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On the Firms' Decision to Hire Academic Scientists

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Abstract

Firms hire scientists to increase their absorptive capacity and generate new knowledge and innovations. In this paper, we analyse a firm's optimal contracting decisions when scientists have differing tastes for science. The contracted scientist engages in multitasking following her own academic agenda and the firm's agenda and each task delivers distinct outcomes. Our setting disentangles the productivity and absorptive capacity effects for the firm as well as the preference and opportunity cost effects for the scientists. The *productivity* effect refers to a scientist's contribution to profits by improving efficiency or by developing new products. The *absorptive capacity* effect relates to the ability of the hired scientist to assimilate the knowledge produced elsewhere for the benefit of the firm. The *preference* effect reflects the fact that scientists, unlike other knowledge workers, have a taste for science and accept lower wages when allowed to pursue a personal academic agenda. The *opportunity cost* effect captures the fact that top scientists have better options in academia. In a baseline model we show that firms do not reward academic outcomes and only hire top scientists when academia is a poor alternative to joining the private sector. We then extent the analysis allowing for asymmetric information about the scientists' taste for science, a nominal effort constraint and the lack of complementarity between research activities.

Keywords: Economics of Science; R&D activities; Academia; Incentive provision; Multitasking; Absorptive capacity.

JEL Classification: D25, D86, J31, O31, O32

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1 Introduction

The successful implementation of a firm's research and innovation agenda critically depends upon the recruitment of knowledge workers and the effective management of their incentives. Drucker (1959) defines such individuals as high-level workers who apply their theoretical and analytical knowledge to achieve high levels of productivity and creativity. A specific group of these knowledge workers are the scientists, for whom the ability to create and use knowledge is driven by an inherent taste for science: an intrinsic motivation to pursue scientific research. Acknowledging the value added by such workers, some notorious firms have managed to attract researchers who are top scientists in their fields.[1]

A broad literature on the economics of science has focused on the firms' motivations to hire scientists in the past years. In the 1990s, various authors started exploring the benefits for firms of investing in science to increase their absorptive capacity, defined as the ability to identify, assimilate and use scientific knowledge (e.g. Cohen and Levinthal 1989, 1990; Rosenberg 1990; Arora and Gambardella 1994; Dasgupta and David 1994; Stephan 1996; Cockburn and Henderson 1998). This investment generally consists in hiring scientists who can increase commercial gains by promoting the firm's research program but who can also understand and contribute to a broader research agenda, one that is recognised and valued by the academic community.

Sauermann and Cohen (2010) argue that a more insightful analysis of innovation requires that we pay close attention to the individuals involved and design carefully tailored incentive contracts. They show that individual-level motives can affect not only innovative efforts (in terms of the number of hours worked) but also the nature of worker performance. Intellectual challenge, income and independence are shown to have a positive influence on output, while job security and responsibility have a negative impact. Similarly, Banal and Macho-Stadler (2010) show that commercial rewards motivate academic scientists to search for ground-breaking innovations. Finally, Lacetera and Zirulia (2012) show that inter-firm competition also impacts incentive contracts in a model that combines the intensity of competition in the product market, the degree of knowledge spillovers and the intrinsic motivation of the scientists to pursue basic research.

The literature establishes that hiring scientists creates value subject to their incentives being properly understood and monitored. However, and to the best of our knowledge, no analysis has yet questioned how academically driven a scientist should be for a firm to hire her and maximize

[1] "Top scientist" is used throughout this paper to refer to scientists with a strong 'taste for science' who also enjoy the recognition of the academic community.

profits. In other words, more needs to be done to characterize a firm's optimal investment in basic science.[2]

The aim of this paper is to shed light on the circumstances and factors that influence a firm's contracting decisions when hiring academic scientists. It does so by incorporating very specific aspects of the contracting relationship that are particularly salient when considering academic scientists.

Firstly, we consider that scientists have the ability to engage in multi-tasking and can devote efforts to both, the firm's research agenda and to their own academic research. Even if both activities qualify as research and can exhibit some complementarities, their respective outcomes differ. In particular, academic outcomes are valuable to the scientists not because they increase the firm's profits but because they are valued and recognised by the scientific community. This approach allows us to address a concern raised in Stern (2004) according to which many of the empirical studies devoted to measuring a scientist's value added confound the so-called preference and productivity effects. The *productivity* effect refers to a scientist's ability to increase profits by improving efficiency or by developing new products. The *preference* effect reflects the fact that scientists with a taste of science have an intrinsic motivation to pursue research and will therefore accept lower wages when allowed to do so. We address the issue raised in Stern (2004) by separating these effects.

Secondly, we consider that a firm typically faces a pool of academic scientists who differ in their intrinsic motivation to do science . The contracted scientist's taste for science directly impacts the firm's resulting *absorptive capacity* and the *opportunity cost* faced by the scientist who leaves academia. Indeed, we assume that top scientists have a greater ability to absorb knowledge produced elsewhere and contribute to the firm's profits as knowledge brokers, but, the same scientists can also aim for top jobs in academia and thus have a higher opportunity cost of accepting the firm's offer.[3] Hence, we consider that a scientist's taste for science impacts both, the willingness to conduct scientific research and the value of her outside option.

Our results can be summarized as follows. In the baseline model, where the firm can verify the scientists' *types* reflecting the intensity of their taste for science, the hiring decision is entirely

[2] We rationalize private investments in basic research in the spirit of Murdock (2002) and Bénabou and Tirole (2003 and 2016). When agents have an intrinsic motivation to pursue a task, allowing them to allocate some time to this task is a valuable instrument that can control participation and incentives.

[3] The opportunity cost effect has empirical support in Zucker et al (2002) who estimate the likelihood of scientists moving from 'academe to commerce' in a duration model where the scientist's decision to move or not depends on the scientist's quality and her reservation wage. In their setting the scientist's reservation wage depends negatively on the frequency of offers received from industry and positively on the number of top-quality universities in the local area, which increases options to remain in academia.

driven by the absorptive capacity, preference, and opportunity cost effects. The productivity effect plays no role. This is so because in our setting scientists can contribute equally to the firm's agenda, regardless of their taste for science. Private firms hire top scientists when the offer from academia is a poor alternative. When this is not the case, firms select the weakest type of scientist: those with the lowest taste for science. The optimal contract is one in which only the outcomes related to the firm's agenda are rewarded. Academic achievements go unrewarded. The effort dedicated by the scientist to her own academic scientific agenda is guided solely by her taste for science.

We test the robustness of these results in different scenarios. In the first of these, we consider that the scientist's taste for science is private information. Hence, the firm must ensure that the contract it offers will deter the scientists it does not want to attract. We show that the firm must reward academic outcomes to attract top scientists. This means that performance pay for scientific achievements serves as a screening device. This result supports findings in Sauermann and Roach (2014, p.32) who establish that "Scientists who believe themselves to be of high ability and who train at top tier institutions have a higher price of publishing". Consequently, we show that adverse selection may lead to a selection bias whereby the firm is less inclined to target scientists with the strongest intrinsic motivation to pursue science. [4]

In the second scenario, we consider that the scientist's choice of efforts is subject to a fixed nominal effort budget constraint (as in Cohen et al. 2018). Thus, the more effort the scientist devotes to her own academic research agenda, the less she can devote to the firm's agenda. We consider that, under the constraint, efforts can be either curtailed or enhanced. We show that the optimal contract is immune to the consideration of the nominal effort budget constraint.[5] The target type remains the same unless it is the type of scientist that is most affected by the introduction of the constraint.

In the third and last scenario, we show that, in the absence of any complementarity between research activities, the contracted scientist focuses on a single agenda: the one promising the highest expected returns. Consequently, the firm can no longer benefit from the productivity effect and the preference effect simultaneously. To deter scientists from focusing on their academic agenda, the reward for non-academic outcomes must be increasing with the scientist's type. In such a context, top scientists are hired to pursue their own scientific research agenda as

[4] Liu and Stuart (2014) show that only employees who occupy leadership roles are rewarded for their publications, while technicians go unrewarded.

[5] More precisely, we show that that there exists a multiplicity of optimal contracts and that the initial contract is one solution.

they would require a large incentive payment to spend time on the firm's agenda. Hence these are hired with the view that they will specifically contribute to the firm's absorptive capacity.

The paper proceeds as follows. In Section 2 we provide a brief literature review on how investment in science and the build-up of absorptive capacity in firms have evolved over time. In Section 3 we present the baseline model and derive initial results. In Section 4 we consider several extensions of the baseline model. We conclude in section 5.

2 The build-up of absorptive capacity in practice

In the 1920s, large US corporations such as AT&T, General Electric, DuPont and Eastman Kodak established in-house research groups pursuing far-sighted basic research alongside research of a more applied nature. The research on polymers, for example, conducted in the mid-1920s by DuPont at Purity Hall, its basic research laboratory, led to two discoveries with enduring impact that entered commercial production in the 1930s: neoprene and nylon (Hounshell and Smith 1988). In these years, big firms gradually developed their internal scientific capabilities to gain a better understanding of the physical phenomena that were giving rise to increasingly complex technical problems (Hoddeson 1981).

The golden age of corporate research, however, began to wane after the 1950s. Indeed, in the 1980s and 1990s large firms became more reliant on external inventions and focused on incremental innovation. In these decades, it was the universities, public research centres and research-intensive start-ups funded by venture capitalists that were to take the lead in the emerging research fields of biotechnology, information technologies, nanotechnology and the like.[6] Arora et al. (2015) argue that today the division of innovative labour is considerable: large firms that still invest in scientific capabilities do so in order to be effective buyers of knowledge rather than to produce research. This suggests that firms nowadays build their absorptive capacity so as to benefit from knowledge generated elsewhere, notably in academic institutions, rather than to participate in the creation of knowledge internally (Cohen and Levinthal 1989).

However, it is also the case that many of today's large corporations originated as science-based start-ups and continue to invest and produce basic research. The commercial biotechnology company, Genentech, founded in 1976 by a venture capitalist and a scientist, publishes an average of 200 academic publications a year.[7] Likewise, Google publishes hundreds of academic papers

[6] Arora et al. (2015) show that the propensity of large firms to publish scientific results declined between 1980 and 2007, whereas their propensity to patent increased but that their patents continue to cite science at the same rate as before.
[7] https://www.gene.com/stories/the-paper

every year, with one of its senior research scientists summing up the attractiveness of the company for researchers as follows: "You get to influence great products by working with great engineers, while having the freedom to do research alongside some of the world experts in machine learning."[8]

Zucker and Darby (2014) provide evidence that firms in many sectors have moved from a "scientists in industry" model to a "corporate-academic" model. In the former, the research agenda of scientists is not left to their discretion and they receive no incentives to collaborate with academia. In the latter, more recent approach, corporate scientists are free to select their research agenda, and they receive incentives to publish and to be active participants in the broader academic community. In the words of the authors: "A 'corporate-academic' model has developed and become institutionalized over the last three decades which emphasizes attracting the best and brightest scientists, providing them with a commensurate increase in autonomy including initiation of bench-level collaborations with top university scientists in which valuable tacit knowledge is transferred in both directions."

3 The baseline model

In this section we introduce our baseline model and key variables. We then discuss the setting and assumptions in greater details. Finally, we solve for the optimal hiring decision and its associated contract. A summary table of the notation used in the model is set out in the Appendix.

3.1 The setup

The hiring and contracting decisions are captured in a sequential game. Its timing is depicted in figure 1 below.

[8] https://research.google.com/workatgoogle.html

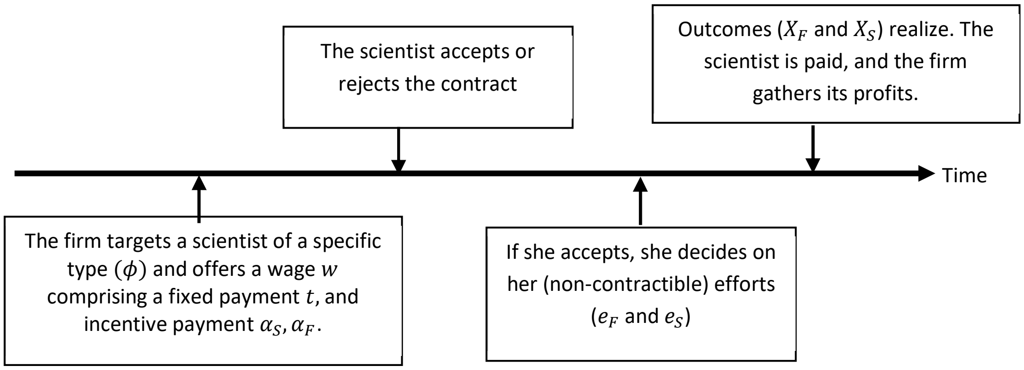

Fig. 1: The timing of the game.

3.1.1. The scientists

Each scientist is characterized by a *type* that captures her marginal utility of academic research, or taste for science. We consider that scientists are not scarce. While some differ in their taste for science, there are also many scientists who share the same type. The parameter $\phi \in \left[\underline{\phi}, \overline{\phi}\right]$ denotes the strength of the scientist's type.

Once contracted, the scientist can devote time both to the firm's research projects and to her own research agenda. Let e_F denote the effort devoted to the firm's agenda and e_S the effort dedicated to her own scientific agenda. We do consider that these activities might be complementary and so assume that the cost, to the scientist, of exerting both efforts, denoted $C(e_F, e_S)$, is given by

$$C(e_F, e_S) = \frac{1}{2}(e_F^2 + e_S^2). \tag{1}$$

When exerting these efforts the scientist generates two distinct outcomes. Outcome $X_S = e_S + \varepsilon_S$ measures her academic achievements. These are solely valuable to the scientist who obtains utility ϕX_S from such outcomes. This enables us to capture the preference effect depicted in Stern (2004). Outcome $X_F = e_F + \varepsilon_F$ denotes the firm's tangible financial revenues. The variables ε_F and ε_S are random shocks with zero mean.

The contracted scientist gathers a utility given by

$$U(\phi; e_F, e_S) = w + \phi X_S - C(e_F, e_S), \tag{2}$$

where w is the wage.

To evaluate the reservation utility, we assume that when a scientist rejects the contract, she can stay in academia and devote herself entirely to her academic research agenda and receive a reservation utility equal to $\underline{U}(\phi; e_S) = \underline{w} + \phi X_S - C(e_S)$. The wage is composed of a fixed fee and a variable component whereby academic achievements are rewarded with a rate α, thus $\underline{w} = \underline{t} + \alpha X_S$.[9] Without any loss of generality, we will let $\underline{t} = 0$. Maximizing $\underline{U}$ over e_S leads us to $e_S = (\alpha + \phi)$ and a type-dependent reservation utility given by

$$\underline{U}(\phi) = \frac{1}{2}(\alpha + \phi)^2. \tag{3}$$

3.1.2. The firm

The firm wants to hire a scientist who can potentially fulfil two functions. The first is to generate inventions leading to more efficient production processes or novel products via her dedication to the firm's research agenda. This function generates returns to the firm given by τX_F, where $\tau \geq 0$ which captures the *productivity effect* introduced by Stern (2004). The second is to contribute to the firm's *absorptive capacity* via her ability to understand and use knowledge produced outside the firm's boundaries via her motivation to pursue a more academic agenda. We denote ρX_A the profits accruing to the firm from investing in absorptive capacity where $X_A = \phi + \varepsilon_A$. The parameter ε_A is a random variable with zero mean and $\rho \geq 0$ is the marginal return associated with such an investment. From the above, it follows that the firm's overall profits are given by

$$\Pi = \tau X_F + \rho X_A - w. \tag{4}$$

3.1.3. The contract

We consider efforts as not verifiable, while the outcomes X_F and X_S are. We assume that the firm uses a linear contract composed of a fixed component and a performance-contingent payment based on these outcomes so that $w = t + \alpha_F X_F + \alpha_S X_S$.[10] The fixed fee t, α_F and α_S are all endogenously determined. We consider incentive payments that are non-negative $\alpha_F \geq 0$ and $\alpha_S \geq 0$.

[9] One can think of αas being stronger in academic institutions where promotion is dependent upon academic achievements.

[10] As argued in Lacetera and Zirulia (2012, p.553), linear contracts are not only commonly observed, but also justifiable on theoretical grounds in Holmstrom and Milgrom (1987) and Bose et al. (2011).

3.2 The underlying motivation for the setup.

The paper addresses investment in absorptive capacity by considering that a firm chooses the type of scientist it wants to hire on the understanding that a stronger type will contribute more to its absorptive capacity. Scientists with a higher marginal utility of academic research are more intrinsically motivated to pursue basic research. Consequently, these scientists are more likely to know of and understand the latest research findings and technological advances generated outside the firm and adapt them to its needs. Thus, as argued in the introduction, and supported by the literature, we consider investment in absorptive capacity as the contracting of specific human capital.[11] That said, we understand that this is a very specific form of investment. Clearly, firms can undertake other strategies to increase their absorptive capacity by improving their connectedness to the scientific community. Zucker et al (2002) distinguish between 'affiliated scientists', who are those who move from an academic job to industry and 'linked scientists' who remain affiliated to research institutes but collaborate with industry.[12]

While the productivity effect, captured by τX_F, may be easier to conceptualise, one may have difficulties understanding the returns associated with the investment in absorptive capacity, namely ρX_A. Cohen and Levinthal (1989) contend that "firms may conduct basic research less for particular results than to be able to identify and exploit potentially useful scientific and technological knowledge generated by universities or government laboratories, and thereby gain a first mover advantage in exploiting new technologies. Likewise, basic research may permit firms to act as a rapid second mover in the face of spillovers from a competitor's innovation."

There is an open debate in the literature as to what is meant by absorptive capacity and whether one has in mind the potential or realized absorptive capacity.[13] We rely on the initial definition proposed by Cohen and Levinthal (1990) whereby absorptive capacity refer to an ability to absorb and understand knowledge. Hence, we consider that it relates to an intrinsic capability which pertains to a scientist, whether she engages in any research agenda or not. Under these circumstances one may suggest that the variable ϕ is not verifiable and known only to the scientist when the contract is issued. We address this concern analysing optimal contracting under adverse selection.

[11] See, for instance, Sauermann and Cohen (2010).

[12] The importance of connectedness related to publication and dissemination of research by industry scientists alone or in collaboration with academic scientists receives support in Jong and Slavova (2014) and Simeth and Raffo (2014). See also Perkmann et al (2013) for a review of different forms of academic engagement and university-industry relations.

[13] See Cohen and Levinthal (1990), Zahra and George (2002) and Todorova and Burisin (2007)

The framework we consider assumes that the academic outcomes (X_S) have no impact on the firm's profits. Before extending the initial setting, we address concerns around this hypothesis solving for the optimal contract when academic outcomes may generate either positive or negative commercial spillovers for the firm. Gans et al. (2017) claim that firms may be reluctant to permit their scientists to publish in academic journals and might be more inclined to protect their ideas through secrecy. Yet, evidence suggests that some firms also benefit from encouraging publications: "From its inception, Genentech co-founder Herb Boyer insisted on publishing their discoveries in academic journals—as a stamp of quality—proving that they were in league with the best academic institutions, and to lure the best and brightest minds in bioscience to the company".[14]

An important assumption of the model is that the contracted scientist engages in multitasking. We separate activities that seek outcomes which are directly valuable to the firm, because they generate financial revenues (via the creation of new products, patents and/or more efficient production processes), from activities that are valued by the scientist herself, because they are recognised by the scientific community even though they are not directly valuable to the firm (such as academic publications). This approach is closely related to that developed by Bénabou and Tirole (2016) and allows us to consider the firm's incentive to promote in-house academic research.[15] Doing so it enables us to give support to Cockburn and Henderson (1998) who show that that incentivising in-house researchers to publish in academic journals, as an additional perk, allows them to attract top scientists in a context where types are not verifiable. We also address the possibility that scientist's efforts allocation is constrained and spending more time on one task means having to spend less on the other.

Finally, some concerns can be raised about the cost function. As such, it fails to capture potential costs associated with multitasking whereby pursuing two agendas increases the cost of efforts. In fact, the cost function is such that research activities exhibit some complementarity. Indeed, assume that a scientist devotes e to research. If she devotes all of her time to a single agenda she incurs a cost $C = C(e, 0) = C(0, e)$. If, instead, she divides her time in such a way that she spends se on her agenda with $s \in]0,1[$, we have $C(se, (1 - s)e) < C$. In other words, we consider settings where the research needed to enhance the firm's core business and the scientist's academic research are closely related. In order to challenge this assumption, we compare our findings to those that prevail when there are no complementarities between research activities and we have $C(se, (1 - s)e) = C(e, 0) = C(0, e)$ for any $0 < s < 1$. We do so by considering that the cost function $C(e_F, e_S) = \frac{1}{2}(e_F + e_S)^2$. It enables us to address the findings

[14] https://www.gene.com/stories/the-paper

[15] Murdock (2002) also separates outcomes that benefit the firm from those that benefit the agent, albeit in a different context.

in Gambardella et al. (2015) showing that some firms may offer less autonomy to scientists working on projects close to the firm's core business.

3.3 Optimal contracting in the basic framework

The scientist maximizes (2) and selects her efforts such that the marginal cost of each effort matches its marginal benefit:

$$e_F = \alpha_F \text{ and } e_S = \alpha_S + \phi. \tag{5}$$

The firm perfectly anticipates these effort levels and maximizes its expected profits:

$$\max_{w,\phi} \tau X_F^e + \rho X_A^e - (t + \alpha_F X_F^e + \alpha_s X_S^e), \tag{6}$$

where X_F^e, X_S^e and X_A^e are the expected values for X_F, X_s and X_A respectively; hence, we have $X_F^e = e_F, X_S^e = e_s$ and $X_A^e = \phi$.

The firm must take into consideration the following participation and feasibility constraints:

$$U(\phi; e_F, e_S) \geq \underline{U}(\phi) \tag{7}$$

for all ϕ, where $\underline{U}(.)$ is given by (4), and

$$\underline{\phi} \leq \phi \leq \overline{\phi}, \tag{8}$$

$$\alpha_F \geq 0 \text{ and } \alpha_S \geq 0. \tag{9}$$

Clearly, the fixed payment t is set such that the participation constraint binds and the firm's expected profits are given by

$$\Pi^e = \tau e_F + \rho\phi + \phi e_S - \frac{1}{2}(\alpha + \phi)^2 - C(e_F, e_S). \tag{10}$$

Proposition 1: *The firm contracts either the strongest or the weakest type of scientist:*

$$\phi^* = \overline{\phi} \ \textit{if} \ (\rho - \alpha) \geq 0, \ \textit{and} \ \phi^* = \underline{\phi} \ \textit{otherwise.}$$

The performance-contingent part of the optimal transfer is such that only outcomes directly related to the firm's research agenda are rewarded and there is no reward for the scientist's own academic outcomes: $\alpha_F = \tau$ and $\alpha_S = 0$. In equilibrium we have $e_F = \tau$ and $e_S = \phi$. The fixed fee is such that the scientist obtains her reservation utility.

Proof: See Appendix.

The hiring decision does not depend on the productivity effect because all scientists, irrespective of their type, share the same ability to contribute to the firm's agenda.[16] Whether the firm hires a strong type or not depends on the sign of $(\rho - \alpha)$, which measures the net benefit

[16] The productivity effect would matter in a context where the two research agenda exhibit some complementarity that is beneficial to the firm, that is whereby Π^e would depend on the product $(X_F^e X_S^e)$.

from investing in absorptive capacity. This accounts for the fact that the firm must deter scientists from remaining in academia if it wants to build up its absorptive capacity. Hence the only deterrent to contracting a scientist who is strongly motivated to conduct scientific research is her reservation utility from remaining in academia, which is type dependent. When this is sufficiently low, the firm contracts the scientist with the strongest taste for science to pursue an academic agenda not because of any greater dedication to the firm's agenda but because of her greater dedication to her own academic agenda. This dedication results in greater non-pecuniary benefits (namely ϕe_S) and puts downward pressure on the wage the scientist is willing to accept to work for the firm. This is in line with the findings in Stern (2004) and Sauermann and Roach (2014) showing that scientists are willing to accept lower wages when given the opportunity to "be scientists" meaning that they can pursue a research agenda from which they derive some personal gratification.

In terms of overall remuneration, the contracted scientist is made residual claimant of the profits she generates when devoting time to the firm's agenda. She then devotes $e_F = \tau$ to the firm's agenda and receives expected performance contingent pay equal to τ^2 whether she is of a strong or a weak type. Hence, the expectation is that both types receive the same "bonus" payment. The fixed component, however, is higher for the strong type in order to match her higher reservation utility.

3.3.1 Allowing for spillovers from academic outcomes towards the firm's profits

Before we extend the basic setting to test its robustness, we consider a situation where academic outcomes may impact profits as we consider that the profits are given by

$$\Pi = \tau X_F + \rho X_A + \upsilon X_S - w, \qquad (11)$$

where υ could be either positive or negative.

The efforts exerted by the scientist remain unchanged.

Corollary 1: *In the presence of spillovers, the optimal hiring decision is such that the firm contracts either the strongest or the weakest type of scientist:*

$$\phi^* = \overline{\phi} \ \text{ if } \ (\rho - \alpha) + \upsilon \geq 0,$$

$\phi^* = \underline{\phi}$ *otherwise. Thus, the firm is keener to contract the strongest type in the presence of positive spillovers* $\upsilon > 0$ *and deterred from doing so in the presence of negative spillovers* $\upsilon < 0$.

The optimal wage is such that $\alpha_F = \tau$ *and* $\alpha_S = \max\{\upsilon, 0\}$. *The fixed fee is such that the scientist obtains her reservation utility.*

Proof: See Appendix.

In conclusion, the scientist remains a residual claimant of all the benefits she generates for the firm in the presence of positive spillovers. This means that she has additional incentives to follow her own agenda. When spillovers are negative, the contract depicted in proposition 1 remains optimal as we must have $\alpha_S \geq 0$ and the firm is more likely to hire the lowest type.

4. Extending the basic framework and testing the robustness of the optimal contract

In this Section we present three extensions to the basic framework. First, we consider that the scientists' types are private information. In a second extension efforts are subject to a nominal effort budget. Finally, in the third extension we examine the outcome that arises when there is no complementarity between research activities.

4.1 Optimal contracting under adverse selection

We examine whether the optimal contract and hiring decision are robust to the introduction of asymmetric information and assume that the scientist's type is not verifiable. The problem of the firm consists in writing a contract that (i) maximizes its profits, (ii) guarantees that the target type will accept the contract it offers and, finally, (iii) deters other types from applying. The issue is complicated by the fact that scientists face countervailing incentives: stronger types require a wage that matches their higher reservation utility, but they also derive greater satisfaction from dedicating themselves to their own academic scientific agenda, which puts downward pressure on their wages.

Only a few theoretical papers have addressed contracting in settings involving multitasking and adverse selection. Bénabou and Tirole (2016) consider a scenario in which agents engage in two tasks, one of which leads to a contractible outcome that positively correlates with the worker's privately known type. They show that the distortions generated by adverse selection and the resulting incentive schemes depend on the market structure. Under monopsony the aim is to reduce informational rents. This is achieved via a contract that under-incentivises the low type of worker. As firms compete for workers, their focus shifts to separating types. This is done thanks to high-powered incentive schemes aimed at strong types which deter them from engaging in tasks producing less contractible outcomes. De Fraja (2016) characterizes the optimal public funding of research institutions by a government that favours applied over basic research. Institutions view both types of research as perfect substitutes, differ in their prestige and are privately informed about their ability to conduct research. He shows that, in the presence of adverse selection, the more efficient and more prestigious institutions are required to perform too much applied research to reduce their informational rents. In sum, attention is biased in both papers towards the principal's favoured task, namely contractible outcomes in Bénabou and Tirole (2016) and applied research in De Fraja (2016).

The main difference between our approach and that adopted in these two papers is that we consider a setting in which the firm knows that scientists of all possible types are available, and it wishes to target a specific type. This seems consistent with the way science-related jobs are advertised in social networks, where job offers targeting a specific type of candidates are posted and the selection criteria announced are often so detailed that candidates not matching them would be discouraged to apply. [17] In our setting, the firm does not have to set up separating contracts that satisfy the participation constraint of each type. It needs only guarantee that the type it targets is willing to accept the contract, while the same contract does not satisfy the participation constraint for all other types. In this context, informational rents are not an issue.

To solve for the optimal contract, we will consider that the firm can only hire two types of scientist: $\phi \in \left\{\underline{\phi}, \overline{\phi}\right\}$ and that there are many scientists of each type. These are the only relevant types in the basic framework. Thus, and as said before, the firm's problem is to write a contract that will only appeal to the type it targets.[18]

Let us then consider that the firm wants to contract a scientist of type $\hat{\phi}$. It issues a contract which specifies the wage $\widehat{w} = \hat{t} + \hat{\alpha}_F X_F + \hat{\alpha}_S X_S$.

Given this incentive scheme if it attracts a scientist of type ϕ', which is possibly different from $\hat{\phi}$, the contracted scientist exerts the following efforts: $e_F(\phi') = \hat{\alpha}_F$ and $e_S(\phi') = \hat{\alpha}_S + \phi'$. Hence the devotion to the firm's agenda is the same no matter which type accepts the contract. However, notice that we have

$$e_S(\phi') = e_S(\hat{\phi}) + (\phi' - \hat{\phi}). \tag{12}$$

Under adverse selection, when the firm targets type $\hat{\phi}$, it must write a contract that satisfies two conditions. Firstly, type $\hat{\phi}$ must accept a contract which requires that

$$\hat{t} + \hat{\alpha}_F e_F(\hat{\phi}) + \hat{\alpha}_S e_S(\hat{\phi}) + e_S(\hat{\phi})(\hat{\phi}) - C\left(e_F(\hat{\phi}), e_S(\hat{\phi})\right) \geq \underline{U}(\hat{\phi}), \tag{13}$$

[17] See for instance https://jobs.sciencecareers.org/

[18] Were we to assume that there was a scarcity of scientists (for instance only one scientist), then the firm's problem would be in making sure that the hired scientist selects the contract that matches her type. This alternative approach, however, is not in line with our research question which focuses rather on the type of scientist the firm wants to hire.

Secondly, the other type must be deterred from applying, which holds provided:

$$\hat{t} + \hat{\alpha}_F e_F(\phi') + \hat{\alpha}_S e_S(\phi') + e_S(\phi')(\phi') - C\big(e_F(\phi'), e_S(\phi')\big) \leq \underline{U}(\phi'), \qquad (14)$$

for $\phi' \neq \hat{\phi}$.

Proposition 2: *The contract* $\{\overline{t}, \overline{\alpha}_F, \overline{\alpha}_S\}$ *targeting a strong type satisfies incentive compatibility and leaves no rents to the strong type provided the performance-contingent payments are sufficiently high. Specifically, we must have* $\overline{\alpha}_S \geq \alpha$*. In contrast, the contract* $\{\underline{t}, \underline{\alpha}_F, \underline{\alpha}_P\}$ *targeting a weak type satisfies incentive compatibility and leaves no rents to the weakest type of scientist provided* $\underline{\alpha}_S \leq \alpha$*.*

Proof: See Appendix.

This result shows that the parameter $\overline{\alpha}_S$ acts not as an incentive but as a screening device. Since the optimal contract in the baseline model does not reward academic outcomes, it systematically fails to attract strongly motivated scientists. However, when a weak type is targeted, incentive compatibility is not an issue leading to the following result.

Corollary 1: *If it is optimal to select a weak type scientist under symmetric information, then the contract with symmetric information satisfies incentive compatibility and remains optimal.*

Proposition 3: *The optimal asymmetric information contract targeting a strong type of scientist is such that*

- *The scientist obtains her reservation utility*
- *The incentive pay associated with the firm's research agenda is* $\overline{\alpha}_F = \tau$
- *The incentive pay associated with the scientist's agenda is such that* $\overline{\alpha}_S = \alpha$*.*

Proof: The proof of proposition 1 establishes that (i) the objective function is concave in (α_F, α_S), (ii) setting $\alpha_F = \tau$ is optimal irrespective of the value of α_S, and (iii) the optimal un-constrained value for α_S is $\alpha_S = 0$, irrespective of α_F. Therefore, when the incentive constraint $\alpha_S \geq \alpha$ applies, it becomes optimal to set $\alpha_S = \alpha$. ■

The firm incurs a cost when it wants to hire a strong type because it must reward her for her academic achievements. The optimal hiring strategy depends on whether this cost is worthwhile. In any case, the firm is less inclined to contract scientists with the strongest intrinsic motivations to pursue science.

Proposition 4: *Under adverse selection, the optimal contracting strategy is as follows:*

- *When* $2\left(\overline{\phi}-\underline{\phi}\right)(\rho-\alpha)\leq\alpha^{2}$ *the firm selects the weakest type and relies on the baseline contract with symmetric information whereby* $\alpha_F=\tau$ *and* $\alpha_S=0$.
- *When* $2\left(\overline{\phi}-\underline{\phi}\right)(\rho-\alpha)>\alpha^{2}$ *the firm selects a strong type of scientist and sets* $\alpha_S=\alpha$.

Proof: One must compare the first best contract targeting a weak type with a second-best contract targeting a strong type and we have

$$\left[\Pi(\overline{\phi})-\Pi\left(\underline{\phi}\right)\right]=\left(\overline{\phi}-\underline{\phi}\right)(\rho-\alpha)-\frac{1}{2}\alpha^{2} \tag{15}$$

where $\Pi(\phi)$ if the firm's profits when targeting type $\phi\in\left\{\underline{\phi},\overline{\phi}\right\}$. ■

The table below summarizes our findings in terms of the hiring strategy.

	$(\rho-\alpha)\leq 0$	$(\rho-\alpha)\in\left[0,\frac{\alpha^{2}}{2\left(\overline{\phi}-\underline{\phi}\right)}\right]$	$(\rho-\alpha)\geq\frac{\alpha^{2}}{2\left(\overline{\phi}-\underline{\phi}\right)}$
Baseline model	$\underline{\phi}$	$\overline{\phi}$	$\overline{\phi}$
Adverse Selection	$\underline{\phi}$	$\underline{\phi}$	$\overline{\phi}$

Table 1: Contrasting the optimal hiring strategies.

Note that the performance pay associated with the research undertaken in line with the firm's agenda is never distorted as $\alpha_F=\tau$.

The presence of adverse selection triggers potential losses. It may lead to a selection bias whereby the firm targets a weak type as opposed to a strong type. Alternatively, it may lead the firm to reward academic outcomes when it would not do so under symmetric information. This extension enables us to understand why some firms may decide to reward academic achievements as supported empirically in Liu and Stuart (2014).

4.2 Optimal contracting under a nominal effort budget

Here we introduce the possibility that a scientist may be resentful at having to spend time on the firm's agenda as it prevents her from pursuing her own agenda. To incorporate this concept, we follow Cohen et al. (2018) and assume that the scientist's choice of efforts is subject to a fixed *nominal* effort budget:[19]

$$e_S + e_F = E, \tag{16}$$

where $E > 0$ is the value of the *overall effort endowment*.

Taking the constraint into consideration, the scientist maximizes her expected utility and selects efforts

$$e_F' = \frac{1}{2}(\alpha_F - \alpha_S - \phi + E) \text{ and } e_S' = \frac{1}{2}(\alpha_S - \alpha_F + \phi + E).^{20} \tag{17}$$

Thus, a scientist with a stronger taste for science spends more time on her own agenda and less on the firm's. The firm perfectly anticipates these efforts and maximizes its expected profits subject to constraints (8) and (9).

Proposition 5: *There exist multiple optimal contracts. Setting $\alpha_F = \tau$ and $\alpha_S = 0$ remains an optimal solution.*

Proof: The objective function, given by (10), is now separable and concave in (α_F, α_S) and ϕ. We have

$$\frac{d\Pi^e}{d\alpha_F} = \frac{\alpha_S - \alpha_F + \tau}{2}, \quad \frac{d\Pi^e}{d\alpha_S} = \frac{\alpha_F - \alpha_S - \tau}{2}. \tag{18}$$

Therefore, Π^e reaches a maximum at all (α_F, α_S) such that $\alpha_F - \alpha_S = \tau$. Setting $\alpha_F = \tau$ and $\alpha_S = 0$ is one solution and optimality is guaranteed due to the concavity. ■

The multiplicity of solutions arises because, in this setting, efforts are linearly dependent. Hence, the firm loses the ability to tailor each of them independently and, thus, it requires only one instrument which is captured by $(\alpha_F - \alpha_S)$.

To analyse the optimal hiring decision, we need to consider two possibilities: one in which the constraint induces greater effort and one in which it induces lower effort. There is a distinction between the effort that a scientist *wants* to devote to research and the effort that she *can* devote to research.

[19] Banal-Estañol and Macho-Stadler (2010) also consider that scientists have to make choices when deciding on which research activity to pursue. In their paper, ideas come randomly to scientists who then decide whether to pursue them or to wait for another.

[20] For some values of α_F, α_S and E we have $e_F' = E$ and $e_S' = 0$ or $e_F' = 0$ and $e_S' = E$. The comparative statics are obvious.

The baseline model characterizes the effort that the scientist *wants* to devote to research when she operates without any constraint and simply responds to her taste for science and the incentive contract. When $\alpha_F = \tau$ and $\alpha_S = 0$, which remains optimal when the constraint applies, we have $e_S + e_F = (\tau + \phi)$ where $\phi \in \{\underline{\phi}, \overline{\phi}\}$. To conduct a meaningful robustness check we let

$$E = \tau + \phi_\lambda, \text{where } \phi_\lambda = \lambda\overline{\phi} + (1-\lambda)\underline{\phi}, \qquad \lambda \in [0,1] \tag{19}$$

Hence, we have $\phi_1 = \overline{\phi}$, and $\phi_0 = \underline{\phi}$. When setting $\lambda = 0$ we capture a situation in which, unless she is of the weakest type, the effort endowment is such that the scientist must curtail the overall effort she exerts when the contract is such that $\alpha_F = \tau$ and $\alpha_S = 0$. The constraint is more of a burden for the strongest types of scientists who are, somehow, the most frustrated when contracted. By opposition, when $\lambda = 1$, all but the strongest types would be devoting too little overall effort to both tasks in the absence of any constraint. In this case, imposing $e_S + e_F = E$ will have greater implications when the firm seeks to hire the weakest type who is the most affected of them all. By allowing λ to vary from 0 to 1, we consider cases where the constraint can either promote or restrict the scientist's overall efforts.

Proposition 6: *The firm contracts type*

- $\overline{\phi}$ *when* $(\rho - \alpha) \geq \frac{1}{2}(\overline{\phi} - \phi_\lambda)$,
- $\underline{\phi}$ *when* $(\rho - \alpha) \leq -\frac{1}{2}(\phi_\lambda - \underline{\phi})$,
- $\phi^{**} = \phi_\lambda + 2(\rho - \alpha)$ *otherwise.*

Proof: Taking the derivative with respect to the type we have

$$\frac{d\Pi^e}{d\phi} = (\rho - \alpha) + \frac{E - \tau - \phi}{2}. \tag{20}$$

Clearly the objective function is now concave in ϕ and reaches a maximum at

$$\phi^{**} = E + 2(\rho - \alpha) - \tau. \tag{21}$$

The optimal hiring decision depends on whether $\phi^{**} \in [\underline{\phi}, \overline{\phi}]$.■

The introduction of a constraint on the overall efforts has limited implications for the optimal incentive scheme, other than allowing for a multiplicity of solutions. Thus, surprisingly perhaps, the optimal contract is immune to the presence of the constraint.

The optimal hiring decision is, however, affected. Fig 2 below gives a visual representation of how it may be distorted. Let $\phi_M = \frac{1}{2}(\overline{\phi} - \underline{\phi})$.

	$(\rho-\alpha)<-\phi_M$	$-\phi_M<(\rho-\alpha)<0$	$0<(\rho-\alpha)<\phi_M$	$\phi_M<(\rho-\alpha)$
Baseline Model	$\underline{\phi}$	$\underline{\phi}$	$\overline{\phi}$	$\overline{\phi}$
$\lambda=0$	$\underline{\phi}$	$\underline{\phi}$	$\underline{\phi}+2(\rho-\alpha)$	$\overline{\phi}$
$\lambda=1/2$	$\underline{\phi}$	$\frac{1}{2}\left(\overline{\phi}+\underline{\phi}\right)+2(\rho-\alpha)$		$\overline{\phi}$
$\lambda=1$	$\underline{\phi}$	$\overline{\phi}+2(\rho-\alpha)$	$\overline{\phi}$	$\overline{\phi}$

Table 2: Contrasting the optimal hiring decision.

When $\lambda=0$ and all scientists, but those of the weakest type, must curtail their overall effort, the firm is less inclined to invest in absorptive capacity since $\phi^{**}<\overline{\phi}$. When $\lambda=1$ and all scientists, except the strongest types, must increase their overall effort, the hiring decision is biased in favour of stronger types since $\underline{\phi}<\phi^{**}$. Finally, we can see that when $\lambda=1/2$, the hiring decision is biased towards targeting stronger types when $-\phi_M<(\rho-\alpha)<0$ and weaker types when $0<(\rho-\alpha)<\phi_M$. In conclusion, the firm's optimal hiring decision depends on who is the most affected by the constraint. It is biased towards those who are the least affected.

4.3 Optimal contracting in the absence of complementarities between research activities

Let us assume that the cost of efforts depends only on the overall exerted effort as opposed to how these are spread:

$$C(e_F,e_S)=\frac{1}{2}(e_F+e_S)^2. \tag{22}$$

The scientist maximizes (2) and selects her efforts comparing the marginal cost of each effort and its marginal benefit. Notice that the marginal cost associated with each activity is equal to $(\boldsymbol{e_F}+\boldsymbol{e_S})$. Hence, the scientist's decision will be guided by the marginal returns and she will focus on the agenda that promises higher returns.

Proposition 7: *The optimal efforts are given as follows. Given any (α_F,α_S), we have*

$$e_S=\alpha_S+\phi \textit{ and } e_F=0 \textit{ provided } \phi>\alpha_F-\alpha_S$$

$$e_S=0 \textit{ and } e_F=\alpha_F \textit{ provided } \phi<\alpha_F-\alpha_S$$

And any combination of efforts such that $e_S+e_F=\alpha_F$ if $\phi=\alpha_F-\alpha_S$.

Proof: Note that

$$du=\left(\alpha_S+\phi-(e_F+e_S)\right)de_S+\left(\alpha_F-(e_F+e_S)\right)de_F. \tag{23}$$

If the scientist type is such that $\phi > \alpha_F - \alpha_S$, her utility increases with e_S so long as $\left(\alpha_S + \phi - (e_F + e_S)\right) > 0$ and $de_F = 0$. Therefore, it reaches a maximum at $e_S = \alpha_S + \phi$ and $e_F = 0$. If the scientist type is such that $\phi < \alpha_F - \alpha_S$, her utility increases with e_F so long as $\left(\alpha_F - (e_F + e_S)\right) > 0$ and $de_S = 0$. Therefore, it reaches a maximum at $e_S = 0$ and $e_F = \alpha_F$.■

Thus, if the optimal contract from the basic model is implemented whereby $\alpha_S = 0$ and $\alpha_F = \tau$, the contracted scientists with types $\phi > \tau$ devote themselves to their academic agenda and those with a type $\phi < \tau$ devote themselves to the firm's agenda. The specific type $\phi = \tau$ has no strong preference and would devote a total effort equal to τ to either agenda or to a bit of both. Let us assume that $\tau \in \left[\underline{\phi}, \overline{\phi}\right]$ to capture the more complex situation where scientists of a strong type do not select the same agenda as those of a weak type.

The scientist's behaviour implies that the firm cannot benefit simultaneously from the productivity and the preference effects. It will benefit from one or the other depending on which type it hires and what agenda this type devotes herself to. While all scientists would devote effort $e_F = \tau$ to the firm's agenda in the baseline model, there is now the possibility that the contracted scientist spends no time on the firm's agenda unless the rewards are high enough ($\alpha_F > \phi + \alpha_S$). As a result, the productivity effect, and more precisely the size of the variable τ, will play a more prominent role in this setting.

Taking the scientist's behaviour into consideration the firm must select a type and design a contract that maximizes it profits.

Clearly, the fixed fee guarantees that the contracted scientist gets not rents. We then have

$$\Pi^e = \begin{cases} \tau\alpha_F + \rho\phi - \frac{1}{2}(\alpha_F)^2 - \frac{1}{2}(\alpha + \phi)^2 & \text{if } \phi < \alpha_F - \alpha_S, \\ (\rho + \alpha_S + \phi)\phi - \frac{1}{2}(\alpha_S + \phi)^2 - \frac{1}{2}(\alpha + \phi)^2 & \text{if } \phi > \alpha_F - \alpha_S. \end{cases} \tag{24}$$

Proposition 8: *As was the case in the baseline model, it is not optimal to reward academic achievements so that the firm sets $\alpha_S = 0$.*

Proof: Notice that

$$(\rho + \alpha_S + \phi)\phi - \frac{1}{2}(\alpha_S + \phi)^2 - \frac{1}{2}(\alpha + \phi)^2 = (\rho\phi) - \frac{1}{2}\phi^2 - \frac{1}{2}(\alpha_S)^2 - \frac{1}{2}(\alpha + \phi)^2. \tag{25}$$

Therefore, setting $\alpha_S > 0$, as opposed to $\alpha_S = 0$, decreases the firm's profits gathered when the scientist devotes herself to her academic agenda. It has no impact on the firm's profits gathered when the scientist devotes herself to the firm's agenda. Finally, it decreases $\alpha_F - \alpha_S$ which increases the cost of incentivising the scientist to focus on the firm's agenda. ■

Given Proposition 8, we can re-write the firm's objective function as

$$\Pi^e = \begin{cases} (\rho-\alpha)\phi - \frac{1}{2}\alpha^2 - \frac{1}{2}\phi^2 - \frac{1}{2}(\alpha_F)^2 + \tau\alpha_F & \text{if } \phi < \alpha_F, \\ (\rho-\alpha)\phi - \frac{1}{2}\alpha^2 & \text{if } \phi > \alpha_F. \end{cases} \tag{26}$$

The proposition below depicts the optimal hiring decision and shows that in absence of complementarities between research activities the hiring decision is biased towards weaker types who devote their attention to the firm's agenda.

Proposition 9: *The optimal contract and hiring decision are such that*

- *When $(\rho-\alpha) < 0$, the firm selects type $\underline{\phi}$ and sets $\alpha_F = \tau$.*
- *When $0 < (\rho-\alpha) < \underline{\phi}$ the firm sets $\alpha_F = \tau$. The firm contracts type*

$$\phi = \begin{cases} \underline{\phi} \ \text{ if } 2(\rho-\alpha)\left(\overline{\phi}-\underline{\phi}\right) + \underline{\phi}^2 < \tau^2, \\ \overline{\phi} \ \text{ otherwise.} \end{cases}$$

  If contracted the type $\underline{\phi}$ focuses on the firm's agenda while type $\overline{\phi}$ focuses on her academic agenda.
- *When $\underline{\phi} < (\rho-\alpha) < \tau$ the firm sets $\alpha_F = \tau$. The firm contracts type*

$$\phi = \begin{cases} (\rho-\alpha) \text{ if } 2(\rho-\alpha)\left(\overline{\phi}-\underline{\phi}\right) + (\rho-\alpha)\left(2\underline{\phi}-(\rho-\alpha)\right) < \tau^2, \\ \overline{\phi} \ \text{ otherwise.} \end{cases}$$

  If contracted the type $(\rho-\alpha)$ focuses on the firm's agenda while type $\overline{\phi}$ focuses on her academic agenda.
- *When $\tau < (\rho-\alpha)$ the firm sets $\alpha_F = \tau$ and selects type $\overline{\phi}$ and lets the scientist focus on her academic agenda.*

Proof: See Appendix.

The table below summarizes our findings. Notice that one can write the cost function as

$$C(e_F, e_S) = \frac{1}{2}(e_F^2 + e_S^2) + \gamma e_F e_S, \tag{27}$$

where $\gamma = 0$ in the basic framework and $\gamma = 1$ when research activities are independent.

	$(\rho-\alpha)<0$	$(\rho-\alpha)\in\left[0,\underline{\phi}\right]$	$(\rho-\alpha)\in\left[\underline{\phi},\tau\right]$	$(\rho-\alpha)>\tau$
$\gamma=0$ (Baseline model)	$\underline{\phi}$	$\overline{\phi}$	$\overline{\phi}$	$\overline{\phi}$
$\gamma=1$	$\underline{\phi}$	$\overline{\phi}$ if τ is sufficiently low, $\underline{\phi}$ otherwise.	$\overline{\phi}$ if τ is sufficiently low, $(\rho-\alpha)$ otherwise.	$\overline{\phi}$

Table 3: Contrasting the optimal hiring decision.

When research activities are independent, the hiring decision is potentially biased towards weaker types because there are additional costs associated with stronger types if the firm wants them to devote their interest to its agenda. Strong types are more inclined to work on their own agenda and must be sufficiently rewarded to be swayed from doing so.

Because the firm must decide on whether it wants to hire a scientist for its productivity in relation to its own agenda or to benefit from the fact that these "pay to be scientists", the variable τ plays a more important role in determining which is the optimal type unless $(\rho-\alpha)$ is either very low or very high.

5 Conclusions

This paper sheds light on factors that influence a firm's hiring decisions when it seeks to build up its absorptive capacity and to generate new innovative knowledge to develop new products by contracting and managing knowledge workers intrinsically motivated to pursue scientific research to different extents. In a context where all scientists are equally capable of contributing to the firm's research projects, but differ in their ability to contribute to an academic agenda and be recognised by the academic community, we show that the optimal contract provides uniform incentives, regardless of those differences. Academic research outcomes are only rewarded in the presence of adverse selection when the firm seeks scientists who are strongly motivated to do science. Research outcomes in line with the firm's agenda are always rewarded so that the scientist is made residual claimant of the profits she generates and is adequately incentivised.

Optimal investment in absorptive capacity is thus determined primarily by the net benefit of contracting a scientist, which accounts for the cost of deterring her from remaining in academia. Our results support the findings in Stern (2004) and Sauermann and Roach (2014) showing that scientists are willing to accept lower wages because they value the opportunity to "be scientists" and to pursue a research agenda from which they derive some personal gratification.

We show that the firm is less keen to invest in scientific research when information is asymmetric and when there are no complementarities between research activities. Under adverse selection, the cost of attracting intrinsically motivated scientists increases because the firm must reward their academic achievements. When research activities are independent, the cost of attracting a scientist with a strong taste for science increases because she is more reluctant to devote her time to the firm's research agenda than her less academically driven peers. When, however, the scientist's decision is subject to a nominal effort constraint, the firm is keener to invest in scientific research when the constraint leads the scientist to increase her overall effort.

Our results have several policy implications. Competition for scientists is likely to be more intense in areas where there is a high degree of complementarity between applied and basic research. Scientists with a strong taste for science will be sought by firms offering contracts that give them some autonomy to pursue their own academic research agenda and to publish. As a result, universities and research centres might have to revise their compensation schemes and salaries if they hope to retain these scientists. Offering more flexible working conditions and allowing scientists to choose their working hours can boost the recruitment of top scientists who may be frustrated by more restrictive working environments.

This paper also contributes, we believe, to the literature on 'corporate science', in the same line as Zucker and Darby (2014), and lends support to the arguments of both advocates and critics of the arguments put forward by Arora et al. (2015) that the golden age of corporate research has come to an end. We have described the reasons that explain the decision, taken by some firms, to hire top scientists and to allow them to publish, but we have also outlined the reasons that lead other firms to hire knowledge workers with a weaker taste for scientific research. By considering that all scientists can equally contribute to the firm's agenda, we have brought to light the cost and benefits that come with hiring such knowledge workers that are maybe less straightforward such as the impact of the scientists preference for doing research on their optimal wage, the absorptive capacity they can bring to the firm and the opportunity costs they face when leaving academia which affects the salary they are willing to accept. In Cohen et al. (2018) the authors refer to yet another feature of scientists that will influence their desire to leave academia, namely the fact that some feel rewarded when their scientific findings have a direct applicability and have the potential to address important issues that the world faces today. This consideration could lead to further extensions of our baseline model whereby scientists value their contribution towards certain firms' research agenda.

APPENDIX A. Notation

Summary of the notation used in the model.

Type	Parameter	Assumptions	Definition
Endogenous	ϕ	$\phi \in [\underline{\phi}, \overline{\phi}]$	The scientist's taste for basic science. Let $\phi_M = \frac{1}{2}(\underline{\phi} + \overline{\phi})$.
	t	$t \geq 0$	Fixed component of the scientist's salary offered by the firm. $w = t + \alpha_F X_F + \alpha_S X_S$
	α_F	$\alpha_F \geq 0$	Scientist's performance-contingent pay associated with the firm's research agenda output (X_F).
	α_S	$\alpha_S \geq 0$	Scientist's performance-contingent pay associated with the scientist's own academic research agenda output (X_S).
Exogenous	$\underline{t}$	$\underline{t} = 0$	Fixed component of the salary offered in an academic job. $\underline{w} = \underline{t} + \alpha X_S$
	α	$\alpha \geq 0$	Performance-contingent pay for scientific output (X_S) in an academic job.
	τ	$\tau \geq 0$	Marginal benefit for the firm from the scientist's outcomes when working on the firm's research agenda: $\Pi = \tau X_F + \rho X_A - w$ where $X_F = e_F + \varepsilon_F$
	ρ	$\rho \geq 0$	Marginal benefit for the absorptive capacity gained by the firm by hiring an academic scientist with type ϕ: $\Pi = \tau X_F + \rho X_A - w$ where $X_A = \phi + \varepsilon_A$
	E	$E > 0$	Overall total nominal effort endowment the scientist can devote to the firm: $e_S + e_F = E$

APPENDIX B. Proofs

Proof Proposition 1 and Corollary 1: The firm's optimal fixed fee is such that the participation constraint binds. Therefore, the firm must then select the variables α_F, α_P and ϕ that maximize the following expression:

$$\Pi^e = \tau e_F + \rho\phi + e_S(\phi + \upsilon) - C(e_F, e_S) - \frac{1}{2}(\alpha + \phi)^2, \tag{28}$$

where efforts are given by $e_F = \alpha_F$ and $e_S = \alpha_S + \phi$, and $\upsilon = 0$ for proposition 1.

We allocate the Lagrange multipliers λ_F and λ_S for the constraints $\alpha_F \geq 0$ and $\alpha_S \geq 0$ respectively:

$$\mathcal{L} = \Pi^e(\alpha_F, \alpha_S, \phi) - \lambda_F \alpha_F - \lambda_S \alpha_S. \tag{29}$$

Differentiating the Lagrange function, we obtain the following

$$\frac{\partial \mathcal{L}}{\partial \alpha_F} = \tau - \alpha_F - \lambda_F, \tag{30}$$

$$\frac{\partial \mathcal{L}}{\partial \alpha_S} = \upsilon - \alpha_S - \lambda_S, \tag{31}$$

$$\frac{\partial \mathcal{L}}{\partial \phi} = (\rho - \alpha) + \upsilon. \tag{32}$$

The objective function is strictly concave in (α_F, α_S) since the Hessian matrix associated with these variables is negative definite. Moreover, it is clear from the above that the optimal performance-contingent pay parameters are not type-dependent. Hence, we can treat the determination of the optimal (α_F, α_S) and the optimal type as separate issues.

Optimal (α_F, α_S): When $\lambda_F = 0$ and $\lambda_S = 0$ the unique solution is such that $\alpha_F = \tau$ and $\alpha_S = \upsilon$. This solution maximizes satisfies both constraints provided $\upsilon \geq 0$ and is therefore the optimal solution. When $\upsilon < 0$, it is optimal to set $\alpha_S = 0$, and in this case $\lambda_S = \upsilon$. Setting $\alpha_F = \tau$ remains optimal.

Optimal type: The objective function is increasing in ϕ when $(\rho - \alpha) + \upsilon > 0$ and decreasing in ϕ when $(\rho - \alpha) + \upsilon < 0$. ■

Proof of Proposition 2: Let $U(\phi', \hat{\phi})$ denote type ϕ' utility when accepting a contract meant for type $\hat{\phi}$:

$$U(\phi', \hat{\phi}) = \hat{t} + \hat{\alpha}_F e_F(\phi') + \hat{\alpha}_P e_S(\phi') + e_S(\phi')\phi' - C(e_F(\phi'), e_S(\phi')). \tag{33}$$

Using the expressions for the efforts, we can rewrite $U(\phi', \hat{\phi})$ as

$$U(\phi', \hat{\phi}) = U(\hat{\phi}, \hat{\phi}) + e_S(\hat{\phi})(\phi' - \hat{\phi}) + \frac{1}{2}(\phi' - \hat{\phi})^2. \tag{34}$$

Type ϕ' does not accept a contract meant for type $\hat{\phi}$ provided $U(\phi', \hat{\phi}) \leq \frac{1}{2}(\phi' + \alpha)^2$. Moreover, any contract leaving no rents to the targeted type is such that $U(\hat{\phi}, \hat{\phi}) = \frac{1}{2}(\hat{\phi} + \alpha)^2$.

Using the expression above for $U(\phi', \hat{\phi})$ and the fact that $U(\hat{\phi}, \hat{\phi}) = \frac{1}{2}(\hat{\phi} + \alpha)^2$, incentive compatibility holds provided

$$e_S(\hat{\phi})(\phi' - \hat{\phi}) + \frac{1}{2}(\phi' - \hat{\phi})^2 \leq \frac{1}{2}(2\alpha + \phi' + \hat{\phi})(\phi' - \hat{\phi}). \tag{35}$$

The two inequalities in the proposition 2 can be deducted using the fact that $e_S(\hat{\phi}) = \hat{\alpha}_S + \hat{\phi}$ and setting $(\phi' - \hat{\phi}) = (\underline{\phi} - \overline{\phi})$ when the strong type of scientist is targeted and $(\phi' - \hat{\phi}) = (\overline{\phi} - \underline{\phi})$ when the weak type is targeted. ■

Proof of Proposition 9: The objective function of the firm is given by

$$\Pi^e = \begin{cases} \tau\alpha_F + \rho\phi - \frac{1}{2}(\alpha_F)^2 - \frac{1}{2}(\alpha + \phi)^2 & \text{if } \phi < \alpha_F, \\ (\rho - \alpha)\phi - \frac{1}{2}\alpha^2 & \text{if } \phi > \alpha_F. \end{cases} \tag{36}$$

Notice that the function $\left[\tau\alpha_F + \rho\phi - \frac{1}{2}(\alpha_F)^2 - \frac{1}{2}(\alpha + \phi)^2\right]$ is separable and concave in α_F and ϕ. It reaches a maximum at $\phi = (\rho - \alpha)$ and $\alpha_F = \tau$.

When $(\rho - \alpha) \leq 0$, the solution is trivial as the firm has no interest in hiring a strong type. It maximizes its profits selecting the weakest type and setting $\alpha_F = \tau$. When $(\rho - \alpha) \geq \overline{\phi}$, one can easily show that the firm is strictly better-off contracting the strongest type and letting her focus on her agenda. (Notice that if it wants the strongest type to focus on the firm's agenda it must set $\alpha_F = \overline{\phi}$.) When $0 < (\rho - \alpha) < \overline{\phi}$, the firm has two options.

Option 1 (reservation value): Select type $\overline{\phi}$ which focuses on her academic agenda and generate profits $(\rho - \alpha)\,\overline{\phi} - \frac{1}{2}\alpha^2$. This option can be thought of as a reservation value for the firm.

Option 2: Select the type and contract that solve

$$\max_{\alpha_F,\phi} \left[\tau\alpha_F + \rho\phi - \frac{1}{2}(\alpha_F)^2 - \frac{1}{2}(\alpha + \phi)^2\right] \text{ s.t } \alpha_F \geq \phi. \tag{37}$$

Setting up the Lagrangian leads to the following solutions:

- If $0 < (\rho - \alpha) \leq \tau$, the optimal contract is given by $\alpha_F = \tau$ and $\phi = \max\left\{\underline{\phi}, (\rho - \alpha)\right\}$. This outcome if preferable to the reservation value provided

$$2(\rho - \alpha)\left(\overline{\phi} - \underline{\phi}\right) + \hat{\phi}\left(2\underline{\phi} - \hat{\phi}\right) < \tau^2,$$

  where $\hat{\phi} = \min\left\{(\rho - \alpha), \underline{\phi}\right\}$.

- If $\tau < (\rho - \alpha) < \overline{\phi}$, the optimal contract is given by $\alpha_F = \phi = \frac{1}{2}(\tau + \rho - \alpha)$. This leads to profits given by

$$\Pi^e = \frac{1}{4}(\tau + \rho - \alpha)^2 - \frac{1}{2}\alpha^2.$$

  The firm is always better-off with option 1.

In conclusion, option 2 is preferable to the firm provided $0 < (\rho - \alpha) \leq \tau$ and τ is large enough.

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