

# Research incentives and research output

by

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Post print version of:

Jørgensen, F. & Hanssen, T-E.S. (2018): Research incentives and research output.

Higher Education. DOI: 10.1007/s10734-018-0238-1

## Abstract

This paper first briefly reviews the worldwide development of the size of the university sector, its research merits and authorities' use of incentive systems for its academic staff. Then, the paper develops a static model of a researcher's behaviour, aiming to discuss how different salary reward schemes and teaching obligations influence his or her research merits. Moreover, special focus is placed on discussing the importance of the researcher's skills and of working in solid academic environments for quality research. The main findings are as follows: First, research achievements will improve irrespective of the relative impact quantity and quality of research have on researchers' salaries. Second, small changes in fixed salary and teaching duties will not influence the amount of time academics spend on research and, as such, their research merits. Third, because research productivity, i.e. the number of pages written and research quality increase with the researcher's skills and effort, both these figures signal a researcher's potential when adjusting for his or her age and the kind of research carried out. Finally, because researchers' utility depends on factors beyond salary and leisure time, employers have a number of instruments to use in order to attract skilled researchers in a globalised market.

Keywords: Research effort, time allocation, research merits, reward schemes, skills

JEL: I23, L38, O38

## **1. Introduction**

Human capital has a central role in determining the wealth of nations (Manuelli and Seshadri, 2014). Part of the reason for this is that individuals with more or higher-quality human capital achieve a higher performance (Dimov and Shepherd, 2005) and produce higher-quality goods (Stokey, 1991). One of the most important investments to be made in human capital is education (Becker, 1964), and cross-country studies have found a strong correlation between per capita output and the average number of years spent at school (Mankiw et al., 1992). It is therefore not surprising that investing in the higher education system is vital for future economic growth (Browne et al., 2010).

During the 20<sup>th</sup> century higher education expanded tremendously. It is estimated that approximately half a million students were enrolled at higher education institutions in the year 1900 (see Schofer and Meyer, 2005). In the 1960s, the rate at which the student numbers increased began accelerating (Lorenz, 2012). In 1970, the number of students at higher education institutions had reached 2.5 million; in 2000, there were 100 million students; and in 2010, there were 178 million students (Tremblay et al., 2012).

Along with the growth in enrolment rate, both the number of academic staff at higher education institutions and the resources (i.e. money) spent on the sector has increased. From 2000 to 2010, for example, the expenditure on tertiary educational institutions in the OECD increased by 48% and the number of students by 33% (OECD, 2014a); consequently, expenditure per student increased by 14%. During the same 10-year period, the number of researchers in the OECD grew by 33%, from 3.1 million to 4.2 million (OECD, 2014b).

Not only has the number of students and staff increased during the last decade, research output has risen as well. The first scientific articles were published in 1665 (Brown, 1972) and, approximately 350 years later, the total number of published scientific articles has exceeded 50 million (Jinha, 2010). This number is likely to double to more than 100 million articles in the next 24 years if the former annual growth rate of 3% continues (Ware, 2006).

The introduction of incentive and reward systems, more qualified academic staff, increased research collaboration and improved research conditions have been said to explain the growth in research productivity observed in the last few decades (Kyvik and Aksnes, 2015). Moreover,

because both researchers and research departments are evaluated based on their publication rate (see e.g. Dries et al., 2008, Stremersch et al., 2007), all parties have strong incentives to publish. However, studies have found that only 1% of the researchers publish in scientific journals every year (Ioannidis et al., 2014) and that 50% of all publications are produced by 10% of academics (Kwiek, 2015). This suggests that there is unused potential for increasing global research output. Consequently, knowledge about how researchers' behaviour can be affected is important in order for the institutions, and policymakers, to implement schemes that can lead to increased research output.

The aim of this paper is, therefore, to present a model that describes a researcher's behaviour. This model forms the basis for discussing how actual research policy measures, such as reward schemes for university academics and their teaching and administrative obligations, influence their research effort and achievements. Consequently, effective measures to increase research output are identified. Moreover, the importance of researchers' skills and working environment for quality research are analysed. Because approximately one-third of total research man-years in the EU countries are conducted by staff at universities (Kunnskapsdepartementet, 2015), their research conditions are important for countries' research output.

Earlier articles addressing the behaviour of researchers theoretically and empirically include Levin and Stephan (1991) and Jung (2014). The former focuses, in particular, on how the number of articles published in scientific journals varies with the researchers' age. The latter addresses similar issues in the sense that it discusses how research productivity changes by career stage and academic discipline. In addition, it attempts to identify factors influencing research productivity and how the same factors vary through researchers' careers. Neither of these two works, however, provide as detailed a description of researchers' behaviour as this article. This makes our work more suitable to discuss the influence of many different research policy measures.

The structure of the paper is as follows. In Section 2, we briefly review the development of incentive research schemes at universities. Then, in Section 3, we develop a general static model of a researcher's behaviour with thorough discussion and interpretation of the functions used and the optimal solutions. To formulate tractable mathematical solutions and derive more exact results, we specify the actual functions of the model more precisely in Section 4 and comment

on the results. Finally, the most interesting conclusions, policy implications and weaknesses of the article are summarised in Section 5.

## **2. The development of incentive research schemes towards universities**

New public management (NPM) spread in the 1980s as a means to make the public sector efficient and transparent, and thus accountable (Lorenz, 2012). NPM provides a set of practical control technologies through which policies and their instrumentation can be translated into practices that change structures, processes and behaviours on the ground (Enders and Westerheijden, 2014). Although institutional autonomy and academic freedom are fundamental values in higher education (Bleiklie, 1998), NPM has been the guiding governance model of university reforms in Europe for the last 20 years (Hüther and Krücken, 2013).

The introduction of NPM to the higher education sector has led to an increased emphasis on performance (Tolofari, 2005), using, for example, performance-based university research funding systems, or PRFS (see e.g. Hicks, 2012, Schubert, 2009). Research output is one of the parameters by which the institutions in the sector can be measured, and as a result, an effort has been made to develop good publication indicators.

Broadly speaking, there are three main groups of PRFS. These are the panel-based model, the citation-based model and the publication-based model (Aagaard et al., 2014), each of which have their benefits and disadvantages. The panel-based model implies that a panel of the university staff is appointed and given the task of conducting a peer review. The citation-based model addresses the degree to which the research produced is cited by fellow researchers.<sup>1</sup> Finally, the publication-based model evaluates the number of articles published. As such, the first is a peer-review evaluation method and the last two are bibliometric evaluation methods.

The first countries to introduce PRFS were the United Kingdom, in 1986, and Spain, in 1989 (Hicks, 2012). In 1990, Australia launched its own PRFS based on a bibliometric evaluation of the employees at the nation's higher education institutions (Aagaard et al., 2014). In the Australian system, all publications are counted equally, irrespective of the impact of the journal in which they were published. As a result, most of the increase in the number of research articles published annually came through low-impact journals (Butler, 2004).

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<sup>1</sup> In Hanssen and Jørgensen (2014), Hanssen and Jørgensen (2015) and Hanssen et al. (2018), a researcher's skills are measured by the number of times his works are cited.

Later, countries such as Sweden, Finland, Denmark, Norway and the Netherlands also introduced performance-based research indicators to their research funding (Hægeland et al., 2014). However, these countries have all designed their PRFS slightly differently. In Sweden, 20% of the research funding is allocated based on how the institutions perform with regard to the number of publications, the number of citations and external research funding. In Finland, the solidity of the universities' research departments is based on the number of completed PhDs, scientific publications, external research funding, the number of completed PhDs by foreign students and the number of foreign staff. Denmark allocates research funds to universities based on the number of students who finish their studies within a predetermined time frame, the amount of external research funding they attract, scientific publications and the number of completed PhDs. The Norwegian system also takes into account the number of completed PhDs, research funding from The Research Council of Norway and research funding from the European Union (Hægeland et al., 2014). Based primarily on the experiences of Australia, Norway also opted for a system in which scientific publications were classified into two levels to promote publication in channels with high impact (Aagaard et al., 2014). Total research output (publication points) is thus a weighted sum of the number of articles published, using their scientific level as weights. Finally, the research component of the base funding of institutions in the Netherlands is based on the number of PhDs (and a particular degree in technology), research schools and a historical component.

This brief review of these five countries' PFRS suggests that the number of completed PhDs is considered an important research indicator, as they all use this metric in their funding system. It is also worth noting that the Netherlands does not use bibliometric assessments when allocating funds to universities.

Although the stated objective of introducing the PFRS is to redistribute resources based on the resulting performance of the institutions, the redistributive effect is often limited (Hægeland et al., 2014). However, because the fixed costs are often large for most research institutions, this is a good thing, as large annual fluctuations in funding can cause institutions to go bankrupt (Hicks, 2012). Nevertheless, implementing research funding systems that reward institutions with good results tends to improve the results of the sector and lead to higher research productivity. In Norway, for example, the incentive system has resulted in increasing publication frequency, due to both a large increase in the share of researchers with publication

activity and an increase in the average publication activity among publishing researchers. The quality of research has become neither better nor worse (Aagaard et al., 2014).

### 3. A static model for a researcher's behaviour

To discuss a researcher's behaviour and research merits we introduce the following three central functions.

- The researcher's utility or goal function
- The salary function the researcher faces
- The quality function; that is the relationship between the quality of the researcher's research, skills and work effort
- Some definition equations between time spent on different activities.

The mathematical formulation of the model draws on previous work by Jørgensen and Wentzel-Larsen (1995).

#### 3.1 The researcher's goal function

Let us assume that a researcher's utility ( $U$ ) is given by the following function<sup>2</sup>:

$$(1) \quad U = U(S, L, P, Q) \text{ where } U_S, U_L, U_P, U_Q > 0, U_{SS}, U_{LL}, U_{PP}, U_{QQ} \leq 0$$

In Eq. (1),  $S$  represents the researcher's total salary,  $L$  his leisure time,  $P$  his research production measured by the number of pages written, and finally,  $Q$  represents the quality of his written pages, for example, measured by the number of times his works are cited and their impacts on society in a broader sense (societal impacts), see for example, Hanssen and Jørgensen (2015) Bornmann (2017) and Hanssen et al. (2018). The higher the value of  $Q$ , the higher his research quality. Furthermore, it is assumed that the utility function has the usual properties, i.e. it is strictly quasi-concave.<sup>3</sup>

The reasons for including  $P$  and  $Q$  as independent variables in the utility function are twofold. First, for purely altruistic and etic reasons or occupational pride, researchers find it satisfying to have a large research production of high quality, see for example Hesli and Lee (2013) and Swidler and Goldreyer (1998). Second, high  $P$  and high  $Q$  can positively influence the

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<sup>2</sup> Here and throughout the article the notation  $Y_X$  means the partial derivative of  $Y$  with respect to  $X$  etc.

<sup>3</sup> A thorough discussion of quasi-concave functions can be found in Sydsæter and Hammond (2006).

reputation of a researcher (Petersen et al., 2014). Universities can also reward skilled researchers by providing better technical equipment, better access to research assistants, more travel funding, etc. The degree to which these rewards are used differs to some extent among universities. The relationships between  $U$  and  $P$  and between  $U$  and  $Q$ , therefore, will depend not only on the researcher, but also on the working conditions at the university where he is employed. When assuming  $U_P = U_Q = 0$ , we are left with the “classical” optimisation problem, where the utility of the researcher is being determined by salary and leisure time alone.

Because the number of pages written differs substantially across disciplines and between theoretical researchers and the more applied ones, one cannot use  $P$  as an indicator of researchers’ productivity without considering the type of research carried out. This is, for example, verified by Piro et al.(2013) and Rørstad and Aksnes (2015) who used Norwegian data. When measuring publication output with the compound production measure (article equivalents) and fractionalising according to the number of total authors, researchers from the humanities and social sciences produced far more than their colleagues in natural science, medicine and technology.<sup>4</sup> Hence, the influence of  $P$  on researchers’ utility will vary across fields and type of research.

### 3.2 The salary function

The salary ( $S$ ) of a researcher is defined by the following function:

$$(2) \quad S = S(P, Q, E) \text{ where } S_P, S_Q, S_E > 0, S_{PP}, S_{QQ}, S_{EE} \leq 0$$

in which  $E$  is the time the researcher uses for external paid activities, such as consulting, directorships, etc. As emphasised earlier, universities throughout the world have introduced incentive schemes aiming to stimulate their academic staff to concentrate on publishing a large number of articles in well-recognised journals. This makes it reasonable to assume that  $S$

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<sup>4</sup> It is reasonable to assume a positive monotonic relationship between the number of pages produced ( $P$ ) and the number of article equivalent ( $AE$ ). Note, that  $AE$  is not the same as the value of the publication indicator ( $PI$ ) used in Norway.  $PI$  is a weighted average of the number of article equivalents using the journals’ impact factors as weights. Hence, the value of  $PI$  depends on both  $P$  and  $Q$ .

increases non-convexly with  $P$  and  $Q$ .<sup>5</sup> Moreover, a partial increase in  $E$  will increase  $S$ , because the researcher will choose the highest paid external activities first,  $S_{EE} < 0$ .

It is reasonable to assume that an increase in the number of pages produced will have greater influence on salary if the quality of these pages is high, and vice versa. It is also likely that the prospect for a researcher to get highly paid external assignments improve if his research merits are good, mainly because this will make the researcher better known and his results more credible. Based on the above, it is thus reasonable to assume that the cross derivatives  $S_{PQ}, S_{EP}, S_{EQ} > 0$ .

Salary normally increases with seniority. Moreover, older researchers have a larger network than the younger ones, making it easier for the former to obtain highly paid external activities. Consequently, for fixed values of  $P, Q$  and  $E$ , the value of  $S$  is higher for seniors than for juniors. The shape of the  $S(P, Q, E)$  function will also vary between universities, due to the different possibilities of getting external engagements. All other things being equal, the value of  $S$  is probably higher for university staff employed at reputable universities located in major cities than for their counterparts.

The  $S(P, Q, E)$  function is of particular interest for the purpose of this article because the authorities can affect its shape by giving instructions or guidelines to the universities regarding how the academic staffs' research merits should influence their salaries. Although the universities have some freedom to design their own wage-setting incentive schemes, the official guidelines are of great importance in all European countries, with Sweden and United Kingdom being the prime exceptions (Aghion et al., 2007).

Consequently, the shape of the  $S(P, Q, E)$  function is an important instrument for designers of research policy. If, for example, the authorities want to put more weight on research quality, the  $(\frac{S_Q}{S_P})$  fraction will increase. An extreme case is when the universities focus most on research quantity, implying that  $(S_Q/S_P) \approx 0$ . In practice, this implies, broadly speaking, that the evaluation of an employee's research merits is mostly based on how high a pile his scientific

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<sup>5</sup> The assumption made that the marginal influence on salary of increased research quality is non-increasing may be open to debate, but most universities (at least in Europe) have wage systems that limit large wage differentials among the staff.



production makes. Quite a few academic staffs all over the world claim that the above, unfortunately, applies for many incentive schemes at universities, as far as remunerating research merits are concerned. Also the increased focus on societal impacts of the research (Bornmann, 2017) is met by opposition by academics claiming that it will make researchers less free to follow their own interests, which will subsequently reduce the quality of research.

Finally, it is important to note that while the choice of becoming a researcher is partly driven by pecuniary motives (Janger and Nowotny, 2016), it is a mistaken belief that pay incentives alone can create effective levels of motivation (de Lourdes Machado-Taylor et al., 2016). This could be one reason why performance related pay, often introduced as part of the management-by-results doctrine, is probably not the best way of managing higher education institutions (Kallio and Kallio, 2014). The above arguments are the main reasons why we include  $P$  and  $Q$  as independent variables in the researcher's goal function.

### 3.3. The quality function

The quality of the researcher's publications is defined by the following function:

$$(3) \quad Q = Q(t, T, I) \quad Q_t, Q_T, Q_I > 0, Q_{tt}, Q_{TT}, Q_{II} < 0$$

in which  $t$  is the average time used on each page of research produced, whereas  $T$  represents the time the researcher uses to stay up to date in his or her field of research, i.e. to read relevant scientific literature, to attend conferences, etc. The higher the values of  $t$  and  $T$ , the more work is put into writing pages and the more updated he is on relevant research literature, respectively. Finally,  $I$  is an index representing the general academic qualification of the researcher; the higher the value of  $I$ , the better his academic qualifications. The value of  $I$  depends on his academic degree, his skills for research and, not least, the extent of deliberate practise or experience (Ericsson et al., 1993, Hanssen and Jørgensen, 2015). Our a priori assumptions, regarding the first and second derivatives, imply that the relationships between  $Q$ , on one hand, and  $t$ ,  $T$  and  $I$ , on the other hand, increase concavely; that is, the marginal effects on quality of increasing effort and qualification are diminishing. Further reasonable restrictions placed upon the quality function may be that  $Q_{tT}, Q_{tI}, Q_{TI} > 0$ , meaning that the marginal effects of increasing efforts (higher values of  $t$  and  $T$ ) are higher for skilled researchers than for the less skilled ones.

It is reasonable to assume that the marginal rate of substitution of research effort for skills diminishes rapidly.<sup>6</sup> This is illustrated in Figure 1. The research quality along each curve ( $Q_0$ ,  $Q_1$  and  $Q_2$ ) is constant, and  $Q_2 > Q_1 > Q_0$ . This implies that when  $Q = Q_i$  ( $i = 0, 1, 2$ ), there are minimal substitution possibilities between skills and efforts on research quality when  $I < I_i$  ( $i = 0, 1, 2$ ).

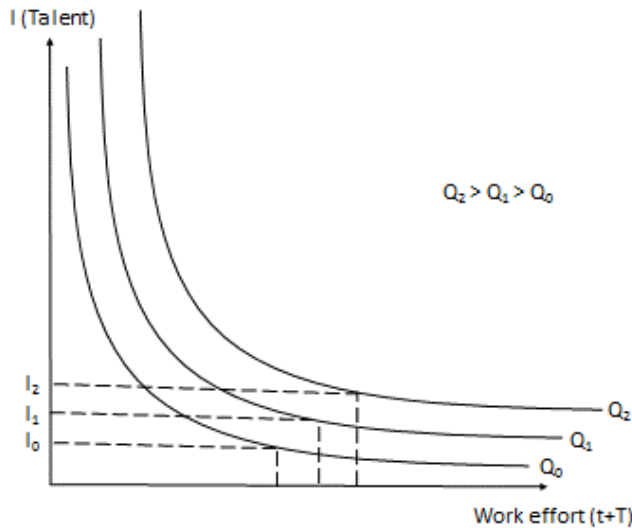


Figure 1: Substitution possibilities between the researcher's skills ( $I$ ) and work effort ( $t + T$ ) for three different levels of research quality:  $Q_0$ ,  $Q_1$  and  $Q_2$ .

The shapes of the curves in Figure 1 will vary across disciplines, type of research and the researcher's academic environment. Skills up to a certain level seem to play a significant role in academic performance across all disciplines, in particular for science subjects (see for example Furnham and Monsen, 2009, Hambrick and Meinz, 2011). This draws in the direction of slower curves in Figure 1 and higher threshold values of  $I_i$  ( $i = 0, 1, 2$ ) for researchers working in science fields. Moreover, it could be argued that for empirical studies whose quality critically depends on time-consuming and thorough work to obtain reliable data, hard work can, to a larger extent, compensate for skills. This means that the curves in Figure 1 become steeper and the dotted horizontal curves shift downwards.

<sup>6</sup>  $\left(-\frac{\partial I}{\partial t}\right)_{Q=Q^*} = \frac{Q'_t}{Q_i}$  and/or  $\left(-\frac{\partial I}{\partial T}\right)_{Q=Q^*} = \frac{Q'_T}{Q_i}$  diminish rapidly.

Recent research also concludes that being part of a good research environment has a positive effect on researchers' merits (Hanssen et al., 2018, Kenna and Berche, 2011). Azoulay et al. (2010) have for example identified a sizeable and permanent decline in the quality adjusted publication output for collaborators of eminent academic life scientists who die premature and unexpected. Consequently, for any given values of  $t$ ,  $T$  and  $I$ ,  $Q$  should be higher for researchers working in large, solid research environments, than for those working in dull environments. This makes the curves in Figure 1 shift to the right and become steeper. The latter can be due to his research merits are probably less influenced by his own skills when working in a solid academic environment.

Finally, we find it important to emphasise that we have made the tacit assumption that the researcher's perception of the quality of his research in Eq. (3) coincides with the employer's perception in the salary function Eq. (2). This is an important and reasonable assumption because both employees and employers currently evaluate the quality of written papers from the international rankings of the journals in which they are published.

### 3.4 Definition equations

The last two equations we introduce are the following:

$$(4) \quad R = t \cdot P + T$$

$$(5) \quad L = A - D - R - E$$

Eq. (4) states that the total time a researcher uses for research ( $R$ ) is the sum of time used for writing the papers ( $t \cdot P$ ) and time used for reading relevant scientific literature ( $T$ ). In Eq. (5),  $A$  represents available time (approximately  $24 \cdot 360 = 8640$  hours per year) and  $D$  is the time required for teaching, supervising and administrative duties. Consequently, Eq. (5) states that leisure time ( $L$ ) is the difference between available time ( $A$ ) and the amount of time spent working ( $D + R + E$ ).

In the following, we regard the researcher's time used for teaching and administrative duties ( $D$ ) to be exogenous to him. In many countries,  $D$  is decided by standard national rules for different academic positions. In Norway, for example, a professor, an associate professor and

an assistant professor spend, respectively, approximately 38, 35 and 36 hours per week on  $D$  (Egeland and Bergene, 2012). The amount of time universities' academic staff must spend on teaching and administrative duties is regarded as an important research policy instrument. Lower (higher) values of  $D$  will, in general, provide them with better (poorer) research opportunities, at least when it comes to teaching undergraduate students.<sup>7</sup> It is, however, worth noting that teaching graduate students can drive research output, in particular when they are integrated in research activities (Horta et al., 2012).

Finally, it is worth mentioning that seeking research funding is considered an essential part of academic life (Ma et al., 2015), perhaps particularly in fields relying on costly experiments. A comparative study has, for example, found that astronomer's submit more grant applications than psychologists (Von Hippel and Von Hippel, 2015). As university leaders to a greater extent than before express an expectation that academics should apply for external funding, innovation time spent on developing grant applications may be considered being a part of  $D$ .

### 3.5 Interpretation of the first-order conditions for optimal behaviour

Plugging Eqs. (2), (3), (4) and (5) in (1) gives

$$(6) \quad U = U(S(P, Q(t, T, I), E), A - D - t \cdot P - T - E, P, Q(t, T, I))$$

The  $P$ ,  $t$ ,  $T$  and  $E$  variables are controllable for the researcher. Thus, his problem is to find the values of these variables that maximise  $U$  for given values of  $D$  and  $I$ . After some mathematical computation, the first-order conditions for maximum  $U$  can be written as

$$(7) \quad \frac{Q_t}{Q_T} = P$$

$$(8) \quad \frac{S_P}{S_E} + \frac{U_P}{U_L} = t$$

$$(9) \quad \frac{S_E}{Q_T} - \frac{U_Q}{U_S} = S_Q$$

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<sup>7</sup> In Norway, for example, general guidelines indicate that professors and associate professors should not use more than approximately 50% of their working time on teaching and administrative duties. Figures from Egeland and Bergene (2012) show, however, that these groups use only 30% of their total working time for research.

$$(10) U_L = U_S \cdot S_E$$

Assuming the second-order conditions for maximising  $U$  are met<sup>8</sup>, Eqs. (7), (8), (9) and (10) determine how optimal values of  $P$ ,  $Q$ ,  $t$ ,  $T$  and  $E$  depend on the required time spent on teaching and administrative duties ( $D$ ) and the researcher's academic ability ( $I$ ), that is

$$(11) P^* = P(D, I), Q^* = P(D, I), t^* = t(D, I), T^* = T(D, I), E^* = E(D, I)$$

The definitional equations above then indirectly decide how much time the researcher uses for writing ( $t^* \cdot P^*$ ), research activity in total ( $t^* \cdot P^* + T^*$ ), paid external activities ( $E^*$ ), working ( $D + t^* \cdot P^* + T^* + E^*$ ) and leisure time ( $A - D - t^* \cdot P^* - T^* - E^*$ ).

Let us have a closer look at the first-order conditions: Eq. (7) implies that the marginal rate of substitution between  $T$  and  $t$  when  $Q = Q^*$  is equal to  $P$ .<sup>9</sup> This means that the researcher will allocate his research time such that the last hour spent on research will provide the same improvement in research quality, no matter whether it is spent on written work or on reading relevant literature. It is worth noting that this condition applies for all  $U_S, U_L, U_P, U_Q > 0$  and  $I$  values, meaning that the condition does not depend on the shape of the researcher's goal function or research abilities. This is reasonable because Eq. (7) shows how the researcher should allocate his time between different research activities (reading and writing).

Eq. (8) states that in the optimum, the sum of the marginal rate of substitution between  $E$  and  $P$  (when  $S = S^*$ ) and between  $L$  and  $P$  (when  $U = U^*$ ) equals the time spent writing each page.<sup>10</sup> To interpret Eq. (8) further, it is useful to rephrase it by multiplying both sides by  $\frac{S_E}{t}$ .

Then, we get

$$(8^*) \frac{\frac{U_P}{U_L} \cdot S_E}{t} = S_E - \frac{S_P}{t}$$

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<sup>8</sup> Based on our a priori assumptions about the functional forms, it is reasonable to assume that the second-order conditions are met.

<sup>9</sup>  $\left(-\frac{\partial T}{\partial t}\right)_{Q=Q^*} = \frac{Q_t}{Q_T}$ .

<sup>10</sup>  $\left(-\frac{\partial E}{\partial P}\right)_{S=S^*} = \frac{S_P}{S_E}$ ,  $\left(-\frac{\partial L}{\partial P}\right)_{U=U^*} = \frac{U_P}{U_L}$ .

When the researcher's utility is independent of the number of pages he writes ( $U_P = 0$ ),  $S_E = \frac{S_P}{t}$  according to (8\*). This means that when maximising utility, the increase in salary of spending an extra hour on external activities ( $S_E$ ) equals the increase in salary of spending an extra hour on writing research ( $S_P/t$ ). However, if the researcher puts weight on research volume (i.e.,  $U_P > 0$ ), it follows from (8\*) that  $S_E > \frac{S_P}{t}$  in the optimum, meaning that the increase in salary resulting from spending the last hour on paid external activities is greater than the increase in salary from spending it writing more pages. The researcher is therefore willing to take a salary reduction to have more pages of research written. If, for example,  $S_E=500$  NOK/hour and  $\frac{S_P}{t} = 400$  NOK/hour, he is willing to pay NOK100 to spend an extra hour on writing rather than doing external activities.<sup>11</sup>

Rephrasing Eq. (9) by multiplying both sides by ( $Q_T \cdot U_S$ ) gives

$$(9^*) \quad U_S \cdot S_E = U_S \cdot S_Q \cdot Q_T + U_Q \cdot Q_T$$

In the optimum, the researcher's increased utility due to the increased salary from spending one additional hour on paid external activities ( $U_S \cdot S_E$ ) is equal to the total increase in utility resulting from spending one additional hour reading relevant literature. The latter increase in utility is the sum of two components. First, ( $U_S \cdot S_Q \cdot Q_T$ ) expresses the increase in utility caused by increased  $T$ , leading to higher quality research and, thereby, higher salary. Second, ( $U_Q \cdot Q_T$ ) is the direct increase in utility due to higher research quality following reading an extra hour of relevant literature.

In cases when  $U_Q > 0$ , it thus follows that  $S_E > S_Q \cdot Q_T$ , meaning that the researcher is willing to reduce his salary to attain higher quality research. The marginal willingness to pay for reading research literature for one hour, rather than working one hour, on external paid activities is  $\left(Q_T \cdot \left(-\frac{\partial S}{\partial Q}\right)_{U=U^*}\right)$ .<sup>12</sup> If, for example,  $S_E = 500$  NOK/hour and  $S_Q \cdot Q_T = 400$  NOK/hour, the researcher is willing to take an NOK 100 salary reduction to spend the last hour reading relevant literature, instead of working on paid external activities. If the researcher does not experience

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<sup>11</sup> 1 €  $\approx$  9.5 NOK.

<sup>12</sup>  $\left(-\frac{\partial S}{\partial Q}\right)_{U=U^*} = \frac{U_Q}{U_S}$

increased utility from improving the quality of his research alone, then ( $U_Q = 0$ ),  $S_E = S_Q \cdot Q_T$ . This means that in the optimum, reading an extra hour of relevant literature yields the same salary increase as working an extra hour on external activities.

Finally, Eq. (10) states that in the optimum, the increase in utility from one hour more leisure time ( $U_L$ ) equals the increase in utility from spending one additional hour on paid external activities ( $U_S \cdot S_E$ ). Note that Eq. (10) applies no matter the weight the researcher puts on his research merits alone (the values of  $U_P$  and  $U_S$ ) and his skills ( $I$ ).

Before we leave the general model, we find it worthwhile to emphasise two things. First, in the case when the researcher's utility does not depend on how well he is doing as a researcher ( $U_P = U_Q = 0$ ), the first-order conditions express that the last hour spent working generates the same increase in salary no matter whether the researcher writes, reads actual literature or works on external paid activities. The researcher will thus allocate his working time to maximise his salary. In contrast, when  $U_P, Q_Q > 0$ , he will not allocate his working time to maximise salary, but will allocate more time on research at the expense of salary. Second, the researcher's actual behaviour is based on his subjective beliefs regarding the shapes of the  $S(P, Q, E)$  and  $Q(t, T, I)$  functions. The objective function ( $Q^0(t, T, I)$ ) (in particular) can differ substantially from the subjective one for inexperienced researchers.

## 4 A closer specification of the actual functions

### 4.1 Conditions for specification

To discuss how the researcher's behaviour or the optimal (chosen) values of  $P^*$ ,  $t^*$ ,  $T^*$  and  $E^*$  are influenced by required time spent on teaching duties ( $D$ ) and his skills ( $I$ ), the first-order conditions can be differentiated with respect to  $D$  and  $I$ . The  $\frac{\partial Z}{\partial Y}$  ( $Z = P^*, t^*, T^*, E^*, Y = D, I$ ) derivatives, however, are complicated and, consequently, are difficult to interpret. Moreover, we want to discuss in more detail how the salary function facing the researcher influences his behaviour. For these reasons, we will specify the actual functions more precisely.

Our choice of functional forms is based on the following considerations: First, the functions must be reasonable and thus, as far as possible, in accordance with the signs of the derivatives imposed on them in Section 3. Second, they must lead to manageable mathematical expressions for how skills ( $I$ ), required time spent on teaching duties ( $D$ ) and the salary function

$(S(P, Q, E))$ , influence the researcher's behaviour, represented by the values of  $P^*, t^*, T^*$  and  $E^*$ .

#### 4.2. Chosen specification

Based on the above, we introduce the following functions:

$$(12) \quad U = U(B) = U(\beta_1 \cdot S + \beta_2 \cdot \ln L + \beta_3 \cdot P + \beta_4 \cdot Q), \quad U_B > 0, \quad \beta_1, \beta_2, \beta_3, \beta_4 > 0$$

$$(13) \quad S = \tau_0 + \tau_1 \cdot P + \tau_2 \cdot Q + \tau_3 \cdot E, \quad \tau_0, \tau_1, \tau_2, \tau_3 > 0$$

$$(14) \quad Q = \alpha_0 \cdot t^{\alpha_1} \cdot T^{\alpha_2} \cdot I^{\alpha_3}, \quad \alpha_0 > 0, \quad 0 < \alpha_1, \alpha_2, \alpha_3 < 1$$

It follows from Eq. (12) that if  $U_{BB} < 0$  then  $U_{SS}, U_{LL}, U_{PP}, U_{QQ} < 0$ . In this case, the researcher has quasi-linear tastes because the marginal rates of substitution between leisure time, on one hand, and salary, number of pages published and their quality, on the other hand, only depend on leisure time, see for example, Nechyba (2011).<sup>13</sup> When  $U_{BB} = 0$ , we will have  $U_{SS} = U_{PP} = U_{QQ} = 0$  and  $U_{LL} < 0$ . In this situation, the utility function will be additive and  $L$  exhibits diminishing marginal utility while marginal utilities are constant for  $S, P$  and  $Q$ .

The salary function in Eq. (13) does not fully satisfy all the requirements suggested in Section 3. We tried out different specifications of it, such that either one, two or three of the cross derivatives ( $S_{PQ}, S_{EP}, S_{EQ}$ ) are positive, without being able to find a tractable mathematical solution. However, it is easy to interpret; the authorities or employers can influence the salary of the researcher through the parameters  $\tau_0, \tau_1$  and  $\tau_2$  in Eq. (13). A partial increase in  $\tau_0$  can be interpreted as a general increase in the researcher's salary; thus, the researchers' unions are particularly interested in increasing  $\tau_0$ . If the authorities change the criteria for researchers' salary and promotion in a way that makes the quality of the published work relatively more important than quantity, the proportion  $\left(\frac{\tau_1}{\tau_2}\right)$  will, according to Eq. (13), be reduced. The salary per hour from paid external activities in Eq. (12) is represented by  $\tau_3$ . Eq. (13) implies that the value of  $\tau_3$  is considered independent from  $P$  and  $Q$ , i.e. how good of a researcher he is. Note

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<sup>13</sup>  $\frac{U_S}{U_P} = \frac{\beta_1}{\beta_3}, \frac{U_S}{U_Q} = \frac{\beta_1}{\beta_4}, \frac{U_P}{U_Q} = \frac{\beta_3}{\beta_4}, \frac{U_L}{U_S} = \frac{\beta_2}{L \cdot \beta_1}, \frac{U_L}{U_P} = \frac{\beta_2}{L \cdot \beta_3}, \frac{U_L}{U_Q} = \frac{\beta_2}{L \cdot \beta_4}$ . A thorough discussion of different types of utility functions can be found in Nechyba (2011).



that this does not mean that  $\tau_3$  is independent of researchers' personal characteristics. There are many characteristics beyond research skills that can influence the potential for income from external activities; for example, the ability to communicate with potential clients and to promote his own expertise.

Eq. (14) implies that  $EL_t(Q) = \alpha_1, EL_T(Q) = \alpha_2, EL_I(Q) = \alpha_3$ , in which  $EL_k(Q)$  denotes the elasticity of  $Q$  with respect to  $k$  ( $k = t, T, I$ ). Hence, when  $0 < \alpha_1, \alpha_2, \alpha_3 < 1$ ,  $Q$  increases concavely with  $t, T$  and  $I$ . Moreover, it is easy to verify that  $Q_{tT}, Q_{tI}, Q_{TI} > 0$  and thus, comply with earlier assumptions. A further interpretation of Eq. (14) is that low (high) values of  $\alpha_1$  and  $\alpha_2$  (compared to  $\alpha_3$ ) mean that hard work can, to a limited (high) extent, compensate for skills, in regard to producing research of high quality.<sup>14</sup> Because active and stimulating working environments boost employees' productivity, the value of  $\alpha_0$  increases the more solid the academic community is where the researcher is employed.

#### 4.3 Model solutions

Using Eqs. (7)–(10) in combination with Eqs. (12)–(14), gives, after some mathematical computation, the following expressions for the optimal values of  $P, t, T$  and  $E$ :

$$(15) \quad P^* = a \cdot I^b$$

$$(16) \quad t^* = \frac{\beta_3 + \beta_1 \cdot \tau_1}{\beta_1 \cdot \tau_3}$$

$$(17) \quad T^* = \frac{\alpha_2}{\alpha_1} \cdot t^* \cdot P^* = \frac{\alpha_2}{\alpha_1} \cdot \frac{\beta_3 + \beta_1 \cdot \tau_1}{\beta_1 \cdot \tau_3} \cdot a \cdot I^b$$

$$(18) \quad E^* = A - D - \frac{\beta_2}{\beta_1 \cdot \tau_3} - t^* \cdot P^* \cdot \left(1 + \frac{\alpha_2}{\alpha_1}\right) = A - D - \frac{\beta_2}{\beta_1 \cdot \tau_3} - \frac{\beta_3 + \beta_1 \cdot \tau_1}{\beta_1 \cdot \tau_3} \cdot a \cdot I^b \left(1 + \frac{\alpha_2}{\alpha_1}\right)$$

in which  $a = \left[ \frac{\alpha_0 \cdot \alpha_1^{1-\alpha_2} \cdot \alpha_2^{\alpha_2} \cdot (\beta_3 + \beta_1 \cdot \tau_1)^{\alpha_1 + \alpha_2} \cdot (\beta_4 + \beta_1 \cdot \tau_2)}{(\beta_1 \cdot \tau_3)^{\alpha_1 + \alpha_2}} \right]^{\frac{1}{1-\alpha_2}}$ ,  $b = \frac{\alpha_3}{1-\alpha_2}$ . Our previous restrictions imposed on the  $\alpha, \beta$  and  $\tau$  values imply that  $a, b > 0$ .

<sup>14</sup> Our specification of the quality function implies that the marginal rates of substitution between  $t, T$  and  $I$  are holding quality constant are  $\frac{\partial t}{\partial T} = -\frac{\alpha_2}{\alpha_1} \cdot \frac{t}{T}, \frac{\partial t}{\partial I} = -\frac{\alpha_3}{\alpha_1} \cdot \frac{t}{I}, \frac{\partial T}{\partial I} = -\frac{\alpha_3}{\alpha_2} \cdot \frac{T}{I}$

Using Eqs. (3), (4) and (5), the expressions for the researcher's chosen values of leisure time ( $L^*$ ), the total time he chooses to spend on research ( $R^*$ ) and the chosen quality of the research produced ( $Q^*$ ) can then be written as follows:

$$(19) \quad L^* = \frac{\beta_2}{\beta_1 \cdot \tau_3}$$

$$(20) \quad R^* = t^* \cdot P^* \cdot \left(1 + \frac{\alpha_2}{\alpha_1}\right) = \frac{\beta_3 + \beta_1 \cdot \tau_1}{\beta_1 \cdot \tau_3} \cdot a \cdot I^b \cdot \left(1 + \frac{\alpha_2}{\alpha_1}\right)$$

$$(21) \quad Q^* = \frac{\beta_3 + \beta_1 \cdot \tau_1}{\alpha_1 \cdot (\beta_4 + \beta_1 \cdot \tau_2)} \cdot P^* = \frac{\beta_3 + \beta_1 \cdot \tau_1}{\alpha_1 \cdot (\beta_4 + \beta_1 \cdot \tau_2)} \cdot a \cdot I^b$$

#### 4.4 Further interpretation of the model's results

Eq. (17) shows that there is a proportional relationship between the amount of time the researcher spends reading relevant literature ( $T^*$ ) and writing ( $P^* \cdot t^*$ ). This is valid independent of the parameters in the salary and utility functions, and for all positive transformations of the quality function. One should, therefore, be sceptical when a researcher claims he spends little time writing but much time reading. If that claim were true, he must believe that the  $\left(\frac{\alpha_2}{\alpha_1}\right)$  ratio is very high. From Eq. (19), it also follows that the researcher's demand for leisure time ( $L^*$ ) only depends on how he values salary compared to leisure time (the values of  $\beta_1$  and  $\beta_2$ ) and the income possibilities from external paid work ( $\tau_3$ ). Moreover, Eq. (21) shows a proportional relationship between the amount of research ( $P^*$ ) and its quality ( $Q^*$ ), meaning that high quality research is likely produced by researchers publishing a lot of papers.

Let us now discuss how actual research policy measures, represented by the parameters  $\tau_0, \tau_1, \tau_2$  and  $D$ , influence the researcher's behaviour.<sup>15</sup> This is an important discussion, not least because universities with high autonomy when it comes to wage setting and teaching duties to the staff seem to perform better than those with less such autonomy (Aghion et al., 2007). Moreover, we will elaborate on how the researcher's skills ( $I$ ) influence his behaviour and research merits. It is worth noting that the researcher's fixed salary, represented by the  $\tau_0$ ,

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<sup>15</sup> The values of  $\tau_0, \tau_1, \tau_2$  and  $D$  can, to some extent, vary among universities within the same country, but in many European countries, trade unions and central authorities can affect these figures, in particular  $\tau_0$ .

does not influence the researcher's behavior at all. A closer inspection of the equilibrium solutions above provides the basis for the following conclusions:

#### *The weight put on the number of pages published*

When the researcher's salary becomes more dependent on research quantity, measured by the number of pages published ( $\tau_1$  increases), the values of  $P^*$ ,  $t^*$ ,  $T^*$ ,  $Q^*$  and  $R^*$  will increase, whereas the value of  $E^*$  will decrease. It is easily seen from Eq. (19) that  $L^*$  is not influenced by  $\tau_1$ . This means that the increase in total time spent on research ( $R^*$ ) is equal to the reduced time spent on external activities ( $E^*$ ). Our model formulation implies that when more emphasis is placed on quantity, it will increase the quality of research as well ( $Q^*$  increases).

#### *The weight put on research quality*

More emphasis placed on research quality (increasing  $\tau_2$ ) will influence  $P^*$ ,  $T^*$ ,  $Q^*$  and  $R^*$  in the same direction as an increase in  $\tau_1$ ; the researcher will publish more pages of higher quality and, consequently, spend more time doing research. Because his demand for leisure time in this case is also independent of  $\tau_2$ , the increase in total research time equals the reduction in time spent on external activities. Contrary to the case when  $\tau_1$  increases, it follows from Eq. (15) that the time the researcher spends on each page published ( $t^*$ ) is independent of the weight the regulators put on research quality; increasing  $\tau_2$  increases quality only through more time spent on reading relevant literature ( $T^*$ ).

#### *Teaching and administrative duties*

Higher requirements from the employer regarding teaching and administrative duties (increasing  $D$ ) will decrease the researcher's time spent on external activities accordingly, see Eq. (18). Small changes in such working conditions, thus, will influence neither the quantity nor the quality of his research.

#### *The researcher's skills*

Neither the time spent on each page written ( $t^*$ ), nor the researcher's demand for leisure time ( $L^*$ ), are influenced by his skills ( $I$ ). More skilled researchers will, however, spend less time on paid external activities ( $E^*$ ). Taking into consideration the model specifications, this result is reasonable. When the potential to earn money from external activities (according to Eq. (13)) is not influenced by the researcher's skills, whereas the improvement in quality from spending

more time per page written and from reading relevant literature is greater the more skilled he is, he will spend more working hours on research than will his less skilled counterparts.

Based on the expressions above, it can be found that  $El_I P^* = El_I T^* = El_I R^* = El_I Q^* = b$ , where  $El_I(q)$  denotes elasticity of  $q$  ( $q = P^*, T^*, R^*, Q^*$ ) with respect to  $I$ . Because  $b > 0$ , more skilled researchers will write more pages of higher quality and spend more time reading relevant literature and on research in general. From the definition of  $b$  in Eq. (18), it also follows that

- $b$  increases with  $\alpha_2$  and  $\alpha_3$ . This means that the more influenced the quality of research is by the researcher's skills and the time spent reading relevant literature, the more the  $P^*, T^*, R^*$  and  $Q^*$  values are influenced by  $I$ , relatively speaking.
- $b > \alpha_3$ . This means that there are mechanisms via the researcher's behaviour that make the research quality vary more, relatively speaking, with skills ( $I$ ) than the quality function indicates. It comes from more skilled researchers spending more time reading relevant literature than less skilled researchers.
- When  $\alpha_3 > 1 - \alpha_2$ , it follows that  $b > 1$ . The more the quality of research is influenced by the researcher's skills and the time he uses for reading relevant literature, the more likely it is that  $P^*, T^*, Q^*$  and  $R^*$  increase convexly with  $I$ .

#### *Influencing the researcher's utility function*

The parameters  $\tau_0, \tau_1, \tau_2$  and  $D$  (above) are directly controllable for universities and/or authorities. Indirectly, however, they can influence researchers' behaviour through campaigns focusing on increasing their work ethic and intrinsic motivation<sup>16</sup>; that is increasing the values of  $\beta_3$  and  $\beta_4$  in Eq. (12). It is easy to confirm from the equilibrium solutions above that this will cause more and better research, due to more time spent on research at the expense of external paid work.

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<sup>16</sup> The interrelationships between the effects on work effort of intrinsic motivation and external payment schemes is discussed in Grepperud and Pedersen (2006).

In the special case where the researcher only cares about salary and leisure time ( $\beta_3 = \beta_4 = 0$ ), all expressions above (except Eq. (19)) will become less complicated. The relative changes in  $P^*$ ,  $T^*$ ,  $R^*$  and  $Q^*$  when  $I$  changes by one percentage point ( $b$  value) are, however, unchanged. In particular, it is worth noting that the expression in Eq. (16) for optimum work effort per page written can be reduced to  $t^* = \frac{\tau_1}{\tau_3}$ . This implies that the researcher would allocate his working hours to maximise his salary. As a result, the time spent on each page written will be similar to the ratio of increased salary from writing one additional page ( $\tau_1$ ), to increased salary from working one additional hour on paid external activities ( $\tau_3$ ).

*The model's results seen in the light of the internationalization of research*

Even though some cultural, political and language barriers still exist in the research community, higher education and research activities have become increasingly internationalized. This has led to extensive ranking of universities worldwide which, in turn, influences their attractiveness to researchers and students (Delgado et al., 2013, Elken et al., 2016). In this respect, our model has both strengths and weaknesses. Its strength is its focus on how attractive a workplace is for researchers, dependent on their level of utility ( $U$ ); they enjoy working there. The shape of the utility function varies individually depending on the weights placed on salary, leisure time and achieved research merits.

The fact that research merits ( $P$  and  $Q$ ) are independent arguments in the researcher's goal function means that an institution's academic reputation is important when academics decide where they want to work. A number of studies confirm that working in solid academic departments enhance an individual's research achievements and, thereby, their utility, see for example Stankiewicz (1979), Kenna and Berche (2011), and Hanssen and Jørgensen (2018). Moreover, our model results imply that every researcher's utility increases with salary and the potential for external income and decreases with teaching duties. These factors are to some extent controllable for national governments and for each institution. Summing up, the model reveals that many factors beyond salary affect where researchers want to work. The weight researchers put on doing good research, compared to salary and leisure time, decide to what extent academic reputation and solid working environments can compensate for low salary and long working days.

Another implication of increased globalisation of research is that it causes higher academic mobility (Kim, 2017) and higher turnover of university staff. This makes it harder for each university to influence the employees' attitudes or shape their utility functions (in particular the  $\beta_3$  and  $\beta_4$  parameters in Eq. (12)). In this way, internationalization of research causes fewer possibilities for the universities to influence the attitudes and behaviour of their staff.

The increased mobility of academic staff due to internationalization leads to the transformation of the model's results on individual behaviour to long-term institutional and national research performance should be done with caution. The model concludes, for example, that heavier teaching duties (increasing  $D$ ) will only affect researchers' time spent on external activities, ( $E$ ) whilst an increase in fixed salary ( $\tau_0$ ) will not affect their behaviour at all. These conclusions can only apply to the institutional level over a very short period of time and/or when the staff's mobility is almost absent. Institutions offering heavy teaching duties and low salaries will, according to our modelling, reduce researchers' utility and, subsequently, attract less competent researchers, those with lower skills ( $I$ ). Thus, employers who embark on such a strategy will be outperformed in a global market. The last statements gain support from Aghion et al. (2007) (2007) and Aghion et al. (2010) in their comprehensive analyses of universities' performance in Europe and the US. Affluent and autonomous universities having the opportunity to spend a lot of money on teaching (resulting in low  $D$ ) and on good and flexible wage schemes ( $\tau_0, \tau_1$  and  $\tau_2$  are controllable) perform highest.

## **5. Concluding remarks**

This paper first briefly reviews the worldwide development of the university sector, the use of reward systems for university employees and the measurement of research output. It concludes that new public management thinking has resulted in more focus on quantitative research measures and external incentives, leading to a significant increase in the number of published articles. Then, it presents a model that describes the behaviour of a researcher characterised by the time spent on activities such as writing research papers, reading relevant literature and paid external work. The model also estimates the researcher's demand for leisure time and, thereby, the total time spent working. In our model, the behaviour of a researcher depends on the following:

- The researcher's utility function. It is assumed that the researcher's utility is influenced by salary, leisure time and research achievements.
- The researcher's skills.
- The quality function, that is, the researcher's perception of how the quality of the written scientific production is influenced by the work effort put into each page written, time spent reading relevant literature and his own skills.
- The salary function, that is, how the researcher's salary is influenced by the number of pages written, the quality of the research and the time used for external paid activities.
- The time the researcher is required to teach, supervise and perform administrative duties.

The last two points are controllable for employers, central authorities and trade unions and, as such, are relevant research policy measures. Researchers' utility functions can be indirectly influenced by the same groups through campaigns giving research achievements higher status.

The general model set up in Section 3 and the first-order conditions for maximising the researcher's utility give rise to a number of interesting interpretations. In the optimum, the researcher will allocate his total research time ( $R^*$ ) such that the last hour spent on his written work ( $t^* \cdot P^*$ ) should yield the same improvement in research quality ( $Q^*$ ) as spending the last hour reading relevant literature ( $T^*$ ). Moreover, the increase in his utility from one hour more of leisure time ( $L^*$ ) equals the increase in utility following from spending one additional hour on paid external activities ( $E^*$ ). These two conclusions hold irrespective of the shape of the researcher's goal function ( $U(S, L, P, Q)$ ) and his skills ( $I$ ).

By introducing special but reasonable functions in Section 4, we have found that changing the basic salary ( $\tau_0$ ) will not influence the researcher's behavior and, thereby, the quantity ( $P^*$ ) and quality of his research ( $Q^*$ ). More weight placed on research quantity (increasing  $\tau_1$ ) and on research quality (increasing  $\tau_2$ ) will increase both the amount of research and its quality, due to researchers spending more time on research work ( $R^*$ ) at the expense of doing external paid work ( $E^*$ ). The total amount of leisure time ( $L^*$ ) and, consequently, working hours ( $R^* + E^* + D$ ) will be unchanged. Furthermore, the model shows that a slightly higher requirement concerning teaching and administrative duties (increasing  $D$ ) will influence neither the quality of research nor the demand for leisure time; such an increase will only lead to the researcher spending less time doing external paid work. Finally, the model reveals skilled researchers (with

high  $I$ ) will spend more time on research and, consequently, produce more pages of higher quality research than their less skilled colleagues. Total work time is independent of the researchers' skills, meaning that increased time used for research activities exactly outweighs reduced time spent on external paid work.

Taking the model formulation and its results as starting points, we can make several policy implications. First, increasing the weight placed on research quantity will increase its quality and vice versa; the model solutions imply a proportional relationship between quality and quantity. Thus, the most important thing to improve research performance is that employers appreciate research and not whether they focus on quality or quantity. This is supported by studies finding a positive correlation between researchers number of papers and number of citations (Sandström and van den Besselaar, 2016), and that the higher number of papers a researcher publishes, the higher the proportion of these papers are among the most cited (Larivière and Costas, 2016). Second, when adjusting for applicants' age, scientific field and type of research (theoretical or empirical), the number of pages written (research quantity) signals their skills, research effort and research achievements. Hence, applicants for academic positions who have done the same types of research could be ranked according to the number of written pages. This measure of research activity is easy to operationalize, making the evaluation work much easier for universities and, thereby, saving them from costly and time-consuming evaluations procedures. Third, the model confirms that skilled researchers with good research records want to spend less time doing external paid work, implying that promoting such possibilities has less impact on the most able researchers than for their counterparts. Massive advertising of good external income possibilities may, thus, be counterproductive because it will attract the least skilled researchers. Fourth, the model reveals that every employer has ways to influence employees' utility and, thereby, the attractiveness of the workplace. Because employees' goal functions differ, it is sensible to make individual salary agreements and teaching schemes to maximise overall satisfaction.

The above discussion reveals the strength of our model. Its mathematical formulation enables us to discuss in a consistent way how actual means for authorities and employers to boost research, either through the salary schemes (the values of  $\tau_0, \tau_2$  and  $\tau_3$ ), through creating an academic environment that encourages research (the values of  $\beta_3$  and  $\beta_4$ ), and through offering employees easy teaching duties (the value of  $D$ ). Additionally, the model focuses on the importance of being competitive in order to attract clever researchers (the value of  $I$ ). The



model is thus an important supplement to all the empirical studies referred to herein, because it reveals the interrelationships between research policy instruments on one hand and researchers' behaviour and subsequently research outcome on the other hand.

Despite the model's stringency, we find it important to emphasise its most prominent weaknesses when using it for policymaking. Ranking researchers' skills by the number of pages they have written requires that they assess their own skills correctly. If their abilities to assess their own skills vary considerably, the number of pages written per unit of time can send a wrong signal with regard to their skills. Inexperienced researchers will, as mentioned earlier, probably be less able to evaluate their skills than the more experienced ones, making this method particularly unreliable for evaluating inexperienced researchers. Second, the number of pages written ( $P$ ) will, according to our model, depend on the degree to which the workplaces where the researcher has worked have stimulated research (the values of  $\beta_3$  and  $\beta_4$ ). There are also indications that being associated with post-doctoral fellows or doctoral students, for example as supervisors, can positively influence the value of  $P$ . In "fast-moving" research, characterised by rapid cumulative progress through many publications with short intervals, postdoctoral fellows appear to be more prevalent (Igami et al., 2015). A study of peer reviewed publications by all doctoral students in Quebec also found that young scholars contribute to a considerable proportion of new knowledge created (Larivière, 2012). All else being equal, the numbers of pages produced will, thus, overestimate the skills of researchers who have been members of solid working environments, compared to researchers who have worked in less stimulating ones. Third, social ties between researchers and editors of journals can influence our measures of research production ( $P$ ) and its quality ( $Q$ ). A recent study by Colussi (2017) found that during an editor's appointment, his or her former graduate students can expect an increase in the number of articles published by 15%. Moreover, articles by former graduate students of an editor receive on average 6.7 more citations when this editor is in charge. The performance of researchers with such ties will, thus, be overstated. Lastly, as emphasised earlier, one has to adjust for the applicant's age, the subject area and the kind of research carried out.

It is also important to note that our model is a static one and shows the individual short-term effects of different policy measures. The long-term effects at an institutional and national level could be different, as far as research performance is concerned. Our model shows, for example, that a general increase in salary independent of the researcher's merits and less heavy teaching

duties are poor instruments for boosting individual research. In the long-run, however, a higher fixed salary and fewer teaching duties will increase all researchers' utility and, thereby, make the workplace more attractive. This will, in turn, attract more good scientists who, according to our model, perform better and improve the academic environment. For universities in small countries, it is particularly important to offer a combination of salary, leisure time, teaching duties and academic environment that make them attractive (provide high  $U$ ) to the international community of researchers.

Despite the above-mentioned limitations, the paper has nevertheless presented a model that provides a realistic description of a researcher's behaviour and, thus, is useful for universities, trade unions and politicians dealing with research issues. The increased focus on different reward schemes to boost research in many countries makes the model particularly relevant now; as long as the chosen specifications of the actual functions in Section 4 are reasonable, their outcomes will be too. It is also worth noting that over a short period, it is likely that neither the composition of the workforce at universities nor its working conditions will change much. This supports the relevance of our model.

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