an impact factor ($P_{\text{var-c2}} = 0.30$) and the international outputs with an impact factor ($P_{\text{var-c3}} = 0.45$), independent from the SDA.
Generally, the assignment of the weight in the analysis represents a qualification output for a scientific product in B_i and C_i; the estimation of the publications that were published in journals with an international character (0.75) weigh more than those in national journals (0.25).
The three functions (8, 9 and 10) have been weighted Q_i (7) depending on the number of co-authors involved in the publication.

e. We calculated the standard value of the three productivity scores (8, 9 and 10) for each SDA (with respect to the mean and variance of productivity for each SDA) in Z^{Bi}. Z^{Ci} *and* Z^{Hi};

$$Z^{B_{ij}} = \frac{B_{ij} - \overline{B_{ij}}}{\sigma^2_{B_{ij}}} \quad \forall\, j = SDA\ 1 \text{ to } SDA\ 14 \tag{11}$$

$$Z^{C_{ij}} = \frac{C_{ij} - \overline{C_{ij}}}{\sigma^2_{C_{ij}}} \quad \forall\, j = SDA\ 1\ (\text{to})\ \text{SDA}\ 14 \tag{12}$$

$$Z^{H_{ij}} = \frac{H_{ij} - \overline{H_{ij}}}{\sigma^2_{H_{ij}}} \quad \forall\, j = SDA\ 1\ (rmto)\ SDA\ 14 \tag{13}$$

f. The scientific productivity (type II) for assignments and awards was measured in relation to the responses on the following variables:Var-c23 to c34 rapresent the commitment of researchers to that type of scientific productivity, measured by number of offices and national and international awards.We considered that one of the variables explaining scientific productivity should take into account the positions and awards to any researcher. This vision is born from an observation of the reality of the workplace as found by the Higher Education and Accreditation Council of Taiwan (HEACT). In HEACT, the combination of scientific output and awards are a measure of the scientific productivity of a researcher. For the estimation of this second type of output, scientific productivity was used an index of co-graduation (14):

$$C_i(R) = \left(\sum_{k=\text{var}-\text{c23}}^{\text{var}-\text{c34}} X_{ik} P_k \right) \tag{14}$$

where normalisation is equal to

$$Z^{C_i(R)_j} = \frac{C_i(R)_j - \overline{C_i(R)_j}}{\sigma^2_{C_i(R)_j}} \quad \forall\, j = SDA\ 1\ to\ SDA\ 14 \tag{15}$$

where P_k are the weights depending on the national or international qualification of the variable in question. These weights were chosen subjectively by author but are consistent with the proportion of the weighting given in formulas (8, 9, 10).

g. In addition to traditional productivity (scientific output), there is a type of productivity manifested by the transfer of technology and knowledge. Patent activities are an example of this type of productivity, but the activity based on the advice (that is consulting work outside of the university) given outside of the university by researchers must be added.
   This productivity was measured as an absolute through the simple request of many external consultants authorised by the university and estimated using productivity external advice (PEA approved by the University that is consulting work outside of the university; see Table 4):

$$\text{PEA}_i = \text{VAR-C}_{35}. \tag{16}$$

The normalisation is equal to:

Table 4 Productivity external advice (PEA) (approved by the university) variables layout

VAR-C35	21—As part of your academic activities. have you worked as an advisor approved by the university?
VAR-C36	22—How much time do you spend (in annual %) providing advice authorised by university?
VAR-C37	23—Do your research projects produce patents?
VAR-C38	23a—If "Yes" how many records on the university's behalf?
VAR-C39	23b—If "Yes" how many records on your own behalf

Table 5 Productivity educational (PE) variables layout

VAR-C40	1—In one year how many undergraduates (on average) do you teach?
VAR-C41	2—In one year how many students (on average) do you have in your classroom?
VAR-C42	3—How many hours of lessons are devoted to teaching annually?
VAR-C43	4—In one year how many students (on average) do you examine?
VAR-C44	5—How much knowledge from your scientific research spills over into your teaching?

$$Z^{PEA_{ij}} = \frac{PEA_{ij} - \overline{PEA_{ij}}}{\sigma^2_{PEA_{ij}}} \quad \forall\, j = SDA\ 1\ to\ SDA\ 14 \tag{17}$$

h. The final measure of productivity is the teaching dimension (or educational productivity PE), which is dependent on the teaching load indicated by the interviewees in the variables (see Table 5) (VAR-C40, VAR-C41, VAR-C43) in the questionnaire. The teaching dimension is estimated based on the number of students on average that are present in the classroom, the number of undergraduates, and the number of exams (VAR-C40, VAR-C41, VAR-C43),
where PE is

$$\mathrm{PE}_i = \text{VAR-C}_{40} + \text{VAR-C}_{41} + \text{VAR-C}_{43} \tag{18}$$

and normalisation is equal to

$$Z^{PE_{\mathrm{ij}}} = \frac{PE_{\mathrm{ij}} - \overline{PE_{\mathrm{ij}}}}{\sigma^2_{PE_{\mathrm{ij}}}} \quad \forall\, j = SDA\ 1\ to\ SDA\ 14 \tag{19}$$

i. Lastly, all of the dimensions of productivity estimated in steps have been aggregated into a single index of overall academic productivity, with a weighted average weight compared to the total recognised by the respondents for each dimension of the productivity of a researcher over the overall productivity declared, defined by an MPI (multidimensional productivity index).
The MPI was constructed using a weighted index of co-graduation (20). The MPI is a measure of the total annual academic productivity. Indeed, it was necessary to divide the scientific productivity across 5 years because the question asked the interviewees to provide the required number of publications and awards during the past 5 years. The other dimensions of productivity were the result of annual statements, so it was not necessary to divide these by the 5 years:

$$\begin{gathered} MPI_i = \left| \left(Z^{B_{ij}}/5 \times P_B \right) + \left(Z^{C_i(R)_j} \times P_{C(R)} \right) + \left(Z^{PEA_{ij}} \times P_{PEA} \right) + \left(Z^{PE_{ij}} \times P_{PE} \right) \right| \times 100 \\ \text{dove } P_B = 0.32;\ P_{C(R)} = 0.18;\ P_{PEA} = 0.10;\ P_{PE} = 0.40;\ \sum P = 1 \end{gathered} \tag{20}$$

Results

The interviewees were academics qualified in different scientific research fields and roles (see Table 9).

Of all of the subjects, 36.7 % are women and the remaining men. Over 53 % have had experience abroad, and most have a positive perception of their profession (10.5 % gratifying + 19.7 % very satisfying + 19.9 % excellent).

Most of the participants have family ties (approximately 53 % have children). These researchers believe that children affect their productivity at work (over 50 % said productivity is influenced by family ties). 50 % of the respondents with families or family ties, assessed their commitment to family above the normal average. This result is reflected by participation in leisure activities (69 % have little free time, which is high compared to the 8.4 % who try to make time for leisure activities, while 1.10 % reported having a large amount of free time for leisure activities).

Only 4.4 % feel wealthy, which is low compared to the 44 % who view their economic status as being intermediate, while the rest say that their economic status is below the European average (average salary of an academic in Europe). Despite negative opinions regarding economic conditions, most of the respondents find security in their employment status (about 66 %).

Most of the respondents are aged 50 years or below, but there is a certain percentage of older respondents (see Table 10).

Regarding questions on the average daily time dedicated to work and to network relationships in the research, the following results emerge. The average number of hours devoted to academic work daily mostly falls between 6 and 12 h, divided between teaching, scientific and bureaucracy. It seems paradoxical that most interviewees stated that 1–3 h per day on average are spent on bureaucratic tasks. This fact explains the various components of the academic load, which confirm our theory of departure (academic productivity as a combination of the various multilateral components: scientific, teaching, external, and bureaucratic).

The first element to be analysed is the similarity in the results of the three scores of scientific productivity to the results from the first type of scientific productivity. This analysis should be carried out both in relation to the SDA and independent of the SDA.

The three score productivity (average value) did not differ statistically for each SDA (both absolute and standardised) (ANOVA test, $p < 0.05$) (see Table 6).

Table 6 ANOVA results between Z^{Bi}. Z^{Ci} *and* Z^{Hi}

Italian SDA classification	*F*	*p-value*
Area 01—Mathematical and Computer Sciences	0.000480	0.999520
Area 02—Physical Sciences	0.000034	0.999966
Area 03—Chemical Sciences	0.000115	0.999885
Area 04—Earth Sciences	0.000042	0.999958
Area 05—Biological Sciences	0.010083	0.989968
Area 06—Medical Sciences	0.000829	0.999172
Area 07—Agricultural and Veterinary Sciences	0.000139	0.999861
Area 08—Civil Engineering and Architecture	0.000003	0.999997
Area 09—Industrial and Computer Engineering	0.118423	0.888342
Area 10—Antiquities philological literary historical and artistic	0.000351	0.999649
Area 11—Historical philosophical pedagogical and psychological	0.000289	0.999711
Area 12—Legal Studies	0.000340	0.999660
Area 13—Economics and statistics	0.000014	0.999986
Area 14—Political and Social Sciences	0.000140	0.999860

Source Elab. StatEcon Area—year 2013 on data of year 2012

An analysis of the correspondence between the three scores and the standardised absolute productivity (independent from the SDA) shows significant differences (see Table 7). In fact, the B score (or bibliometric score) shows a correspondence to the C score (tau_b = 0.629), while both are different from the H index.

This result depends primarily on the fact that until a few years ago, the Italian scientific community paid little attention to publishing in international indexed journals. Therefore, although we asked respondents to provide us with their h index, we found missing values in many cases.

Therefore, as the bibliometric criterion is a statistically robust or reliable criterion, the following analyses will account for the B score. The other score of scientific productivity will be added for an easy comparison.

The scientific productivity (first type) differs for the different SDAs. This result is normal and depends on the different attitudes of the SDA.

It is possible to identify a list of the SDAs that display greater scientific productivity (see Table 8). However, for an effective comparison between the average scores of the SDA, it is necessary to analyse the results of the standardised values of scientific productivity (Z^{Bi}). In fact, the table displays the areas with the greatest scientific productivity such as Area 09—Industrial and Computer Engineering, followed by Area 06—Medical Sciences.

Table 7 Kendall's tau_b results between Z^{Bi}. Z^{Ci} *and* Z^{Hi} scores

		Z-B	Z–C	Z-H
Z-B	Kendall's tau_b	1.000	0.629	0.192
	p value		0.000	0.000
Z-C	Kendall's tau_b	0.629	1.000	0.184
	p value	0.000		0.000
Z-H	Kendall's tau_b	0.192	0.184	1.000
	p value	0.000	0.000	

Source Elab. StatEcon Area—year 2013 on data of year 2012

Table 8 Ranking list of Italian SDA classification in relation to the average *B* scores scientific productivity

Area 02—Physical Sciences
Area 03—Chemical Sciences
Area 06—Medical Sciences
Area 07—Agricultural and Veterinary Sciences
Area 09—Industrial and Computer Engineering
Area 04—Earth Sciences
Area 05—Biological Sciences
Area 01—Mathematical and Computer Sciences
Area 12—Legal Studies
Area 11—Historical. philosophical. pedagogical and psychological
Area 13—Economics and statistics
Area 08—Civil Engineering and Architecture
Area 14—Political and Social Sciences
Area 10—Antiquities philological literary historical and artistic

Source Elab. StatEcon Area—year 2013 on data of year 2012

The results of the descriptive statistics show the average scientific productivity, its variability (standard deviation), the minimal productivity (zero, because there are clearly researchers who do not produce scientifically) and the maximum productivity. In addition, we estimated the average confidence interval within which the average scientific productivity of researchers in the SDA population varies (see Table 9—Descriptive statistics). High levels for the standard deviation represent SDA where there is significant volatility. This volatility is attributed to the presence of researchers that produce significantly more compared to others who produce little, always in the same SDA. The analysis of scientific productivity shows a significant difference between SDAs, both in the mean scores and in the variability (see Table 9).

The first level of scientific productivity is independent from the academic role in the Italian SDA classification (p value > 0.05). This trend is not confirmed for SDAs 5 (p value $= 0.0003$), 10 (p value $= 0.0001$) and 13 (p value $= 0.0330$) (see Table 10).

The frequency distribution of the respondents in relation to the scientific productivity of the second type (see Table 11) shows the percentage of those who have none of the analysed variables. In fact, 45.4 % are not refereed in ISI journals (VAR-C_{23}), 72 % are not refereed in non-ISI journals (VAR-C_{24}), 90.4 % had no assignments for the direction of research institutions (VAR-C_{25}), 90.2 % were not on the board of any international journals (VAR-C_{26}), 89.8 % had never received an international award (VAR-C_{27}), 88.7 % had not received a national award (VAR-C_{28}), 86.9 % were not responsible for coordinating international research projects (VAR-C_{29}), 70.4 % were not responsible for coordinating national research projects (VAR-C_{30}), 57.7 % did not participate in international research projects (VAR-C_{31}), 32.5 % did not participate in national research projects

Table 9 Descriptive statistics of B productivity scientific score

Italian SDA classification	*N*	Mean	SD	95 % Confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
1	165	81.1794	102.23846	65.4636	96.8952	0.00	531.10
2	64	254.6734	400.53071	154.6238	354.7230	0.00	2347.30
3	111	187.0189	211.77942	147.1830	226.8548	0.00	1397.00
4	33	115.5758	82.41760	86.3517	144.7998	0.00	332.20
5	171	108.3673	116.96173	90.7111	126.0234	0.00	747.10
6	170	165.0638	194.99126	135.5408	194.5867	0.00	1125.60
7	74	135.4757	162.81648	97.7542	173.1972	0.00	1020.50
8	67	65.9104	55.38315	52.4014	79.4195	0.00	238.70
9	189	116.0757	93.69447	102.6314	129.5199	0.00	480.60
10	108	57.7935	48.51622	48.5388	67.0482	0.00	267.00
11	74	72.7000	48.73045	61.4101	83.9899	0.40	292.30
12	58	76.4690	70.63065	57.8976	95.0403	0.00	293.20
13	148	67.4480	57.96875	58.0312	76.8647	0.00	341.10
14	42	58.7262	61.71248	39.4952	77.9572	0.00	394.30
Total	1474	112.4447	153.13026	104.6209	120.2685	0.00	2347.30

Test of homogeneity of variances results on B score between SDA (Levene Statistic $= 18.209$ p value $= 0.000$); ANOVA test results on B score between SDA (p value $= 0.000$), *Source* Elab. StatEcon Area—year 2013 on data of year 2012

(VAR-C_{32}), 63.4 % were not discussants in international conferences (VAR-C_{33}) and 67 % were not discussants at national conferences (VAR-C_{34}).

The second level of scientific productivity is independent from the academic role in the Italian SDA classification (p value > 0.05). This trend is not confirmed for SDAs 1 (p value $= 0.0037$), 5 (p value $= 0.0041$), 9 (p value $= 0.0061$) and 10 (p value $= 0.0072$) (see Table 12).

The results of the descriptive statistics show the average scores of the second type of scientific productivity, its variability (standard deviation), the minimal productivity (zero, because clearly there are researchers who do not produce scientifically) and the maximum productivity. In addition, we estimated the average confidence interval within which the average scientific productivity scores of researchers in the SDA population varies (see Table 13). The standard deviation is low and differs depending on the SDA (see Table 13). The analysis of scientific productivity showed a significant difference depending on the SDA in both mean scores (see Table 13).

The following Table 14 is a list of the SDA that present the average productivity score from highest to lowest.

The results below show the significant positive correlation between the productivity of patents and the scientific productivity of the first and second type and the productivity of services (PEA). These results (see Table 15) prove that a score indicating more scientific productivity of the first ($p = 0.1999$) and second type ($p = 0.2287$) corresponds to greater productivity in patents. This finding confirms the theorising by the existing literature on the subject.

The results of the descriptive statistics show the average PEA (Productivity External Advice approved by the University) scores, their variability (standard deviation), the minimal productivity (zero, because clearly there are researchers who do not produce scientifically) and the maximum productivity. In addition, we estimated the average confidence interval within which the average PEA scores of researchers in the SDA population varies (see Table 16). The standard deviation is low and differs depending on the SDA (see Table 16). The analysis of the PEA mean scores displays a significant difference depending on the SDA in both mean scores (see Table 16).

Table 10 Pearson Chi square between the results on B score between academic roles in single Italian SDA classification

SDA	Value	df	p value
1	669.9	679	0.5906
2	384.0	360	0.1841
3	728.3	707	0.2811
4	146.7	140	0.3329
5	962.7	816	0.0003
6	788.3	750	0.1612
7	361.8	345	0.2560
8	381.0	372	0.3621
9	960.7	912	0.1281
10	588.1	462	0.0001
11	407.8	390	0.2576
12	258.1	222	0.0486
13	916.9	840	0.0330
14	197.6	180	0.1758

Source Elab. StatEcon Area—year 2013 on data of year 2012

Table 11 Distribution % of respondents in relation to identifying variables of scientific productivity of the second type

N	VAR-C23	VAR-C24	VAR-C25	VAR-C26	VAR-C27	VAR-C28	VAR-C29	VAR-C30	VAR-C31	VAR-C32	VAR-C33	VAR-C34
0	45.4	72.0	90.4	90.2	89.8	88.7	86.9	70.4	57.7	32.5	63.4	67.0
1	8.2	9.7	7.5	6.1	7.7	8.1	8.1	14.3	19.9	15.5	11.6	9.3
2	6.6	8.3	1.6	2.1	1.4	2.0	3.2	7.9	11.2	22.5	10.4	9.6
3	6.6	5.3	0.1	1.0	0.6	0.6	0.9	4.0	6.0	14.1	5.0	5.4
4	5.4	1.8	0.3	0.3	0.2	0.3	0.2	1.2	2.2	4.9	1.7	1.8
4 - 6	12.1	2.0		0.1	0.1	0.1	0.3	1.2	1.5	4.8	3.0	2.4
> 6	15.7	0.8	0.1	0.1	0.1	0.2	0.3	0.9	1.5	5.8	5.0	4.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source Elab. StatEcon Area—year 2013 on data of year 2012

Table 12 Pearson Chi Square between the results on C_iR productivity scientific score between academic roles in single Italian SDA classification

SDA	Value	df	p value
1	696.8	600	0.0037
2	326.2	330	0.5487
3	673.6	672	0.4755
4	145.0	130	0.1742
5	862.7	756	0.0041
6	755.9	720	0.1717
7	349.3	345	0.4249
8	311.8	306	0.3978
9	863.4	762	0.0061
10	409.4	342	0.0072
11	342.4	330	0.3075
12	247.4	240	0.3575
13	699.9	700	0.4940
14	167.9	150	0.1503

Source Elab. StatEcon Area—year 2013 on data of year 2012

Table 13 Statistics of C_iR productivity scientific score

SDA	N	Mean	SD	95 % Confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
1	165	4.1091	5.56628	3.2535	4.9647	0.00	26.50
2	64	7.6406	5.85758	6.1774	9.1038	0.00	25.25
3	111	7.2905	7.65985	5.8497	8.7314	0.00	38.00
4	33	6.9621	6.62710	4.6123	9.3120	0.00	33.00
5	171	6.7135	9.03306	5.3498	8.0771	0.00	81.75
6	170	6.9044	7.32125	5.7959	8.0129	0.00	38.50
7	74	6.3615	5.97571	4.9770	7.7459	0.00	25.25
8	67	3.7090	4.40097	2.6355	4.7824	0.00	24.00
9	189	6.7937	6.48529	5.8631	7.7242	0.00	31.75
10	108	2.9120	3.55371	2.2341	3.5899	0.00	25.75
11	74	3.6385	4.86780	2.5107	4.7663	0.00	31.00
12	58	3.0345	3.70172	2.0612	4.0078	0.00	17.50
13	148	5.5541	5.48758	4.6626	6.4455	0.00	25.75
14	42	3.4167	4.03403	2.1596	4.6738	0.00	15.50
Total	1,474	5.6013	6.51347	5.2685	5.9340	0.00	81.75

Test of homogeneity of variances results on C_iR score between SDA (Levene Statistic = 6.614 p value = 0.000); ANOVA test results on C_iR score between SDA (p value = 0.000), *Source* Elab. StatEcon Area—year 2013 on data of year 2012

The SDA with higher productivity PEA are shown in the Table 17.

The educational productivity (PE*)* differs across the 14 SDAs (see Table 18). On average, the teaching load is 184 students per respondent, with a high variability of ±300 students. This high variability shows that there are researchers in an SDA with a teaching

Table 14 Ranking list of SDA in relation to the average C_iR scores scientific productivity

Area 02—Physical Sciences
Area 03—Chemical Sciences
Area 04—Earth Sciences
Area 06—Medical Sciences
Area 09—Industrial and Computer Engineering
Area 05—Biological Sciences
Area 07—Agricultural and Veterinary Sciences
Area 13—Economics and statistics
Area 01—Mathematical and Computer Sciences
Area 08—Civil Engineering and Architecture
Area 11—Historical philosophical pedagogical and psychological
Area 14—Political and Social Sciences
Area 12—Legal Studies
Area 10—Antiquities philological literary historical and artistic

Table 15 Correlations results

	Z_B	B anno	Z_CiR	CIR	Z_PE	PE
Patents	0.1630	0.1999	0.0944	0.2287	0.0475	0.0242
	(1,474)	(1,474)	(1,474)	(1,474)	(1,474)	(1,474)
	0.0000	0.0000	0.0003	0.0000	0.0678	0.3540

Source Elab. StatEcon Area—year 2013 on data of year 2012

load that is very different from others (the 6,100 students for the most productive teacher respondent in SDA 12, for example).

The average score in productivity teaching between the SDA are different and influenced by the variability (see Table 18), although it is clear that the SDAs with the greatest teaching loads are SDAs 1, 5, 6, 7, and 12.

Econometric modelling or multidimensional models

The complexity of the indices for previous productivity (in four dimensions) is enclosed in the MPI (20). The overall academic productivity is, on average, similar across the 14 SDA (p value = 0.646) and independent of the SDA (p value = 0.711) (see Table 19).

These results confirm that the combination of the four dimensions of productivity can achieve a level representing the overall productivity in the various SDAs, despite any substantial differences in the scientific productivity of the first type.

The weight, considering the dimension of productivity in each SDA, shows that the academic average educational productivity counts for 85 % of all of the productive activity of a researcher, followed by scientific productivity of the first (12 %) and second type (3 %) and, lastly, external productivity (0.3 %) (see Table 20).

These data confirm an initial analysis that the academic productivity of a researcher cannot be measured and qualified using only the estimate of scientific productivity; the

Table 16 Statistics of PE productivity scientific score

	N	Mean	SD	95 % Confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
1	165	0.7030	2.08720	0.3822	1.0239	0.00	10.00
2	64	0.5938	1.49835	0.2195	0.9680	0.00	10.00
3	111	0.8108	1.98409	0.4376	1.1840	0.00	10.00
4	33	1.3030	2.02307	0.5857	2.0204	0.00	8.00
5	171	0.5614	1.68052	0.3077	0.8151	0.00	10.00
6	170	0.6471	1.91664	0.3569	0.9373	0.00	10.00
7	74	0.9189	1.83390	0.4940	1.3438	0.00	10.00
8	67	1.2836	2.41087	0.6955	1.8716	0.00	10.00
9	189	1.9683	2.99273	1.5388	2.3977	0.00	10.00
10	108	0.4815	1.42397	0.2099	0.7531	0.00	10.00
11	74	1.0676	2.28953	0.5371	1.5980	0.00	10.00
12	58	0.6552	1.46960	0.2688	1.0416	0.00	8.00
13	148	1.3446	2.13718	0.9974	1.6918	0.00	10.00
14	42	0.8095	1.74241	0.2665	1.3525	0.00	10.00
Total	1474	0.9640	2.12876	0.8553	1.0728	0.00	10.00

Test of homogeneity of variances results on PEA score between SDA (Levene Statistic = 9.827 p value = 0.000); ANOVA test results on PEA score between SDA (p value = 0.000); *Source* Elab. StatEcon Area—year 2013 on data of year 2012

Table 17 Ranking list of SDA in relation to the average PEA scores scientific productivity

Area 09—Industrial and Computer Engineering
Area 13—Economics and statistics
Area 04—Earth Sciences
Area 08—Civil Engineering and Architecture
Area 11—Historical. philosophical. pedagogical and psychological
Area 07—Agricultural and Veterinary Sciences
Area 03—Chemical Sciences
Area 14—Political and Social Sciences
Area 01—Mathematical and Computer Sciences
Area 12—Legal Studies
Area 06—Medical Sciences
Area 02—Physical Sciences
Area 05—Biological Sciences
Area 10—Antiquities philological literary historical and artistic

results show that the estimation of productivity must be measured in relation to all of the dimensions of the produced output (see Fig. 3).

Furthermore, academic productivity is dependent (p value < 0.05, Chi square tests) on the SDA, and this result is confirmed across all 4 of the dimensions of academic productivity (see Table 20).

Table 18 Statistics of PE productivity scientific score

SDA	*N*	Mean	SD	95 % Confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
1	165	142.9212	289.26279	98.4565	187.3859	0.00	2,400
2	64	85.2500	96.13202	61.2369	109.2631	0.00	355
3	111	148.6216	147.49182	120.8783	176.3650	0.00	803
4	33	106.7576	164.57882	48.4005	165.1147	0.00	852
5	171	152.5497	220.86760	119.2082	185.8912	0.00	1,704
6	170	163.0706	294.17307	118.5308	207.6103	0.00	2,484
7	74	146.8108	330.98407	70.1280	223.4936	0.00	2,465
8	67	168.2239	148.12309	132.0938	204.3539	0.00	752
9	189	149.2222	157.42412	126.6334	171.8110	0.00	1,052
10	108	170.5926	217.20566	129.1595	212.0256	0.00	1,220
11	74	255.5405	265.92878	193.9298	317.1512	0.00	980
12	58	438.1379	819.50574	222.6599	653.6160	0.00	6,100
13	148	300.1081	333.66073	245.9065	354.3098	0.00	2,604
14	42	249.8571	351.91432	140.1929	359.5214	0.00	1,730
Total	1474	183.7585	300.11497	168.4249	199.0921	0.00	6,100

Test of homogeneity of variances results on PE score between SDA (Levene Statistic = 7.496 *p* value = 0.000); ANOVA test results on PE score between SDA (*p* value = 0.000); *Source* Elab. StatEcon Area—year 2013 on data of year 2012

Table 19 MPI multidimentional productivity index

SDA	N	Mean	SD	95 % Confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
1	165	55.7918	46.20286	48.6896	62.8940	0.27	330.62
2	64	44.8677	30.00054	37.3737	52.3616	0.41	119.42
3	111	51.6299	48.43825	42.5186	60.7412	0.43	319.40
4	33	52.6912	51.44638	34.4491	70.9333	2.27	249.66
5	171	51.4346	47.04048	44.3335	58.5357	1.64	323.83
6	170	49.1216	48.59478	41.7640	56.4792	0.60	375.82
7	74	42.7682	45.22259	32.2910	53.2455	0.47	235.47
8	67	53.9188	40.10067	44.1375	63.7001	0.05	192.93
9	189	55.2554	42.80091	49.1139	61.3970	0.97	243.43
10	108	52.4315	37.50705	45.2768	59.5861	3.40	170.42
11	74	53.3482	38.46142	44.4375	62.2590	1.06	184.16
12	58	48.6350	61.34546	32.5050	64.7650	0.28	441.97
13	148	48.8824	38.43771	42.6383	55.1264	0.72	276.60
14	42	44.5021	40.33445	31.9330	57.0712	1.12	176.13
Total	1474	51.1862	44.37760	48.9188	53.4536	0.05	441.97

Test of homogeneity of variances results on MPI score between SDA (Levene Statistic = 0.813 *p* value = 0.646); ANOVA test results on MPI score between SDA (*p* value = 0.711); *Source* Elab. StatEcon Area—year 2013 on data of year 2012

Table 20 The weight results that takes every dimension of productivity in each SDA

SDA	*B* (%)	CiR (%)	PAE (%)	PE (%)
SDA-01	10	3	0	87
SDA-02	35	5	0	59
SDA-03	19	4	0	77
SDA-04	17	5	1	77
SDA-05	12	4	0	84
SDA-06	16	3	0	80
SDA-07	15	4	1	81
SDA-08	7	2	1	90
SDA-09	13	4	1	82
SDA-10	6	2	0	92
SDA-11	5	1	0	93
SDA-12	3	1	0	96
SDA-13	4	2	0	94
SDA-14	4	1	0	94
Total	11.9	2.9	0.3	84.7
Sqm	8.6	1.4	0.5	9.9

Chi square tests between 4 productivity scores in SDA classification are: *B* score (p value = 0.000); CiR score (p value = 0.0283); PEA score (p value = 0.000); PE score (p value = 0.000). *Source* Elab. StatEcon Area—year 2013 on data of year 2012

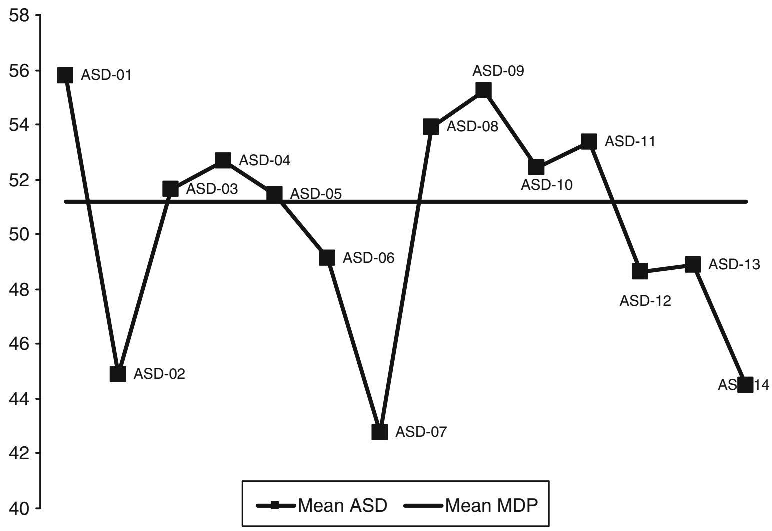

Fig. 3 Graphical representation of MPI scores mean in 14 ASD compared to MDP mean (that is multidimentional productivity Italian mean)

The overall productivity (academic productivity) is significantly correlated (see Table 21) with the 4 dimensions: average annual scientific productivity of the first type (0.6524), average annual scientific productivity of the second type (0.5285), the productivity external advice (0.7278) and, lastly, teaching productivity (0.7325).

Table 21 Correlations scores between 4 productivity scores

	Z_B	Z_CiR	Z_PEA	Z_PE	Z_MPI
Z_B		0.2413	0.2000	0.2170	0.6524
		(1,474)	(1,474)	(1,474)	(1,474)
		0.0000	0.0000	0.0000	0.0000
Z_CiR	0.2413		0.1346	0.1383	0.5285
	(1,474)		(1,474)	(1,474)	(1,474)
	0.0000		0.0000	0.0000	0.0000
Z_PEA	0.2000	0.1346		0.8765	0.7278
	(1,474)	(1,474)		(1,474)	(1,474)
	0.0000	0.0000		0.0000	0.0000
Z_PE	0.2170	0.1383	0.8765		0.7325
	(1,474)	(1,474)	(1,474)		(1,474)
	0.0000	0.0000	0.0000		0.0000
Z_MIR	0.6524	0.5285	0.7278	0.7325	
	(1,474)	(1,474)	(1,474)	(1,474)	
	0.0000	0.0000	0.0000	0.0000	

Source Elab. StatEcon Area—year 2013 on data of year 2012

Table 22 Multiple regression model-dependent variable: Z_MPI-independent variables: Z_B; Z_CiR; Z_PEA; Z_PE

Parameter	Estimate	Standard error	*T* Statistic	*p* value
CONSTANT	0.0064	0.0231	0.2785	0.7806
Z_B	1.4285	0.0242	58.9099	0.0000
Z_CiR	1.0919	0.0239	45.6762	0.0000
Z_PEA	1.0785	0.0480	22.4717	0.0000
Z_PE	0.9725	0.0482	20.1874	0.0000

Analysis of variance

Source	Sum of *s*quares	df	Mean Square	*F* ratio	*p* value
Model	14,390.6	4	3,597.66	4,575.56	0.0000
Residual	1,155.04	1,469	0.786277		
Total (corr.)	15,545.7	1,473			

R-squared = 92.57 percent, R-squared (adjusted for d.f.) = 92.5498 percent, Standard Error of Est. = 0.886723, MAE = 0.599315, DW = 1.89514 ($p = 0.0221$), Lag 1 residual autocorrelation = 0.0523369

With respect to a multivariate analysis, we select the model that explains the greater variability explained by the independent variables and with the lower standard error. This choice was made using a multiple regression model.

The output shows the results of fitting a multiple linear regression model to describe the relationship between Z_MIR and 4 independent variables (see Table 22). The equation of the fitted model is

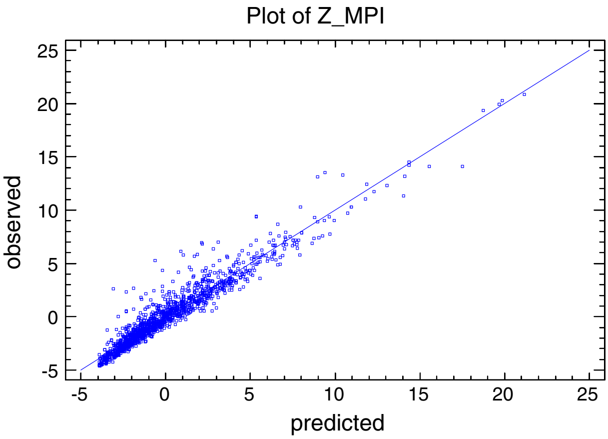

Fig. 4 Plot of Z_MPI

$$Z\_MPI = 1.4285 * Z\_B + 1.091 * Z\_CiR + 1.078 * Z\_PEA + 0.9724 * Z\_PE + 0.886723$$

.

Because the p value in the ANOVA table is less than 0.05, there is a statistically significant relationship between the variables at the 95.0 % confidence level.

The R-squared statistic indicates that the model as fitted explains 92,57 % of the variability in Z_MPI. The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 92.5498 %. The standard error of the estimate shows that the standard deviation of the residuals is 0.886723. This value can be used to construct the prediction limits for new observations. The mean absolute error (MAE) of 0.599315 is the average value of the residuals. The Durbin–Watson (DW) statistic tests the residuals to determine whether there is any significant correlation based on the order in which they occur in the data file. Because the p value is less than 0.05, there is an indication of possible serial correlation at the 95.0 % confidence level. The residuals are plotted against the row order to determine if there is any visible pattern (see Fig. 4).

In determining whether the model can be simplified, notice that the highest p value for the independent variables is 0.0000 belonging to Z_B. Because the p value is less than 0.05, that term is statistically significant at the 95.0 % confidence level. Consequently, we most likely do not wish to remove any variables from the model.

Conclusion

This work shows a first attempt to estimate the overall productivity of academics. This analysis proves our hypotheses. The overall productivity of an academic researcher is the result of the combination of a series of output that he or she produces.

The attempt to go beyond the estimates and assessments of academic productivity in addition to the scientific qualification creates the possibility for a new evaluation of multidimensional productivity. We need to proceed with further research to determine if the estimated and tested model is adaptable to measurement of the productivity of academic researchers working in European and non-European universities.

The results obtained, however (as a case of estimates obtained using the results of a sample survey), are the result of a working reality that Italian academics are flooded by a myriad of activities that are not always consistent with the primary aims of the work of a researcher with an organisational and environmental well-being at the limit of iper productivity (or hyper productivity).

The estimate of the sizes for the four indicators of productivity are the result of a literature search of the primary techniques used to assess productivity in academia. By comparing the most significant indicators, we managed to select all of the technical aspects missing in the Italian system of evaluation. This process allowed for us to add additional variables characterising the various aspects of productivity.

Having identified the multidimensional nature of academic productivity, the research can intersect with phenomena such as brain drain, organisational well-being and stress, per capita income, research funds (insufficient or inadequate), the relationship between the administrative system and academic productivity, the social sphere and family.

To correlate all of these scenarios with productivity will require analysing all or most aspects of economic theory as related to productivity.

Meanwhile, the multivariate models used to estimate significant results for a manufacturing complex can also be used in terms of the disciplinary areas of science.

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