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The economics of research, consulting, and teaching quality: theory and evidence from a technical university — Source link

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The economics of research, consulting, and teaching quality: Theory and evidence from a technical university

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L'économie de la recherche, de conseil et de la qualité de l'enseignement: Théorie et évidence lors d'une université technique

Résumé

On étude l'effet des activités de recherche ainsi que de conseil sur la qualité de l'enseignement universitaire au niveau individuel. Nous proposons un modèle théorique dans lequel les universitaires consacrent du temps limité entre les trois activités, sur un horizon de deux périodes, dans l'hypothèse de retombées positives de la recherche sur la demande individuelle de conseil et sur la qualité de l'enseignement, en tenant compte des effets du cycle de vie sur les incitations. Les propositions du modèle sont testées en utilisant les données d'évaluation des enseignants d'une école italienne d'ingénierie de taille moyenne. Nous constatons que l'expérience de recherche améliore la qualité de l'enseignement, mais seulement si elle ne se traduit pas par la croissance des occasions de conseil. Dans ce cas, l'expérience de recherche a un effet dissuasif trop forte à investir du temps dans l'enseignement, et en détériore la qualité.

Mots-clés : enseignement supérieur ; conseil ; recherche ; économie de la science

The economics of research, consulting, and teaching quality: Theory and evidence from a technical university

Abstract

We investigate the effect of both research and consulting on higher education teaching quality at the individual level. We propose a theoretical model in which academics allocate limited time between three activities, over a two period horizon, under the assumption of positive spillovers from research to both consulting opportunities and teaching, and of life cycle effects on incentives. Propositions from the model are tested against teaching evaluation data from a mid-sized Italian engineering faculty. We find that research experience improves teaching quality, but only if it does not translate into large consulting opportunities. In that case, research experience provides too strong a disincentive to invest time in teaching, and quality deteriorates.

Keywords: higher education; teaching; academic consulting; research; economics of science

JEL: I21, I23, L84, O30

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1. Introduction *

Trade-offs and complementarities between contemporary universities' three missions (education, research, and, for want of a more comprehensive term, knowledge transfer to industry) have long been the object of enquiry of both social scientists and practitioners. Feedback and conflicts can arise both at the organizational level (as a result of universities' strategic choices concerning the regulation and allocation of funds among the three activities) and at the individual level, due to academics' responses to immediate economic incentives and long-term career strategies (Etzkowitz, 2004; Bonaccorsi and Daraio, 2007; Sanchez-Barrioluengo, forthcoming). The organizational and individual levels are interconnected, to the extent that the way universities regulate their faculties' time allocation and duties affect both the economic incentives and the career perspectives of individuals. Yet, we have only a partial understanding of the efficiency of universities' regulations. This is due to the lack of evidence on the signs and the intensity of spillovers from research and technology transfer to education, and between one another, as well as to the paucity of theoretical models of individual academics' decisional processes (witness the limited references on the topic one can find in Stephan's [1996, 2010] classic surveys).

In this paper, we address these gaps in the literature by focusing on selected activities through which individual academics pursue the three missions. In particular, we concentrate on the quality dimension of teaching (as measured by students' evaluations) and on how it is affected by both publishing (an output measure of research efforts) and consulting (a traditional, though under-studied, form of knowledge transfer to industry).

We propose a dynamic model in which individual academics allocate their effort to the three activities over a two period time horizon, under several assumptions on the trade-offs and complementarities between the activities, as well as on the mediating effects of academic seniority and disciplinary affiliation. We derive a number of testable propositions on how research experience and consulting opportunities affect teaching quality. First, we posit a non-linear effect of research experience on teaching quality: (i) negative in disciplines with limited consulting opportunities as well as in disciplines with large opportunities, but only for academics with a strong scientific reputation; and (ii) positive in disciplines with consulting opportunities both of great number and independent of scientific reputation. Second, we suggest that consulting opportunities may generate a positive effect on teaching quality, conditional on scientific reputation being necessary to exploit them; in all other cases, the effect is negative. Finally, we posit a negative effect of seniority on teaching quality for all disciplines where consulting opportunities are both significant and unrelated to scientific reputation.

We test our propositions against a 3-year panel of SETE (Students' Evaluation of Teaching Effectiveness) data at the course and instructor level, which we obtained from an Italian mid-sized engineering faculty and

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first exploited in Bianchini, Lissoni, and Pezzoni (2013). Under a set of assumptions on the consulting opportunities that the local economy offers to academics from the various disciplines represented in the faculty, we find that teaching quality is, on average, inversely related to consulting opportunities, and that this holds especially for senior scientists. At the same time, we find that the effect of research experience, as measured by the stock of publications, is positive and significant only for those disciplines where consulting opportunities are of great number and the propensity to publish is low (which we interpret as indicative of a decoupling between scientific reputation and consulting opportunities).

The paper is structured as follows. After a brief review of the literature (Section 2), we set out our theoretical model (Section 3). Data and empirical methodology are described in Section 4, which also includes background information on the technical university under observation. Section 5 reports our results and discussion. Section 6 concludes.

2. Background literature

In recent years, the evaluation of universities and their staff's activities has become a dominant theme in the discussion on the European higher education system (Geuna and Martin, 2003; Daraio et al., 2011; Rebora and Turri, 2013). Much of the public debate and most policy proposals have focused on the evaluation of research activities, both at the individual and at the departmental level. Overall, the aims of these assessment exercises, and the redistributive policies based upon them, consist of the creation incentives for individuals to engage in high quality research, and in creating positive economic spillovers from such research *via* technology transfer and other "third mission" activities. Despite many pleas in that direction, much less attention has been paid to the evaluations of teaching quality, also in light of the possible trade-offs and complementarities with the other two activities.

As a result, we face a lack of comprehensive evidence on these matters. Most of the empirical studies produced so far have considered only two activities at a time. For instance, the vast empirical literature on university–industry technology transfer has explored the link between research productivity and academic patenting or academic entrepreneurship, usually finding a positive association (among others: Thursby and Thursby, 2002; Breschi, Lissoni, and Montobbio, 2007; Carayol, 2007; Lissoni et al., 2008; Czarnitzki and Toole, 2010; Crespi et al., 2011; see also: Lawson, 2013; Perkmann et al., 2013). In addition, recent findings have shown that such university–industry relationships can also influence scientists' research agendas (Hottenrott and Lawson, 2014). Similarly, the higher education literature has explored the teaching-research nexus in depth. In particular, Ramsden and Moses (1992), Hattie and Marsh (1996), and Jenkins (2004) find a (weak) positive correlation among the two dimensions, but their evidence is not theoretically grounded, as well as tenuous and quite controversial.

As for the teaching–consulting link, this is the least explored. Lee and Rhoads (2004) find that consulting has a negative impact on teaching commitment. Just recently, some scholars have started to consider jointly the relationship between teaching, research and other forms of knowledge transfer. Landry et al. (2010), based on a sample of Canadian researchers belonging to different research fields, explore the complementarities and trade-offs between six activities undertaken by academics: publishing, teaching, informal knowledge transfer, patenting, engaging in spin-off formation and consulting services. While publishing, patenting, spin-off creation, consulting and informal knowledge transfer appear to be complementary, teaching and publishing are found to be substitutes (and bear no relationship to the other activities). In the same line, Sanchez-Barrioluengo (forthcoming) finds research and technology-transfer are positively correlated, but negatively affect teaching quality.

As for the theoretical literature, this is very limited and it generally represents individual academics as economic agents who must choose how to allocate their time between two activities only. Early contributions by McKenzie (1972) and Becker Jr. (1975) look at time allocation between research and teaching as a simple (and static) utility maximization problem. More recently, Walckiers (2008) considers the viewpoint of a university, which offers a menu of contracts to professors differing in their preferences for teaching and research. He shows that bundling together the two activities is optimal in most cases. El Ouardighi, Korgan, and Vranceanu (2013) also consider the problem of professors' time allocation between research and teaching, but from a dynamic perspective. They show that when spillovers between the two activities exist in both directions, specialization is most likely to emerge. Faria (2002) models a scholar's allocation of time between academia and professional activities outside it, and finds a negative impact of opportunities for such activities (associated to political and business networks) on research productivity.

Useful, albeit sparse inputs to a comprehensive theory come from the mix of theoretical and empirical analyses of academics' incentives to pursue one or another of the activities under consideration. Concerning research, a 'taste for science' hypothesis has been put forward (Stern, 2004), which suggests that academics are intrinsically motivated to do research, up to the point of being ready to pay for it, in terms of lost opportunities to engage in more financially rewarding activities (see also Stephan, 2012). This is consistent with some findings from the literature on academic entrepreneurship, which portray scientists as individuals passionate for research and hungry for research-related funding, but with relatively naive ideas about the pursuit of market goals (Thursby and Thursby, 2003). Jensen, Thursby, and Thursby (2003) report that top scientists may abstain from disclosing potentially marketable technologies, as they would face higher opportunity costs (in terms of distraction from research) if required to engage in development activities.

Based on a survey of PhD students in life sciences, physics and chemistry at U.S. institutions, Roach and Sauermann (2010) show evidence of a 'taste for teaching' as well. Teaching is considered as 'interesting' or 'extremely interesting' by about 70% of their sample, while the corresponding percentage for commercialization activities is around 40%.

Finally, Lach and Schankerman (2004, 2008) provide strong evidence that, when it comes to technology transfer activities, academic scientists are highly sensitive to financial incentives. In particular, their decision to disclose their patentable research results to the university depends heavily on the royalty-sharing schemes put in place by the administration. This sensitiveness may be mediated by age and seniority. Thursby and

Thursby (2004) find that the propensity of faculty members to engage in collaboration with industry may depend not only on personal preferences and personal interests, but also on life cycle effects. In this respect, older scientists may be more willing to cash in on the market gains of their knowledge assets than their younger colleagues, who are bound to research by the need to climb up the academic ladder (Audretsch and Stephan, 1996). This may hold especially for professors of continental European countries, whose academic environment is characterized by lower competition and higher job security than the U.S. one. Nevertheless, technology transfer activities, and consulting in particular, may be related not only to income opportunities or commercialization efforts, but also directly linked to academics' research projects, i.e. being motivated by the desire to gain insights or access research materials. The distinction is important because of its impact on the nature of spillovers towards research (Perkmann and Walsh, 2008).

When considering academics' incentives to engage in technology transfer we should also pay attention to demand factors, especially when comparing researchers from different disciplines. A broad distinction can be made between basic science (including mathematics) and engineering (applied) fields, with the former offering fewer consulting opportunities than the latter. Lee and Rhoads (2004), based on a survey of U.S. faculty members, suggest that 52% of engineering academics engage in consulting, while the corresponding percentage is 24.2% for mathematics and 29.2% for physical sciences. Based on a sample of UK academics, D'Este and Patel (2007) find that engineers are markedly more prone to get involved in consultancy activities than mathematicians and physicists. In their sample 81% of researchers in mechanical engineering, 74.4% in civil engineering and 69.8% in electrical and electronic engineering interact with companies through external consulting, whereas such percentages drop to 37.4% for physicists and to only 20.4% for mathematicians. Similar findings come from Landry et al. (2010), who compare engineers and natural scientists and from Rentocchini et al. (2014), who show that more than 70% of Spanish academics in engineering engage in consulting, as opposed to 40% in other disciplines.

3. A theoretical model of effort allocation between teaching, research and consulting

3.1 Model description

We present, in a stylized fashion, the problem of dynamic effort (alternatively, time) allocation by an individual academic between three basic activities:

1. teaching: not only intended to represent classroom time (which we supposed as exogenously given), but also preparation (on which teaching quality depends);
2. research: aimed at publishing in peer-reviewed journals;

3. consulting: which encompasses a broad range of firm-directed knowledge transfer activities, unrelated to ongoing research and paid for by the customers, rather than the university (from professional advice to laboratory testing, expert witnessing or small-scale entrepreneurship).

We assume the academic to be active in two periods: period 1, when she is a 'junior' scientist; and period 2, when she is 'senior'.[1] We assume that, in each period, the academic has an effort (time) endowment τ to allocate between teaching (e_T), research (e_R), and consultancy (e_C). Her utility function is time-invariant, as follows:

$$u(e_R, e_T) = u_R(e_R) + u_T(e_T) + m, \tag{1}$$

where u_R and u_T are, respectively, the benefits from research and teaching (strictly increasing and concave functions of efforts), while m is the income. Income comes only from consultancy,[2] in the form of fees per time unit φ. In particular, given a consultancy fee φ, income can be expressed simply as φe_C. Consultancy fee φ plays a key role in the model and it is assumed to be influenced by three characteristics of the academic: namely, her scientific discipline, seniority and past research effort.

Disciplines matter to the extent that they offer different consulting opportunities. In particular, we assume a broad divide to exist between basic and applied sciences (engineering), with the latter facing a large demand for consulting, especially from small and medium sized firms (we will elaborate more on this in Section 4). The model captures this heterogeneity by means of a continuous parameter x affecting φ, with disciplines ordered by increasing consulting opportunities, i.e. $\frac{\partial \varphi}{\partial x} > 0$.

As for seniority, we assume φ to change over an academic's career, with φ^2 (fee in period 2, when the academic is 'senior') being larger than φ^1 (fee in period 2, when the academic is 'junior'). The assumption is meant to capture the effect on consulting opportunities that seniority may have *per se*, for instance by going along with the academic's social capital inside and outside the university.

Finally, we assume φ^2 also to depend positively on the effort devoted to research in period 1, under the assumption that scientific reputation (derived from publications) acts as a signal for perspective buyers of consultancy services. In particular, we assume:

$$\varphi^1(x) \leq \varphi^2(x, e_R^1), \text{ with } \frac{\partial \varphi^2}{\partial e_R^1} > 0. \tag{2}$$

The academic chooses efforts in order to maximize her overall utility, defined as the sum of utility in the two periods (we assume no discounting to take place). Notice that the only link between the two periods is that the economic returns from consulting in the second period increase due to the research effort performed in the first.

[1] In our model, we do not distinguish between academic rank and seniority. In the empirical analysis, both rank and age will be used as independent variables.

[2] We do not consider explicitly the professor's wage, which is not problematic as long as it does not depend on past or current research and teaching effort. This assumption is discussed in the following section.

Empirically, we cannot observe the academic's effort nor the time she allocates to the different activities. We will observe instead the quality of her teaching, as measured by students' assessment, which we assume to depend positively on current teaching effort and non-negatively on past research effort.[3] Formally, we posit the existence of a teaching quality function, *T(.)*, increasing and concave in its argument. In our two period setup, teaching quality levels are thus: $T^1=T(e_T^1, 0)$ and $T^2=T(e_T^2, e_R^1)$.

3.2 A discussion of the assumptions

A brief discussion of our assumption is in order.

First, our utility function implies, consistent with the 'taste for science' and 'taste for teaching' literature we reviewed in Section 2, that both teaching and research provide an intrinsic 'satisfaction' to the academic, while consultancy provides income, but no intrinsic 'satisfaction'. As for teaching, we can also rationalize our assumption by further assuming that, for such an activity, academics are paid a fixed wage; or, more generally, that explicit monetary incentives associated to teaching are of limited importance (especially if compared to profit opportunities from consulting), as it is the case in most universities worldwide. Similarly, while we recognize that research excellence has a positive impact on career advancement, we assume the latter not to generate additional income. This is indeed the case in all university systems (such as the Italian one) where seniority affect wages as heavily as rank advancement, and rank advancement itself is considerably based on seniority (and, in any case, any additional income from advancement is negligible compared to income gains from consulting).[4]

Second, we do not distinguish between the substantive quality of teaching (as reflected by the instructor's contribution to the students' understanding of the subject) and the one perceived, or reported, by students, which may also be influenced by the instructor's personality or the expected success in passing exams. We are forced to make such assumptions based on the data at our disposal, which come exclusively from students' evaluations, as it is most often the case in the literature.[5]

Third, we assume disciplines to differ only in terms of consulting opportunities. They do not affect directly the utility function (with some disciplines generating more utility than others), since what matters for our purposes is the relative level of effort. They also do not affect teaching quality, as perceived by students, which is a more restrictive assumption (as students may enjoy some courses more than others, depending on the discipline). However, we will argue that, in the case of our empirical exercise, this is not a problematic issue.

Last, but not least, we posit the existence of unidirectional and positive spillovers from research to both teaching and consulting, while we exclude any feedback between the latter or any reverse spillovers to research. This is justified because, given our empirical application, we are interested only in those consultancy services that merely involve the use of existing knowledge, defined as 'opportunity-driven' consulting by

[3] Notice also that we are not considering a learning-by-doing effect in teaching, which would have complicated the entire setting without adding further insights.

[4] Nevertheless, such an effect would have simply increased the return from research effort in the first period.

[5] Section 4.1.1 is fully devoted to a discussion of the issue of teaching quality evaluation through students' questionnaires.

Perkmann and Walsh (2008). This assumption would be less justifiable for more 'research-driven' forms of consulting[6]. As for assuming no benefits from consulting on teaching quality, this may raise the objection that instructors' involvement with industry may bring along several opportunities to improve existing educational programs, or to create new ones (see Stephan, 2001, for some historical examples). More generally, university–industry relations (including consulting) may benefit students by creating new or better job opportunities. While not denying the importance of these two effects, we observe that the former materializes over the medium to long term (as changing syllabi requires time), while the latter mostly concerns graduate students or, in the case of undergraduates, has to be mediated by the universities' job placement offices. This leaves our model best suited to capture the short-term impact of consulting on the instructor's performance, as seen in the classroom, during reception hours and in the care taken when preparing and distributing course materials.

3.3 Analytical solution

The model is solved by backward induction. In period 2, after adding the time constraint to the utility function, the academic solves the following unconstrained maximization problem:

$$\max_{e_R^2, e_T^2} u_R(e_R^2) + u_T(e_T^2) + \varphi^2(\tau - e_R^2 - e_T^2). \tag{3}$$

The first order conditions (FOCs) are:

$$u'_R(e_R^{*,2}) = \varphi^2(\mathrm{x}), \tag{4}$$

$$u'_T(e_T^{*,2}) = \varphi^2(\mathrm{x}). \tag{5}$$

By putting the equilibrium values into the utility function (1) we obtain $u^{*,2}=u^{*,2}(e_R^{*,1},x)$, which implies that the equilibrium utility in period 2 is a function of the equilibrium research effort in period 1 (and disciplinary field x).

In period 1, the academic maximizes the total utility over two periods. By applying the envelope theorem to obtain $\frac{du^{*,1}}{de_R^1}$, we can derive a second set of FOCs:

$$u'_R\left(e_R^{*,1}\right) + \varphi_R^2(e_R^{*,1}, x)\left(\tau - e_T^{*,2} - e_R^{*,2}\right) = \varphi^1(x), \tag{6}$$

$$u'_T(e_T^{*,1}) = \varphi^1(\mathrm{x}). \tag{7}$$

[6] Formally, positive spillovers between research and consulting could be represented by assuming $u_R(e_R; e_C)$, with $u_R(.)$ increasing in both arguments and the cross-derivative being positive. Such an assumption would increase the allocation of effort to research and consulting and reduce teaching effort.

Given equilibrium efforts, equilibrium values for teaching qualities are given by: $T^1=T(e_T^{*,1}, 0)$ and $T^2=T(e_T^{*,2}, e_R^{*,1})$.

3.4 Model implications

From the model, we derive the equilibrium relations involving teaching quality and:

1. academic seniority;
2. past research activity;
3. consulting opportunities.

As for *seniority effect*, we compare the teaching quality in periods 1 and 2 ($T^{*,1}$ and $T^{*,2}$). Concavity of both u_R and u_T implies that juniors academics will invest more than seniors both in research and teaching. This yields *a priori* ambiguous results: on the one hand, the seniors' teaching effort (e_T^2) is lower, which affects negatively their teaching quality; on the other hand, the seniors' teaching quality benefits from past research effort e_R^1. It is only by considering the role of discipline-specific consulting opportunities that we can resolve this ambiguity, at least in part.

In disciplines with limited consulting opportunities (low φ), the academic seniority effect is likely to be limited, and possibly positive. This is because both the research and teaching efforts are expected to be relatively constant over time, so that seniors put in as much teaching effort as juniors ($e_T^{*,1} \approx e_T^{*,2}$). This leaves the sign of the effect to be determined by the impact of e_R^1 on teaching quality, which is positive.

In disciplines where consulting opportunities abound, but scientific reputation does not act a signal ($\frac{\partial \varphi^2}{\partial e_R^1}$ close to zero), the seniors' consulting fee φ^2 will be rather high, regardless of their past research record. Junior academics, therefore, do not have the incentive to invest much in research in period 1, and will engage considerably in consulting in period 2 (when they are seniors). Therefore, the seniority effect will be most likely negative.

The most ambiguous case occurs for disciplines with abundant consulting opportunities, conditional on scientific reputation, where academics both invest heavily in research when juniors and dedicate considerable efforts to consulting when seniors.

Ambiguity also surrounds the *research productivity effect* (impact of past research on present teaching quality). On the one hand, past research is by assumption an input to current teaching quality; on the other hand, a high research output (publications) as junior may increase the consultancy fee in the second period, thus reducing the teaching effort e_T^2. The ambiguity can be resolved only by putting forward specific assumptions on the form of teaching quality function.

If $T(.)$ is highly concave in e_R^1 (the marginal returns of research in period 1 on teaching quality in period 2 drop quickly), we can expect a non-linear effect (an inverted-U relationship)[7]. In disciplines with significant consulting opportunities, and no signaling value attached to scientific reputation, the overall propensity to publish will be low, so that a marginal variation in past research efforts is likely to have an overall positive effect on teaching quality. In equally opportunity-rich disciplines, but with strong signaling value of research, the average propensity to publish will be higher, so that we can expect a negligible or even negative effect of past research efforts. The same should hold in disciplines with limited consulting opportunities.

As for the *consulting opportunity effect*, this is captured by variations in the parameter x. Thus, we get:

$$\frac{dT^1}{dx} = \frac{\partial T^1}{\partial e_T^1}\frac{de_T^{*,1}}{dx}, \tag{8}$$

$$\frac{dT^2}{dx} = \frac{\partial T^2}{\partial e_T^2}\frac{de_T^{*,2}}{dx} + \frac{\partial T}{\partial e_R^1}\frac{de_R^{*,1}}{dx}. \tag{9}$$

From equations (4)–(7), by applying the implicit function theorem, we obtain:

$$\frac{de_T^{*,1}}{dx} = \frac{\varphi_x^1}{u''_E}, \tag{10}$$

$$\frac{de_R^{*,1}}{dx} = \frac{\varphi_x^1 - \varphi_{xR}^2\left(\tau - e_T^{*,2} - e_R^{*.2}\right) + \frac{\varphi_R^2\varphi_x^2}{u_R''} + \frac{\varphi_R^2\varphi_x^2}{u_T''}}{u''_R + \varphi_{RR}^2\left(\tau - e_T^{*,2} - e_R^{*.2}\right) + \frac{\left(\varphi_R^2\right)^2}{u_R''} + \frac{\left(\varphi_R^2\right)^2}{u_T''}}, \tag{11}$$

$$\frac{de_T^{*,2}}{dx} = \frac{\varphi_x^2 - \frac{de_R^{*,1}}{dx}\varphi_R^2}{u''_E}, \tag{12}$$

$$\frac{de_R^{*,2}}{dx} = \frac{\varphi_x^2 - \frac{de_R^{*,1}}{dx}\varphi_R^2}{u''_R}. \tag{13}$$

Based on our assumptions so far, (10) is unambiguously negative, while (11), (12) and (13) have an uncertain sign. Once again, the nature of consulting activities may help in providing some predictions.

If the signaling effect of research is limited, i.e. φ_{xR}^2 is low, (11), (12) and (13) are negative, which implies that more consulting opportunities are detrimental to teaching quality both for junior and senior academics.

If φ_{xR}^2 is large enough, (11) is positive, while (12) and (13) are negative. It follows, from equations (8) and (9), that consulting opportunities are detrimental to teaching quality when the academic is junior, while the effect is ambiguous when she is older. In period 1, an increase in the consulting opportunities necessarily reduces the effort in teaching: the academic will dedicate more efforts both to consulting (e_C^1) and to research (e_R^1), the latter being necessary to send signals to the consultancy market. In period 2, though still distracted

[7] Interestingly, Mitchell and Rebne (1995) find an inverted-U relationship both between teaching and research, and between consulting and research.

by consulting, the academic will base her teaching quality on the large value of e_R^1, thus compensating (at least partially) for the negative effect of lower e_T^2.

4. Data and methodology

4.1 Data

All data for our empirical exercise come from the engineering faculty of an Italian mid-sized public university (14,000 students, mostly undergraduates; 563 faculty members) established in 1982, as a spin-off of a larger and older institution located nearby. Both the university and its engineering faculty were created as a 'territorial university', i.e. one that should cater for the local demand of qualified technicians and professionals, and contribute to technology transfer at the local level. In the period under consideration, it consisted of four main departments, built around as many broad groups of disciplines: (i) basic science (i.e. physics, chemistry, mathematics); (ii) civil engineering; (iii) electronic engineering; (vi) mechanical engineering. As for academic ranks and teaching loads, at the time of data collection the Italian academic ranking system was a three-layered one, with full professors (*professore ordinario*) as the most senior figures, followed by associate and assistant professors (*professore associato* and *ricercatore*, respectively). All positions were tenured, with teaching loads set locally, within a range set by national legislation (see Lissoni et al., 2011, and references therein).[8]

Teaching evaluation data come from archival records reporting SETE results for all courses from academic year 2005/06 to 2007/08.[9] Questionnaires were distributed at the end of each course and compiled on the spot by all the students attending classes on evaluation day, under the supervision of another student, and not by the instructor (as a guarantee of anonymity; see Appendix A for a template).

Our observations are courses. For each course we know the instructor's name, age, gender, the number of courses which she was in charge of, and whether she belonged to the faculty staff or was an external appointee (at the time of the evaluation). In case of tenured instructors (the only ones we retain for our exercise), we have information on their rank and discipline, as well the number of total publications and citations listed under their name in the Web of Knowledge database, published by the Institute for Scientific Information, from 1975 to the first observation year. In addition to that we also have information about the number of patents held by the instructor, as registered at the U.S. and/or European patenting offices.

[8] Full and associate professors in our university had the same teaching workload (120 classroom hours), while the national legislation established no or reduced workloads for assistant professors, depending on their seniority. As a matter of fact, most assistant professors did teach as much as their seniors, as refusing to do so would have been a considered a display of uncooperative behavior (due to the high student/professor ratios and limited funding for attracting valuable external instructors), with negative consequences for promotion. Some courses were assigned to external instructors, such as young master's degree graduates (not yet enrolled in a PhD program), professors from other universities, or local professionals. With very few exceptions, all courses consisted of 60 hours of classroom teaching and delivered the same number of credits. The academic years were organized into three quarters, with each course being taught in one quarter only, each quarter having three to five courses (degrees in civil or construction engineering were the only exception, being structured by semesters).

[9] During the three years of observation, the faculty of engineering offered seven different bachelor's degrees and ten master's degrees.

Summing up, our database consists of unbalanced panel data, composed of 1,546 observations on 175 tenured professors over three observation years, during which no internal organizational changes took place.

<< TABLE 1 APPROXIMATELY HERE >>

<< TABLE 2 APPROXIMATELY HERE >>

Table 1 illustrates the number of instructors by scientific field and academic rank at the beginning of the time span (2005).[10] The sample is quite uniform across both rank and field. The department of basic science appears the smallest in terms of size, with only six full professors. In contrast, the department of mechanical engineering is the largest, followed by civil and electronic engineering. Overall, and in each department, the number of assistant professors is slightly higher compared to that of assistant full professors.

We measure the past research effort of each professor by using either her stock of publications (proxy for quantity) or her stock of citations (proxy for quality). Table 2 provides some descriptive statistics. Consistent with the existing literature on scientific productivity of scientists (Stephan, 2010), we do observe an extremely high asymmetry in both dimensions, that is to say the coexistence of many unproductive professors (no publications) with a few 'superstars'. Furthermore, we find significant differences across departments, with basic science being characterized by a higher average number of past publications and citations. While this difference may depend upon the specificity of the knowledge production process of each discipline (with physicists and mathematicians typically publishing more than engineers; see King, 2004), some circumstantial evidence exists which points at a more substantive explanation. In particular, the latest nation-wide research evaluation assessment conducted in Italy (VQR 2004–2010), ranked the engineering faculty's department of basic science well above the national average (for universities of the same size), while the engineering departments were in line with the average.

As for measuring consulting activities, we do not dispose of information at the individual level, as this would require accessing sensitive data that are very hard, if not impossible, to obtain.[11] Luckily, cross-disciplinary differences in terms of consulting opportunities are large enough to allow us to test our model's predictions by focusing merely on a set of dummy variables, which capture each individual academic's disciplinary affiliation. We base our argument on both some general statements on the science–industry relationship, as provided in Section 2, and on some remarks on how the relationship unfolds in the specific case of the engineering faculty and its surrounding economy.

The engineering faculty is located in a high-GDP, manufacturing-intensive area of northern Italy dominated by metalworking and mechanical industries. Within the private sector, the largest demand of graduates in

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[10] Only few professors changed their academic rank during the time window considered, whilst none moved to other departments (disciplinary fields).

[11] Some previous studies collected information on consulting and other knowledge-transfer activities through surveys on a large sample of scientists. This approach does not seem attractive in our case, due to the relatively small size of the sample and an expected high rate of non-response. Moreover, due to traditional weakness in their governance, Italian universities have for long exerted little control on extra-academic engagements of their faculty, although their authorization should be required by law. This implies that little or no records are available at the university administrative level, which may concern the faculty consulting activities.

engineering comes from the small and medium enterprises (SMEs), which represent the backbone of the local economy and work mostly as specialized suppliers of components and machines for scale-intensive and traditional sectors, both in Italy and worldwide. This suggests that members of the engineering faculty's four departments face sensibly different demand of consulting services:

- For *civil engineers*, local consulting opportunities abound, as they arise from a large demand for projects and expert assessment of infrastructure as well logistic and production sites, coming from both firms and local administrations.
- Similarly, *mechanical engineers* help meet the large demand for professional expertise expressed by the many local SMEs when dealing with their core metalworking and mechanical business.
- As for *electronic engineering*, they face a mix of local demand (for consultancy concerning process innovation and the insertion of electronics and IT in mechanical products), as well some national demand, often mediated by consortia of universities.
- Members of the *basic science* department, on the contrary, have very limited consulting opportunities, due to the local and national paucity of science-based industries.

Some recent results from the VQR 2004-2010 confirm this view. These data include, among others, information on revenues per capita obtained by each university department from contract research and professional services. While being just a fraction of what individual academics earn from their overall consulting activities,[12] these revenues can be used to rank departments. They are the largest in the department of civil engineering, followed by mechanical and electronic engineering, and, much distanced, by all disciplines represented by the department of basic science (ANVUR, 2013).

Some evidence in the same direction comes from the academic patenting data (see again Table 2). The total number of patents is limited, and a few professors hold most of them. Most notably, the electronic and mechanical engineers exhibit the highest share of patents per professor, most of which are not owned by the universities but by private firms, which suggests that they are the result of consulting or, at most, contract research. Civil engineers do not have patents, which is explained by the nature of the consulting activities they are involved in, which rarely result in inventions.

Finally, the four broad disciplines differ also in terms of the importance that scientific reputation may have to increase an individual academic's consulting opportunities. In the absence of a strong publishing tradition (especially in peer-reviewed journals), and in consideration of eminent local nature of demand for consultancy, civil engineering is the field with the least value of scientific reputation as signal. For the same reason, at the opposite end we find all disciplines in basic science, with electronic and mechanical engineering in between.

[12] They mainly originate from the few contracts that the individuals prefer to sign via the department, rather than personally, whenever they need to use some of the department's facilities or as part of informal arrangements (aimed at trading some revenue vs more freedom to take time to attend to personal business matters).

4.1.1 The measurement of teaching quality: a note on SETE data and self-selection

Albeit widely used, especially by higher education administrators and scholars, SETE data have been the object of several controversies. Their reliability rests on the assumption that students are well positioned to monitor their instructor's performance, thanks to their classroom experience. Year after year, the SETE methodology has become more comprehensive and accurate, with more specific evaluation criteria and precise implementation guidelines.

The main criticism of SETE data portrays them as flawed by the distorted incentive they would provide to instructors. The latter would be pushed to engage in popularity contests among students, which would have little to do with the students' effective learning, or would affect it negatively (Emery, Kramer, and Tian, 2003; Braga, Paccagnella, and Pellizzari, 2014). We notice, however, that the SETE data collected from the engineering faculty were not meant to have, nor had they ever had, any impact on the instructors' utility, as they did not affect wages or career advancement (as it was, and still is the case for most Italian universities). They were collected only to comply with existing legal requirements and never published or discussed in faculty meetings.[13] Only the instructor (along with the dean of the faculty) knew her evaluation results, and all adjustments of teaching style or syllabi were entirely left to the instructor's goodwill.[14] Finally, still nowadays, Italian universities never request individual SETE data from job applicants, nor consider them in decisions on promotions. In conclusion, this passive attitude towards teaching evaluation is reassuring for our use of data, as we may expect that instructors never acted strategically, i.e. with the aim of manipulating their SETE scores.

Neither is self-selection of students in high teaching-quality vs. low-quality courses an issue, as the engineering faculty students' curricula were and still are set rigidly by a mix of legal and local regulations. Students can choose among a fairly high number of curricula, grouped according to their professional orientation (business, civil, electronic and mechanical engineering), but have very few or no optional courses and only one instructor is available for each course.[15] Courses are assigned to instructors largely on a seniority basis, with senior faculty members choosing both for themselves and for their junior colleagues, to whom they are usually tied by a strong master/apprentice relationship. This could introduce a bias in our data, with more senior scientists choosing courses from which they expect higher student' evaluations; as we will see, however, we find that seniority is negatively associated to students' evaluations (when the association is significant). Thus, if the bias exists, it does not invalidate our results.

4.2 Methodology

[13] In Italy, SETE data collection, by means of standard questionnaires (possibly adapted by the individual institutions), is promoted by the National Committee for the Evaluation of the University System, a governmental agency created in 2000 with the specific purpose to coordinate the evaluation activities of public universities, which constitute the vast majority of Italian higher education institutions. As a matter of fact, the data were never used.

[14] Bianchini (2014), using the same data, shows that students' evaluations do not provide any feedback to improve future teaching performance, either at the university or the individual level.

[15] Self-selection might still occur across degrees. However, Bianchini, Lissoni, and Pezzoni (2013) show that students' characteristics, which vary across degrees, do not have any significant impact on their teacher evaluations.

We proceeded in two steps. First, we explored the students' questionnaires by means of exploratory factor analysis (EFA), in order to build a synthetic indicator of teaching quality, and further synthetic indicators of environmental conditions that may affect students' judgment. We retained three factors, which, based on the correlation with single items of the questionnaire, we defined as: "teaching quality" of the professor; "overall quality" of the degree; and "infrastructure quality" (more details in Appendix B).

Second, we ran a regression model with teaching quality as the dependent variable, and the instructor's characteristics (academic rank, stock of publications or citations and disciplinary affiliation) as the main explanatory variables. As for controls, we considered some further individual characteristics of the instructor (age, gender, overall teaching load and whether she was teaching the course for the first time or not), as well as some environmental conditions, such as the overall quality of the degree, the quality of infrastructure, the size of the class, the level of the degree (bachelor vs. master) and time dummies.[16] For the complete list of independent variables, see Appendix C.

Our time series is very short, and no major changes in the organization of the courses, or assignment to instructors, occurred during the observation period. As our main concern was mainly to preserve the sample size we implemented a pooled cross-section model (ordinary least squares estimation), including a set of time dummies to account for potential macro-level changes.[17] Since the same courses are most often taught by the same instructors over the years, we needed to account for the possible correlation in the error terms over time. We dealt with this problem by clustering the standard errors at the professor level.

Based on the theoretical conclusions formulated in Section 2, we produced three different model specifications, the results of which are reported in the following section. Model (1) looks at the *academic rank*, *past research productivity* and *consulting opportunity* effect without distinguishing between disciplines. The research productivity effect was investigated considering a nonlinear (quadratic) formulation. In model (2), we connected academic ranks with scientific fields, using "assistant professor in basic sciences" as the reference category. Finally, model (3) keeps the interaction between rank and field, but substitutes the nonlinear effect with the interaction between stock of publications and disciplines.

5. Results

Table 3 reports the estimated coefficients for the main explanatory variables and controls (see Appendix D for the full list of controls). Note that all specifications exhibit a satisfactory explanatory power (R^2 always close to 0.50).

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16 Our original exercise also included, among the controls, the instructor's stock of patents, which one may assume to be a proxy of external commitment, but we never found it significant. Notice however that Goel and Göktepe-Hultén (2013), for a sample of German scientists, find that consulting, i.e. the form of interaction with industry that is most relevant in our case, has no robust impact on academic patenting.

17 Since most of the information is captured by time-invariant dummies (i.e. scientific field, academic rank), controlling for individual fixed-effects would make it impossible to carry out our empirical exercise.

<< TABLE 3 APPROXIMATELY HERE >>

Results from model (1) show that the academic rank, research productivity and consulting opportunity effects are clearly in line with the predictions of our theoretical model.

Concerning rank (which proxies for the "seniority" variable in our theoretical model), we notice that, on average, both associate and full professors obtain lower evaluations than assistant professor, although the effect for associate professor is weaker and not statistically significant. We interpret this rank effect as the result of the larger consulting opportunities available to full professors.

As for research productivity, we do find a nonlinear effect, i.e. an inverted-U relationship between the stock of publication and teaching quality.[18] This suggests that past research productivity has an initial positive impact on teaching quality. However, diminishing returns may kick in over a certain threshold (approximately 33 publications over a professor's life cycle). Our model suggests that this happens when, for high publication levels, the marginal impact of publications on teaching quality becomes too small to compensate for the negative effect associated with the larger number of consulting opportunities that come with a solid scientific reputation. Finally, consulting opportunity effect has the expected sign. As basic science is the reference, it is possible to appreciate the negative and significant coefficients for all consulting-oriented fields. These results are explained by our theoretical argument, which points at the lower commitment to teaching in profession-oriented disciplines, whose members tend to face extra-academic engagements.

Our model predicts that rank and productivity effects may differ across disciplines. Indeed, this is what we find in model (2). First, no rank effect is observed in basic science. On the contrary, associate and full professors of engineering perform constantly worse than the benchmark group (assistant professor in basic science). Second, the magnitude of the coefficients for associate and full professor in civil engineering are similar, whereas for mechanical and electronic engineering the coefficient is larger (in absolute value) for full professors. In civil engineering, the nature of consulting opportunities, which usually relate to consolidated areas of knowledge, is such that scientific reputation does not really matter. The opposite, instead, is the case for mechanical and electronic engineering.

Finally, in model (3) we explore a different formulation for the research productivity effect, based on interaction of the stock of publications with the field effect. We find that the marginal effect of publications is not significant for basic science and mechanical engineering, while it is positive and significant both for electronic and, especially, for civil engineering. As shown in Table 2, civil engineering and basic science represent the two extremes in terms of propensity to publish. Therefore, we interpret this evidence as suggesting that past research commitment is particularly beneficial to teaching quality when scientists tend to publish less, and the consulting opportunities abundant (as is the case for civil engineering). Conversely, the marginal effect of past research productivity is null when scientists publish a lot and consulting opportunities

[18] The stock of citations never turns out to be significant and to be parsimonious we have omitted the specification from Table 3. Results are however available upon request.

are limited (as in the basic sciences). Last, some mixed evidence emerges in those disciplines with an average propensity to publish and where consulting opportunities are of significant number (mechanical and electronic engineering).

One concern in our interpretation of our results has to do with the possibility that discipline dummies may capture factors other than consulting opportunities, which could affect students' evaluations. First, academics active in some disciplines could be systematically better teacher (say, basic scientists could be more naturally gifted or enjoy teaching more than engineers). However, we are not aware of any systematic evidence supporting this view.[19] Second, students could generally prefer courses in some disciplines, and consistently evaluate them better than the others. But in our case, we can safely presume engineering students to have a preference, if any, for engineering disciplines over purely scientific ones. Since we find that SETE scores tend to be lower for engineering courses, we may conclude that, at most, our estimated coefficients for such disciplines suffer from a positive bias, which is compatible with our interpretation. Still, students' preferences for engineering courses could affect (positively) their expectations in terms of the instructor's performance. As high expectations can be more easily disappointed, this could lead to lower evaluations. In this case, our estimated coefficients would be negatively biased, which runs against our interpretation. This possibility is not easy to dismiss. However, we ran separate regressions for undergraduate and graduate courses and found no significant differences in terms of estimated coefficients. As it is reasonable to assume the "high expectation" explanation to apply more easily to graduate students than to bachelor ones, we draw some comfort from the result.[20]

6. Conclusions and policy implications

Our paper contributes to an emerging area of research that looks at the various relationships between universities' three missions (teaching, research and technology transfer). In particular, we examined the effect of research and consulting activities on the quality of teaching at the individual level. We attached great importance to mediating factors, such as academic seniority and the disciplinary affiliation of individuals. The former influence the link between research, consulting and teaching quality via several life cycle effects; the latter do the same due to the different levels of demand for consulting services faced by academics in different disciplines. We outline these complex interactions by means of a stylized model, according to which academics distribute their research, consulting and teaching efforts over a two period horizon, with past research influencing positively both the quality of teaching and (in some discipline but not others) the amount of consulting opportunities.

[19] In contrast, evidence from economics and business schools (e.g. Ponzo and Scoppa, 2013) shows that mathematics instructors receive significantly worse evaluations from students.
[20] The results of these regressions are available upon request.

Some of our results confirm previous evidence, whereas the majority of our findings add to the literature by pointing out the large differences across disciplines. As for the seniority, for instance, studies from the 1950s and the 1960s found indeed a positive effect (e.g. Downie, 1952), but the relation turned out to be insignificant in some studies from the 1970s and the 1980s (e.g. Linsky and Straus, 1975). We do find a non-significant effect, but only for basic science. In contrast, for engineering professors, who face significant consulting opportunities, the effect is negative, as predicted by our theoretical model.

As for the research–teaching nexus, we prove it to be nonlinear and heavily dependent on cross-disciplinary differences, which may account for the inconclusiveness of the evidence produced so far by the literature.

Finally, our negative findings on the consulting–teaching nexus are in line with Lee and Rhoads (2004) on U.S. data, but in disagreement with those of Landry et al. (2010), who detect no correlation between the two activities.

Despite these contributions, our study suffers from a number of limitations. First, we did not have access to micro-level indicators of academics' level of engagement in consultancy activities. Our conclusions are based on the coefficients estimated for a set of disciplinary dummies, in a context in which we can safely presume differences in consulting opportunities were greater across disciplines than across individuals within each discipline. However, in order to generalize our results, we should try to collect information at the individual level, which in turn would requiring building a larger sample.

Second, we should test our model over a longer time horizon, possibly including more than one university and extending the analysis to other scientific fields, such as the social sciences and humanities (see the recent discussions in Amara, Landry, and Halilem [2013] and Olmos-Penuela, Castro-Martinez, and D'Este [2014]). Finally, different proxies of teaching quality, less dependent on subjective judgment, might provide more robustness to our findings.

As for policy implications, our findings suggest that, from a social welfare viewpoint, the optimal mix of academics' activities varies by disciplines. In disciplines where consulting opportunities abound and come along with scientific reputation, academics ought to face few obstacles when engaging in consulting, as they put early life cycle investment into research activities, which in turn may benefit teaching quality, too. The opposite holds in those sectors where consulting does not build on scientific excellence, and ends up detracting from teaching quality. Here the contracts binding the academic to the university should focus on teaching, either by imposing (and enacting) restrictions on consulting activities, or by requiring the academic to share a significant amount of her revenue with the university. The second option, besides lowering to some extent the academic's incentive to engage in consulting, would bring cash to universities at a time when governments require it to step up their self-financing capabilities. Notice that this policy recommendation would be pretty radical if proposed for university systems in countries such as Italy or Spain (and several other continental European countries), in which equality of treatment is ensured by national legislation. In such systems, the central government fixes both the wages and the teaching duties of academics regardless of discipline and gives little freedom to university administrations when it comes to regulating or incentivizing their staff's other activities. As a consequence, academics in consulting-oriented disciplines hardly share their consulting revenues, nor can be pushed to do research when this is unnecessary for improvement of their consulting opportunities. Notice that these policy conclusions are in line with those of Sanchez-Barrioluengo (forthcoming), who suggests that Spain's "one-size-fits-all" model of universities as centers of excellence in education, research and third mission initiatives relies upon unrealistic expectations on the interaction between the three activities.

Still, our recommendations need to be assessed against the extent of potential beneficial effects of consulting that may compensate for lower teaching quality, such as the stage and job opportunities that academics with close contacts with industry can bring along.

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Tables

Table 1. Number of professors by academic rank and scientific field

Rank/Field	Basic science	Civil eng.	Electronic eng.	Mechanical eng.	Total
Assistant	10	17	14	25	66
Associate	13	11	13	17	54
Full	6	15	13	21	55
Total	29	43	40	63	175

Table 2. Stock of publications, citations, and patents by scienfitic field

Scientific field	Mean	Std	Min	Max
Stock of publications				
Basic science	15.93	23.71	0	83
Civil eng.	2.67	4.25	0	15
Electronic eng.	7.03	7.39	0	33
Mechanical eng.	2.83	4.25	0	22
Stock of citations				
Basic science	241.21	468.84	0	1662
Civil eng.	23.41	40.09	0	166
Electronic eng.	69.66	78.95	0	359
Mechanical eng.	31.03	63.78	0	327
Stock of patents				
Basic science	0.20	0.68	0	3
Civil eng.	0.19	0.79	0	5
Electronic eng.	0.98	1.74	0	6
Mechanical eng.	0.76	1.83	0	9

Table 3. Regression results

	(1) TQ	(2) TQ	(3) TQ
RANK ASSIS	ref		
RANK ASSOC	-0.1512 (0.1181)		
RANK FULL	-0.3121** (0.1403)		
STOCK PUB	0.0274** (0.0123)	0.0267** (0.0124)	
STOCK PUB SQ	-0.0004** (0.0002)	-0.0004** (0.0002)	
BASIC SCIENCE	ref		
CIVIL	-0.4385*** (0.1573)		
ELECT	-0.5214*** (0.1457)		
MECH	-0.4716*** (0.1381)		
BASIC SC * ASSIS		ref	ref
CIVIL * ASSIS		-0.3181* (0.1767)	-0.5804*** (0.1776)
ELECT * ASSIS		-0.4278** (0.2167)	-0.6103*** (0.2152)
MECH * ASSIS		-0.4361* (0.2210)	-0.5664*** (0.2138)
BASIC SC * ASSOC		-0.0747 (0.2141)	0.0290 (0.2131)
CIVIL * ASSOC		-0.6614** (0.2980)	-0.8678*** (0.2651)
ELECT * ASSOC		-0.5259** (0.2158)	-0.7542*** (0.2436)
MECH * ASSOC		-0.5765*** (0.2001)	-0.6601*** (0.1982)
BASIC SC * FULL		-0.2682 (0.2334)	-0.2025 (0.2405)
CIVIL * FULL		-0.6393*** (0.2370)	-1.1302*** (0.2608)
ELECT * FULL		-0.8553*** (0.2558)	-1.1419*** (0.2799)
MECH * FULL		-0.6996*** (0.2060)	-0.7891*** (0.2051)

(continued)

BASIC SC * STOCK PUB			-0.0030
			(0.0044)
CIVIL * STOCK PUB			0.0780***
			(0.0213)
ELECT * STOCK PUB			0.0298**
			(0.0122)
MECH * STOCK PUB			0.0070
			(0.0154)
Controls	yes	yes	yes
Obs	1,546	1,546	1,546
R^2	0.5018	0.5052	0.5276

Notes: ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Robust standard errors are reported in parenthesis.

Appendix

Appendix A - Questionnaire template

Section A (*organization of the degree*)

A1. Is the overall workload for the academic period acceptable?

A2. Is the overall organization for the academic period acceptable?

Section B (*organization of the course*)

B3. Have the arrangements for examination been clearly defined?

B4. Are the hours of teaching activities respected?

B5. Is the teacher actually available for explanation/clarification?

Section C (*teaching*)

C6. Is the prior knowledge owned sufficient to understand?

C7. Does the teacher stimulate interest towards the subject?

C8. Does the teacher explain the topics in a clear way?

C9. Is the relationship between workload and granted credits acceptable?

C10. Is the teaching material adequate for learning purposes?

Section D (*infrastructure*)

D12. Are the classrooms adequate for lessons?

D13. Are the classrooms and the equipment adequate for exercises?

Section E (*interest and satisfaction*)

E14. Am I interested in the course topics?

E15. Overall, am I satisfied with the course?

Note: the items related to the underlying latent factor of teaching quality are highlight in bold (see Appendix B for details).

Appendix B – Teaching quality measure

We implemented an EFA on all items of the questionnaire (except one in Section C, which concerns laboratory activities and it is relevant for only a small minority of courses) to unveil the latent structure explaining the covariance of the original data. The outcome of this procedure consisted of a synthetic indicator of teaching quality and further synthetic indicators of environmental conditions that may affect students' judgment. More precisely, we made use of the principal axis method in extracting the latent factors. In order to obtain the estimation of the prior communality we computed the squared multiple correlation between a given variable and the other observed variables. Last, we allowed factors to be correlated with each other using the 'promax' rotation method (the factors are uncorrelated at the time they are extracted, it is only later that their orthogonality constraint is relaxed). Table 4 shows that only three factors have an eigenvalue larger than one. Factor 1 accounts for 74% of the common variance, followed at great distance by factors 2 and 3 (which explain respectively 15% and 12%), with all the following factors scarcely relevant. We retain these latent factors for our analysis. From Table 5, we notice that the three factors lend themselves to an immediate interpretation as 'latent variables', as they are correlated, respectively, with sections B, C, E, A and D of the questionnaire. As for interpretation, factor 1 is readily identified with teaching quality, while factors 2 and 3 capture quality of the overall organization of the degree (what we define as overall quality) and infrastructure quality.

Table B1. Eigenvalues of the reduced correlation matrix

Factor	Eigenvalue	Difference	Proportion	Cumulative
1	6.397	5.120	0.736	0.736
2	1.277	0.249	0.147	0.883
3	1.028	0.533	0.118	1.001
4	0.495	0.339	0.057	1.058
5	0.156	0.061	0.018	1.076
6	0.095	0.090	0.011	1.086
7	0.004	0.028	0.001	1.087
8	-0.023	0.041	-0.003	1.084
9	-0.065	0.013	-0.007	1.077
10	-0.078	0.033	-0.009	1.068
11	-0.111	0.040	-0.013	1.055
12	-0.150	0.004	-0.017	1.038
13	-0.154	0.021	-0.018	1.020
14	0.175		0.020	1.000

Table B2. Factorial structure (three latent factors retained)

	Teaching qual. (factor 1)	*Overall qual.* (factor 2)	*Infrastructure qual.* (factor 3)
A. Organization of the degree			
A1_M - period workload	-14	96*	-4
A2_M - period schedule	3	80*	-3
B. Organization of the course			
B3_M - exam mode	76*	-8	-3
B4_M - punctuality	69*	-11	-4
B5_M - willingness	81*	-10	8
C. Teaching			
C6_M - preliminary notions	28*	32	21
C7_M - raise interest	80*	9	1
C8_M - clarity	87*	5	-5
C9_M - credits	11	68*	5
C10_M - teaching material	67*	14	0
D. Infrastructure			
D12_M - classroom	1	-1	84*
D13_M - laboratory	-4	0	84*
E. Interest and satisfaction			
E14_M - general interest	43*	28	9
E15_M - overall satisfaction	82*	18	-2

Note: Each factor loading is limited to decimal points, rounded to the nearest integer, and multiplied by 100, thus eliminating the decimal point. The asterisks appear next to the factor loading the absolute value of which is greater than 0.40.

Appendix C

Table C1. Variable description

Variable name	**Description**
Main variables	
TQ	Overall teaching quality (factor 1 – synthetic indicator)
RANK ASSIS	Dummy = 1 if professor's academic rank is 'assistant'
RANK ASSOC	Dummy = 1 if professor's academic rank is 'associate'
RANK FULL	Dummy = 1 if professor's academic rank is 'full'
BASIC SCIENCE	Dummy = 1 if professor's disciplinary field is basic science
CIVIL	Dummy = 1 if instructor's disciplinary field is civil engineering
ELECT	Dummy = 1 if professor's disciplinary field is electronic engineering
MECH	Dummy = 1 if professor's disciplinary field is mechanical engineering
STOCK PUB	Professor's stock of publications from 1975 to the first observation year
Controls	
AGE	Professor's age
GENDER	Dummy = 1 if professor's gender is female
STOCK CIT	Professor's stock of citations from 1975 to the first observation year
STOCK PAT	Professor's stock of patents
NEW PROF	Dummy = 1 if the professor teaches the course for the first time
LOW LOAD	Dummy = 1 if the professor teaches one course per year
MIDDLE LOAD	Dummy = 1 if the professor teaches two or three courses per year
HIGH LOAD	Dummy = 1 if the professor teaches more than three courses per year
CLASS SIZE	Number of delivered questionnaires
BA PROG	Dummy = 1 if the degree level is bachelor
MA PROG	Dummy = 1 if the degree level is master
OVERALL QUAL	Overall quality of the degree (factor 2 – synthetic indicator)
INFRAST QUAL	Infrastructure quality (factor 3 – synthetic indicator)
TD 2005	Time dummy (academic year 2005/06)
TD 2006	Time dummy (academic year 2006/07)
TD 2007	Time dummy (academic year 2007/08)

Appendix D

Table D1. Other estimates (control variables)

	(1) TQ	(2) TQ	(3) TQ
(Table 3 for the main results)	…	…	…
AGE	-0.0122*	-0.0118*	-0.0120**
	(0.0064)	(0.0063)	(0.0061)
GENDER	-0.1003	-0.1022	-0.0695
	(0.0981)	(0.0999)	(0.0938)
STOCK PAT	0.0358	0.0335	0.0424
	(0.0359)	(0.0335)	(0.0378)
NEW PROF	-0.0664	-0.0517	-0.0285
	(0.1351)	(0.1313)	(0.1363)
LOW LOAD	ref	ref	ref
MIDDLE LOAD	0.0322	0.0442	0.0193
	(0.0997)	(0.1010)	(0.1038)
HIGH LOAD	0.1184	0.1019	0.1213
	(0.1706)	(0.1768)	(0.1759)
CLASS SIZE	-0.0000	0.0001	-0.0004
	(0.0012)	(0.0013)	(0.0012)
BA PROG	ref	ref	ref
MA PROG	0.1581***	0.1609***	0.1594***
	(0.0556)	(0.0563)	(0.0537)
OVERALL QUAL	0.5564***	0.5572***	0.5486***
	(0.0332)	(0.0335)	(0.0322)
INFRAST QUAL	0.2347***	0.2356***	0.2289***
	(0.0373)	(0.0364)	(0.0339)
TD 2005	ref	ref	ref
TD 2006	0.0709*	0.0743**	0.0721*
	(0.0382)	(0.0374)	(0.0374)
TD 2007	0.0396	0.0421	0.0450
	(0.0432)	(0.0427)	(0.0429)
Obs	1,546	1,546	1,546
R^2	0.5018	0.5052	0.5276

Notes: ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Robust standard errors are reported in parenthesis.

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