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Scientometrics (2023) 128:4475–4507
https://doi.org/10.1007/s11192-023-04770-x

Empirical evidence on the relationship between research and teaching in academia

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Received: 3 October 2022 / Accepted: 7 June 2023 / Published online: 22 June 2023

Abstract

Research and *teaching* are the two most characteristic activities of the professional life of academics. Since the second half of the last century, a plurality of studies focused on the link between these activities, with often contrasting conclusions. While some studies are in line with the von-Humboldtian view of research and teaching as synergistic activities, other studies theorize their uncorrelation or even negative tension. This divergence of views probably stems from the fact that investigations are often based on heterogeneous, limited and difficult-to-generalise data, using mainly qualitative metrics. This paper deepens the study of the research-teaching link, through a survey of 251 academics from Politecnico di Torino, i.e., one of the major Italian technical universities. From a methodological point of view, research and teaching are both analysed from the dual perspective of *workload* and *quality of results* obtained, on the basis of data of various kinds, including bibliometric indicators, teaching satisfaction indexes, number of credits awarded to students, etc. Next, a correlation analysis investigates possible links between teaching and research, showing that they tend to be weak and/or statistically insignificant. For instance, the investigation excludes both (i) the existence of a negative link in terms of workload—contradicting considerations such as "*Those who do more teaching have less time to do research and* vice versa"—and (ii) the existence of a positive link in terms of the quality of the results obtained—contradicting considerations such as "*Those who obtain high quality results in research are likely to do the same in teaching and* vice versa". The results of this study are limited to the Italian context and do not necessarily have general validity. Nevertheless, they enhance previous findings in the scientific literature and may be useful for university administrators and those involved in the formulation of incentive strategies for academics.

Keywords Research · Teaching · Academics · Workload · Quality of results · Quantitative indicators · Discipline normalization · Politecnico di Torino · Correlation analysis · Principal component analysis

Extended author information available on the last page of the article

Introduction and literature review

Research and *teaching* are the two predominant knowledge-dissemination activities in the working day of academics (Burke-Smalley et al., 2017). Opinions on possible links, interactions or even interferences between them are extremely varied. Since the time of von Humboldt, most academic institutions claimed research and teaching among their pivotal missions, with a close connection, and mutual stimulation (Harland, 2016; Sinclair, 2013; Teichler, 2017). On the other hand, some academics argue that research and teaching are sometimes decoupled or even reciprocally interfering (Gendron, 2008; Moya et al., 2015).

The policies of most higher education institutions promote research at the expense of teaching. For instance, career advancements (and salaries) are typically linked to research results and not to teaching results (Cadez et al., 2017), and universities usually stimulate academic staff to improve in terms of scientific output through internal research evaluation exercises (Franceschini & Maisano, 2017; Karlsson, 2017). Conversely, the evaluation of teaching is often limited to checking the fulfilment of a minimum number of hours per year, without any evaluation of real effectiveness or, even when it is carried out, not linking the result to any incentive or penalty (Brownell & Tanner, 2012; Moya et al., 2015). Additionally, academic institutions and mentors generally encourage young researchers (i.e., future professors) to carry out research activities organically during their (post-)doctoral studies, but they rarely provide pathways to train them for teaching activity (Burke-Smalley et al., 2017; Hollywood et al., 2020; Shortlidge & Eddy, 2018). As a result, academics generally tend to focus more on research, "economising" on teaching and related activities, such as student tutoring, mentoring, thesis supervision or, more generally, those activities that may "steal time" from research (Cadez et al., 2017; Teichler, 2017).

The university incentives to focus on research at the expense of teaching are sometimes more explicit. In some cases, academics who achieve significant results in research are rewarded with a reduction in the contractual teaching workload. On the other hand, academics who do not achieve "decent" research results (e.g., a minimum number of publications in medium–high impact journals, such as those within the SCImago Journal Rank's (SJR) Q_1 or Q_2) can be "punished" with extra teaching loads (Brownell & Tanner, 2012; González-Pereira et al., 2010). This debatable form of compensation certainly contrasts with von Humboldt's synergistic view of the research-teaching duo (Sinclair, 2013).

For more than half a century, the research-teaching relationship in academia has been the subject of numerous scientific investigations, from the different perspectives of *students* and *academics*. Regarding the perspective of students, the learning benefits of integrating research and teaching are documented in a variety of studies, some of which show that students can benefit significantly from activities that allow them to develop their research skills (Brew, 1999; Elton, 2001). Other studies show that engaging students in research challenges that are anchored in a real-life context gives them the opportunity to develop critical thinking and to better absorb/apply what they have learned (Coombs & Elden, 2004). Healey et al. (2010) show that the benefits of linking research and teaching in class are also visible to students, who feel that having an active researcher as a teacher helps to improve interest, understanding and enthusiasm for the subject. Furthermore, integrating research into teaching can foster interdisciplinarity and collaboration between students and teachers (Le Heron et al., 2006). The scientific literature also includes studies within *pedagogy* and *learning sciences*, which propose direct experiments of innovative educational practices and evaluate their effects on student learning (Vermeir et al., 2017).

Table 1 Four-quadrant scheme related to the analysis of *research* and *teaching* (columns), from the dual perspective of *workload* and *quality of results* (rows)

	Workload	Quality of results
Research	(a)	(b)
Teaching	(c)	(d)

A more anthropological perspective of the research-teaching link is that of academics, who have to manage teaching and research on a daily basis—with the related synergies, interferences and, not infrequently, ongoing assessments. According to some studies, there is a positive mutual stimulus (Shortlidge & Eddy, 2018; Trautmann & Krasny, 2006). While for other studies, the two activities are disconnected and even in conflict (Burke-Smalley et al., 2017). Cadez et al. (2017) documented a positive correlation concerning excellent academics, which sounds like: "*Best researchers are often best teachers*". On the other hand, Brennan et al. (2019) showed that good teachers are not necessarily good researchers and vice versa. Recent research theorises a potential synergy between research and teaching that should be cultivated and stimulated with appropriate institutional tools/incentives, in line with a Socratic *maieutic* perspective (Shortlidge & Eddy, 2018). Other studies argue that recognising and rewarding teaching and research excellence through appropriate institutional incentives is a relevant policy lever to foster their development and integration (Burke-Smalley et al., 2017).

The aforementioned diversity of opinions and (apparent) contradictions are probably the consequence of inherent analysis limitations, such as the fact that the samples of academics examined are often restricted to a few dozen subjects, which makes comparisons and generalizations difficult (Lawson et al., 2015). In addition, analysis methodologies are heterogeneous and often adapted to extremely different socio-cultural contexts, which often evolve dynamically, preventing comparisons and/or generalisations. Lastly, evaluations are mostly *qualitative* and based on the results of subjective indicators (Brennan et al., 2019). Although the implementation of studies of general validity is precluded by the previous limitations, it remains interesting to monitor the research-teaching relationship in different contexts, in order to broaden the analysis domain and identify any trends, specificities or discrepancies. This article takes an in-depth look at the research-teaching link by considering both of these activities from the dual viewpoint of the *workload* and *quality of results* obtained by individual academics, as illustrated in the four-quadrant scheme in Table 1 (Stack, 2003).

The analysis is carried out using quantitative indicators referring to a sample of several hundred academics affiliated with *Politecnico di Torino*, i.e., one of the most important Italian technical universities with a mixed population of academics, ranging from mathematicians to mechanical engineers, chemists, material scientists, physicists, management engineers, etc. This university provides several tens of study programmes in engineering and architecture to approximately 35 thousand national/international students (www.polito.it, last accessed on February 2023). After defining appropriate indicators for the quadrants in Table 1, a (*bivariate* and *multivariate*) correlation analysis is provided to answer two major research questions:

(RQ#1) "*Is there any (direct/inverse) relationship between the research and teaching workload of individual academics?*". The scholarly literature includes several conflicting arguments in this regard; for example—in line with a form of "scarcity model" that postulates scarcity of time and energy—it seems reasonable to assume that those academics who spend more time in research conceptually tend to spend less time in teaching and vice versa, leading to a negative relationship. On the other hand, it might be argued (i) that academics who are more active in research tend to be more organized in teaching, being able to sustain a high workload in both activities, or (ii) that some academics "economize" in both activities, perhaps because they are engaged in administrative or non-academic activities, leading to a positive relationship (Hattie & Marsh, 1996).

(RQ#2) "*Is there any (direct/inverse) relationship between the quality of research results and that of teaching results of individual academics?*". Some arguments suggest that the abilities underlining successful teaching and those underlining successful research are similar, leading to a positive relationship that sounds like: "*Those who obtain high quality results in research are likely to do the same in teaching*" (Cadez et al., 2017). Other arguments suggest that research and teaching simply require different, often even "orthogonal", qualities that may or may not coexist in the same person, leading to a nearly zero relationship (Barnett, 1992).

Although the scientific literature includes other analyses aimed at developing similar research questions, the proposed methodology is characterized by the use of strictly quantitative indicators constructed on a relatively large dataset. Nevertheless, it remains interesting to compare the results of this study and those of other studies based on different methodological approaches.

The remainder of this paper is organised into four sections. Section "Methodology" describes the research methodology, including the procedure to select a sample of academics, collect data and construct indicators, both for research and teaching. Section "Empirical results" presents a statistical correlation analysis structured in two stages: *bivariate* analysis, using Pearson's correlation coefficient, and *multivariate* analysis, based on Principal Component Analysis. Section "Conclusions" summarises the original contributions of this research, its implications, limitations and suggestions for future research. The Appendix section provides additional material for further investigation.

Methodology

The flow chart di Fig. 1 outlines the methodological structure of the research, which is described in detail in the following four subsections: (2.1) selection of the sample of academics, (2.2) data collection and indicators relating to *research*, (2.3) data collection and indicators relating to *teaching*, and (2.4) correlation analysis.

Selection of the sample of academics

In Italy, every tenured academic belongs to one-and-only-one specific "Scientific and Disciplinary Sector"—in Italian "Settore Scientifico Disciplinare" or just "SSD"—of 383 in all (Abramo et al., 2019; Maisano et al., 2020); a complete list is accessible at (Ministero dell'Istruzione, 2022). For the sake of simplicity, the expression "discipline" will be used from here on. Although the academics from *technical* universities—like Politecnico di Torino, henceforth abbreviated as "PoliTO"—are scientifically more homogeneous than those from *generalist* universities, they may belong to disciplines with significant differences in terms of propensity to publish and cite (Maisano et al., 2020).

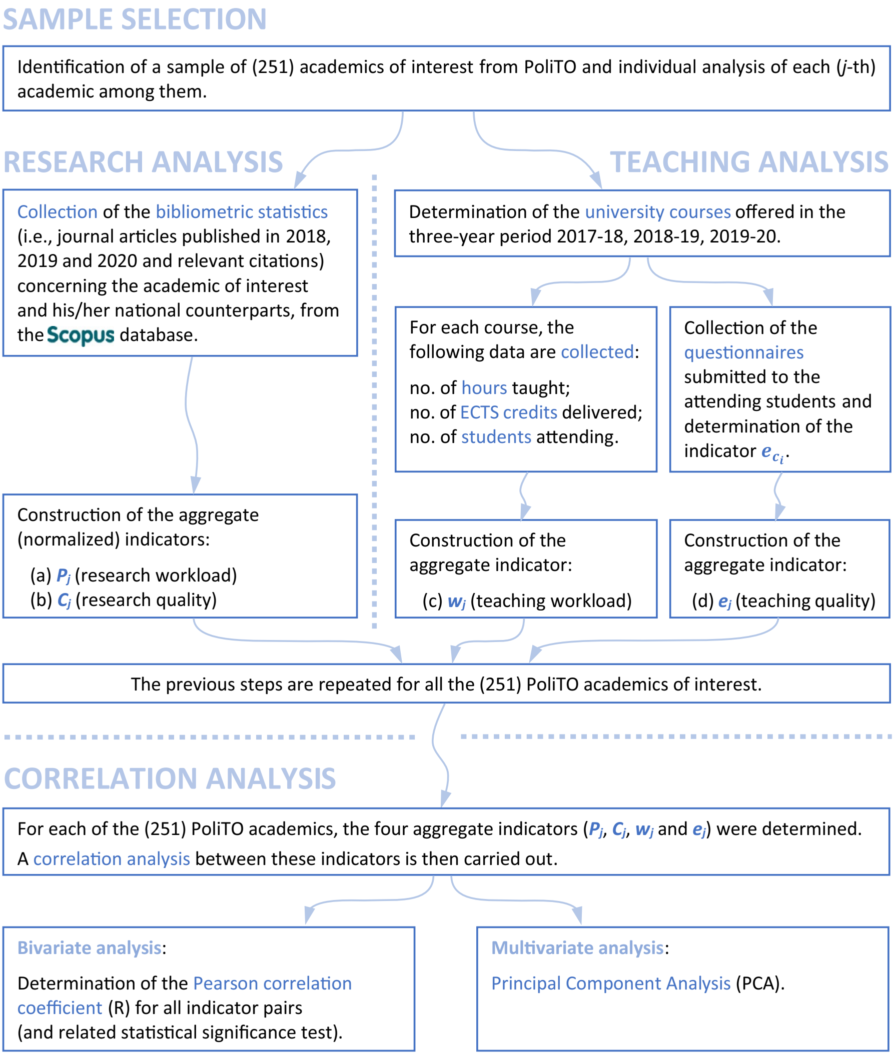


Fig. 1 Flow chart summarising the methodological approach

PoliTO comprises a population of around 900 tenured academics (i.e., *assistant*, *associate* and *full professors*). Table 2 describes the sample of selected PoliTO academics, who belong to sixteen disciplines (i.e., A, B, C, …, O, and P) that are very specific of engineering (Consiglio Universitario Nazionale, 2022). The selection was limited to academics with a relatively well-established career, both in terms of research and teaching, in order to avoid possible "outliers", such as young academics with little teaching experience. Therefore, only active academics with a permanent contract with PoliTO in the three-year period 2018 to 2020 and, at the same time, with any Italian university (including PoliTO) in the five-year period 2013 to 2017 were considered. This eight-year permanent contract period protects against possible changes in the staff number (henceforth abbreviated as N), due to retirements, new hires, transfers, etc. It is also a form of assurance that the population of

Table 2 Sample of academics (from PoliTO and all Italian universities) selected for the analysis

Discipline	Abbreviation (SSD)	Staff number (N)	
		PoliTO	All Italian universities
A. Chemical foundations of technologies	CHIM/07	11	140
B. Physics of matter	FIS/03	15	292
C. Structural mechanics	ICAR/08	14	256
D. Thermal engineering and industrial energy systems	ING-IND/10	12	127
E.Applied mechanics	ING-IND/13	23	162
F. Mechanical design and machine construction	ING-IND/14	22	140
G.Design methods for industrial engineering	ING-IND/15	4	75
H.Manufacturing technology and systems	ING-IND/16	16	134
I.Industrial mechanical plants	ING-IND/17	5	129
J.Materials science and technology	ING-IND/22	19	188
K.Excavation engineering and safety	ING-IND/28	5	18
L.Electrical engineering	ING-IND/31	14	158
M.Business and management engineering	ING-IND/35	8	168
N.Telecommunications	ING-INF/03	26	291
O.Information processing systems	ING-INF/05	43	583
P.Mathematical analysis	MAT/05	14	583
	Total	251	3444

Academics belong to sixteen disciplines, which are characteristic of the engineering field

academics considered is relatively homogeneous in terms of contractual obligations, incentives, etc.

The second last column of Table 2 reports the N values related to the selected PoliTO academics, for each of the disciplines of interest. The resulting sample of 251 individuals covers more than ¼ of the whole population of PoliTO academics. Academics were identified through the public directory https://cercauniversita.cineca.it/php5/docenti/cerca.php.

Data collection and indicators relating to research

Research data basically concern scientific publications by the academics of interest and relevant citations obtained. In order to implement a *discipline normalization*—allowing comparisons between academics from heterogeneous scientific disciplines (Franceschini & Maisano, 2014; Moed, 2010)—the sample of PoliTO academics was extended to academics belonging to the same disciplines but affiliated to all the Italian universities. Consistently with the data regarding PoliTO staff, only academics with a permanent contract in the period from 2013 to 2020 were considered. The last column of Table 2 shows the resulting number of academics selected from all (Italian) universities (including PoliTO), which will simply be referred to as "*All*".

For all academics, the corresponding Scopus Author ID was manually determined, in order to uniquely identify the publication output (Kawashima & Tomizawa, 2015). The Scopus database was chosen since (i) it provides a higher degree of coverage than Web of Science (WoS) for the discipline of interest (Visser et al., 2021), and (ii) at least for Italian academics, it is generally more accurate than WoS, due to the systematic cleaning undergone in the recent *national research quality assessment exercises* (denominated "VQRs") (Franceschini et al., 2016; Franceschini & Maisano, 2017; D'Angelo and van Eck, 2020).

For each of the academics of interest, the publications produced in the three-year period from 2018 to 2020 were identified. This period seems reasonably broad to provide a "taste" of individual research output, absorbing temporary interruptions due to health problems, maternity leave, sabbaticals, etc. Publications produced later (i.e., from 2021 onwards) were excluded as they are still too "immature" in terms of citation impact (Bar-Ilan & Halevi, 2018). Only papers in international scientific journals were considered (De Bellis, 2009). For each *j*-th academic's article, the issue year (i.e., 2018, 2019 or 2020), the number of co-authors, and the number of citations obtained by journal papers up to the time of data collection (i.e., February 2023) were also collected. These data are used to construct two (normalized) bibliometric indicators for each PoliTO academic, as described below.

Discipline-normalised total no. of papers, fractionalized by no. of co-authors:

$$P_j = \frac{\text{Total no.of fractionalized papers by the academic } j \text{ (from PoliTO)}}{\text{Avg.tot.no.of fractionalized papers by all Italian academics in the same discipline of } j} = \frac{\sum_{\forall i \,\text{by}\, j}\left(\frac{1}{a_{i,j}}\right)}{\left\{\frac{\sum_{\forall k \in All}\left[\sum_{\forall i \text{ by } k}\left(\frac{1}{a_{i,k}}\right)\right]}{N}\right\}} \tag{1}$$

j being the academic of interest from PoliTO; $All \equiv \{\dots, j, \dots\}$ being the set of academics from all Italian universities, in the same discipline of *j*; *k* being a generic academic $\in All$; $N = |All|$ being the cardinality of the set *All* (see last column of Table 2); *i* being the generic *i*-th paper by the *j*-th/*k*-th academic; $a_{i,*}$ being the number of co-authors of the *i*-th paper by the *j*-th/*k*-th academic (i.e., "*" in the subscript).

The fractionalization by number of co-authors was introduced to make a fair comparison between academics with different propensities for co-authorship (Franceschini et al., 2010; Perianes-Rodriguez et al., 2016). Moreover, given that the propensity to publish papers may depend on the discipline—i.e., the scientific production of academics belonging to certain disciplines may tend to be higher/lower than that of academics belonging to other disciplines—P_j implements a discipline normalisation (cf. denominator of the last term of Eq. 1) (Franceschini & Maisano, 2014; Maisano et al., 2020; Moed, 2010; Prathap et al., 2016).

P_j is used as a proxy for the *workload* spent on research by a certain academic (cf. quadrant (a) of the scheme in Table 1). In fact, it is assumed a proportionality between the effort expended in research activities—whether carried out on independent initiative or financed within the framework of projects, specific funding, etc.—and the dissemination of the publishing results (De Bellis, 2009). The adoption of this indicator deserves further explanation. In principle, publication is a final act (not necessarily due) of a previous research activity. In other words, it is not an *obligation* since all research, although relevant and rigorous, does not necessarily result in publication(s). Extending the reasoning, the number of publications is not necessarily proportional to the research workload, also since the workload required to achieve one publication is not a fixed quantity.[1] That said, it is appropriate to make a few remarks on the Italian academic context of the last 10–15 years. Recent *national research quality assessment exercises* (VQRs) and the pervasive use of bibliometric criteria to assess research output have increasingly pushed academics to "valorize" their research activity in terms of publications on Scopus-indexed or WoS-indexed scientific journals of a certain relevance (e.g., with relatively high Impact Factor or SJR values). Whether one likes it or not, academics who do not conform to this practice are inevitably penalised (Franceschini & Maisano, 2017; Karlsson, 2017); this applies both to younger academics, who would jeopardise promotions and career advancement, and to senior academics, who would be cut off from participation in scientific committees of strategic importance in various fields (e.g., projects, public competitions and selections, institutional positions, etc.). From this perspective, it is improbable that—at least in the Italian academic context of the last 10 to 15 years—individuals with a relevant research activity (on a quantitative basis) would not have "valorised" it in terms of scientific publications. In addition, the fact of considering publications in Scopus-indexed or WoS-indexed journals, excluding non-indexed journals or other types of publications (such as conference proceedings), constitutes a further guarantee that each publication reflects substantial workload.

Discipline-normalised average no. of citations per paper:

$$C_j = \frac{\sum_{\forall y}\left\{\frac{\text{Avg.no.of cites per paper issued in the year}\,y,\text{for the academic}\,j\,\text{(from PoliTO)}}{\text{Avg.no.of cites per paper issued in the year}\,y,\text{for all Italian academics in the same discipline of}\,j}\right\}}{\text{no.of issue years}}$$

$$= \frac{\sum_{\forall y}\left\{\frac{\frac{\sum_{\forall i\,\text{by}\,j,y}\left(c_{i,j,y}\right)}{|i\,\text{by}\,j,y|}}{\left(\frac{\sum_{\forall k\in All}\left[\frac{\sum_{\forall i\,\text{by}\,k,y}\left(c_{i,k,y}\right)}{|i\,\text{by}\,k,y|}\right]}{N}\right)}\right\}}{|y|}, \tag{2}$$

j being the academic of interest from PoliTO; $All \equiv \{\ldots, j, \ldots\}$ being the set of academics from all Italian universities, in the same discipline of j; k being a generic academic $\in All$; $N = |All|$ being the cardinality of the set All (see last column of Table 2); i being the generic i-th paper by the j-th/k-th academic; $c_{i,*,y}$ being the total number of citations

[1] For example, one academic may publish one article per year in a high-quality journal and another may publish four articles per year in low-quality journals, yet both may spend the same number of hours (i.e., *workload*) for their respective output. It would not be fair to say that the second academic has four times more research workload than the first one.

obtained up to the moment of data collection (i.e., February 2023) by the i-th paper of the j-th/k-th (i.e., "*" in the subscript) academic of interest, issued in the y-th year; $|i \text{ by } *, y|$ being the total number of papers, issued in the year y, of the j-th/k-th academic of interest; $y \in \{2018, 2019, 2020\}$ being the single issue year (the total issue years are $|y| = 3$).

C_j embeds two forms of normalization: by discipline and by age, since both these factors can affect the propensity to obtain citations (Franceschini & Maisano, 2014; Moed, 2010). Precisely, the (annual) citations per article of each PoliTO academic (j) are divided by the average value of the same quantity, with reference to the totality of academics from all universities, in the same discipline of j (cf. the last term of Eq. 3). Then, the discipline-normalized statistics related to the three issue years are combined with a simple arithmetic mean (i.e., $\frac{\sum_{\forall y}\{\cdots\}}{|y|}$). Fractionalization by number of co-authors (which is implemented in P_j, cf. Eq. 1) is not needed here, since C_j is not "size dependent" (Prathap et al., 2016).

Describing the average level of diffusion of papers produced by a certain academic, C_j is used as a proxy for the *quality of research results* (Braun et al., 2010; De Bellis, 2009; Moed, 2010).

Data collection and indicators relating to teaching

For over twenty-five years, questionnaires have been regularly administered to students at the end of each PoliTO's B.Sc. or M.Sc. course, in order to assess the quality of teaching. These questionnaires—which have undergone several improvements over the years—cover various aspects, such as *course organization*, *teacher effectiveness*, *infrastructure*, *student's interest/satisfaction*, etc. Table 4 (in the appendix) reports the questionnaire template used in the academic years 2017–2018, 2018–2019 and 2019–2020. Each of the eighteen questions (q1 to q18) is rated on a four-level ordinal scale, with the following numerical conversions: 1 = "Definitely not", 2 = "More no than yes", 3 = "More yes than no", 4 = "Definitely yes", expressing an increasing level of liking/satisfaction regarding the item of interest. For each question, the mean value of respondent ratings is determined. The authors are aware that arithmetically averaging numerical ratings expressed on *ordinal* scale levels (i.e., 1, 2, 3 and 4 in this case) is conceptually questionable (Franceschini et al., 2019, 2022; Roberts, 1979).

The five (k-th) questions from q9 to q13 specifically concern "teaching effectiveness" (cf. Table 4); the mean values of the relevant respondent ratings can be aggregated through a further arithmetic mean:

$$e_{c_j} = \frac{\sum_{q=\mathrm{q}9}^{\mathrm{q}13}\left(e_{c,q_j}\right)}{5}, \tag{3}$$

c representing every single (B.Sc. or M.Sc.) annual course taught by j in the academic years 2017–2018, 2018–2019, and 2019–2020. This reference period is consistent with that used in the research analysis (i.e., 2018, 2019, and 2020, cf. Section "Data collection and indicators relating to research"). The offset of half a year back (e.g., 2017–2018 versus 2018, etc.) in some ways compensates for the *lead time* associated with the publication of scientific papers, from the moment of their submission (Björk & Solomon, 2013). e_{c,q_j} being the mean value of the respondent ratings related to the q-th question, considering the c-th course.

The e_{c_j} values related to all courses taught by any j-th PoliTO academic of interest were collected from the PoliTO website (www.polito.it). For reasons of confidentiality, the data are presented at an aggregate level and without making explicit the names of the academics involved. Other (publicly available) data were collected and used to construct the indicators related to teaching, precisely s_c, i.e., number of students attending the c-th course, and $ECTS_c$, i.e., number of ECTS (European Credit Transfer and Accumulation System) credits[2] associated with the c-th course.

For the sake of simplicity, each academic is assigned exclusively to the courses of which he/she is the holder, not just a collaborator. This assumption is justified by the fact that a course's organization, content and teaching method, which are decisive for its effectiveness, are generally the responsibility of the course holder (not collaborators). Moreover, the selected academics all have a relatively well-established career (i.e., at least eight years with a permanent university contract) and did most of their teaching work as course holders rather than collaborators.

Two aggregated indicators are used to describe the teaching activity of each academic. The first one is a proxy of teaching workload, which depends on the two factors: *amount of teaching delivered to students* and *number of students attending every course*. The first factor can be expressed in terms of ECTS credits associated with the relevant courses. Focusing on the Italian university scenario, each academic is usually required to deliver at least 12 ECTS per year.[3] Of course, the number of ECTS credits delivered by some academics may be higher than this lower bound. Focusing on the second factor, several preparatory/accompanying (teaching) activities tend to increase with the number of students: e.g., tutoring/mentoring, practical exercises/workshops, supervision of internships, theses/dissertations, proofreading of coursework, assistance to undergraduates with applications for admission to doctoral or postgraduate master's programmes, etc. In addition, some courses include laboratory exercises in small groups (e.g., no more than 10–20 units), which must be replicated several times, significantly increasing the workload of the academics involved.

These two factors are aggregated into the following indicator:

$$w_j = \sum_{\forall c \text{ by } j} \left(s_{c_j} \cdot ECTS_{c_j} \right), \tag{4}$$

c being each course taught by j during the three-year reference period (2017–2018, 2018–2019 and 2019–2020); s_{c_j} being the number of students in the specific c-th course held by j;

$ECTS_{c_j}$ being the number of ECTS credits associated with each c-th course held in the reference period by j. w_j can be interpreted as the total number of credits obtained by students who attended the course(s) held by j, i.e., a proxy for the quantitative impact of

[2] In the Italian university system, each credit point corresponds approximately to 25 working hours (European Commission, 2017).

[3] Rare exceptions are academics with part-time contracts or enjoying teaching reductions as they serve important institutional roles (e.g., management of departments, faculties, colleges, graduate schools, etc.).

these course(s) on the student population. This indicator is currently used in PoliTO as a proxy for the teaching workload of individual faculty members.

The aggregation through a multiplicative model (cf. Eq. 4) is typical of indicators that aggregate heterogeneous quantities (e.g., in this case, number of students and number of ECTS credits) (Franceschini et al., 2019, 2022).

The second aggregated indicator is defined as:

$$e_j = \frac{\sum_{\forall c \text{ by } j} \left(e_{c_j} \cdot ECTS_{c_j} \right)}{\sum_{\forall c \text{ by } j} \left(ECTS_{c_j} \right)}. \tag{5}$$

e_j is actually a weighted average of the e_{c_j} values (cf. Eq. 3) with respect to the corresponding ECTS credits; e_j is used as a proxy for the quality of teaching, since it depicts the average teaching effectiveness.

Correlation analysis

The analysis described in Sects. "Data collection and indicators relating to research" and "Data collection and indicators relating to teaching" makes it possible to determine four aggregate indicators for each (j-th) of the 251 PoliTO academics of interest: P_j and C_j concerning research, and w_j and e_j concerning teaching. Next, the (presumed) link between research and teaching is studied through a correlation analysis between these indicators, which is organized in two parts: *bivariate* analysis and *multivariate* analysis. Although the two research questions (RQ#1 and RQ#2, at the end of Section "Introduction and literature review") basically refer to the relationship between the two indicators of *workload* (P_j and w_j) and those of *quality of results* (C_j and e_j), it is useful to study all six potential correlations between the above four indicators, because they could give extra insights to the interpretation of the results obtained.

Regarding the bivariate analysis, the potential correlation between pairs of indicators is assessed through the *Pearson's correlation coefficient* (R) (Ross, 2021). The choice of R is driven by (i) its relative simplicity (Franceschini et al., 2019) and (ii) the absence of other forms of non-linear relationships between the pairs of datasets, as observed by a preliminary graphical investigation (cf. Section "Results of correlation analysis").

Regarding the multivariate analysis, it aims to integrate and confirm the results of the bivariate analysis, providing a complementary analytical perspective. A *Principal Component Analysis* (PCA) of the four indicators of interest is performed, being particularly effective for relatively large datasets with several potentially correlated variables (Abdi & Williams, 2010; Bro & Smilde, 2014).

Empirical results

Relevance of normalizations

A relatively laborious task of the present study was the construction of bibliometric indicators for research evaluation (cf. Eqs. 1 and 2). A large sample of academics were involved: i.e., 3,444 at the Italian level ("All Italian universities"), of which 251 from PoliTO (cf. Table 2). The several normalizations implemented by the indicators in use

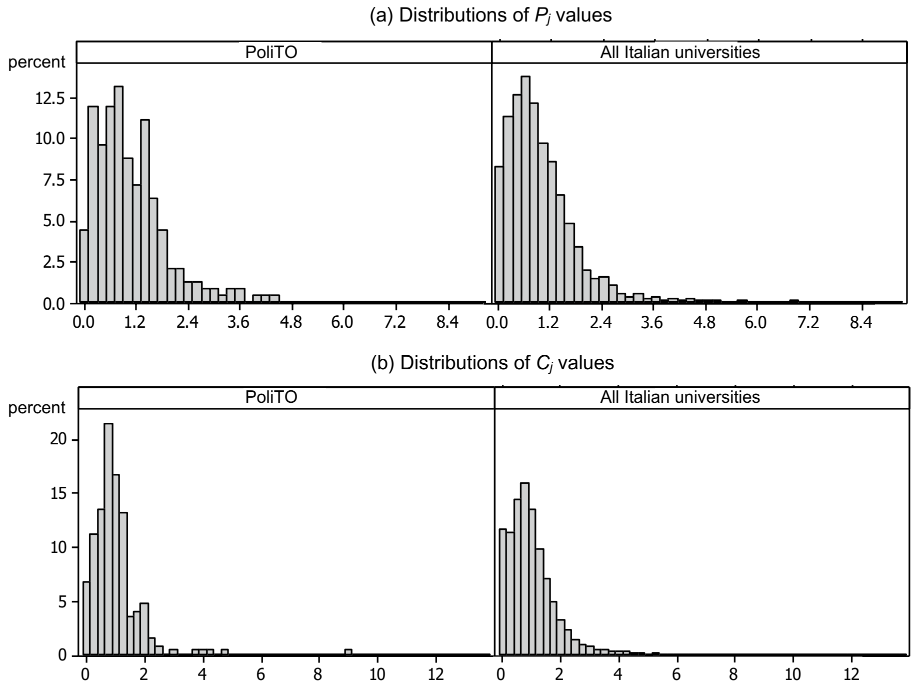


Fig. 2 Qualitative comparison of P_j and C_j distributions related to PoliTO academics and those from all the national universities. Analysis was carried out using Minitab® statistical software

contribute to avoid undue comparisons (cf. Section "Data collection and indicators relating to research".); Section A.2 (in the appendix) provides some evidence of this.

Indicators resulting from the analysis

For each of the 251 PoliTO academics, both the aggregate indicators relating to research (i.e., P_j and C_j) and those relating to teaching (i.e., w_j and e_j) were determined. Table 5 (in the appendix) collects these indicators for each academic, with additional information regarding academic position (i.e., *assistant*, *associate*, or *full* professor) and gender (i.e., *male* or *female*). Figure 9 (in the appendix) contains relevant histograms and descriptive statistics.

The distributions of P_j, C_j and w_j are right-skewed, while that of e_j is left-skewed. Surprisingly, the e_j values are polarised between a minimum value of 2.64 and a maximum of 3.86. This may denote a certain homogeneity in the teaching quality of PoliTO academics, but also a biased use of the four-level scale by respondents (cf. Section "Data collection and indicators relating to teaching"), resulting in a reduction of its potential discriminatory power (Franceschini et al., 2019). The fact that the distributions of P_j, C_j and w_j are right-skewed denotes the presence of so-called "outliers" located in the right-hand tail, with significantly higher performance than the rest of the population (e.g., one academic with $P_j > 4$ and another with $C_j > 9$ are noted).

It is interesting to note substantial agreement between the P_j and C_j distributions related to PoliTO academics and those from all the national universities (see Fig. 2). This indicates

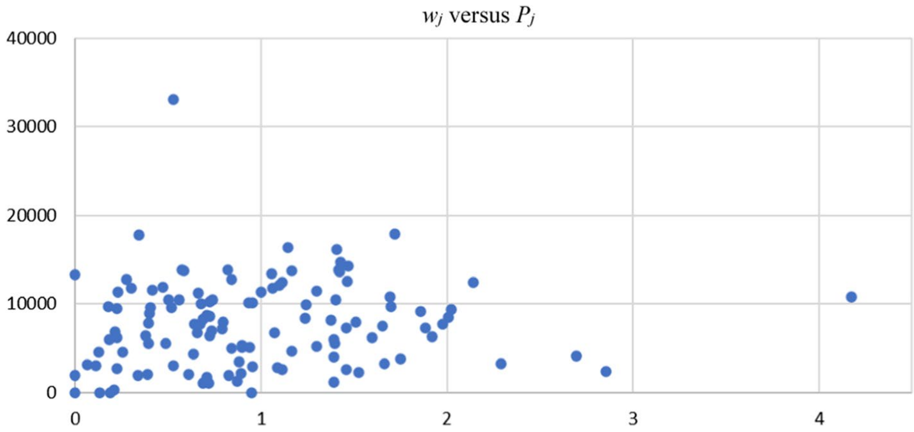


Fig. 3 Scatter plot of w_j versus P_j values, for the PoliTO academics of interest (cf. Table 5, in the appendix)

that the overall performance of PoliTO's population reflects quite well that of the corresponding national counterpart universities.

Results of correlation analysis

Results of bivariate analysis

A preliminary investigation revealed the general absence of non-linear relationships between the pairs of indicators. For example, there is no non-linear relationship (e.g., higher-order polynomial, exponential, logarithmic, etc.) appearing from the scatter plot of w_j versus P_j values in Fig. 3. Similar considerations can be extended to the other pairs of indicators.

Table 3 contains the R values for the pairs of indicators of interest, accompanied by the p-value for the significance test of R being zero (i.e., null hypothesis of absence of correlation) (Ross, 2021). The correlation analysis was carried out considering both academics in their totality ("Total") and subsets by "Discipline", "Academic position" and "Gender".

From a preliminary analysis of Table 3, statistically significant correlations (i.e., p-value < 0.05) are very few. Considering the totality of academics ("Total"), there is only a weak positive correlation (R $\approx +0.224$) between P_j and C_j values—confirming that research productivity and impact tend to "go hand in hand" (Sandström and van den Besselaar, 2016)—and an even weaker positive correlation (R $\approx +0.129$) between P_j and w_j values. Interestingly, these correlations may disappear and new ones may emerge when considering subsets of academics (e.g., for discipline, academic position or gender). For example, the correlation between P_j and w_j is not significant for many subsets, while some correlations are only present at the level of specific discipline, such as that between C_j and w_j for disciplines "A. Chemical foundations of technologies" and "D. Thermal engineering and industrial energy systems". At a later stage, we will return to comment more specifically on these results (cf. Section "Answering to research questions").

Finally, it should be remembered that the R coefficient tends to lose its effectiveness for subsets with less than 25–30 units (Ross, 2021), with the risk of revealing false

Table 3 Pearson correlation coefficients (R) for each pair of the indicator series (i.e., P_j, C_j, w_j and e_j) in Table 5 (in appendix)

(Sub-)set of academics		P_j vs. C_j (a) vs. (b)	P_j vs. w_j (a) vs. (c)	P_j vs. e_j (a) vs. (d)	C_j vs. w_j (b) vs. (c)	C_j vs. e_j (b) vs. (d)	w_j vs. e_j (c) vs. (d)
Total		**0.224***	**0.129***	0.105	0.033	0.043	– 0.057
(N = 251)		(0.000)	(0.042)	(0.102)	(0.597)	(0.505)	(0.373)
Discipline	A. CHIM/07	0.327	0.239	– 0.516	**0.656***	0.356	0.194
	(N = 11)	(0.326)	(0.479)	(0.104)	(0.029)	(0.282)	(0.568)
	B. FIS/03	**0.518***	– 0.163	0.281	0.068	0.078	– 0.457
	(N = 15)	(0.048)	(0.563)	(0.310)	(0.809)	(0.783)	(0.087)
	C. ICAR/08	0.351	0.077	– 0.199	– 0.166	– 0.010	0.096
	(N = 14)	(0.219)	(0.792)	(0.496)	(0.570)	(0.972)	(0.744)
	D. ING-IND/10	**0.702***	0.310	0.106	**0.592***	0.007	**– 0.639***
	(N = 12)	(0.011)	(0.326)	(0.743)	(0.042)	(0.983)	(0.025)
	E. ING-IND/13	0.377	0.338	– 0.063	0.304	0.061	0.174
	(N = 23)	(0.076)	(0.115)	(0.787)	(0.159)	(0.792)	(0.451)
	F. ING-IND/14	0.270	**0.546***	– 0.191	0.066	– 0.264	**– 0.443***
	(N = 22)	(0.224)	(0.009)	(0.393)	(0.771)	(0.235)	(0.039)
	G. ING-IND/15	0.916	**0.965***	0.513	0.927	0.652	0.718
	(N = 4)	(0.084)	(0.035)	(0.487)	(0.073)	(0.348)	(0.282)
	H. ING-IND/16	– 0.010	– 0.139	0.260	– 0.223	0.224	0.061
	(N = 16)	(0.972)	(0.608)	(0.331)	(0.407)	(0.404)	(0.821)
	I. ING-IND/17	**0.965***	0.716	– 0.077	0.692	– 0.087	– 0.668
	(N = 5)	(0.008)	(0.174)	(0.902)	(0.195)	(0.890)	(0.218)
	J. ING-IND/22	**0.469***	0.185	0.345	0.451	– 0.144	– 0.028
	(N = 19)	(0.043)	(0.450)	(0.161)	(0.053)	(0.568)	(0.911)
	K. ING-IND/28	0.381	0.039	– 0.129	– 0.556	– 0.223	– 0.570
	(N = 5)	(0.527)	(0.950)	(0.836)	(0.331)	(0.718)	(0.316)
	L. ING-IND/31	**0.673***	0.322	0.527	0.022	0.362	0.261
	(N = 14)	(0.008)	(0.262)	(0.053)	(0.940)	(0.204)	(0.368)
	M. ING-IND/35	0.665	– 0.426	– 0.324	0.253	– 0.648	– 0.151
	(N = 8)	(0.072)	(0.292)	(0.433)	(0.545)	(0.083)	(0.721)
	N. ING-INF/03	– 0.002	– 0.179	0.126	– 0.242	– 0.098	– 0.303
	(N = 26)	(0.993)	(0.381)	(0.558)	(0.234)	(0.648)	(0.150)
	O. ING-INF/05	0.142	– 0.062	0.129	– 0.192	**-0.389***	0.051
	(N = 43)	(0.362)	(0.691)	(0.411)	(0.217)	(0.010)	(0.747)
	P. MAT/05	0.253	0.114	0.400	– 0.044	0.512	– 0.431
	(N = 14)	(0.382)	(0.698)	(0.175)	(0.881)	(0.074)	(0.142)
Acad. position	Full Profs	**0.204***	0.064	0.126	0.134	0.172	– 0.081
	(N = 112)	(0.031)	(0.504)	(0.185)	(0.158)	(0.069)	(0.395)
	Associate Profs	0.132	0.084	0.044	– 0.111	– 0.150	– 0.110
	(N = 119)	(0.154)	(0.363)	(0.638)	(0.231)	(0.110)	(0.242)
	Assistant Profs	**0.463***	0.170	0.199	– 0.049	– 0.127	0.231
	(N = 20)	(0.040)	(0.474)	(0.430)	(0.836)	(0.614)	(0.356)
Gender	Male	**0.299***	0.119	0.120	0.089	0.032	– 0.042
	(N = 189)	(0.000)	(0.102)	(0.103)	(0.225)	(0.663)	(0.574)
	Female	0.083	0.174	0.043	– 0.075	0.080	– 0.103
	(N = 62)	(0.521)	(0.176)	(0.745)	(0.560)	(0.545)	(0.435)

Table 3 (continued)

In brackets are the corresponding p-values for the significance test of the correlation coefficient being zero (i.e., null hypothesis of absence of correlation) (Ross, 2021); cases in which $p < 0.05$—i.e., rejection of the null hypothesis with a 95% confidence level—are those marked with the symbol "*"

correlations.[4] Therefore, almost all correlations concerning disciplinary subsets are of little relevance (i.e., $N < 25$, cf. Table 3).

Results of multivariate analysis

The PCA was applied to the indicators of interest, which are essentially quantitative variables with a relatively high sample size (251 units). To facilitate the comparison, the indicators—which have different numerical ranges and variances—were previously standardised[5]: this operation was carried out automatically through the Minitab® statistical software. Figure 4 summarises the PCA results. It is worth noting that (i) any principal component is a linear combination of the source indicators and (ii) the principal components e mutually orthogonal (uncorrelated) variables by construction (Abdi & Williams, 2010; Bro & Smilde, 2014).

The summary table (a) and *scree plot* (b) show that the first two principal components—i.e., PC1 and PC2, both with eigenvalue > 1 (Bro & Smilde, 2014)—together explain a significant portion of the total variance, i.e., $0.345 + 0.265 = 0.610$. Regarding PC1, the predominant coefficients are those relating to P_j (0.669) and C_j (0.649), while regarding PC2, the predominant coefficients are those relating to w_j (0.653) and e_j (-0.752). This confirms the decoupling between research and teaching that emerged from the bivariate analysis: PC1, which is predominantly linked to research indicators, is uncorrelated to PC2, which is predominantly linked to teaching indicators. Additionally, the *loading plot* (c) and *biplot* (d) confirm the strong correlation between P_j and C_j and the weak/absent correlation between the other pairs of indicators.[6]

Answering to research questions

Returning to the two research questions (cf. Section "Introduction and literature review"), we provide punctual answers in the light of the analysis results.

(RQ#1) "*Is there any (direct/inverse) relationship between the research and teaching workload of individual academics?*". In contrast to the findings of other studies, the present one shows no negative link between research and teaching workload (Burke-Smalley et al.,

[4] Extremizing, for a subset of only two units, the correlation would by definition always be perfect (i.e., $R = +1$ or -1).

[5] Standardisation was performed through the so-called z-score: $z = \frac{x-\mu}{\sigma}$., being x the observed indicator, μ and σ the sample mean and sample standard deviation respectively (Ross, 2021).

[6] Precisely, the cosine of the angle between pairs of vectors indicates the correlation between the corresponding indicators. Highly correlated indicators (such as P_j and C_j) point in similar directions; uncorrelated indicators (such as w_j and e_j) are nearly perpendicular to each other. Furthermore, the cosine of the angle between a vector and an axis indicates the importance of the contribution of the corresponding indicator to the principal component (e.g., P_j and C_j contribute mainly to PC1, while w_j and e_j contribute mainly to PC2) (Abdi and Williams, 2010; Bro and Smilde, 2014).

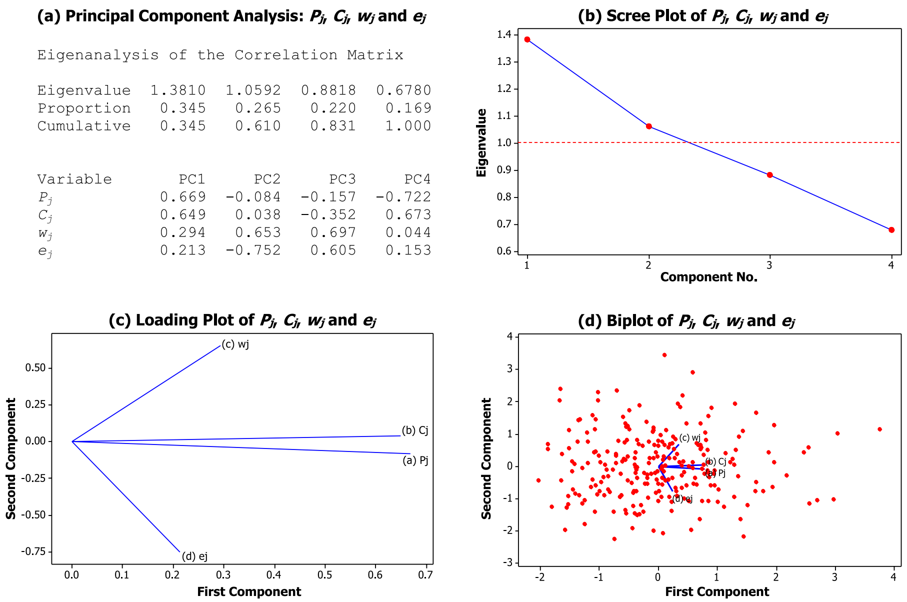


Fig. 4 Summary of the results of the PCA application to the P_j, C_j, w_j and e_j indicators, for the 251 PoliTO academics of interest. The analysis was conducted using Minitab® statistical software

2017). Therefore, at least in the limited context of PoliTO academics, the basic idea of the "scarcity model" (cf. Section "Introduction and literature review") would seem to be contradicted. On the other hand, a weak positive link seems to emerge, suggesting that academics who are more productive in terms of research (P_j) also tend to deliver more teaching (w_j). This may probably stem from the fact that the more active academics tend to be equally active in both research and teaching, by virtue of their better ability to organize their time, while the least active tend to be equally inactive in both contexts. Another reason might be that those academics who deliver more teaching not infrequently have collaborators and a larger pool of students that may also support research—e.g., through theses, dissertations, etc.

(RQ#2) "*Is there any (direct/inverse) relationship between the quality of research results and that of teaching results of individual academics?*". The lack of correlation seems to explain that those academics who produce research with the highest average impact/diffusion in the scientific community are not necessarily the most didactically effective. This result is in line with the findings of other studies, including those by Hattie and Marsh (1996) and Marsh and Hattie (2002), which—while relying on different methodological approaches and on a meta-analysis of dozens of other heterogeneous studies—conclude that research and teaching quality are nearly uncorrelated. These authors themselves provide a plausible explanation for this result, which can be summarized as follows: "*Those academics who devote more time to research have higher quality results,*[7] *but those who devote more time to teaching do not appear to be more effective teachers.*[8] *Therefore, assuming (but not conceding) that there may be a relationship (positive or negative) between the workload in teaching and the workload in research, this does not imply the existence of any relationship in terms of the quality of the respective results"*. Considering the subsets of academics, particularly discipline "O. Information processing systems", one can even observe a relatively weak negative correlation. It is not easy to find a plausible justification for such local behaviour; perhaps those who offer more effective and creative teaching tend, by contrast, to retreat into more routine research, and vice versa.

The above answers to research questions certainly have practical implications for funding agencies and university administrators. We believe that some earlier considerations by Marsh and Hattie (2002) fit this framework very well: "*Good researchers are neither more nor less likely to be effective teachers than are poor researchers. Good teachers are neither more nor less likely to be productive researchers than are good teachers. There are roughly equal numbers of academics who—relative to other academics—are: (a) good at both teaching and research, (b) poor at both teaching and research, (c) good at teaching but poor at research, and (d) poor at teaching but good at research. Thus, personnel selection and promotion decisions must be based on separate measures of teaching and research and on how academics provide evidence that their research and teaching are mutually supporting*".

Conclusions

Main findings and implications

This article focused on the (presumed) link between *research* and *teaching* in academia, considering each of them from the dual perspective of *workload* and *quality of results*. Partially contrasting with other state-of-art studies and the apparent academic myth that these two activities are complementary (Harland, 2016; Teichler, 2017), it revealed some decoupling between them. Firstly, there seems to be no negative link to support considerations like: "*Those who do more teaching tend to neglect research more*". Only a few weak negative correlations—which are, however, not statistically significant—are noted at the level of some disciplines (e.g., "O. Information processing systems" and "H. Manufacturing technology and systems", in Table 3). On the other hand, the quality of teaching results seems to be unrelated to both (i) research

[7] Consider the positive correlation between P_j and C_j (cf. second column of Table 3) which is also widely documented in the scientific literature (De Bellis, 2009).

[8] Consider the uncorrelation between w_j and e_j (cf. last column of Table 3) which is also documented in the scientific literature (Marsh and Hattie, 2002).

workload and (ii) quality of research results. This to some extent contradicts the findings of other studies, according to which "*Those who excel in research are more propense to excel in teaching*" (Cadez et al., 2017). The results of a *bivariate* analysis based on Pearson's correlation coefficient between pairs of indicators (with relevant significance test) were confirmed by a *multivariate* analysis based on PCA.

On the other hand, it is surprising to observe that the conclusion that teaching and research are nearly uncorrelated activities—although carried out in a different context, period and methodological approach—is fully in line with the results of other previous studies (Marsh & Hattie, 2002). The results of the study can be taken into consideration by university administrators and those involved in formulating incentive strategies for academics. Furthermore, the methodological framework adopted could be replicated in other universities to observe possible similarities/differences.

A relevant aspect of this research is the use of quantitative indicators built on a relatively large database. In fact, discipline-normalisations were implemented based on the bibliometric statistics of more than 3,000 other Italian academics, in order to ensure a fair comparison among PoliTO academics. Furthermore, the indicator e_j, which depicts the teaching effectiveness, is constructed taking into account several thousands of student-satisfaction ratings by B.Sc. and M.Sc. students.

Limitations

This research has several limitations, summarised as follows. The indicators in use—although bibliometrically rigorous—are still proxies for what they are meant to represent (i.e., *workload* and *quality of results* in research and teaching). Since the study is limited to academics from a single technical university (i.e., PoliTO), results do not necessarily apply to other technical or—*a fortiori*—generalist universities. Moreover, the assessment of the research and teaching workloads could have been more in-depth by having additional specific data (currently being collected), such as data on (i) ongoing research projects and (ii) students tutored for internships or dissertations. Lastly, the comparison between individual academics did not consider the organizational and managerial tasks that they carried out.

Future research

Regarding the future, several research activities will be undertaken to overcome at least part of the previous limitations. A *factorial plan* (Ross, 2021) will be constructed to assess more precisely the effects and interactions of certain contingent factors on the link between research and teaching, such as *discipline*, *gender*, *academic position*, *career stage*, *contractual obligations*, *incentives/bonuses* of academics. Then, the study will be extended to other technical and generalist universities, having found a way to uniformly assess and compare the teaching performance of academics.

Table 4 Example of questionnaire submitted to PoliTO students at the end of each (B.Sc. or M.Sc.) course (translation from Italian)

Aspect	Question	
Course period	q1	Is the overall teaching load acceptable?
	q2	Is the teaching schedule well organized?
Course organization	q3	Have the examination procedures been clearly defined and explained?
	q4	Was the teaching done consistently with what stated on the "Teaching Portal"?
	q5	Was my prior knowledge sufficient for understanding the subject matter?
	q6	Is the workload required by this course commensurate with the credits awarded?
	q7	Are the course materials (both recommended and provided) adequate for the study of the subject matter?
	q8	Are supplemental educational activities (tutorials, labs, seminars, visits, etc.) useful for learning the subject matter?
Teaching effectiveness	q9	Does the teacher (academic) adhere to teaching schedules?
	q10	Is the teacher (academic) available to provide clarification and explanation?
	q11	Does the teacher (academic) interact effectively with students, stimulating their interest in the subject matter?
	q12	Does the teacher (academic) clearly present the topics?
	q13	Do you believe that the teacher (academic) has effectively coordinated the teaching activities of his/her collaborators (if any)?
Infrastructure	q14	Are the classrooms appropriate?
	q15	Are the facilities and equipment for supplemental instructional activities appropriate?
Interest and satisfaction	q16	Am I interested in the topics of this course (regardless of how they were taught)?
	q17	Am I satisfied with how this course was taught (regardless of my personal interest in the topics)?
	q18	For the purpose of learning, is course attendance helpful?

Each of the eighteen questions (q1 to q18) is rated on a four-level ordinal scale, 1 = "Definitely not", 2 = "More no than yes", 3 = "More yes than no", 4 = "Definitely yes", expressing an increasing level of liking/satisfaction regarding a certain aspect of interest

Appendix

Example of teaching-evaluation questionnaire

Insight into normalisations

This section provides some evidence of the relevance of the normalisations introduced for the construction of bibliometric indicators (cf. Eqs. 1 and 2).

Normalisation by number of co-authors

Figure 5 exemplifies the distribution of the average number of co-authors for the papers examined in the discipline "G. Design methods for industrial engineering" (cf. Table 2).

A certain dispersion of the distribution is noticeable: the average number of co-authors for the papers of individual academics ranges from a minimum of 1.6 to a maximum of 10.7, which makes the proposed fractionalization reasonable (De Bellis, 2009; Henriksen, 2016). Similar considerations can be made for the other disciplines.

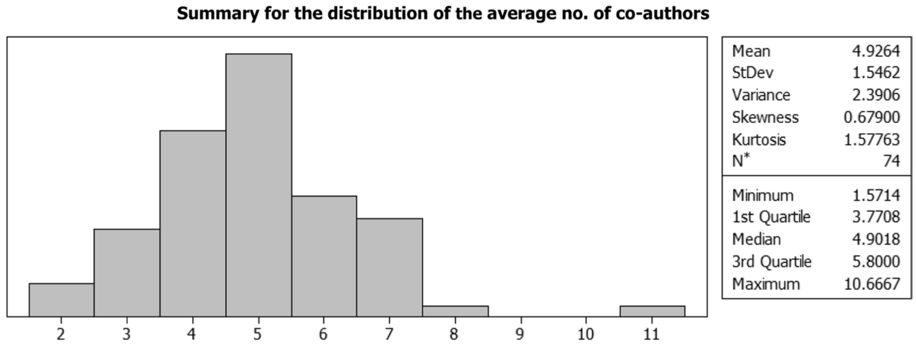


Fig. 5 Distribution of the average number of co-authors for papers published by academics within the discipline "G. Design methods for industrial engineering", during 2018–2020. One of the initial N = 75 academics was excluded from the analysis as he/she did not produce any research papers in this period (cf. Table 2). Analysis was carried out using Minitab® statistical software

Normalization by scientific discipline

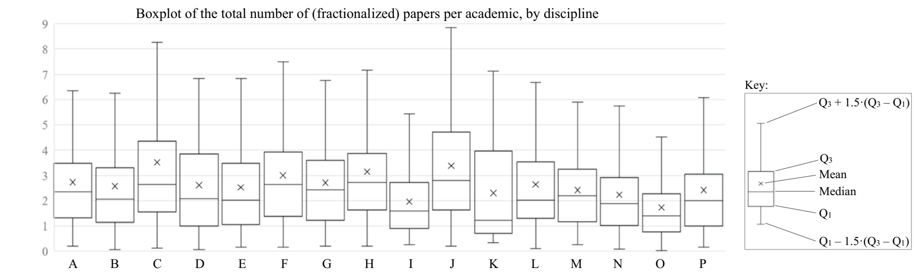
The boxplot in Fig. 6 confirms the existence of systematic differences in terms of propensity to publish between academics from different disciplines. For example, the box of "O. Information processing systems analysts" is significantly smaller than that of "J. Material scientists and technologists", denoting a systematically lower propensity to publish. This confirms the need to introduce the so-called *discipline normalisation*, implemented by P_j (cf. Eq. 1).

Similarly, the boxplots in Fig. 7 summarise the distributions of the average citations per paper for individual academic, referring to papers issued in 2018, 2019 and 2020 respectively, discipline by discipline.

These diagrams show systematic differences between the various disciplines in terms of propensity to obtain citations. Consider, for example, the largely non-overlapping boxplots of "J. Materials science and technology" and "P. Mathematical analysis", for papers issued in any year. This confirms the need for the normalisation by discipline, implemented by C_j (cf. Eq. 2).

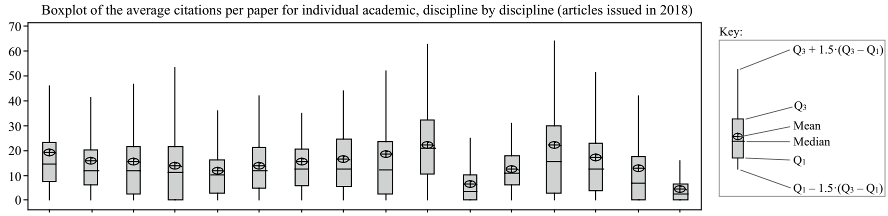
Age normalization

The box plot in Fig. 8 shows that age of a paper significantly influences the "maturation" of its citation impact (Glänzel & Moed, 2013): older papers tend to obtain more citations on average than more recent ones. This confirms the appropriateness of the normalisation by age, implemented by C_j (cf. Eq. 2).

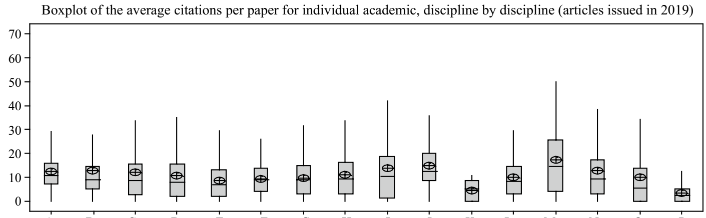


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Mean	2.73	2.57	3.52	2.62	2.52	3.00	2.71	3.14	1.96	3.38	2.30	2.64	2.42	2.23	1.72	2.41
St. dev.	2.00	2.14	3.55	2.10	2.01	2.52	2.00	2.19	1.39	2.53	2.13	2.13	1.60	1.89	1.40	2.06
Q_1	1.31	1.15	1.54	1.00	1.06	1.38	1.21	1.63	0.90	1.62	0.71	1.30	1.17	1.03	0.78	1.00
Median	2.34	2.05	2.64	2.07	2.01	2.65	2.42	2.71	1.58	2.80	1.21	2.01	2.20	1.88	1.38	2.00
Q_3	3.47	3.30	4.35	3.85	3.48	3.93	3.60	3.88	2.73	4.71	3.97	3.54	3.25	2.92	2.28	3.04
Min	0.20	0.07	0.13	0.07	0.17	0.17	0.20	0.20	0.25	0.20	0.33	0.10	0.25	0.09	0.03	0.17
Max	13.14	15.81	29.45	10.91	12.32	21.20	13.49	12.60	7.41	17.14	7.14	14.87	8.50	19.22	15.89	21.58
N	140	292	256	127	162	140	75	134	129	188	18	158	168	291	583	583
N^*	134	285	231	120	153	134	74	126	121	184	17	149	159	283	538	513

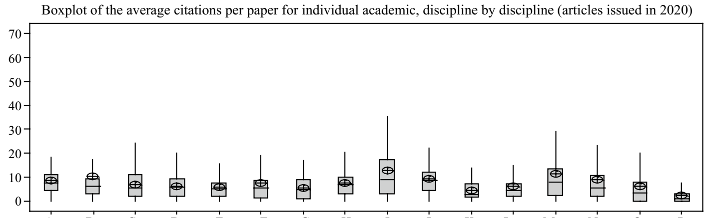
Fig. 6 Boxplot related to the total number of fractionalised papers (cf. Eq. 1) produced by the (Italian) academics examined, in the three-year period 2018 to 2020. Q_1 and Q_3 respectively denote the first and third quartiles of the distributions; N is the total number of academics examined while N^* is the number of academics with at least one article in the reference period



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Mean	19.2	15.7	15.4	13.7	12.0	13.7	15.6	16.5	18.6	22.3	6.6	12.4	22.2	17.3	13.0	4.5
St. dev.	20.8	17.2	17.0	13.3	11.6	10.9	17.0	18.3	23.3	15.3	8.0	9.6	29.6	20.6	21.2	7.3
Q_1	7.5	6.3	2.6	0.0	2.9	5.0	6.0	5.5	2.5	10.6	0.0	6.3	3.0	4.0	0.0	0.0
Median	14.6	12.0	12.0	11.3	10.3	12.0	12.4	12.6	12.3	20.7	3.4	11.0	15.6	12.6	7.0	2.5
Q_3	23.3	20.3	21.6	21.4	16.3	21.4	20.4	24.5	23.5	32.4	10.3	18.0	29.7	23.0	17.7	6.4
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	190.0	153.8	99.4	75.3	69.0	53.4	117.7	133.0	121.0	86.0	25.0	59.0	238.0	192.5	229.0	106.0
N	140	292	256	127	162	140	75	134	129	188	18	158	168	291	583	583

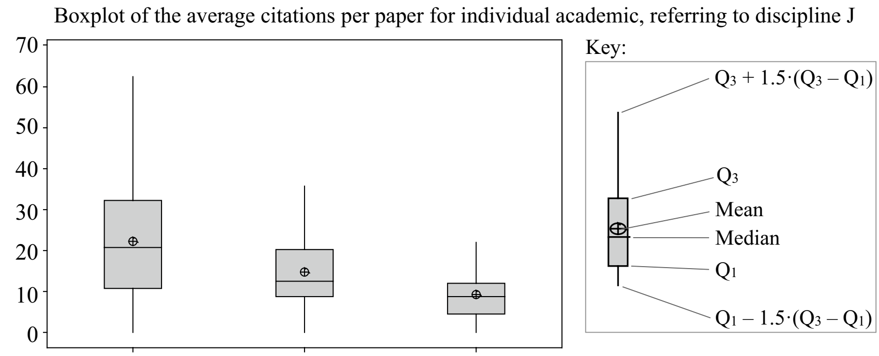


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Mean	12.4	12.8	12.1	10.6	8.7	9.5	9.7	11.0	13.8	14.7	4.6	10.0	17.5	12.9	9.9	3.6
St. dev.	9.4	17.3	14.4	10.6	8.6	7.4	8.1	9.5	15.6	10.3	4.3	8.8	20.1	14.3	13.1	4.5
Q_1	7.3	5.0	2.6	2.0	2.0	4.1	3.0	3.0	1.5	8.7	0.0	3.0	4.0	3.0	0.0	0.0
Median	10.7	8.8	8.7	8.0	7.0	9.0	9.0	9.2	10.5	12.4	5.3	8.3	14.6	9.3	5.5	2.5
Q_3	16.1	14.4	15.6	15.5	13.0	14.0	15.0	16.3	18.8	20.2	8.8	14.6	25.5	17.4	13.8	5.0
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	59.1	134.8	111.0	52.0	42.0	38.0	31.5	44.5	80.0	64.0	10.8	39.3	181.0	99.3	85.0	43.0
N	140	292	256	127	162	140	75	134	129	188	18	158	168	291	583	583



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Mean	8.7	10.5	7.0	6.2	5.8	7.5	5.4	7.6	12.7	9.3	4.3	6.4	11.6	9.1	6.2	2.2
St. dev.	8.2	21.1	6.5	4.9	5.0	23.8	5.1	7.4	14.6	7.6	3.8	8.4	15.0	16.7	9.0	3.3
Q_1	4.3	3.0	2.0	2.0	2.0	1.4	1.0	3.0	3.0	4.5	1.6	2.0	2.6	2.0	0.0	0.0
Median	7.5	6.1	5.4	6.0	5.0	5.5	4.8	6.8	9.0	8.8	2.6	4.3	7.9	5.5	3.5	1.0
Q_3	11.0	9.5	10.9	9.5	7.7	8.5	9.0	10.0	17.5	12.0	7.1	7.4	13.4	10.7	8.0	3.0
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	50.0	187.3	28.5	20.0	24.8	282.5	25.5	55.5	78.0	72.0	13.7	77.0	98.0	222.4	79.0	36.4
N	140	292	256	127	162	140	75	134	129	188	18	158	168	291	583	583

Fig. 7 Boxplots of the average number of citations per paper, for individual academic and discipline by discipline; diagrams refer to papers issued in 2018, 2019 and 2020 respectively. Q_1 and Q_3 denote the first and third quartiles of the relative distributions; N is the total number of academics examined for each discipline (3,444 in total)



	2018	2019	2020
Mean	22.3	14.7	9.3
St. dev.	15.3	10.3	7.6
Q_1	10.6	8.7	4.5
Median	20.7	12.4	8.8
Q_3	32.4	20.2	12.0
Min	0.0	0.0	0.0
Max	86.0	64.0	72.0
N	188	188	188

Fig. 8 Boxplots of the average number of citations per paper for individual academic, referring to discipline “J. Materials science and technology”, for papers issued in 2018, 2019 and 2020. A similar behaviour can be observed for the other disciplines

Resulting indicators

Table 5 contains the indicators (P_j, C_j, w_j and e_j) pertaining to each (j-th) academic, while Fig. 9 contains the histograms of the corresponding distributions and related statistics.

Table 5 Resulting indicators (cf. Section "Methodology") for the 251 PoliTO academics analysed

Discipl	Academic	Acad. position	Gend	(a) P_j	(b) C_j	(c) w_j	(d) e_j
A. CHIM/07	A.1	Associate	M	0.678	1.064	10,016	3.623
A. CHIM/07	A.2	Associate	F	0.663	0.690	11,244	3.068
A. CHIM/07	A.3	Associate	F	1.402	1.043	10,496	3.190
A. CHIM/07	A.4	Full	F	2.294	0.658	10,802	2.769
A. CHIM/07	A.5	Full	M	1.687	2.412	12,616	3.457
A. CHIM/07	A.6	Associate	F	1.720	1.552	17,928	3.161
A. CHIM/07	A.7	Full	M	0.487	1.717	14,860	3.274
A. CHIM/07	A.8	Full	M	1.698	4.179	19,664	3.580
A. CHIM/07	A.9	Associate	F	0.559	1.059	10,394	3.725
A. CHIM/07	A.10	Assistant	F	0.438	0.726	10,678	3.566
A. CHIM/07	A.11	Full	M	1.265	1.255	3768	3.080
B. FIS/03	B.1	Associate	F	0.402	0.551	8934	2.875
B. FIS/03	B.2	Associate	M	1.300	0.774	5152	3.611
B. FIS/03	B.3	Associate	M	0.576	0.960	13,800	3.454

Table 5 (continued)

Discipl	Academic	Acad. position	Gend	(*a*) P_j	(*b*) C_j	(*c*) w_j	(*d*) e_j
B. FIS/03	B.4	Associate	M	0.954	0.502	2908	3.814
B. FIS/03	B.5	Assistant	M	0.789	0.820	14,740	3.480
B. FIS/03	B.6	Full	M	0.678	1.207	12,500	3.416
B. FIS/03	B.7	Associate	F	0.584	0.133	13,740	2.930
B. FIS/03	B.8	Associate	M	0.181	0.382	9642	3.316
B. FIS/03	B.9	Full	M	4.304	1.163	8960	3.693
B. FIS/03	B.10	Full	M	0.637	0.494	12,590	3.460
B. FIS/03	B.11	Associate	M	1.921	1.018	6282	3.463
B. FIS/03	B.12	Full	M	1.311	0.313	3970	3.600
B. FIS/03	B.13	Assistant	M	0.902	0.772	2880	3.678
B. FIS/03	B.14	Associate	M	2.005	1.449	8470	3.000
B. FIS/03	B.15	Associate	M	2.141	0.792	12,438	3.372
C. ICAR/08	C.1	Assistant	F	0.490	2.285	1410	3.250
C. ICAR/08	C.2	Associate	M	0.183	0.105	5946	3.351
C. ICAR/08	C.3	Associate	M	0.230	0.083	11,328	3.284
C. ICAR/08	C.4	Full	M	3.960	1.143	6820	3.177
C. ICAR/08	C.5	Full	M	1.226	1.361	9164	3.444
C. ICAR/08	C.6	Associate	M	0.639	1.468	7672	3.232
C. ICAR/08	C.7	Associate	M	0.687	0.567	1014	3.190
C. ICAR/08	C.8	Full	M	0.948	0.946	6880	2.777
C. ICAR/08	C.9	Associate	M	0.213	0.598	6890	2.830
C. ICAR/08	C.10	Associate	M	2.693	1.323	4160	2.664
C. ICAR/08	C.11	Assistant	M	0.758	0.773	2238	3.082
C. ICAR/08	C.12	Associate	F	1.168	1.050	4668	3.492
C. ICAR/08	C.13	Full	M	0.260	0.316	2948	3.011
C. ICAR/08	C.14	Full	M	0.450	0.499	2514	3.350
D. ING-IND/10	D.1	Full	M	1.585	1.815	10,936	3.631
D. ING-IND/10	D.2	Full	M	0.382	1.211	22,032	2.861
D. ING-IND/10	D.3	Assistant	F	0.765	0.217	5944	3.399
D. ING-IND/10	D.4	Assistant	M	0.000	0.000	1074	3.213
D. ING-IND/10	D.5	Full	M	0.421	0.269	10,568	3.107
D. ING-IND/10	D.6	Full	M	0.860	2.006	9892	3.311
D. ING-IND/10	D.7	Associate	M	4.172	1.264	10,756	3.252
D. ING-IND/10	D.8	Full	M	0.172	0.108	1648	3.548
D. ING-IND/10	D.9	Full	M	3.624	2.045	15,868	3.326
D. ING-IND/10	D.10	Assistant	F	0.000	0.000	1360	3.523
D. ING-IND/10	D.11	Associate	M	0.127	0.217	4576	3.557
D. ING-IND/10	D.12	Full	M	3.677	1.907	5146	3.577
E. ING-IND/13	E.1	Assistant	F	0.674	0.795	2090	2.723
E. ING-IND/13	E.2	Associate	M	0.721	0.541	1020	3.253
E. ING-IND/13	E.3	Associate	F	0.397	0.671	5544	3.390
E. ING-IND/13	E.4	Full	M	0.866	3.032	8148	3.614
E. ING-IND/13	E.5	Full	M	0.846	0.691	11,714	3.627
E. ING-IND/13	E.6	Associate	M	0.656	0.722	6750	3.833

Table 5 (continued)

Discipl	Academic	Acad. position	Gend	(*a*) P_j	(*b*) C_j	(*c*) w_j	(*d*) e_j
E. ING-IND/13	E.7	Full	M	1.183	1.936	8280	3.193
E. ING-IND/13	E.8	Associate	F	1.393	0.926	1110	3.777
E. ING-IND/13	E.9	Assistant	M	0.000	0.000	0	
E. ING-IND/13	E.10	Assistant	M	0.555	0.729	0	
E. ING-IND/13	E.11	Associate	F	1.114	0.444	2552	3.437
E. ING-IND/13	E.12	Full	M	0.674	1.876	11,734	3.721
E. ING-IND/13	E.13	Associate	F	1.883	1.904	7320	2.774
E. ING-IND/13	E.14	Associate	M	0.638	0.900	4272	3.170
E. ING-IND/13	E.15	Associate	M	0.397	0.122	7772	3.101
E. ING-IND/13	E.16	Associate	M	1.389	1.346	5944	3.485
E. ING-IND/13	E.17	Full	M	0.797	0.792	7448	3.368
E. ING-IND/13	E.18	Full	M	1.805	0.461	12,330	3.507
E. ING-IND/13	E.19	Full	M	1.018	0.748	12,764	3.209
E. ING-IND/13	E.20	Associate	M	0.225	0.720	6180	3.270
E. ING-IND/13	E.21	Full	M	0.498	0.786	9978	3.508
E. ING-IND/13	E.22	Associate	M	0.839	0.941	5008	3.372
E. ING-IND/13	E.23	Associate	F	0.212	0.605	300	3.440
F. ING-IND/14	F.1	Full	M	1.287	1.087	6490	3.060
F. ING-IND/14	F.2	Full	M	2.949	1.160	15,336	3.079
F. ING-IND/14	F.3	Associate	F	1.511	0.469	7920	3.497
F. ING-IND/14	F.4	Associate	M	1.072	0.819	6726	2.874
F. ING-IND/14	F.5	Associate	M	1.523	1.309	2240	3.796
F. ING-IND/14	F.6	Full	M	1.356	0.517	13,244	3.272
F. ING-IND/14	F.7	Associate	F	0.389	0.121	2000	3.736
F. ING-IND/14	F.8	Associate	M	0.733	1.248	6940	3.119
F. ING-IND/14	F.9	Associate	F	0.672	0.638	7764	3.325
F. ING-IND/14	F.10	Associate	M	0.898	0.680	5056	3.530
F. ING-IND/14	F.11	Full	F	2.067	1.229	7816	3.213
F. ING-IND/14	F.12	Associate	M	0.900	0.690	5264	3.680
F. ING-IND/14	F.13	Full	M	0.437	0.841	8182	3.330
F. ING-IND/14	F.14	Associate	M	1.598	1.139	6176	3.375
F. ING-IND/14	F.15	Associate	M	0.067	0.106	3160	3.581
F. ING-IND/14	F.16	Full	M	0.222	0.275	7812	3.350
F. ING-IND/14	F.17	Full	M	0.464	1.574	3196	3.375
F. ING-IND/14	F.18	Associate	M	0.726	2.208	6392	3.293
F. ING-IND/14	F.19	Associate	F	0.884	0.709	3410	2.991
F. ING-IND/14	F.20	Full	M	1.778	0.630	7116	3.547
F. ING-IND/14	F.21	Full	M	1.159	1.034	12,254	3.257
F. ING-IND/14	F.22	Full	M	1.278	0.956	6132	3.676
G. ING-IND/15	G.1	Associate	M	0.489	0.876	5544	2.754
G. ING-IND/15	G.2	Full	M	0.286	1.014	6500	3.219
G. ING-IND/15	G.3	Full	M	1.586	1.928	13,413	3.320
G. ING-IND/15	G.4	Associate	F	0.686	0.865	8304	3.114
H. ING-IND/16	H.1	Full	F	0.583	1.122	13,280	3.573

Table 5 (continued)

Discipl	Academic	Acad. position	Gend	$(a)\ P_j$	$(b)\ C_j$	$(c)\ w_j$	$(d)\ e_j$
H. ING-IND/16	H.2	Associate	M	0.795	1.147	7960	2.763
H. ING-IND/16	H.3	Associate	F	1.100	1.590	12,102	3.550
H. ING-IND/16	H.4	Full	M	0.504	0.930	6304	3.500
H. ING-IND/16	H.5	Associate	M	0.520	1.013	9574	3.068
H. ING-IND/16	H.6	Assistant	F	0.000	0.000	5972	3.051
H. ING-IND/16	H.7	Full	M	3.213	1.012	5928	3.182
H. ING-IND/16	H.8	Full	M	1.400	1.085	9128	3.293
H. ING-IND/16	H.9	Full	M	0.965	3.850	6428	3.464
H. ING-IND/16	H.10	Full	M	0.127	0.971	10,290	2.704
H. ING-IND/16	H.11	Associate	M	2.025	0.521	9372	3.468
H. ING-IND/16	H.12	Associate	M	1.702	0.983	9632	3.459
H. ING-IND/16	H.13	Associate	M	1.087	1.842	2780	3.527
H. ING-IND/16	H.14	Associate	F	0.954	0.537	10,170	3.581
H. ING-IND/16	H.15	Associate	M	0.793	2.275	7196	3.362
H. ING-IND/16	H.16	Full	M	0.477	1.668	9198	3.201
I. ING-IND/17	I.1	Assistant	M	0.298	0.167	6600	3.347
I. ING-IND/17	I.2	Associate	M	0.724	1.019	8568	3.126
I. ING-IND/17	I.3	Assistant	F	0.256	0.281	7470	2.637
I. ING-IND/17	I.4	Full	M	0.298	0.167	5832	3.082
I. ING-IND/17	I.5	Associate	M	0.256	0.281	4514	3.731
J. ING-IND/22	J.1	Full	M	1.251	1.006	3080	3.203
J. ING-IND/22	J.2	Full	F	1.634	1.833	4234	3.587
J. ING-IND/22	J.3	Associate	F	0.133	0.224	0	
J. ING-IND/22	J.4	Full	F	1.587	0.963	14,556	3.736
J. ING-IND/22	J.5	Full	M	1.349	1.981	6208	3.562
J. ING-IND/22	J.6	Associate	M	1.751	1.231	3772	3.746
J. ING-IND/22	J.7	Full	F	1.340	1.979	16,010	3.393
J. ING-IND/22	J.8	Full	M	2.471	1.342	10,304	3.731
J. ING-IND/22	J.9	Full	F	0.570	1.259	5644	3.485
J. ING-IND/22	J.10	Assistant	F	0.244	0.183	4686	3.607
J. ING-IND/22	J.11	Full	F	0.972	1.268	7506	3.642
J. ING-IND/22	J.12	Associate	M	1.390	1.021	3946	3.246
J. ING-IND/22	J.13	Full	F	1.506	0.582	3654	3.492
J. ING-IND/22	J.14	Associate	M	2.856	1.219	2330	3.827
J. ING-IND/22	J.15	Associate	M	0.894	0.923	2178	3.633
J. ING-IND/22	J.16	Associate	F	1.164	1.521	13,716	3.380
J. ING-IND/22	J.17	Associate	M	1.665	1.591	3198	3.525
J. ING-IND/22	J.18	Full	F	1.789	1.633	12,868	3.425
J. ING-IND/22	J.19	Full	F	1.426	1.545	4648	3.203
K. ING-IND/28	K.1	Associate	F	0.609	0.654	2026	3.599
K. ING-IND/28	K.2	Associate	F	0.526	0.726	3036	3.440
K. ING-IND/28	K.3	Associate	M	0.341	1.912	1922	3.255
K. ING-IND/28	K.4	Full	M	2.552	1.369	3028	3.169
K. ING-IND/28	K.5	Full	M	2.216	1.953	1452	3.623

Table 5 (continued)

Discipl	Academic	Acad. position	Gend	(*a*) P_j	(*b*) C_j	(*c*) w_j	(*d*) e_j
L. ING-IND/31	L.1	Associate	M	0.379	0.467	6392	3.579
L. ING-IND/31	L.2	Full	M	1.250	1.671	2924	3.379
L. ING-IND/31	L.3	Full	M	0.707	0.327	8880	3.512
L. ING-IND/31	L.4	Full	M	0.768	0.957	8964	3.404
L. ING-IND/31	L.5	Associate	M	1.416	1.035	13,840	3.730
L. ING-IND/31	L.6	Associate	M	1.058	0.583	13,430	3.775
L. ING-IND/31	L.7	Full	M	0.126	0.323	1392	3.235
L. ING-IND/31	L.8	Full	M	0.505	0.267	4970	2.830
L. ING-IND/31	L.9	Full	M	0.941	1.238	5280	3.753
L. ING-IND/31	L.10	Associate	M	0.474	0.523	11,830	3.470
L. ING-IND/31	L.11	Full	M	0.000	0.000	5630	3.090
L. ING-IND/31	L.12	Full	M	0.865	0.830	12,694	2.934
L. ING-IND/31	L.13	Full	M	1.599	0.627	6590	3.630
L. ING-IND/31	L.14	Full	M	1.058	0.841	6574	3.604
M. ING-IND/35	M.1	Full	M	0.000	0.000	9378	3.440
M. ING-IND/35	M.2	Associate	F	1.426	1.613	14,704	3.062
M. ING-IND/35	M.3	Associate	M	1.653	0.595	7458	3.357
M. ING-IND/35	M.4	Full	M	1.481	1.055	8056	3.283
M. ING-IND/35	M.5	Full	M	1.315	1.077	9744	3.411
M. ING-IND/35	M.6	Full	M	0.792	0.516	13,536	3.563
M. ING-IND/35	M.7	Associate	F	1.860	1.199	9080	3.459
M. ING-IND/35	M.8	Full	M	0.379	0.896	16,544	3.398
N. ING-INF/03	N.1	Full	M	1.211	0.402	2052	3.558
N. ING-INF/03	N.2	Associate	M	0.112	0.337	3054	3.462
N. ING-INF/03	N.3	Associate	M	0.828	0.497	1920	3.258
N. ING-INF/03	N.4	Full	M	0.266	0.185	3056	3.413
N. ING-INF/03	N.5	Full	F	0.879	1.140	8720	3.425
N. ING-INF/03	N.6	Associate	M	0.711	0.925	1716	3.404
N. ING-INF/03	N.7	Full	M	0.985	1.106	920	3.760
N. ING-INF/03	N.8	Full	F	3.467	0.960	3546	3.503
N. ING-INF/03	N.9	Associate	M	1.459	2.168	2526	3.332
N. ING-INF/03	N.10	Associate	M	2.292	1.189	3278	3.493
N. ING-INF/03	N.11	Associate	M	0.224	0.759	9498	3.340
N. ING-INF/03	N.12	Associate	M	0.875	0.276	1278	3.857
N. ING-INF/03	N.13	Associate	M	0.000	0.000	1896	3.808
N. ING-INF/03	N.14	Full	M	0.843	0.675	2388	3.628
N. ING-INF/03	N.15	Associate	M	0.950	0.744	0	
N. ING-INF/03	N.16	Full	M	1.682	0.269	2796	3.246
N. ING-INF/03	N.17	Full	M	2.496	1.646	2898	3.427
N. ING-INF/03	N.18	Full	M	1.718	1.977	3024	3.579
N. ING-INF/03	N.19	Full	F	0.987	0.718	2460	3.627
N. ING-INF/03	N.20	Associate	F	0.192	9.042	0	
N. ING-INF/03	N.21	Full	M	0.262	0.039	6846	3.279
N. ING-INF/03	N.22	Assistant	M	0.090	1.064	3864	2.690

Table 5 (continued)

Discipl	Academic	Acad. position	Gend	(a) P_j	(b) C_j	(c) w_j	(d) e_j
N. ING-INF/03	N.23	Associate	F	0.300	0.627	11,808	3.305
N. ING-INF/03	N.24	Full	M	0.202	0.559	5210	3.543
N. ING-INF/03	N.25	Full	M	1.009	0.504	2666	3.144
N. ING-INF/03	N.26	Associate	F	0.224	0.110	2682	3.465
O. ING-INF/05	O.1	Associate	M	0.406	0.231	9564	3.350
O. ING-INF/05	O.2	Full	F	1.829	0.782	12,176	3.638
O. ING-INF/05	O.3	Associate	M	0.932	1.352	10,136	3.307
O. ING-INF/05	O.4	Associate	M	0.504	0.199	10,500	3.550
O. ING-INF/05	O.5	Associate	M	0.276	0.889	12,714	3.188
O. ING-INF/05	O.6	Associate	M	0.841	1.844	12,728	2.850
O. ING-INF/05	O.7	Associate	M	0.528	0.317	33,032	3.582
O. ING-INF/05	O.8	Associate	M	1.692	0.306	10,782	3.476
O. ING-INF/05	O.9	Full	M	0.528	0.317	19,806	3.476
O. ING-INF/05	O.10	Associate	F	1.395	0.757	5496	3.328
O. ING-INF/05	O.11	Associate	F	0.707	0.738	8672	3.408
O. ING-INF/05	O.12	Full	M	2.369	0.660	14,902	3.526
O. ING-INF/05	O.13	Full	M	0.822	0.701	6116	3.566
O. ING-INF/05	O.14	Full	M	0.914	4.055	6904	2.930
O. ING-INF/05	O.15	Associate	M	1.377	1.333	8156	3.586
O. ING-INF/05	O.16	Assistant	F	0.193	0.370	9300	3.307
O. ING-INF/05	O.17	Associate	F	0.739	0.794	10,472	3.267
O. ING-INF/05	O.18	Associate	M	1.460	0.316	7328	3.226
O. ING-INF/05	O.19	Associate	M	1.238	0.910	8342	3.722
O. ING-INF/05	O.20	Full	M	3.386	1.867	12,460	3.327
O. ING-INF/05	O.21	Full	M	1.784	0.820	13,560	3.386
O. ING-INF/05	O.22	Full	M	0.269	1.079	7488	3.317
O. ING-INF/05	O.23	Full	M	3.090	0.882	7520	3.233
O. ING-INF/05	O.24	Assistant	M	0.615	0.752	6848	3.610
O. ING-INF/05	O.25	Associate	M	1.113	0.630	12,382	3.521
O. ING-INF/05	O.26	Associate	M	0.938	1.240	5124	3.443
O. ING-INF/05	O.27	Associate	M	1.301	0.658	11,436	3.256
O. ING-INF/05	O.28	Full	M	2.226	1.374	10,468	3.387
O. ING-INF/05	O.29	Full	M	1.441	1.204	12,470	2.930
O. ING-INF/05	O.30	Full	M	2.653	0.601	8404	3.549
O. ING-INF/05	O.31	Full	M	0.648	0.382	15,458	2.908
O. ING-INF/05	O.32	Associate	M	1.146	0.527	16,296	3.372
O. ING-INF/05	O.33	Full	M	1.634	0.831	15,084	3.466
O. ING-INF/05	O.34	Associate	M	1.978	0.488	7666	3.683
O. ING-INF/05	O.35	Associate	M	0.821	0.588	13,886	3.401
O. ING-INF/05	O.36	Associate	M	1.470	0.852	14,320	3.706
O. ING-INF/05	O.37	Assistant	M	0.483	0.411	3574	3.486
O. ING-INF/05	O.38	Full	M	1.325	0.383	7194	3.050
O. ING-INF/05	O.39	Full	M	1.456	0.709	8550	3.720
O. ING-INF/05	O.40	Associate	M	1.421	0.589	13,624	3.385

Table 5 (continued)

Discipl	Academic	Acad. position	Gend	(a) P_j	(b) C_j	(c) w_j	(d) e_j
O. ING-INF/05	O.41	Associate	M	1.462	0.611	12,562	3.335
O. ING-INF/05	O.42	Associate	M	1.407	0.837	16,104	3.509
O. ING-INF/05	O.43	Associate	M	1.064	0.663	11,780	3.449
P. MAT/05	P.1	Associate	F	0.725	1.037	10,268	3.668
P. MAT/05	P.2	Associate	M	0.000	0.000	0	
P. MAT/05	P.3	Associate	F	0.414	1.356	11,570	3.477
P. MAT/05	P.4	Full	F	1.105	0.631	11,570	3.557
P. MAT/05	P.5	Full	M	0.690	0.871	6960	3.420
P. MAT/05	P.6	Assistant	M	0.207	0.300	7932	3.718
P. MAT/05	P.7	Associate	F	0.000	0.000	13,244	2.797
P. MAT/05	P.8	Full	M	2.900	1.365	10,546	3.675
P. MAT/05	P.9	Associate	M	1.243	0.700	9908	3.519
P. MAT/05	P.10	Full	M	0.656	4.755	7536	3.811
P. MAT/05	P.11	Full	F	0.863	0.915	8140	3.737
P. MAT/05	P.12	Full	M	1.450	2.536	8878	3.715
P. MAT/05	P.13	Associate	F	1.001	1.333	11,360	3.683
P. MAT/05	P.14	Associate	F	0.345	0.744	17,720	3.500

The academic position conventionally refers to the year 2020

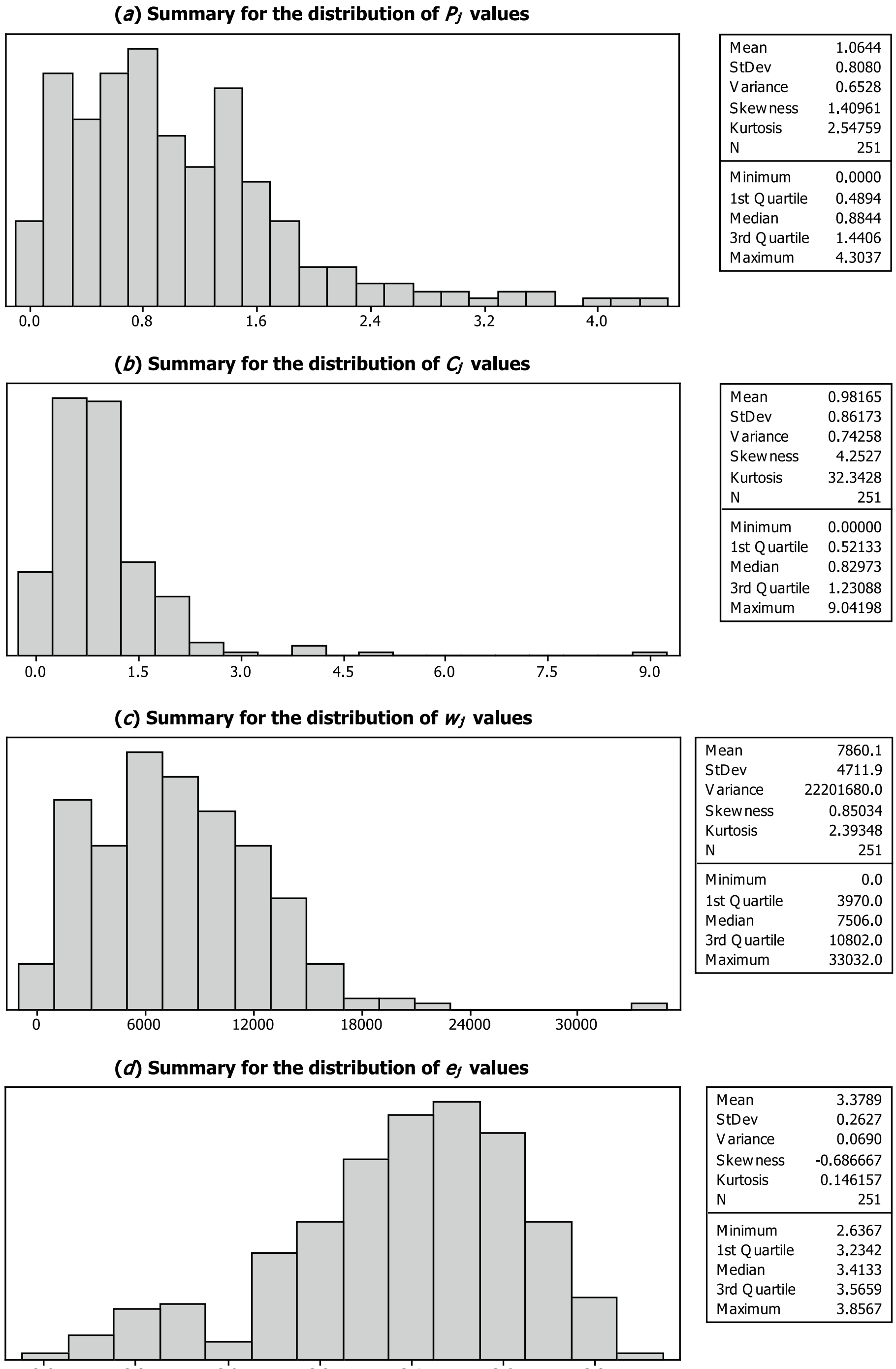


Fig. 9 Histograms and descriptive statistics related to the distributions of the indicators (P_j, C_j, w_j and e_j), for the 251 PoliTO academics of interest. Analysis was carried out using Minitab® statistical software

Acknowledgements This research was partially funded by the European Commission, through the Erasmus+ Project "REMOTE: Assessing and evaluating remote learning practices in STEM" (code 2022-1-ES01-KA220-HED-000085829), within the "KA220-HED Cooperation partnerships in higher education" programme.

Funding Open access funding provided by Politecnico di Torino within the CRUI-CARE Agreement.

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