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Structured abstract

Purpose: Since 1950s a plurality of studies focused on the relationship between *research* and *teaching* in HEIs, with conflicting conclusions. While some studies see these activities as synergically linked, others theorize their decoupling or even negative tension. This divergence is probably because most of the investigations are based on heterogeneous, limited and difficult-to-generalise data. This paper deepens the study of the research-teaching relationship, from the dual perspective of the *workload* and *quality of results* achieved by individual academics.

Study design: This study relies on various empirical data – e.g., bibliometric indicators, teaching-satisfaction indices, number of courses thought, number of students, etc. – for hundreds of academics from Politecnico di Torino (PoliTO), i.e., one of the largest technical universities in Italy. After constructing several indicators concerning research and teaching, their (potential) correlation will be analysed.

Findings: This study seems to exclude both (i) the existence of a negative relationship between research and teaching in terms of workload, contradicting the hypothesis that "*Those who do more teaching have less time for research and vice versa*", and (ii) the existence of a positive relationship in terms of quality of results obtained, contradicting the hypothesis that "*Those who obtain high quality results in research are likely to do the same in teaching and vice versa*".

Originality/value: The paper analyses a relatively large sample of academics – i.e., 251 from PoliTO and more than 3000 from other Italian universities – and adopts several *quantitative* bibliometric indicators, some of which are discipline-normalised.

Limitations: The study is limited to academics from PoliTO. Assessment of research and teaching *workloads* could have been more in-depth with additional data, such as information on ongoing research projects, students tutored for internships, theses, dissertations, etc.

Keywords: Research, teaching, HEI, workload, quality, normalization.

1. Introduction

Research and *teaching* are the two predominant knowledge-dissemination activities in the working day of academics (Burke-Smalley et al., 2017). Most HEIs have long designated research and teaching among their crucial missions, with a close relationship and mutual stimulation (Harland, 2016). On the other hand, these activities sometimes appear disjointed or even reciprocally interfering (Moya et al., 2015). For instance, the policies of many HEIs promote research at the expense of teaching, being career advancements (and salaries) exclusively linked to research results (Cadez et al., 2017; Franceschini and Maisano, 2017). Consequently, academics tend to focus more on research, "economising" on teaching and, more generally, those related activities (e.g., student tutoring/mentoring) that may "steal time" from research (Cadez et al., 2017).

The scientific literature has investigated the research-teaching relationship in HEIs for more than half a century. Some studies considered the synergistic relationship between teaching and research as a prerequisite for establishing a "lean" HEI (Shortlidge and Eddy, 2018). Other studies regard these activities as disconnected and even conflicting (Burke-Smalley et al., 2017). Cadez et al. (2017) documented a positive correlation for 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*. This diversity of opinions and (apparent) contradictions are probably related to the inherent limitations of the studies they stem from, such as: (i) the samples of academics analysed are often as small as a few dozen subjects, which makes comparisons and generalizations difficult (Lawson et al., 2015), and (ii) evaluations are mostly *qualitative* and based on the results of subjective indicators (Brennan et al., 2019).

This paper aims to fill (at least in part) the aforementioned research gap by analysing research and teaching from the dual perspective of *workload* and *quality of results* achieved by individual academics. Furthermore, the analysis is conducted through *quantitative* indicators, built using a sample of hundred academics affiliated with *Politecnico di Torino* (abbreviated as "PoliTO"), i.e., one of the largest Italian technical universities with around 35,000 students. The research-teaching relationship will be studied by answering the following research questions:

(**RQ#1**) "*Is there any relationship between the research and teaching workload of individual academics?*";

(**RQ#2**) "*Is there any relationship between the quality of research results and that of teaching results of individual academics?*".

The remainder of this paper is organised into three sections. Section 2 describes the research methodology, focusing mainly on the construction of indicators. Section 3 presents and discusses the analysis results, answering the previous research questions. Section 4 contains concluding remarks.

2. Methodology

2.1 Selection of the sample of academics

In Italy, every academic belongs to a specific "Scientific and Disciplinary Sector" (SDS or "discipline") of 383 in all (https://www.miur.gov.it/settori-concorsuali-e-settori-scientifico-disciplinari). Although the academics from *technical* HEIs, like PoliTO, are scientifically more homogeneous than those from *generalist* HEIs, they may belong to disciplines with significant differences in terms of propensity to publish and cite (Maisano et al., 2020).

PoliTO comprises a population of around 900 tenured academics. Table 1 describes the sample of selected academics, who belong to sixteen disciplines of engineering and basic sciences (i.e., A, B, C, …). The selection was limited to academics with a well-established career, both in terms of research and teaching, so as to avoid "outliers" like young academics with little teaching experience; operationally, only active academics with a permanent contract with any Italian HEI in the eight-year period 2013 to 2020 were considered. This protects against possible changes in the staff number due to retirements, hires, transfers, etc. The second last column of Table 1 reports the number (N) of selected PoliTO academics, for each of the disciplines of interest. The resulting sample of 251 academics covers more than ¼ of the whole PoliTO academic population.

Table 1. Sample of academics selected for the analysis (breakdown by SDS).

Discipline	SDS	Staff number (N)	
		PoliTO	All 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**

2.2 Academic research indicators

Research data basically concern scientific publications and citations by a sample of PoliTO academics. In order to allow comparisons between academics from different disciplines (Franceschini and Maisano, 2014), the sample was extended to academics affiliated to all Italian HEIs, implementing a *discipline normalization*. Consistently with the data regarding PoliTO academics, only academics with a permanent contract in the period from 2013 to 2020 were considered. The last column of Table 1 shows the resulting number of academics selected from all Italian HEIs, which will be referred to as "All". For each single academic, the corresponding Scopus Author ID was determined to uniquely identify the publications produced in the three-year period from 2018 to 2020. 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 were excluded as they are still too "immature" in terms of citation impact. In addition, only papers in international scientific journals were considered (De Bellis, 2009). These data were used to construct two *ad hoc* bibliometric indicators for each PoliTO academic (Eqs. 1 and 2).

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

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

j being the academic of interest from PoliTO;

$All \equiv \{\dots, j, \dots\}$ being the set of academics from all Italian HEIs, 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 1);

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.

The fractionalization by number of co-authors penalizes academics that systematically produce papers with several co-authors (Franceschini et al., 2010). Given that the propensity to publish papers may depend on the discipline, P_j also implements a discipline normalisation (cf. last term of Eq. 1) (Maisano et al., 2020). P_j will be used as a proxy for the *research workload* by a certain academic.

(b) Discipline-normalised average no. of citations per paper:

$$C_j = \frac{\sum_{\forall y}\left\{\frac{\text{Avg. no. of cites per paper issued in the year } y\text{, for the academic } j \text{ (from PoliTO)}}{\text{Avg. no. of cites per paper issued in the year } y\text{, for all Italian academics in the same discipline of } j}\right\}}{\text{no. of issue years}} = \frac{\sum_{\forall y}\left\{\frac{\frac{\sum_{\forall i \text{ by } j,y}\left(c_{i,j,y}\right)}{|i \text{ by } j,y|}}{\left(\frac{\sum_{\forall k}\left[\frac{\sum_{\forall i \text{ by } k,y}\left(c_{i,k,y}\right)}{|i \text{ by } k,y|}\right]}{N}\right)}\right\}}{3}, \quad (2)$$

$c_{i,*,y}$ being the total number of citations obtained up to the moment of data collection (i.e., August 2022) by the i-th paper of the j-th/k-th (*) 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.

C_j embeds two normalizations: by discipline and by age, since they can both affect the propensity to obtain citations (Maisano et al., 2020). Precisely, the (annual) citations per paper of each PoliTO academic (j) are divided by the average value of the same quantity, with reference to the totality of academics from all HEIs, in the same discipline of j (cf. last term of Eq. 2). Then, the discipline-normalized statistics related to the three issue years are combined through arithmetic mean. Fractionalization by number of co-authors (implemented by P_j) is not needed here, since C_j is not "size dependent" (Maisano et al, 2020). C_j will be used as a proxy of the *quality* of *research* results (De Bellis, 2009).

2.3 Academic teaching indicators

For over twenty-five years, questionnaires have been regularly administered to students at the end of each PoliTO's (B.Sc./M.Sc.) course, to assess teaching quality. Table 2 reports the questionnaire template used in the academic years 2017-18, 2018-19 and 2019-20. 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 (Franceschini et al., 2019; 2022). For each question, the mean value of respondents' ratings is determined.

Table 2. Questionnaire submitted to PoliTO students at the end of each course.

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?

The five (q-th) questions from q9 to q13 specifically concern "teaching effectiveness"; the mean values of the related respondent ratings are aggregated through a further arithmetic mean (Eq. 3):

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

c being every single annual course taught by j, in the academic years 2017-18, 2018-19 and 2019-20. This reference period is consistent with that used in research analysis (i.e., 2018 to 2020);

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 were collected from the website of Politecnico di Torino, together with data about number of students attending the c-th course, and number of ECTS (European Credit Transfer System) credits associated with the c-th course. In the Italian university system, each credit point corresponds approximately to 25 hours of learning enjoyed by students. Two aggregated indicators will describe the teaching activity of academics. The first one is a proxy of teaching workload, which depends on two factors:

- *Amount of teaching delivered to students*, which can be expressed in terms of ECTS credits associated with the relevant courses. In the Italian university system, each academic is usually required to provide at least 12 credits per year.
- *Number of students attending every course*. 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 graduates for applications to doctoral, postgraduate master's programmes, etc. In addition, some courses include laboratory exercises in small groups (e.g., 10-20 units) that must be replicated several times, increasing the workload of academics significantly.

These two factors are aggregated into the following indicator (Eq. 4):

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

c being each course taught by j during the three-year reference period;

s_{c_j} being the number of students in the specific c-th course;

$ECTS_{c_j}$ being the number of ECTS credits associated with each c-th course.

w_j can be interpreted as the total number of credits obtained by students attending the course(s) held by j, i.e., a proxy for the quantitative impact of these course(s) on the student population. This indicator can be used as a proxy for the *teaching workload* of individual faculty members. The aggregation through a multiplicative model is typical of indicators that aggregate heterogeneous quantities (Franceschini et al, 2019).

The second indicator, depicting the average teaching effectiveness, is defined as (Eq. 5):

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

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

The indicators relating to teaching, unlike those relating to research, do not require any discipline normalisation involving academics from other Italian universities, as they use quantities that can be compared between academics from different disciplines.

3. Results

3.1 Indicators and correlation analysis

For the 251 PoliTO academics, the indicators relating to research and teaching were determined. Table 3 collects related descriptive statistics.

Table 3. Descriptive statistics related to the series of indicators. Q_1 and Q_3 denote the first and third quartile of the distributions respectively.

Indicator	Proxy for	Mean	Median	St. Dev.	Q_1	Q_3	Min	Max
$\boldsymbol{P_j}$	Research workload	1.064	0.884	0.808	0.489	1.441	0.000	4.304
$\boldsymbol{C_j}$	Research quality	0.982	0.830	0.862	0.521	12.309	0.000	9.042
$\boldsymbol{w_j}$	Teaching workload	7860	7506	4712	3970	10802	0.000	33032
$\boldsymbol{e_j}$	Teaching quality	3.379	3.413	0.263	3.234	3.566	2.637	3.857

The correlation among indicator series can be evaluated through the Pearson's correlation coefficient (R), which is included between -1 (perfect negative correlation) and +1 (perfect positive correlation). R values close to zero denote no linear correlation (Ross, 2021). The choice of R is driven by (i) its simplicity (Franceschini et al., 2019) and (ii) the likely absence of forms of non-linear relationships between the pairs of indicator series, as observed in a preliminary graphic investigation. Table 4 contains the R values for any pair of indicator series, 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".

Table 4. Pearson correlation coefficients (R) for each pair of indicator series; in brackets are p-values for the significance test of R being zero. Cases of rejection of the null hypothesis ($p < 0.05$) are marked with "*".

	(Sub-)set of academics	P_j vs. C_j	P_j vs. w_j (cf. RQ#1)	P_j vs. e_j	C_j vs. w_j	C_j vs. e_j (cf. RQ#2)	w_j vs. e_j
	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.	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.	**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.	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.	**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.	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.	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.	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.	-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.	**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.	**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.	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.	**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.	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.	-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.	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.	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)

Statistically significant correlations (i.e., p-value < 0.05) are very few. Considering the totality of academics ("Total"), there is a weak positive correlation (R ≈ +0.224) between P_j and C_j, 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 ≈ +0.129) between P_j and w_j. Interestingly, these correlations may disappear and new ones may emerge when considering disciplinary subsets of academics. For example, the correlation between P_j and w_j is significant only for disciplines "F" and "G". Moreover, some correlations are only present at the level of specific discipline and not at aggregate level, such as that between C_j and w_j for disciplines "A" and "D". It is worth recalling that R tends to lose its effectiveness for subsets with less than 25-30 units (Ross, 2021), with the risk of revealing false correlations. Therefore, almost all correlations concerning disciplinary subsets can be considered of little relevance (cf. Table 4).

3.2 Answering to research questions

Partially contrasting with other state-of-art studies (Harland, 2016), the present one reveals a certain decoupling between research and teaching in HEIs. Returning to research questions, we provide preliminary answers in the light of the analysis results.

(RQ#1) "*Is there any relationship between the research and teaching workload of individual academics?*" While the hypothesis of a negative relationship (i.e., "*Those who do more teaching tend to neglect research more*") seems to be rejected (Burke-Smalley et al., 2017), a weak positive relationship emerges: academics who are more productive in terms of research (P_j) also tend to deliver more teaching (w_j). This probably depends on the fact that academics who teach more not infrequently have a larger pool of collaborators and students that may also support research.

(RQ#2) "*Is there any relationship between the quality of research results and that of teaching results of individual academics?*" The quality of teaching results seems to be unrelated to both (i) quantity and (ii) quality of research products, to some extent contradicting the idea that those who excel in research are more propense to excel in teaching (Cadez et al., 2017). Considering the subsets of academics, one can even observe relatively weak negative correlations (see particularly discipline

“O”). It is not easy to find a plausible justification for such behaviour; perhaps those who offer more effective and creative teaching tend, by contrast, to retreat into more routine research, and *vice versa*.

4. Concluding remarks

The results of this study could be used to assess the appropriateness of possible research/teaching incentive strategies within HEIs. Furthermore, the proposed methodological framework could be replicated by other HEIs to consolidate the results. A relevant aspect of this study, which fills at least part of the current research gap, is the use of quantitative indicators relying on a large database. For instance, discipline-normalisations were implemented based on the bibliometric statistics of more than 3000 other Italian academics. Furthermore, e_j, which depicts the teaching effectiveness, is constructed considering thousands of ratings by PoliTO students.

This study has limitations, including the following three: (i) although bibliometrically rigorous, the indicators in use are still proxies for what they are meant to represent; (ii) since the study is limited to academics from a single technical HEI (PoliTO), results do not necessarily apply to other HEIs; (iii) the assessment of the research and teaching workloads could have been more in-depth with additional specific data, such as data about ongoing research projects, students tutored for internships, theses or dissertations, etc.

Several research activities will be undertaken to overcome at least part of the previous limitations, like constructing a *factorial plan* (Ross, 2021) to evaluate more precisely the effects and interactions of *discipline*, *gender* and *position* of academics on the research-teaching relationship, and extending the study to other (technical/generalist) HEIs.

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