

Incentives and Careers in Academia: Theory and Empirical Analysis*

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Abstract

We study career concerns in Italian academia. We mould our empirical analysis on the standard model of contests, formalised in the multi-unit all-pay auction. The number of posts, the number of applicants, and the relative importance of the criteria for promotion determine academics' effort and output. In Italian universities incentives operate only through promotion, and all appointment panels are drawn from strictly separated and relatively narrow scientific sectors: thus the parameters affecting payoffs can be measured quite precisely, and we take the model to a newly constructed dataset which collects the journal publications of all Italian university professors. Our identification strategy is based on a reform introduced in 1999, parts of which affected different academics differently. We find that individual researchers respond to incentives in the manner described by the theoretical model: roughly, more capable researchers respond to increases in the importance of the publications for promotion and in the competitiveness of the scientific sector by exerting more effort; less able researchers are discouraged by competition and do the opposite.

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1 Introduction

Like other economic agents, academics operate under incentives: understanding how they respond to them, beside its independent interest, is indispensable background to any attempt to improve the behaviour and performance of the university sector. In this paper we show how the incentive provided by career concerns influenced the effort and the output of the academics working in Italian universities in the years between 1990 and 2011.

During this period, the Italian university sector followed a complex system of nationally mandated rules, designed to narrow the scope for cronyism by increasing transparency and minimising the room for discretion. While following the principle, common to the university sector of other

countries, that advancement decisions be based on peers' subjective judgement of a candidate's quality, these detailed rules distanced Italian academia from the standard theoretical framework of the academic labour market (e.g. Carmichael 1988, or Siow 1998). For example, appointment, tenure, and promotion decisions were minutely regulated, pay was fully determined by rank and seniority, teaching duties were uniform, there was no review of performance, promotions determined only a small non-negotiable pay rise, horizontal moves could not raise pay, dismissals for low productivity were non-existent in practice. The combined effect of these rules is to make the incentive scheme on the whole rather weak (Perotti 2008). But at the same time, the very meticulousness of the rules and their uniform scrupulous application across universities and subject areas ensure that academic conditions in Italy can be captured accurately and consistently, modelled formally, and measured empirically in a precise manner.

We model academic careers as contests in an uncertain environment, along the lines of Lazear and Rosen's (1981) model of progression in an organisation's hierarchy. The set of rules regulating the careers of Italian academics can be captured formally as an all-pay auction for multiple units (Barut et al 2002). In this model, bidders compete to be awarded one of K identical prizes, with all bidders, winners and losers alike, paying their bid, and the highest K bidders receiving one of the K prizes. Siegel's (2009) comprehensive review notes that the cost incurred by the participants can be monetary, as is the case for the expenditure on R&D where the prize is the award of a patent (Grossman and Shapiro 1986), or it can be a utility cost, given by the exertion of effort, as in Baye et al's (1993) model of lobbying and Anderson et al's (1998) study of rent-seeking. In the Italian academia, effort is exerted to carry out research, and the prizes are the promotions to positions in the next rung of the academic ladder.

The auction model at the basis of our analysis hinges on competitors knowing the relevant parameters affecting the competitive conditions: in our model, these are (i) the number of available posts, (ii) the number of potential competitors, (iii) the relative importance attributed by the appointment panel to the quality and quantity of the publications and to other academic activities, (iv) and

the distribution of their competitors' characteristics. Because of the narrow channelling of the academic careers into a large numbers of separated paths, and of the very long temporal gap between appointment rounds recorded in practice (about four years), it is very plausible to assume that the professors in a given rank in a given scientific discipline were able to form a fairly precise idea of the values of these parameters. The theoretical model of Section 2, therefore, assumes that academics choose their effort, which maps monotonically and deterministically into their output, on the basis of this information. It predicts that different individuals respond differently to changes in the competitive conditions: broadly speaking, more productive academics are encouraged by competition, less productive ones are discouraged. These conclusions are confirmed by our empirical analysis, which uses a newly constructed large dataset, that matches administrative data on all the individuals who have held a post in an Italian university at any time between 1990 and 2011, with all the articles they have authored in that period in journals listed in the Web of Knowledge dataset. Because there are three levels in academic hierarchy, we can run two separate regressions, one studying the assistant professors competing to become associate professors and the other the associate professors competing to become full professors. These obtain similar results, which moreover are robust to changes in the definitions of the variables and in the specification of the model.

The analysis is conducted via a panel estimation with individual fixed effects: because the competitive conditions – the importance of publications, the number of posts, the number of competitors, and an academic's position in the ranking of the people competing for these posts – change from period to period, we estimate the effort exerted by an academic relative to the effort of that same academic in different competitive conditions. The fixed effects estimation factors out the influence of the “type” posited in the theoretical analysis, which accounts for attitudes, skill, education and other idiosyncratic determinants of effort. While in practice some individual characteristics may change from period to period as they are influenced by events unfolding in time, one would expect these to remain relative constant across a person's lifetime, and, encouragingly, we find strong serial correlation in an academic's individual fixed effects (see the discussion of Figure 5,

at the end of Section 6). This is a confirmation of the soundness of our empirical strategy.

Our identification strategy hinges on one important detail of the reform of appointments and promotions rules which came into force in 1999, right in the middle of the period we study, namely a blunt cap of five on the number of applications a candidate could make in each year. This cap, as we show in Proposition 2, alters two of the parameters affecting the competitive conditions, the number of posts and the number of competitors, for some academics, but not for others, in a way that is likely unrelated to other unobservable characteristics determining their effort. Moreover, this cap came as a detail of a broader reform and was unexpected, being intended to reduce the workload of the panels, not to affect the academics' behaviour. It has therefore some of the features of a natural experiment. We show that this aspect of the reform does indeed affect academics in exactly the manner predicted by the theoretical model.

The paper is organised as follows. Section 2 applies the standard all-pay multi-unit auction to the study of academics' career concerns. Our data is described in Section 3. The empirical strategy and its econometric specification are explained in Sections 4 and 5, respectively. Section 6 presents our empirical results, and Section 7 concludes the paper.

2 Theoretical background

A simple extension of the multi-unit all-pay auction model developed by Barut et al (2002) serves well as a stylised model of competition and academic career progression in Italian universities. This is developed fully in Checchi et al (2014), and here we summarise the results relevant to the present analysis.

As we explain below, the Italian academic sector can be quite accurately described as a set of separate populations of academics. The N academics in the representative population all work in the same research area, and compete for promotion to the next rung of their career ladder by exerting costly effort to produce output. In a subsequent stage, K professorships across all the universities in Italy are advertised simultaneously, and the N candidates, labelled $i = 1, \dots, N$, apply for the posts.

They are then assessed by a centrally nominated panel, who appoints simultaneously all the new post holders (see Section 3 below and Appendix B.1 for the details of the process). They incur their effort cost whether or not they are successful, hence our choice of the all-pay auction.

Compared to the set-up of an auction, there are two additional sources of uncertainty on the road from effort to promotion. First, academics exert effort well in advance of the opening of the relevant vacancies, and so, when they choose their effort level, they do not know for certain the criteria which will determine their likelihood of being appointed. A second layer of uncertainty is the stochastic nature of the link between effort and output: whether a given article is accepted in a prestigious journal is, as we all know, partly due to luck. Checchi et al (2014) assume risk neutrality throughout, and simplify the model to a static deterministic set-up, where effort translates instantly and deterministically into output.¹

Research output depends on effort. Candidates differ in their cost of effort: the model assumes that, prior to their choice of effort, each academic is assigned by nature a idiosyncratic parameter, her “type”, $v_i \in [\underline{v}, 1]$, with $\underline{v} \in (0, 1)$, randomly drawn from a uniform distribution $F : [\underline{v}, 1] \rightarrow [0, 1]$, the same for all candidates. v_i may include innate ability, and variables determined before the beginning of the academic career, such as the place of study. It seems natural to assume that, within the research area, the draws for different individuals are not correlated, which makes their interaction a private value auction. The parameter v_i is private information, and therefore it is conveniently captured by the individual fixed effect in the empirical analysis.

If candidate i exerts effort $b_i \in \mathcal{B} \subseteq \mathbb{R}_+$, then she incurs a utility cost given by b_i/v_i . Being inversely related to the utility cost of effort, v_i is therefore a measure of individual i 's *efficiency* in research, which we refer to as individual i 's *productivity*. The benefit of being promoted is normalised to 1, and we assume that candidate i chooses b_i to maximise the difference between the expected benefit and the cost of effort. A strategy for candidate i is thus a function $B : [\underline{v}, 1] \rightarrow \mathcal{B}$, which associates the type v_i to b_i , the effort level exerted.

Effort may be directed towards a variety of academic activities, only one of which is publications

in international refereed journals. A person's chance of promotion may depend also on more subjectively assessed activities, such as teaching, the influence of books published, administration, and perhaps also seeking out influential friends and networks, as it might cross the readers' mind who are familiar with Italian academia. The relative importance of international publications and these other activities, denoted by $x \in [0, 1]$, may vary from research area to research area. In general terms, it depends on the preferences and the relative clout of the members of the cohort of senior professors in the various research areas, among whom the panel will be chosen.² The competitive conditions faced by those vying for promotion also affect their behaviour. We capture them with the parameters K and N , defined above as the number of posts and the number of candidates.

The analysis in Checchi et al (2014) can be summarised in the following result.

Proposition 1. *The optimal strategy for candidate of type i is to exert effort level given by:*

$$B(v_i) = x \int_v^{v_i} y Z'_{KN}(y) dy, \quad (1)$$

where

$$Z_{KN}(b) = \sum_{j=N-K}^{N-1} \frac{(N-1)!}{(N-j-1)!j!} F(V(b))^j (1 - F(V(b)))^{N-j-1}. \quad (2)$$

The proof is in Barut et al's (2002, p 679); the online Appendix A details the changes to adapt it to the present set-up. In (2), $Z'_{KN}(b)$ is the derivative of the function $Z_{KN}(b)$, and $V(b)$ is the inverse of the function B , which associates bids to types. Existence of the inverse follows from monotonicity, the argument for which is standard. The function $Z_{KN}(b)$ is the probability that a candidate who exerts effort b is successful when there are N posts and K competitors, when all *other* candidates follow the bidding function $B(v_i)$ given in (1), and when the distribution of types is $F(v)$.

If $Z'_{KN}(b)$ did not vary with x , then the effort exerted by each candidate type would be proportional to x , the coefficient of proportionality given by a function of the competitive conditions. But because x appears in $V(b)$, then (1) and (2) determine an algebraically complex relationship

between the effort b and the parameters x , K , and N . To understand how this relationship changes in response to changes in exogenous conditions, we compute it for specific values of the parameters.

[insert Figure 1 about here]

We do so in Figure 1, which plots the equilibrium effort level (1), and in Figure 2, which shows how it changes following changes in x , K , and N . In both figures, which are drawn in the special case when the density is constant and so given by $\frac{1}{1-v}$ for $z \in [v, 1]$, the horizontal axis shows an academic's type $v \in [v, 1]$, when $v = 0.15$. In Figure 1, the vertical axis measures the effort exerted as a function of the academic's type, and the parameters are chosen to be close to their average values in the sample, given below in Table 2, $N = 150$, $K = 25$, $x = 0.6$. The solid curve shows the effort level obtained from Proposition (2); ignore for the time the dashed curves. In Figure 2, the vertical axis shows the *change* in the effort exerted by a type v_i academic as a consequence of an exogenous change in one of the parameters, as explained in the caption to the figure. The parameters are the same as in Figure 1, with N increasing as the line becomes thicker from a very low $N = 33$, to $N = 80$, to the sample value shown as the thickest one at $N = 150$.

[insert Figure 2 about here]

Note first of all the striking non-linearity of all the curves; academics of different types respond very differently to changes in exogenous conditions. We design our estimation strategy to capture these differences, as we explain in Section 5. The effect of changes of the importance of publications in the determination of the winners, given by an increase in x , is illustrated in the LHS panel of Figure 2. All types increase their effort, with the effect varying considerably according to the academic's type: productive types respond more strongly, and the range of types who respond strongly depends on the degree of competition. When competition is tough (high N , thick line, long dashes), the increase in effort is concentrated among the most productive types. As competition decreases, more academics increase their effort, though the increase flattens out for the most productive academics, so that the proportional increase in effort is highest for intermediate types. These are testable predictions.

In the other two panels, we show the effect of changes in the competitive conditions. In the middle panel, a decrease in the number of posts; and in the RHS panel an increase in the number of competitors. Not surprisingly, these two figures are similar. We can see that an increase in competition, a lower value of K or a higher value of N , decreases effort, except for productive academics when competition is relatively low to begin with, see the thin solid lines in the middle and the RHS figures. The effect, however, is not evenly distributed: there is a middle range of types who respond more strongly, by reducing more their effort in the face of stiffer competition. This middle range itself shifts towards more productive types when competition increases, compare the troughs as the line becomes thicker, indicating stiffer competition. Also note how, when competition is low enough, productive types *increase* their effort in response to an increase in competition, as the thinner curves show in the middle and the RHS panels.

Upon reflection, these comparative statics effects are intuitive. There are N competitors for K posts. For all types, an increase in effort increases the likelihood of gaining a position in the order. But the change in the cost-benefit balance of a decrease in competition is different for different types, and this generates different responses to change in the exogenous conditions. The reason is that the only gain that matters is being K -th instead of $(K + 1)$ -th: in any other position in the ranking – whether above or below the threshold –, the higher likelihood of improving one’s ranking is wasted effort. The incentive of an extra post is highest for those who are more likely to be at the $(K + 1)$ -th position: since productive types are typically found high up in the ranking, they will be around the threshold position only if many of their competitors have also drawn a very productive type, the chance of which is low, and so they do not change effort much. By the same token, the least productive academics exert very little effort to begin with and so are quite below the $(K + 1)$ -th position, and the encouragement effect of the higher chance of winning is very small. Middle types are instead much more likely to be around the “borderline” position, where gaining one place in the ranking is the difference between being promoted and not being promoted, making their effort more likely to be useful and so increasing it in equilibrium as competition becomes softer.³

We end this section by collecting the results illustrated in this discussion of Figures 1 and 2 into a formally stated conjecture, which constitutes the basis for our econometric strategy.

Conjecture 1. *(i) An increase in the importance of publications increases effort; the strength of the effect increases for more productive academics, but at a decreasing rate for very productive academics. (ii) An increase in competition decreases effort for less productive academics. (iii) This effect is strongest for academics with an intermediate value of the productivity parameter, and this intermediate range of types is shifted to the left when competition is weaker. (iv) Productive academics exert more effort as a consequence of an increase in competition, unless competition is high.*

3 From the theory to the data

The theoretical analysis gives a number of predictions on the effort exerted by candidates to improve performance in a given dimension as a function of a number of observable variables: the importance of the observable dimension of output for promotion, which is given by the variable x , the competitiveness of the sector, determined by the variables K and N , the legal environment which shapes the incentive mechanism, and the distribution of types of the potential applicants for promotion.

Proposition 1 above shows that the effort exerted by academics is a strictly increasing function of their type, given by the parameter measuring their utility cost of effort. However, neither type nor effort are observable directly in the data we have. We use the immediate consequence of Proposition 1 that in turn output is a strictly increasing function of effort, and the lack of an independent measure of effort, to posit the normalisation that one “unit” of effort produces precisely one unit of output.⁴ That is, we proxy effort with output, and we use this proxy for effort as the dependent variable in our econometric strategy. This will therefore be based on the following equation:

$$o_{its} = \alpha_0 + \alpha_x x_{ts} + \alpha_K K_{ts} + \alpha_N N_{ts} + \alpha_h h_{its} + \gamma_C C_{ts} + f_i + \xi_t + \sigma_s + \zeta_u + \varepsilon_{its}. \quad (3)$$

In (3), o_{ist} is the output of academic i , who, in period t , is in scientific sector s . x_{ts} , K_{ts} , and N_{ts} are (functions) of the importance of publications, the number of posts, and the number of competitors in scientific sector s in period t . We measure the importance of publications with the *index of orderliness* in the past promotions in the scientific sector. This is an index which gauges the adherence of a selection from a set to an objective metric of the elements of that set (Checchi et al 2018). Section C.2, in the online appendix, explains precisely how we constructed these variables from the data, which in turn is described in detail in the rest of this section. h_{its} is a vector of two homonymy dummies, constructed in online Appendix C.2.6, to reduce the measurement error due to misattribution of paper written by academics with the same name, and C_{ts} is a vector of time varying controls: the share of women, the average age of the competitors, and the share of the appointments from outside Italian academia. The fixed effects included in (3) account for unobserved differences among individuals, f_i , periods, ξ_t , scientific sectors, σ_s , and universities, ζ_u .

Our data comes from three sources, one collecting individuals, one their journal publications, and the third the outlets where these appear. Information on individuals is the administrative data from the Italian Ministry of Education, University and Research (MIUR). The data contains information on everyone who held an academic position in Italian universities, public or private,⁵ 81,399 individuals in total. For every year from 1990 to 2011, it reports everyone's age and sex, their scientific sector, their university affiliation, and their academic rank. With a handful of exceptions, every person in the dataset has one of three ranks: assistant professor (*ricercatore*), associate professor, and full professor (*professore di seconda* and *di prima fascia*, respectively). A change in a person's rank from one year to the next implies a promotion in the intervening year. Table 1 presents two snapshots of the aggregate faculty in Italian universities, at the beginning and at the end of the period we study. Table A5 in the appendix breaks down this aggregate picture by broad disciplinary area, and throughout the period.

Once appointed, academics are tenured after a brief probation period. Some individuals exit the system before then; if they do so to pursue outside work opportunities, such as a career in a foreign

university, then they may face different incentives from those provided by the promotion process considered here, embodied in the three variables K , N , and x . However, as we explained in detail in Section C.5 in the online appendix, early exit is a rare event for assistants and associate professors, whose effort we aim to explain.

At any given moment, each academic is allocated to one – and only one – of 371 “scientific sectors” (*settore scientifico disciplinare*), strictly separated from each other and created at central level. There was no requirement that all members of a faculty or of a department had to belong to the same scientific sector, and it was not uncommon for a professor in a scientific sector to be in a faculty not closely related to her research interests. These sectors are very important for career progression, as appointments, promotions, and all other evaluations are carried out within each scientific sector. For example, if it is decided that a professor in scientific sector SECS/P02 should be appointed at the University of Bologna, then the appointment panel for this post will be composed exclusively of professors from the same sector.⁶ These scientific sectors are fairly small, their average number of full professors is 43, the standard deviation is 46, and the size distribution is skewed, see Figure A4 in the online appendix.⁷ They are very stable in composition: in the period we consider, only 1,504 assistant professor and 930 associate professors, respectively 3% and 2.4% of the total, change scientific sector either before or upon promotion; more detailed data is in Table A5 in the appendix. Their small size and the stability of their composition make each scientific sector a “small world” where everyone knows everyone else, and suggests that our assumption is not far-fetched that candidates are able to form an accurate assessment of the preferences of the likely membership of the appointment panels. Even though in the 1990s universities were given some managerial and financial autonomy, university professors maintained their status of public employees: pay scales⁸ and career progress were uniform across the country, mechanically determined on the basis of seniority and age, and no merit pay was possible.

Academics had to be hired through public “competitions”, with rigid and uniform rules. All new posts for full and associate professors were authorised by the government, and advertised

simultaneously in all subject areas for all universities in the country; assistant professor positions were filled with a local interview process analogous to the US and UK. Up to the end of the 90s, academics seeking to be promoted made a single application, valid for all posts; this rule changed at the end of the century, as we explain below, in Section 4.3. These national calls happened at approximately four yearly intervals. We have therefore divided out whole period into five subperiods instead of the calendar years, as illustrated by Table A1; see also . In theory, anybody could apply, though in practice potential applicants were academics in the lower rank in the same scientific sector, plus some from similar scientific sectors, and people from outside the Italian university system. Horizontal moves were not possible.

The government also appointed the selection committees for these posts, one each for the 371 scientific sectors. Selection committees choose all the appointees in their scientific sector,⁹ in number equal to the number of posts. They did not, however, specify which academic would go to which institution: this was left to subsequent negotiations between “winners” and institutions.¹⁰ These panels had considerable discretion in establishing criteria for promotion, in the spirit of the self-regulating academia, including the relative importance of outputs and activities such as teaching and contribution to the institution and to the wider society.

In the set-up of the model, it is important to note that there were no “internal” promotions. Someone who had been in post as associate professor in a university had to wait for a full professor post to be advertised, and then apply to the national competition like everyone else. Universities simply did not have the legal authority to sanction a change of rank. This changed at the end of 2010, when another major reform (Law n. 240) introduced a separate channel for internal promotion, making our model less applicable: for this reason, our analysis of career progression ends then.

The second data source is the record of research publications by Italian academics. We have obtained it from the web-version of the Thomson Reuters Web of Knowledge (formerly ISI, WoK hereafter).¹¹ This proprietary dataset indexes more than 12,000 journals in the fields of arts, humanities, sciences and social sciences.¹² For each article, the dataset reports the title, each author’s

surname and first initial, their affiliations, the journal where it appears, and the number of times it is cited by a WoK indexed publication. From this dataset, we have downloaded every article published in the period 1990-2011 where at least one author listed an Italian institution among their affiliations. This harvest yielded almost two million publications, which required a considerable amount of “cleaning” work, described in greater detail in Verzillo (2013). It seems plausible that in some scientific sectors publications in journals not included in the WoK, for example Italian journals, might be important from a career viewpoint. By not accounting formally for publications in non-WoK journals, we implicitly include them in a person’s other academic activities.

We have linked this dataset to the Journal Citation Report, also from Thomson Reuters, our third source of data. This allowed us to attach to every journal its impact factor, as well as the research areas where each journal belongs. Details of the procedure we followed are in Section C.2.7 in the appendix. After cleaning the dataset, we are left with 1,142,971 papers.

To sum up, we run two separate regressions of (various versions of) equation (3), one for assistant professors trying to become associate, the other for associate professors trying to become full professor. While we have the universe of the academics working in Italy in the period, not all enter both regressions. Section C.1 in the appendix reports details of the number of promotions and appointments, and explains in detail why some individuals are excluded. Table 2 reports the summary statistics for the final sample we used to obtain our results.

[insert Table 2 about here]

4 Empirical strategy

4.1 Dealing with sorting by scientific sector, I: Orderliness

The large number of scientific sectors is crucial to our empirical strategy, as it lends plausibility to the assumption that candidates can reliably predict the importance which their appointment and promotion panels will attribute to publications in refereed journals; as mentioned above and explained in detail in Section C.2.3, we measure this importance with Checchi et al’s (2018) index

of orderliness. There remains however a potential endogeneity issue in the allocation of academics to scientific sectors. With many narrowly defined scientific sectors, it is possible that academics may self-select into different scientific sectors within the same research area: thus candidates and panellists would share the same attitude towards the relative importance of publications and other activities. For example, if biologists with a comparative advantage in publishing in refereed journals all opt for a given scientific sector within biology, and the others opt instead for a different one, then the correlation between individual productivity and selection criteria would be a spurious one, generated by the correlation of both variables with the unobservable comparative advantage for publishing in refereed journals in both sets of agents, the panel members and the applicants. The large number of scientific sectors, and the variability of the index x within broad research area (as shown by Figure A2 in the online appendix) makes this a potential problem, as it is clearly relatively easy for an academic to choose the scientific sector within their broad area.

To deal with this problem, we instrument the index of orderliness with two variables which capture the degree of homogeneity of the leadership of a scientific sector, the set of full professors from where the membership of the panel will be chosen. These variables are the standard deviation of the research output of the full professors, and the number of associate and assistant professors per full professor in the sector.¹³ The idea is inspired by the more objective nature of a publication count, which may serve as a default option should the leadership of the scientific sector fail to determine a less objective criterion. Thus a large group of full professors with different publication records may find it more difficult to agree on a subjective criterion, be it the quality of teaching or the extent of the engagement with the wider society, than a smaller group of academics with similar balance between publications and other academic activities.

4.2 Dealing with sorting by scientific sector, II: Competitiveness

By the same token, having small scientific sector within which competition is channelled certainly improves academics' precision in assessing both N and K , the likely number of academics who will

be competing and the likely number of posts competed over. These magnitudes can be reasonably linked to the number of young and old academics, the former affecting the number of applicants for future jobs, and the latter the future pattern of retirements and hence the number of jobs. And as with the importance of publications in refereed journals, smaller scientific sectors exacerbate the peril of academics within a broad research area sorting according to their comparative advantage into sectors with different values of N and K . To deal with this potential spurious correlation between N or K and the academics' individual characteristics which might emerge if academics sorted themselves into different scientific sectors within their broad research area, we exploit a change in an important detail in the nature of the appointment process.

The centralised mechanism regulating promotions and appointments in Italian universities, described briefly in Section 3, and in more detail in Section B.1 in the online appendix, was radically changed with a reform at the end of the 1990s. The reform came into force towards the end of 1999. The main thrust of the reform was to decentralise the appointment process, making it closer to the US and UK model. When an institution received funding to fill a post in a given scientific sector, before the reform it could only choose from the closed list of the winners of the national competition, which it had had no input in. After the reform, a national panel would be formed, whose task it was to appoint to that institution's specific post.¹⁴

A second aspect of the reform can potentially affect the equilibrium effort level derived theoretically in Section 2. Aside from the switch from national to local competition, the law introduced the restriction that the number of applications that a candidate could submit in each year could not exceed five. The rationale behind this rule was to reduce the workload for appointment committees, by limiting the number of applications to a given post. While the decentralisation affected all academics equally, this second aspect of the reform affected different academics differently. This is so because all academics faced the same cap of five applications per year, but the number of new post varied widely by scientific sector, since it depended not only on the size of the scientific sector, which itself varied widely as we showed in footnote 7, but also to esoteric unknowables such as the

pattern of relative clouts of each scientific sector within the faculties in the universities where funds for appointments within the period were allocated.¹⁵ If at the start of their career academics could reasonably anticipate the future trend in the number of posts and competitors in the various scientific sectors, and perhaps even the possibility of a decentralisation in the appointment process in line with international practice, few could have predicted a rule imposing a cap on applications, let alone one of unpredictable tightness. This makes the tightness of the post-reform constraint as good as random, and creates a convenient quasi-experimental environment, one which can address the potential problem of academics self-sorting into sectors according to their different competitive conditions. Appendix E.3 suggests that, indeed, whether or not the constraint was tight was not correlated with the pre-reform output.

We capture empirically the role of this constraint on different individuals, by creating a variable *R*, “Constraints on applications”, which is obtained by counting the number of posts filled in each post-reform year in each scientific sector, attributing a score of 0, 1, 2 according to whether the number of posts filled in that year is less than 5, between 5 and 12, and more than 12, respectively.¹⁶ This variable is set to zero before 1999. As with homonymy, making the variable categorical indicates low, medium, and high likelihood of the constraint binding, reflecting our inability exactly to determine whether the constraint is in fact binding at the time of a person’s promotion, due to erratic time lags between the opening of a vacancy and its filling.

[insert Table 3 about here]

The potential role of this detail of the reform can be gleaned from Table 3. The four top left cells in each half of the table show the average output (in log) of assistant and associate professors, relative to the output of full professors in their discipline. Academics in each group are divided into two sets according to a threshold value of a variable that measures how tight the constraint on the number of application is in their scientific sector. Both groups increase their output after the reform, but the professors who were constrained by the limit of the number of applications, in both samples,

increase their output by less than those who were less constrained. The values in Table 3 are raw population averages; a more formal analysis is in Appendix E.3, where we show that the pre-reform output trend is uncorrelated to the tightness of the constraint. Neither Table 3 nor Appendix E.3 consider the non-linearities highlighted in Section 2, which suggest that different academics respond differently to changes in conditions. We take them into account in our regression specification (7).

4.3 The 1999 reform in theory

A formal theoretical analysis is needed to unravel the overall effect, and to guide the empirical work. We therefore begin by adapting Proposition 1 to the rules set by the new law. We consider the decentralisation first. The rules allowed different panels in the same scientific sector to make their selection according to different criteria, and anecdotal evidence suggests that they did so. We capture this by assuming that when there are K posts available, there are also K different panels, each assigning one post, and by interpreting x as the probability that each of these panels appoints on the basis of the ranking determined by the publications in refereed journals. Thus, with probability x^K all posts are assigned on the basis of publications alone, with probability $Kx^{K-1}(1-x)$ all but one are, with probability $\frac{K!}{2!(K-2)!}x^{K-2}(1-x)^2$ all but two are, and so on, until, with probability $(1-x)^K$, none is.¹⁷ This changes the link between a candidate's effort and her probability of winning, and so, for given K , N , and x , her payoff and thus her incentive to exert effort is different in the post-reform environment.

The cap on the number of applications that a candidate can make in each year can be modelled formally as follows. Consider one of N candidate competing for K posts, and let M be the limit to the number of positions that each candidate could apply for in a year. When $K > M$, the game is richer than that studied in Section 2, because the candidates who face a constraint choose, in addition to effort, which of the posts to apply for. As before, there are no entry costs, so it is payoff maximising for every candidate to enter as many competitions as allowed, and each candidate therefore applies for $\hat{K} = \min\{K, M\}$ positions. Appendix B.2 shows that at any subgame perfect equilibrium of

the game, the expected number of candidates in each competition is $\widehat{N} = N \min \left\{ \frac{M}{K}, 1 \right\}$.

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We can now extend Proposition 1 to the post-reform environment.

Proposition 2. *When K separate “local” panels appoint to the K posts, and candidates can apply to at most M posts, the optimal strategy for each of the N candidates is to exert effort towards publishing in refereed journals given by*

$$B(v_i) = \frac{\sum_{k=0}^{\widehat{K}-1} \binom{\widehat{K}}{k} x^{\widehat{K}-k} (1-x)^k \int_{\underline{v}}^{v_i} y Z'_{\widehat{K}-k, \widehat{N}-k}(y) dy}{\sum_{k=0}^{\widehat{K}-1} \binom{\widehat{K}}{k} (1-x)^{\widehat{K}-k} x^k}, \quad (4)$$

where $Z_{KN}(v)$ is defined above in (2), and $\widehat{K} = \min \{K, M\}$, and $\widehat{N} = N \min \left\{ \frac{M}{K}, 1 \right\}$.¹⁹

Figure 1 in Section 2 illustrates the effect of the reform on effort. The black solid line is the pre-reform level of effort, as explained above. The two additional dotted lines depict the post-reform effort levels when the restriction on the number of applications is not binding (the dash-dotted line) and when this restriction is binding (the dotted line). Comparing these curves to the pre-reform solid line show that more productive academics exert less effort following the reform: the negative effect on effort of the switch to local competition is reinforced by the cap on applications. The less productive academics, on the other hand, exert more effort after the reform when they are registered in a sector where the cap on the number of applications is binding. Recall that whether this cap was binding in a period depends not only on the size of the scientific sector, but also on the pattern of appointments in the different institutions and scientific sectors.

As in Section 2, we can collect the testable implications described above in a formally stated conjecture. Recall that we have postulated a one-to-one relationship between effort and output.

Conjecture 2. *(i) Ceteris paribus, more productive academics reduce effort after the reform. (ii) Academics with a lower value of the productivity parameter exert more effort following the reform if they are in a scientific sector where the cap on the number of applications is binding.*

5 Preliminary results and econometric specification

As we anticipated at the end of Section 3, we estimate our model on two unbalanced panels, one comprising assistant professors aiming to become associate, the other associate professors aiming to become full professor. The panel structure allows us to control for the influence on effort of individual characteristics with the individual fixed effects. Although we have yearly observations both for promotions and for output, it is preferable to choose, for the time dimension of the panel, a longer interval. As we explained, prior to the 1999 reform, all the appointments in each scientific sector in a funding cycle happened at the same time. Moreover, ministerial funding for new professorial posts was not staggered across scientific sectors, so that the pattern of appointments shows distinct peaks: the overwhelming majority of the appointees began working in the same year, a different year of each cycle for associate and full professors. While individual appointments within a scientific sector were no longer necessarily simultaneous after the 1999 reform, in practice the funding cycle did not change under the new rules: all posts, for all scientific sectors, were advertised simultaneously, and the thousands of appointment panels worked in parallel. Thus the highly uneven pattern of appointments continued after 2000. Given this dramatic bunching, it seems preferable to smooth it out by aggregating several years into one period, which therefore constitutes the time unit of our panel. The four year length of a period is a very close approximation to the temporal pattern of appointments, and leads to the aggregation into five periods presented in Figure A1.²⁰ A longer time unit than one year also reflects the gap between the exertion of effort and the publication of the output resulting from that effort. A separate concern could be the existence of a link, for example one created by policy, between productivity and the number of new posts. As Appendix E.4 argues, there is no discernible pattern suggesting that K and N are determined by the natural pattern of promotions, retirements, and change in the sectoral student numbers.

To sum up, at the beginning of each period, candidates form beliefs about the conditions which will be in force at the time the decision on their application for promotion is made, described by

the parameters, x_{ts} , K_{ts} , N_{ts} , and R_{ts} , the importance of publications for promotion, the number of posts, the number of competitors, and, from period 3, the tightness of the constraint in period t and in scientific sector s . These variables have of course the same values for all individuals in the same rank within a scientific sector in each period, and vary by scientific sector and by period. Given these beliefs, the candidates choose how much effort to exert towards publications relative to effort towards other activities. Effort determines publications, which are the individual's output in that period. At the end of the period, the appointment panel assess the candidates. After 1999, the candidates also choose which local competitions they entered. Thus our panel dataset has "professor-period" as the unit of observation; it is unbalanced, as some professors are only present in some periods.

We incorporate the discussion at the end of in Section 4 and take into account the possible presence of constraints on the number of applications, by replacing, in the periods following the reform, the parameters K and N with \hat{K} and \hat{N} , defined in Proposition 2. As explained above, we do not know the precise number of applications allowed to each individual in each period, and we therefore replace \hat{N}_{ts} with $N_{ts} + \lambda R_{ts}$, where R_{ts} is the variable that measures the intensity of the reform in sector s in period t . The first three coefficients of (3) and the interaction of the number of competitors with the variable R , which measures the strength of the constraint are obtained as panel estimations for the two groups of professors we consider, assistant and associate. The estimates are reported below, with the standard errors below the coefficients, and the stars denoting the usual significance thresholds.

$$o_{its} = \alpha_0 + \underset{0.011}{.045^{***}} x_{ts} - \underset{0.004}{0.013^{***}} K_{ts} + \left(\underset{0.027}{0.171^{***}} - \underset{0.002}{0.01^{***}} R_{ts} \right) N_{ts} + \gamma_C C_{ts} + \varepsilon_{itsu}, \quad (5)$$

$$o_{its} = \alpha_0 + \underset{0.01}{.01} x_{ts} + \underset{0.004}{0.014^{***}} K_{ts} + \left(\underset{0.019}{0.035^*} - \underset{0.001}{0.006^{***}} R_{ts} \right) N_{ts} + \gamma_C C_{ts} + \varepsilon_{itsu}, \quad (6)$$

where the fixed effects are all included in the error term. The estimated equations (5), for assistant professors, and (6), for associate professors, show the anticipated signs for x_{ts} and $R_{ts}N_{ts}$, though the former is not statistically significant for associate professors.

The estimates reported above calculate the *average* effect on effort, and thus inevitably neglect the strongly non-linear relationship between an academic’s position in the distribution of types in her scientific sector, and her responses to changes in the parameters which we established in the theoretical analysis. To account for these non-linearities, we divide the sample into groups of professors of similar type. Formally, let \mathcal{Q} be a partition of the set of professors in sector s in period t , and for $q \in \mathcal{Q}$, let $\delta_{its}^q = 1$ if individual i is in the subset $q \in \mathcal{Q}$ in period t , and $\delta_{its}^q = 0$ otherwise. That is, we attach to each individual the percentile of her position, in each period, in the ordering of the academics in her rank. Since \mathcal{Q} is a partition, $\sum_{q \in \mathcal{Q}} \delta_{its}^q = 1$. We then run four separate regressions for both sets of individuals: each using as sample only the professors for whom $\delta_{its}^q = 1$, $q = 1, \dots, 4$, that is those in the same interval of the type distribution in their respective scientific sector.

The results of this exercise are presented in the first two columns of Table 4. These OLS regressions are pooled, because a panel estimation would lead to the academics who change interval from one period to the next to be dropped from the regression samples of both intervals: not only almost one third of the observations would be lost, but the omitted academics are likely to be those most responsive to the conditions in their environment. While the results are consistent with the theoretical analysis and with the results in (5) and (6), in the rest of the analysis, in order to make the most of the panel structure of the dataset, we prefer to resort to a different technique to capture the potential non-linearities: this is to interact the four variables of interest, x_{ts} , K_{ts} , N_{ts} , and R_{ts} , with the ranking dummies δ_{its}^q . We use this technique, in alternative to quantile regression, because the theoretical analysis, where the function F appears in the equilibrium level of effort (1), links a person’s effort to her position in the distribution *within* her scientific sector, not in the entire sample. That is, what matters is not her absolute “type”, but the position of her type in the distribution of her competitors’ types. Thus for example two individuals in different scientific sectors s and s' may exert the same effort, and hence obtain the same output, and they would be placed in the same quantile with a standard quantile regression. However, if one is in the top decile of the types in

her scientific sector (her $\delta_{its}^{q_{10}} = 1$), and the other in the sixth decile of hers (she has $\delta_{its'}^{q_6} = 1$), the theoretical analysis of Section 2 says that these individuals would respond differently to, for example, the same increase in the number of competitors: empirically, this would be reflected in α_{10K} being different from α_{6K} in (7) below. To reflect these non-linearities, we therefore replace (3) with

$$o_{its} = \alpha_0 + \sum_{q \in \mathcal{Q}} \delta_{its}^q \left(\alpha_{qx} x_{ts} + \alpha_{qK} K_{ts} + \alpha_{qN} (N_{ts} + \lambda_q R_{ts}) \right) + \gamma_C C_{ts} + f_i + \xi_t + \sigma_s + \zeta_u + \varepsilon_{its}. \quad (7)$$

Equation (7) is our main specification: all the variables are defined just after (3). In (7), the estimates of the coefficients α_{qx} , α_{qK} , and α_{qN} measure the effect of x , K , and N on the effort of an academic in the q -th element of the partition of the professors of her rank in her scientific sector; $\alpha_{qR} = \alpha_{qN} \lambda_q$ is the additional effect of the constraint on applications introduced by the reform.²¹

6 Main results

Our main results are in Table 4. Our base specification is in the third and fourth columns, which report the coefficients for the two regressions: assistant professors intending to become associate, and associate professors intending to become full professors. These are obtained from the estimation of (7) with the natural log for the variables K and N . Individual output is weighted with the number of co-authors. The clustering of the standard errors is by scientific sector, the level of the main independent variables.²² We run two versions of the main regression, which differ in \mathcal{Q} , the partition of the academics in their scientific sector. Specifically, ordering the N_{st} academics in scientific sector s in period t from the least to the most productive, Table 4 is built using the partition

$$\mathcal{Q} = \left\{ \left(0, \frac{N_{st}}{2} \right], \left(\frac{N_{st}}{2}, \frac{7N_{st}}{10} \right], \left(\frac{7N_{st}}{10}, \frac{9N_{st}}{10} \right], \left(\frac{9N_{st}}{10}, N_{st} \right] \right\}. \quad (8)$$

Instead, we drew Figures 3 and 4 using the results of the regressions based on the partition

$$\mathcal{Q} = \left\{ \left(\frac{(j-1)N_{st}}{10}, \frac{jN_{st}}{10} \right] \right\}_{j=1, \dots, 10}. \quad (9)$$

Thus, for Table 4 we consider four unequally sized groups, those separated by the median, the seventh, and ninth decile. Instead, Figures 3 and 4 are obtained dividing the academics in each scientific sector into ten identical intervals.²³ The reason we use (8) for the table with four groups is help the presentation by having fewer coefficients; we chose unequal sizes for the groups, rather than quartiles, because, as predicted in the theory section and indeed confirmed by Figures 3 and 4, the estimated coefficient are very similar for the types below the median. Comparison of Table 4 and Figures 3 and 4 suggests that the loss of information in the table is limited.

[insert Table 4 and Figure 3 about here]

In detail, Table 4 is organised as blocks of estimated coefficients, one block for each of our variables of interest, (i) the importance of publications in WoK journals, the index of orderliness x , (ii) the log of the number of posts available in the sector, (iii) the log of the number of competitors, and (iv) the additional effect on the 1999 reform measured via the reduction of the number of competitors. Within each block, the four coefficients are the effect of a change in the variable on individuals in different position in the ranking of their scientific sector. Thus the first coefficient is the effect on an academic's output of a change in the orderliness of scientific sector of an academic whose output places her below the median in a given period. And so on for the other coefficients: the second row is the value for individuals whose output is between the median and the seventh decile, the third row for those between deciles seven and nine, and the last row for the top academics, those with output above the ninth decile of the distribution in their scientific sector, in the given period.

In Figures 3 and 4, the horizontal axis is the (inverse) rank of the academic's type in her scientific sector, and the corresponding ordinate measures the effect of a change in the exogenous variable on the output of the academics with that rank. The dashed lines are the 95% confidence interval around the coefficient; we do not shown them in the LHS of Figure 4, to avoid clogging it. This figure shows, as dashed lines, the effect of N alone, that is the effect for those academics for whom the constraint is always slack, $R_{ts} = 0$ for every t , post-reform as well as pre-reform. The solid line is the sum of the coefficients in the third and in the fourth blocks, for N and $N \times R$, that is α_{qN}

and α_{qR} respectively, calculated when R is 2, its maximum possible value. The vertical intercept of the solid line is therefore the effect of a change in the number of competitors on the effort of an academic in a scientific sector where the post-reform constraint on the number of applications is binding whenever she may apply for promotion.

The main qualitative features are the same in the third and fourth columns and in Figures 3 and 4. For both sets of academics, an increase in orderliness increases effort for productive individuals, as predicted by Conjecture 1.(i), derived from the LHS panel of Figure 2, and reduces effort for less productive ones. An increase in competition, whether achieved via a reduction in the number of posts, K , the second block of coefficients, or via an increase in the number of potential applicants, N , the third block, increases effort of high types and reduces effort for high cost types, in line with Conjecture 1.(ii)-1.(iv). One exception to this concordance with the theory given by the assistant professors below the median, who appear to increase marginally their output. Notice also that the differences in response between assistant and associate professors, such as the former being more responsive to an increase in the importance of international publications as selection criterion, may be explained by the fact that the extent of competition differs in the two sectors, and, as Figure 2 shows, relatively small changes in competition may cause large changes in response. The position of the two curves and the coefficients in the first row of Table 4 (the first two columns excepted) suggest an effect not predicted by the theoretical model, a discouragement for the least productive academics: they seem to respond to an increase in orderliness with a *reduction* in their effort.²⁴ Panel (a) on the LHS of Figure 4 also illustrates a result neatly in line with the prediction of the theoretical model: productive (less productive) academics who are constrained in the number of applications they can make respond to increases in the competitiveness of their environment more weakly (more strongly) than their unconstrained colleagues, as predicted by Conjecture 2.(i).

[insert Figure 4 about here]

To get a handle on the quantitative significance of our results, consider the main regressions in Table 4, third and fourth column. Suppose the index of orderliness for promotion to associate

of increased by one standard deviation in the average scientific sector, from 0.6 to 0.73. This would determine an increase in output of 3%, 4.4%, and 9% for an assistant professor whose output is between the median and the seventh decile, between the seventh and the ninth decile, and one whose output is in the top 10% among her peers, respectively. It would however *reduce* by 2.5% the output of an assistant professor whose output is below the median. All these are percentages of the average output of the full professors in the sector. Overall, there are 165 assistant professors in the average sector, and so their aggregate output would increase by $(0.09 \times 0.1 + (0.044 + 0.03) \times 0.2 - 0.025 \times 0.5) \times 165 = 0.98$. That is, the increase in the importance of international publications would thus increase the number of papers written by the assistant professors in the sector by an amount almost equal to the output of a full professor. Similarly, and more specifically, suppose the number of posts for full professor in economics were reduced by 1 (0.92%) in the third period: then similar calculations would predict that this increase in competition would increase the number of papers produced by the economics associate professors by $(0.17 \times 0.1 + (0.019 - 0.012) \times 0.2 - 0.035 \times 0.5) \times 331 \times 1.48 = 7.05$ papers per year, as the average number of paper written by full professors in the sector in the third period is 1.48.

In the next two columns of Table 4, the fifth and the sixth, we report the results of the instrumental variable estimation, using the “homogeneity” of the full professors as instruments for the orderliness index x . As we explain in Section 4.1, this homogeneity is proxied by the standard deviation of the output of the full professors, and by their number relative to the number of assistant and associate professors. Using only the former changes the result only by a small amount, the signs and the order of magnitudes of the coefficients are very close. Comparison of the corresponding columns suggests that the qualitative nature of the results is mostly unchanged relative to the OLS. Some coefficients do change sign, in particular those determining the “competition” variables, K , and N . Recall however we showed in the theoretical analysis (Section 2 and in particular Figure 2) that these variables have been shown to have potentially different effects according to the values of the other parameters. On the other hand, the effect of the orderliness and the effect of the reform on effort,

which are unambiguously signed in the theoretical analysis, are qualitatively similar in columns 3 and 5 and in columns 4 and 6 of Table 4, as the first and the last blocks of coefficients show. The results of the first stage regression are reported in Table A12 of the online appendix.²⁵

In the rest of Table 4 we report some robustness checks; these confirm that the main results change little with the details of the econometric specification chosen, and suggest some interesting considerations. The seventh and eighth columns in the table show the coefficient when the output is measured as the number of papers published in WoK weighted by the position of the journal in the impact factor ordering of journals for that research area according to the impact factor.²⁶ The coefficients are qualitatively very similar to those reported in the first two columns. Together with the high correlation between these measures of output and other plausible ones with different weights for authors and importance of the outlet, these two columns suggest that our results are robust to changes to the way output is measured.

Appointment committees are free to choose the criteria to apply in choosing whom to appoint. We have so far postulated that candidates, when assessing the orderliness of past decision making of these committees, assume that they have ranked the candidates according to the output of those candidates in the period where the appointments take place: that is, they base their decisions on the candidates recent record. On the other hand, the candidates might instead believe that the committees choose to rank individuals according to their entire careers. In this case the position of a candidate might be different, and given that the position of a candidate in the ranking of their scientific sector determines their effort, so would potentially be the effort. In the ninth and tenth columns of Table 4, we therefore report the coefficients estimated when an academic's ranking in their scientific sector is determined by their lifetime achievement, not just the most recent period. These regressions are similar to our base regressions, reported in the third and fourth columns. There are some differences in the coefficients for the parameters measuring competition, K and N , but those for the effect of the reform and the importance of publication do not vary qualitatively, with one important exception. Individuals in the top decile do not appear to increase their effort. This tallies somehow with Figure 1

and the LHS panel of Figure 2, which shows that the response to a change in orderliness tends to become constant for the most productive academics, and therefore lower as a proportion of output. Intuitively, we can think of an academic who, having hit a good number of prestigious outlets in the past, needs little additional effort to gain promotion. This effect is more pronounced when competition is relaxed (the thinner lines in Figure 2), and arguably, in a world where past career is taken into account, competition is more relaxed as the impact of a new paper on the total is more limited than when past successes lose their shine after a few short years. Tables A10 and A11 in online Appendix E report the output of several further regressions, all suggesting that results are robust to a number of changes in the econometric specification.

[insert Figure 5 about here]

The individual fixed effects we estimate offer an interesting confirmation of the soundness of our approach. These fixed effects, which are functions of individuals' types v_i , measure differences in the effort exerted by different individuals who find themselves in identical conditions. Conceptually they capture the "underlying productivity" in normal conditions, and are determined by talents, skills, personality and attitude towards research, which are both unobservable and in principle roughly constant throughout a person's professional life, and should therefore exhibit a degree of serial correlation, though perhaps not perfect, as life events, personal and professional alike, may modify these traits to some extent. 19,046 individuals, 23% of the total (among them one of the authors) appear in both our datasets, first as assistant professors competing to become associate, then as associate professors competing to become full professors. For them, we can therefore estimate two separate fixed effects, which are obtained from completely separate datasets: the parameters are different, and the output of a period appears in both regressions only when a person is promoted to associate professor in periods 2 to 4. Figure 5 plots the fixed effect derived from the regression that estimates effort exerted when competing to become full professor against that exerted, earlier in one's career, to become associate professor. The visual impression of a good association among these two sets of fixed effects is confirmed by the high value, 0.63, of the correlation between them. Note

that there appear to be no qualitative differences between broad research areas. The concentration of the fixed effects pairs on the positive quadrant is a natural consequence of the sample selection, given that those who appear in both regression have been successful in their application for promotion at least once. We find their stability across time as a further confirmation of the correspondence between our theoretical set-up and our empirical specification.

7 Concluding remarks

This paper studies the response of Italian academics to changes in competitive conditions. We study the period from 1990 to 2011. Like in many other countries, appointments and promotions were determined by peer assessed academic quality, but the legislation which governed them, striving to reduce the scope of unethical behaviour by the decision makers, introduced many explicit and detailed rules. These can be mapped into a theoretical set-up which allows a precise quantification of the changes in an individual academic's incentives determined by changes in the competitive conditions of her research area. The model predicts differential responses to competitive conditions for individuals with different characteristics, including their position in the publications and status ranking of her discipline. If the competitive conditions change, for example because more jobs become available, then productive individuals, for whom exerting effort is "cheap", who were therefore exerting a good deal of effort, were already highly likely to be promoted, and so have relatively little incentive to exert "extra" effort. But for someone in the middle of the ranking, the laxer competitive conditions, for example the availability of an additional post, might mean that effort becomes more productive, in the sense that "extra" effort might be rewarded with a relatively large increase in the probability of winning the additional job made available.

Following our theoretical analysis, we include these non-linearities in our econometric strategy, applied to the dataset we have built, which collects the publications in international scientific journals written by academics working in Italian universities. This strategy is made possible by the insular nature of Italian academia, during the period we study, when entry tends to happen at the lowest

level, and early exit is very rare. We find that the model predicts well both the general lines and also the details of the theoretical model, regarding the different response to changes in the exogenous conditions by different types of individuals. Thus our analysis suggests that the contest model described by the multiple-unit all-pay auction does capture the utility function and the behaviour of academics, even where, like in 1990-2011 Italy, the incentives they operate under are rather weak.

We exploit, in testing the model, an important detail of the reform of the university system which took place in 1999, the introduction of an upper limit to the number of applications for promotions an individual could make in each calendar year. Intended to reduce the burden on members of the appointment panels, this had the additional and unintended consequence of relaxing the competitive condition for some, but not all the academics. The correspondence between the theoretical model and the behaviour of the Italian academics we study is confirmed by the empirical analysis, which shows that the most productive academics increased their effort less than those unaffected by the rule, whereas all the less productive ones increased it, just as predicted by the theory. To the extent that the multi-unit all-pay auction model is a good fit of the behaviour of academics, a broad policy indication suggested by our analysis would therefore be that strengthening incentives, for example by rewarding success more explicitly, might generate the expected responses in the direction of increased effort and output by Italian researchers, especially the most productive ones. This paper does not try to determine the overall effect of the reform. This effect is in principle hard to disentangle from any time trend in the work patterns of academics, and is shown to be limited in Battistin et al (2014). It instead uses the way in which details of the reform result in a possibly counterintuitive theoretical effect, which is matched in the empirical analysis. The complexity of the response, proved at a theoretical level and confirmed in the empirical application, hints at an important policy contribution from our paper: it highlights the importance fully to understand the incentives put in play by complex rules in order to anticipate possible unintended effects on individual behaviour created by new legislation, lest they cause unexpected and undesired outcomes.

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Notes

¹They derive this from a dynamic model where risk-neutral academics have rational expectations about the future values of the relevant variables and the nature of the link between current effort and future output. With rational expectations, candidates are able, on average, correctly to anticipate the relevant characteristics of the competitions they will enter, and so to evaluate the expected benefits of effort; with risk-neutrality, expected and future benefits determine incentives and can be left implicit in the presentation.

²For example, if teaching is highly valued by the potential members of the panel, then rational candidates will “shift” their effort from research to teaching. De Philippis (2015) carries out an empirical analysis of the research-teaching trade-off for professors at Bocconi University in Italy. Becker (1975) and (1979), and Mankiw (1998) among others have suggested that there might be complementarities in the individual “production function”, that is that by doing research one becomes a better teacher and vice versa, generating a positive correlation between teaching and research. This correlation could alternatively be a spurious one, with an unobserved underlying variable “academic talent”, improving output in both activities (De Fraja and Valbonesi 2012).

³The situation is reminiscent of the discouragement effect of the follower in patent races, noted by Fudenberg et al (1983), whereby the follower, less likely to win the race, reduces its R&D investment. Our empirical analysis does suggest that this discouragement effect is present in our data, see below, Section 6, in particular Figure 3.

⁴One potential pitfall of this normalisation is that the ranking of type and output is not robust at the lower end of the type distributions, as shown in Figure 1, which shows that, for the typical parameters of the sample, the effort and output of types below the median is similar. In our set-up this is not a problem: many individuals in the lower half of the distribution have identical outputs, and so they are assigned the same rank, that is the same type. Secondly, the regressions we report in the tables group together all individuals ranked below the median in their scientific sector.

⁵At the end of 2012, the sector comprised 96 institutions and employing 54,931 academics and 56,653 non-teaching staff. Public funding exceeds €7bn. The overall cost of tertiary education (including private expenses) is estimated at €14.8bn, 1% of GDP in 2010 (OECD 2013, Table B2.1). Up-to-date information can

be found at cercauniversita.cineca.it/index.php and <http://ustat.miur.it/dati/didattica/italia/atenei>.

⁶With the exception of very small scientific sectors, where there might not be enough qualified professors: professors from similar scientific sectors would be seconded in this case. Some of the panel members may be associate professors (only in the associate professor appointments), some may be in post at the University of Bologna some in post elsewhere, depending on the rules in force at the time the vacancy opens.

⁷To fix ideas, practically all Italian economists are in SECS/P01 “Economics”, which comprised 341 full professors in 2007, SECS/P02 “Economic policy” (149 full professor in 2007), SECS/P03 “Public economics” (107), SECS/P04 “History of economic thought” (20), SECS/P05 “Econometrics” (32), SECS/P06 “Applied Economics” (63), SECS/P07 “Accounting” (229), SECS/P08 “Management” (176), SECS/P09 “Finance” (24), SECS/P10 “Human resources” (41), SECS/P11 “Banking” (105), SECS/P12 “Economic history” (66), SECS/P13 “Commodity economics” (48 full professors).

⁸The salary scales were (and are) overlapping: the lower rungs of the full professor scale being well below the upper rungs of the associate professor’s scale, although promotions maintained length of service so that did not imply a pay-cut.

⁹These selection committees were formed using a combination of election (by peers) and random draw from the set of all full professors (for full professor posts) and all the full and associate professors (for associate professor posts), all *within each scientific sector*. Thus, for example, funding for 44 new associate professorships in economics (SECS/P01) was provided in 1996. The 44 holders of these posts were appointed by a nine person panel which worked in 1997/98. See Checchi (1999) for a detailed account of this process.

¹⁰Importantly, these negotiations did not affect pay in any way, as institutions had no freedom whatsoever to alter a person’s salary, or teaching load, both being determined by law, pay according to the years of service. Institutions could not even refund moving costs.

¹¹The main alternative bibliometric sources are Scopus and Google Scholar. Scopus has a less full coverage of the sciences (Klavans and Boyak, 2007). At the time of writing, Google Scholar has some reliability problems (López-Cózar et al 2014). At any rate, the literature comparing the Scopus and WoK databases (Archambault et al 2009) documents high correlations among the bibliometric measures derived from these different sources.

¹²Most of the analyses we have come across are carried out by economists on economists (Bosquet and Combes (2017) a recent contribution); among the exceptions, Kelchtermans and Veugelers (2011), and Dietz and Bozeman (2005).

¹³Taking each of these measures in turn, or averaging them out, or changing the way they are calculated does not affect the results.

¹⁴The composition of the panel changed only marginally with the reform, with the inclusion of one representative of the institution where the selected candidate would be appointed. Some other details were changed: while each competition was for one post at a given university, the panel could, and typically did, qualify up to two additional candidates (later reduced to one), who could subsequently be appointed to a different university, without an additional selection process.

¹⁵For example if the central administration of a university allocates a post to the faculty of economics, then it is up to the faculty of economics to choose whether the appointee should belong to one scientific sector rather than another. This might depend on short term teaching needs and the current relative number of professors in the various economics scientific sectors, and is almost impossible to predict in advance.

¹⁶There is a degree of arbitrariness in these numbers, to take into account the fact, mentioned above in footnote 14, that the panels could award additional promotions without increasing the number of applications formally made by the candidates. Modifying these boundaries within reasonable values hardly changes the estimated coefficients.

¹⁷This is the extreme case where a panel either relies exclusively on the publications, or ignores them completely. In the polar case where each panel uses the same criterion and gives weight x to publications and $(1 - x)$ to other criteria, the situation is the same as in the national competition: it is still the case that to be promoted it is necessary to be one of the K top ranked among the N applicants.

¹⁸Naturally, if a candidate receives multiple offers, she must reject all but one of them, and so each post not taken is filled with the next preferred available candidate.

¹⁹Since \hat{N} may be non-integer, factorial is replaced by the gamma function when appropriate.

²⁰We have also experimented with different subdivisions for the two panels, one for associate and a different one for full professors, and the results do not vary.

²¹In the theoretical model we showed that R affects K as well as N . We have run all the regressions with

the interaction between K and R and the results are qualitatively unchanged. Including both interactions determines collinearity between the four variables N , K , $R \times N$, and $R \times K$.

²²Table A11 in the appendix shows that the estimations gain little in significance when clustering is at the individual professor rather than at the scientific sector level.

²³Notice therefore that the results reported in Table 4 can be obtained from the regressions used to draw Figures 3 and 4 with the additional restrictions $\alpha_{1z} = \alpha_{2z} = \alpha_{3z} = \alpha_{4z} = \alpha_{5z}$, $\alpha_{6z} = \alpha_{7z}$, and $\alpha_{8z} = \alpha_{9z}$.

²⁴A natural modification of the theoretical model which could determine such discouragement is a non-linear cost of effort: if increased effort along one dimension were to increase the marginal cost of effort along other dimensions, then academics for whom effort is very costly would reduce it in response to an increase in importance, in order to reduce the cost of effort along other dimensions.

²⁵ The table is not straightforward to interpret, due to the presence, for each of the two regressions, of four instrumented variables and eight instruments (one for each of the quartiles for each variable). Given that both the instruments and the instrumented variable have the same value at the scientific sector \times period level, their correlation can be established by collapsing these variables and running the regression with the scientific sector as the panel variable. The estimated coefficients for the two ranks of assistant and associate professors are the following:

$$x_{ts} = \alpha_0 + \frac{0.261^{***}}{0.017} sd_{ts} - \frac{0.934^{***}}{0.124} n_{ts} + \varepsilon_{ts},$$

$$x_{ts} = \alpha_0 + \frac{0.176^{***}}{0.024} sd_{ts} - \frac{0.219}{0.155} n_{ts} + \varepsilon_{ts},$$

where sd_{ts} and n_{ts} are the standard deviation of the output of the full professor in the sector, and their number relative to the entire number of academics in the scientific sector, and x_{ts} the orderliness index. The period fixed effects are included in the error term, and the standard errors, with the usual significance thresholds, are below the coefficients. With the exception of the low significance of the relative size of the group of full professors for promotion to full professor, these correlation obtained in these regressions suggest that the arguments in this paragraph are consistent with the data.

²⁶Correspondingly, the cumulative output used to compute the orderliness index is also computed weighting with the impact factor.

Tables

Table 1:
Number of professors by rank: 1990 and 2011.

| | 1990 | | | 2011 | | |
|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| | Assistant | Associate | Full | Assistant | Associate | Full |
| Number | 15,158 | 14,542 | 12,006 | 24,596 | 16,618 | 15,244 |
| Average age | 39.62 5.55 | 47.85 6.69 | 52.68 7.79 | 44.93 8.32 | 52.55 8.13 | 58.64 7.20 |
| Share females | 0.41 | 0.25 | 0.10 | 0.45 | 0.34 | 0.19 |
| Share WoK | 0.59 | 0.62 | 0.59 | 0.68 | 0.61 | 0.69 |

Note: Standard deviation of age under the corresponding average. Share WoK is the proportion of professors with at least one publication in the WoK dataset.

Table 2:
Summary statistics for the variables used in the regressions

| | Assistant | | Associate | | Full | |
|-------------------------------------|-----------|-------|-----------|-------|--------|-------|
| | Mean | sd | Mean | sd | Mean | sd |
| Output | 0.269 | 0.521 | 0.355 | 0.673 | 1.00 | 0.497 |
| Output weighted with IF | 0.391 | 1.122 | 0.514 | 2.047 | 1.00 | 4.160 |
| Constraint on applications: binding | 0.079 | | 0.064 | | | |
| Constraint on applications: strong | 0.058 | | 0.051 | | | |
| Broad homonymy dummy | 0.277 | | 0.276 | | 0.288 | |
| Narrow homonymy dummy | 0.007 | | 0.006 | | 0.007 | |
| Orderliness index | 0.605 | 0.127 | 0.607 | 0.128 | | |
| Number of posts K | 28.1 | 29.4 | 20.0 | 21.4 | | |
| Number of competitors N | 164.8 | 141.2 | 145.1 | 120.6 | | |
| Average age in the sector | 43.8 | 4.2 | 50.8 | 4.1 | 56.9 | 3.4 |
| Share of women in the sector | 0.418 | 0.186 | 0.299 | 0.177 | 0.162 | 0.139 |
| Promotions from outside | | | 0.184 | 0.170 | 0.066 | 0.179 |
| Sector: Science | 0.251 | | 0.249 | | 0.251 | |
| Medicine | 0.129 | | 0.130 | | 0.126 | |
| Engineering | 0.177 | | 0.176 | | 0.177 | |
| Arts, Hum. & Law | 0.352 | | 0.354 | | 0.354 | |
| Social Sciences | 0.091 | | 0.091 | | 0.091 | |
| Region: North East | 0.228 | | 0.216 | | 0.220 | |
| North West | 0.195 | | 0.219 | | 0.208 | |
| Centre | 0.279 | | 0.273 | | 0.298 | |
| South and Islands | 0.298 | | 0.293 | | 0.275 | |
| Observations | 127,078 | | 107,939 | | 89,757 | |

Note: “Mean” and “sd” are the values computed over the individual-period sample. Output for full professors is the reference value for the scientific sector, and so has mean identically 1. IF is the impact factor. The homonymy dummies are defined in Appendix C.2.6. The variables measuring the constraint on applications reports the percentage of individuals for who the variable R , defined in Section 4.2 takes value 1, when “binding”, and 2 when “strong”. The number of observations is professors \times periods. The variable in the top part vary by individual, those in the second part are constant within the scientific sector-period.

Table 3:
Academics' output Pre- and Post-reform.

| | Pre-reform | Post-reform | Difference |
|---------------------------------|------------|-------------|------------|
| Assistant Professors | | | |
| Unconstrained scientific sector | 1.484 | 1.926 | 0.442*** |
| Constrained scientific sector | 1.781 | 2.036 | 0.254*** |
| Difference-in-difference | | | 0.188*** |
| Associate Professors | | | |
| Unconstrained scientific sector | 1.595 | 2.012 | 0.417*** |
| Constrained scientific sector | 1.87 | 2.214 | 0.343*** |
| Difference-in-difference | | | 0.074*** |

Note: Each cell reports the average output of assistant (top part of the table) and associate (bottom part) professors, relative to the the output of full professors working in the same scientific sector. The label “Constrained scientific sector” identifies the subset of professors who were registered in scientific sectors where the rule on the constraint on application in force after the 1999 reform was above a given threshold, and vice versa.

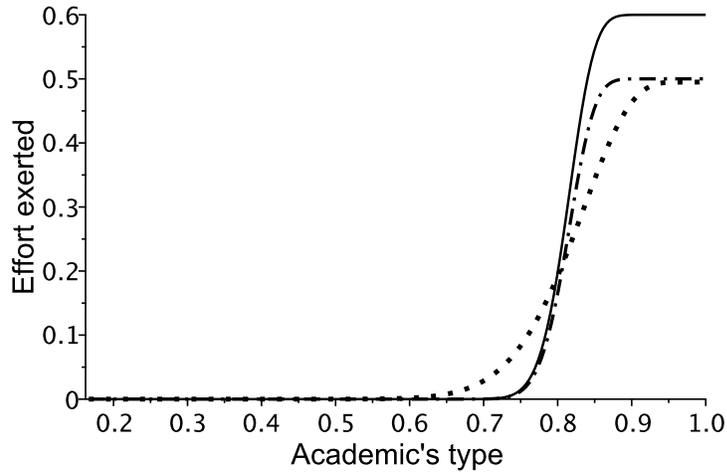
Table 4:
Determinants of Academics' Effort, and Robustness Checks.

| Dependent variable: Individual output in period t | Four Separate Regressions: Sample Split | | Base Regression: coauthors weighting | | Instrumental variables: homogeneity | | Output weighted with impact factor | | Deciles computed using cumulative output | |
|--|--|--------------------|---|--------------------|--|--------------------|---------------------------------------|--------------------|---|--------------------|
| | Assist. | Assoc. | Assist. | Assoc. | Assist. | Assoc. | Assist. | Assoc. | Assist. | Assoc. |
| Orderliness: below median | 0.057*** 0.009 | 0.034*** 0.006 | -0.196*** 0.020 | -0.123*** 0.016 | -0.354** 0.141 | -0.498*** 0.159 | -0.175*** 0.019 | -0.123*** 0.014 | -0.128*** 0.021 | -0.055*** 0.012 |
| Deciles 6 and 7 | 0.206*** 0.030 | 0.162*** 0.025 | 0.024* 0.013 | 0.005 0.012 | 0.526*** 0.113 | 0.371** 0.189 | 0.038*** 0.014 | 0.008 0.014 | 0.110*** 0.021 | 0.045*** 0.014 |
| Deciles 8 and 9 | 0.473*** 0.062 | 0.290*** 0.052 | 0.345*** 0.040 | 0.151*** 0.030 | 1.405*** 0.133 | 1.226*** 0.271 | 0.322*** 0.039 | 0.165*** 0.029 | 0.235*** 0.041 | 0.072*** 0.025 |
| Top decile | 0.901*** 0.126 | 0.521*** 0.102 | 0.709*** 0.081 | 0.287*** 0.062 | 1.795*** 0.283 | 1.478*** 0.410 | 0.614*** 0.070 | 0.257*** 0.059 | 0.084 0.057 | -0.040 0.055 |
| Number of posts: below median | -0.006** 0.003 | -0.005** 0.002 | 0.013* 0.007 | 0.035*** 0.005 | 0.036 0.036 | -0.028 0.034 | 0.011* 0.006 | 0.034*** 0.005 | 0.006 0.006 | 0.021*** 0.004 |
| Deciles 6 and 7 | -0.022** 0.011 | -0.024*** 0.009 | -0.006 0.005 | 0.012*** 0.004 | 0.057 0.049 | 0.012 0.033 | -0.005 0.005 | 0.015*** 0.004 | 0.002 0.009 | 0.015*** 0.005 |
| Deciles 8 and 9 | -0.033 0.026 | -0.044** 0.020 | -0.025* 0.014 | -0.019** 0.008 | 0.095 0.064 | 0.078** 0.037 | -0.033** 0.014 | -0.026*** 0.008 | 0.000 0.014 | 0.000 0.007 |
| Top decile | -0.032 0.051 | -0.019 0.047 | -0.071*** 0.024 | -0.017 0.022 | 0.238*** 0.069 | 0.235*** 0.043 | -0.065*** 0.021 | -0.019 0.021 | -0.004 0.017 | 0.012 0.018 |
| Competitors: below median | 0.013*** 0.005 | 0.011** 0.005 | 0.036* 0.020 | -0.044*** 0.015 | 0.010 0.014 | 0.069*** 0.016 | 0.050** 0.020 | -0.034** 0.017 | 0.005 0.023 | -0.022 0.018 |
| Deciles 6 and 7 | 0.040*** 0.015 | 0.063*** 0.018 | 0.065*** 0.021 | -0.007 0.015 | -0.038 0.027 | -0.013 0.014 | 0.077*** 0.021 | 0.001 0.017 | 0.027 0.026 | 0.003 0.017 |
| Deciles 8 and 9 | 0.04 0.032 | 0.106*** 0.035 | 0.105*** 0.025 | 0.053*** 0.017 | -0.088 0.055 | -0.105*** 0.030 | 0.122*** 0.025 | 0.061*** 0.018 | 0.055* 0.029 | 0.051*** 0.019 |
| Top decile | 0.054 0.055 | 0.150* 0.079 | 0.245*** 0.028 | 0.204*** 0.023 | -0.138** 0.056 | -0.118** 0.049 | 0.241*** 0.026 | 0.189*** 0.023 | 0.142*** 0.028 | 0.144*** 0.021 |
| Effect of reform: below median | -0.001*** 0.001 | 0 0.001 | 0.002 0.001 | 0.002 0.002 | 0.003 0.003 | -0.004 0.003 | 0.001 0.001 | 0.002 0.002 | -0.004** 0.001 | 0.001 0.002 |
| Deciles 6 and 7 | -0.006*** 0.002 | -0.008*** 0.002 | -0.002 0.002 | 0 0.002 | -0.004* 0.002 | 0.002 0.002 | -0.003** 0.001 | -0.002 0.002 | -0.003* 0.002 | -0.005*** 0.002 |
| Deciles 8 and 9 | -0.012*** 0.004 | -0.017*** 0.004 | -0.010*** 0.002 | -0.004 0.003 | -0.014*** 0.005 | 0.005 0.004 | -0.009*** 0.003 | -0.003 0.003 | -0.011*** 0.003 | -0.013*** 0.003 |
| Top decile | -0.032*** 0.009 | -0.033*** 0.008 | -0.033*** 0.006 | -0.040*** 0.005 | -0.038*** 0.007 | -0.028*** 0.007 | -0.031*** 0.005 | -0.033*** 0.005 | -0.035*** 0.005 | -0.034*** 0.006 |
| R-squared | | | 0.434 | 0.361 | 0.279 | 0.157 | 0.363 | 0.283 | 0.201 | 0.111 |
| First stage F-test (p-value) | | | | | 0.000 | 0.000 | | | | |

Note: *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.1$. In all pairs of columns, the number of observations is 120,095 and 90,894 for the 47,572 assistant and the 37,066 associate professors respectively. Standard errors are clustered at the scientific sector and are reported in small font below each coefficient. All the regressions include a constant, the share of appointments from outside the Italian academia, the average age of the potential applicants, the homonymy coefficients as explained in the text, and also scientific sector, university, period and individual fixed effects. Columns 1 and 2 are obtained from four separate OLS regressions, with different samples. In these columns the first coefficient in each block is obtained from the sample constituted by the observations where the professor's output is below the median for the period/scientific sector. The second coefficient is similarly obtained with samples made of the observations from the median to the seventh decile, the third from the seventh to the ninth decile, and the fourth the observations in the top ten percent in each period/scientific sector. The base regression in Columns 3 and 4, where individual output is weighted with the number of co-authors. Columns 5 and 6 are IV estimates with the homogeneity of the set of the full professors in the scientific sector in the period as an instrument for the orderliness index. Columns 7 and 8 are a robustness test with the weighting for the different publications determined by the impact factor; columns 9 and 10 are another robustness test, where an individual's type is computed according to the cumulative output.

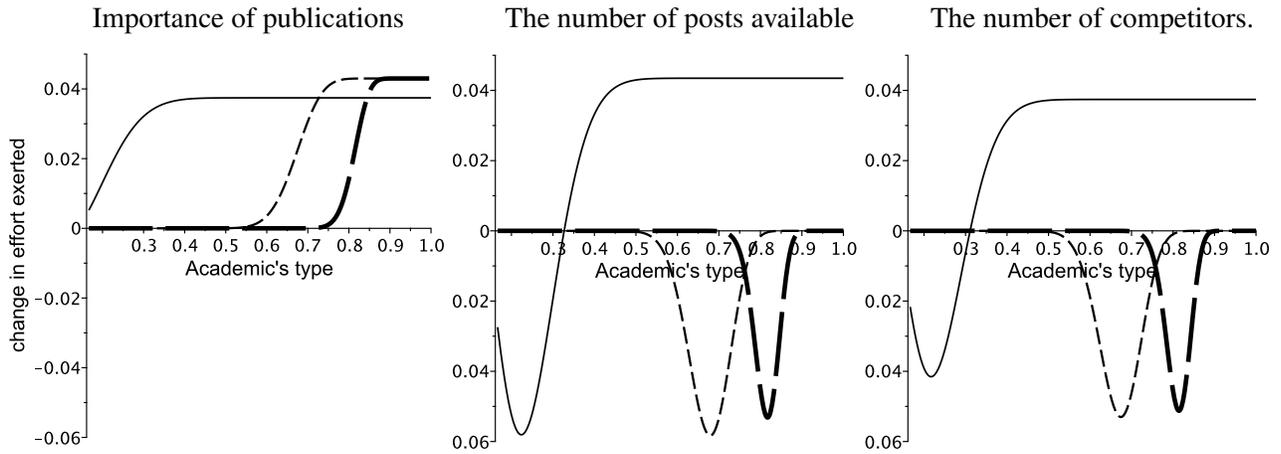
Figures

Figure 1:
Equilibrium effort by ability type pre- and post-reform



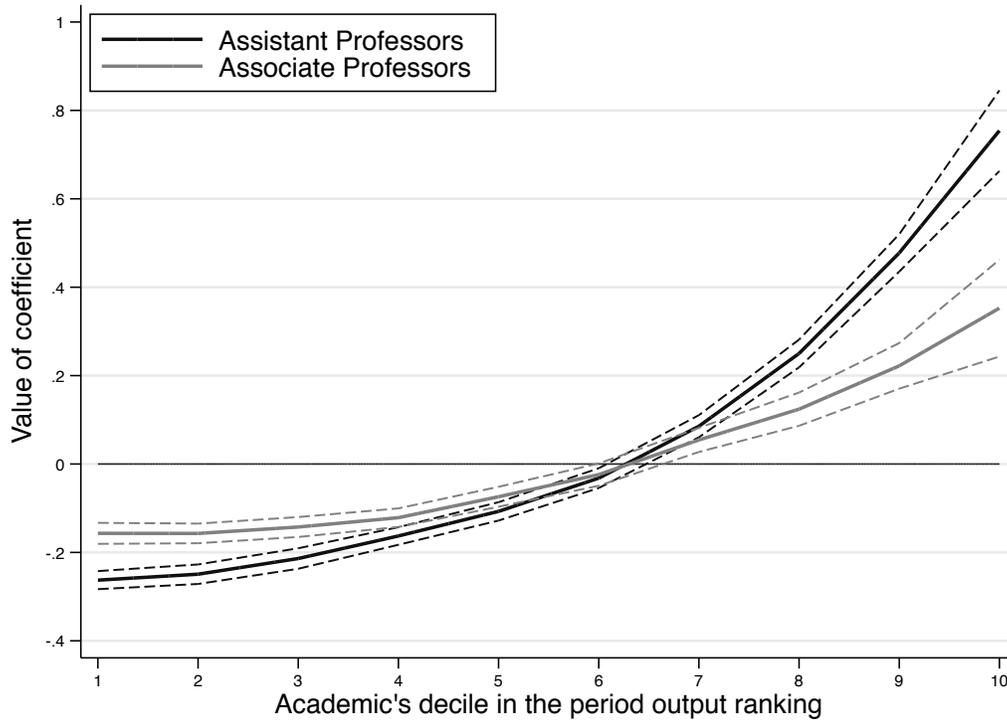
Note: The curves denote the effort exerted by academics of different types, measured along the horizontal axis, for fixed $N = 150$, $K = 25$, $x = 0.6$. The solid line measures the academics' effort, the function in (1). The dashed and dotted lines show the corresponding values of the equilibrium level of effort which results following the changes in the appointment process introduced by the 1999 explained in Section 4.3, determined formally in Proposition 2. The dotted line depicts the full effect of the reform, obtained in (4), the dash-dotted line is the effect the reform would have if the cap on the number of applications, set in the example at $M = 5$, were absent.

Figure 2:
Changes in the parameters



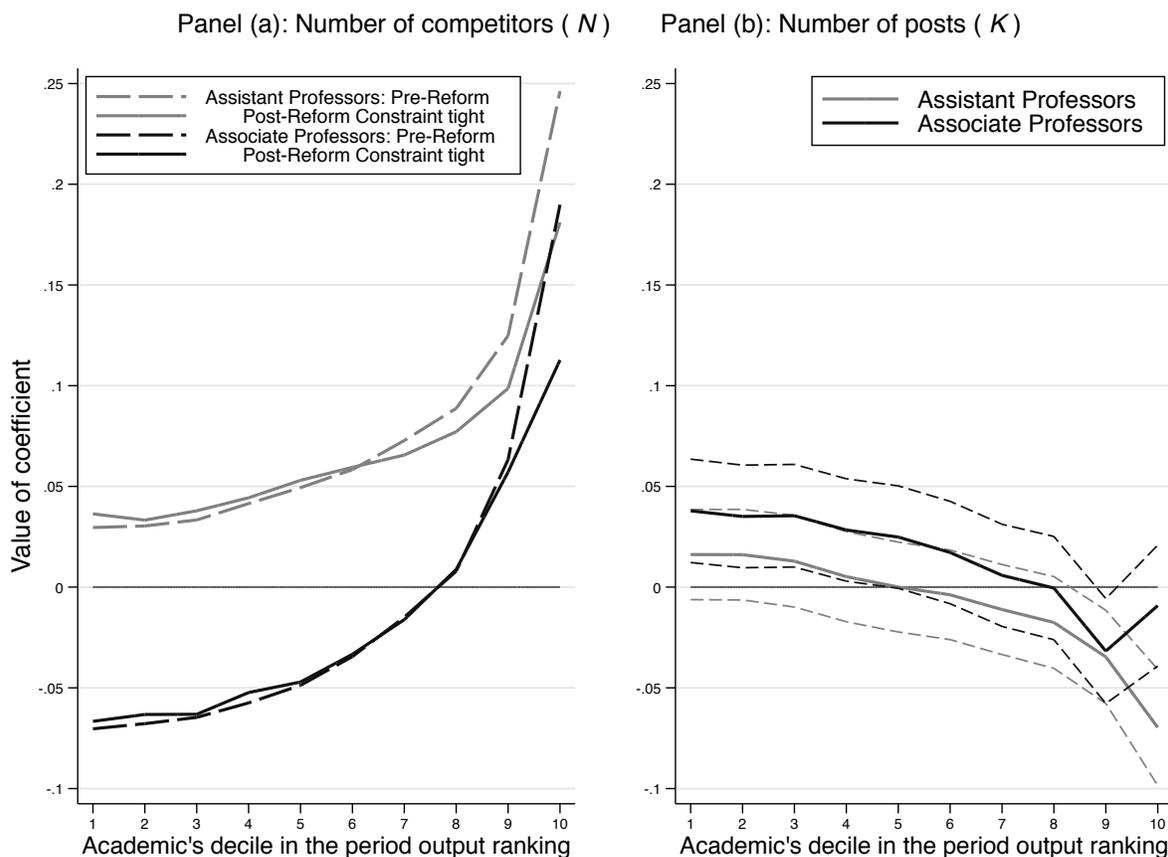
Note: Effect on effort of changes in the three exogenous variables. In each panel, the baseline values are $x = 0.6$, $K = 25$ and three values of N , which increases from 33 to 80 to 150 as the line gets thicker and the dash longer. The LHS panel shows how effort changes as the importance of publications increases by 0.043 from the baseline to 0.557. In the middle panel the number of posts decreases by 3%; and in the RHS panel the number of competitors increases by 4%.

Figure 3:
Effect of a change in the index of orderliness.



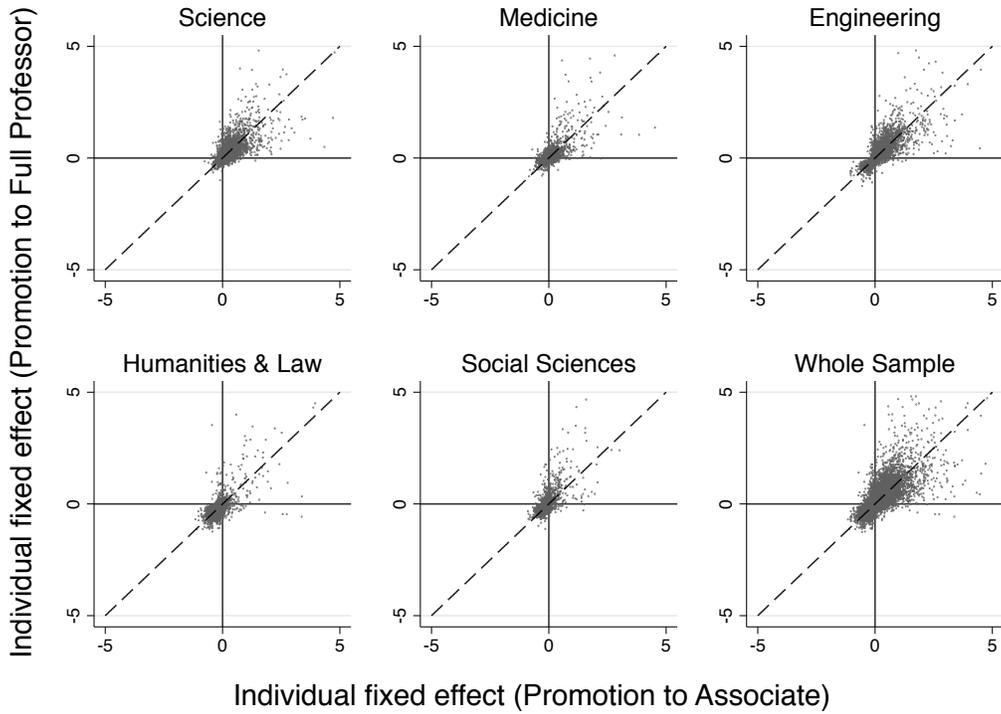
Note: Regression coefficients α_{qx} in estimation (7), for a ten-interval partition of the type distribution. The dashed lines include the 95% confidence intervals.

Figure 4:
Effect of a change in the competitive conditions.



Note: On Panel (a), we draw the regression coefficients α_{qN} in estimation (7), for a ten-interval partition of the type distribution as the solid lines. The dashed lines are the regression coefficients $\alpha_{qR} = \alpha_{qN} \lambda_q$ which account for the additional effect of the constraint on applications introduced by the reform. The confidence intervals are not drawn, so as not to clutter the figure. As Table 4 indicates, the coefficients are significantly different for the highest deciles. Panel (b), where the 95% confidence intervals are included between the dashed lines, reports the coefficients α_{qK} in estimation (7), multiplied by -1 , for a ten-interval partition of the type distribution.

Figure 5:
Individual Fixed Effects for two Promotions.



Note: The plots show the individual fixed effect for promotion to associate professor (the third column of Table 4) and the individual fixed effect for promotion to full professor (the fourth column) for academics who have been promoted twice in the 21 year period. A handful of outliers have fixed effects estimated higher than 5, which are off the scale of the two axes.