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Positions and rewards: The allocation of resources within a science-based entrepreneurial firm

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ABSTRACT

We study the link between resource allocation and employee publication in the open science in a quantitative case study of one science-based, entrepreneurial firm. We bridge the literature on incentives with that on authority structures to argue that a positive relationship between rewards and productivity will be strongest for individuals in positions of scientific leadership within the firm. In a novel dataset, we find that prolific publishers receive greater year-end bonuses and are allocated additional direct reports, but this relationship only holds for individuals in scientific leadership roles. These results contribute to our understanding of resource allocation processes and reward structures in science-based firms.

1. Introduction

The role of incentive structures in promoting knowledge creation and other forms of entrepreneurial activity within science-based firms has received considerable attention in the literature. To date, scholars have examined hiring policies in science-based firms (Stern, 2004) and the proclivities of university-trained scientists to work in private firms (e.g., Roach and Sauermann, 2010; Lacetera and Zirulia, 2012; Sauermann and Stephan, 2013). For a limited set of pharmaceutical firms, Henderson and Cockburn (1994) have linked pro-publication policies to innovative productivity. In a quantitative case study, Bhaskarabhatia and Hegde (2012) examine the effect of IBM's decision to adopt a pro-patent incentive regime.

Despite the deepening of our understanding of the link between human resource practices, publishing, and patenting, scholars have devoted much less attention to the inventive context *within* firms, including the potential interrelationships among a range of factors such as resource allocation practices, corporate culture, incentive plans, and the distinct positions and roles that knowledge workers hold within organizations (Murray, 2004 is a notable exception). This dearth stems not from a lack of interest (for example, see Audretsch et al., 2007; Grimaldi et al., 2011), but in the obstacles associated with collecting data on the activities of scientists and the management systems in place in R&D organizations within for-profit firms.

In this paper, we provide quantitative evidence of the link between publication and rewards in a large—but still entrepreneurial—firm, which we label "BTCO" to preserve anonymity. We argue that the reward structure for these activities may not be uniform across BTCO's knowledge workers. Specifically, although it is not a written policy, we hypothesize that the organization's incentive system will be targeted to most generously reward knowledge-generating activities for those individuals in more senior, scientific leadership roles in the company. To examine these issues, we investigate a longitudinal dataset that span the years 2001–2008. As we follow individual scientists over time, we can study the effects of year-to-year variation in each individual's publication success. We link this measure of knowledge production to two outcomes within the organization: the amount of discretionary compensation earned, and changes in the individual's span of control (i.e., number of direct reports allocated to them). Consistent with Henderson and Cockburn (1994), we equate the allocation of rewards as a tangible indicator of senior management's priorities (e.g., the incentive structure) within this entrepreneurial firm. Moreover, we measure the *allocation* of rewards, rather than the *promise* of rewards because this is a more easily observable outcome within the organization.

Surprisingly, we find that this organization, which espouses organization-wide support for publication activities, does *not* reward the median, publishing individual. However, when we condition our regressions on specific organizational roles, we then find

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that those employees who are in positions of authority within the organization are rewarded for publishing, but not the technicians who populate these leaders' laboratories. Specifically, laboratory heads that publish receive greater monetary compensation, as evidenced by the size of their year-end bonuses, and a greater share of organizational resources, as proxied by an individual's number of direct reports.

The paper proceeds as follows. Section 2 reviews the literature on scientific production within for-profit firms, and the motivations underpinning these activities. In Section 3, we develop two interrelated hypotheses with regards to the contingent incentive structure underlying scientific activities. Section 4 describes our setting, data collection, and measures, and Section 5 presents our findings. A final section concludes and discusses some implications for future research.

2. Publishing and incentives in the private sector

The question of how to induce employees to behave in an entrepreneurial manner is a seemingly permanent element in the set of challenges facing leaders of large, established companies. In fact, certain theories suggest that as organizations age they invariably must be designed in ways that lead to the reinforcement of their existing activity sets, which implies that inertia is inevitable (Sorenson and Stuart, 2000). Particularly for companies in fast-paced environments, however, many scholars argue that entrepreneurial activities are essential for rejuvenation of the firm's capabilities (e.g., Henderson and Clark, 1990). Our question is not why established firms engage in entrepreneurial activities or even whether they will succeed in these endeavors. Rather, we ask: how does a focal decision, to engage in one type of knowledge-generating activity, permeate the intra-organizational context of the firm and the allocation of organizational resources?

Our trace of entrepreneurial activity is an employee's participation in the external ecosystem within which the scientific discovery process is embedded: the publication of scientific results in academic journals. At first glance, there is little motivation for for-profit firms to participate in open Science, given the associated costs. No doubt many academics can empathize with the time and effort that is required to craft the right turn of phrase, to adjust figures and graphs to be just so, and to attend to the minutiae that is part and parcel of the publication process. In fact, given the sizeable time costs of writing and revising research papers, BTCO's current management has recently introduced policies to reduce the number of submissions to second- and third-tier academic journals. BTCO management emphasized that they were not discouraging public disclosure of scientific findings. They continue to authorize conference submissions and to sanction presentations in a variety of venues, but they actively discourage the submission of these results to low quality journals. They simply perceive little value in the production of non-momentous papers.

Second, publication is disclosure. Although it is possible to time the submission of publications so that they do not interfere with patent filings, firms that publish unavoidably disclose a great deal of information about the focus of their research endeavors (Gans and Stern, 2003). In contrast to patenting activity, a central role of publishing is to allow the reproduction and independent corroboration of a scientist's findings (Merton, 1957). If a scientific finding is not replicable, the validity of the result is questionable. In consequence, a byproduct of the publication process is to facilitate the advancement of potential competitors to a similar point in the scientific production frontier (Dasgupta and David, 1994). By contrast, patents are much less explicit: they are often written as broadly as possible to encompass an array of commercialization strategies. Because Science is an integral component of a firm's capabilities in industries such as biomedicine, open publication is tantamount to a revelation of strategic intent.

Lastly, publication contributes to the conversion of firm-specific human capital to its general form, When firms permit researchers to publish, they not only endow specific individuals with the credit for their discoveries; they also divulge this information to the public. It then becomes possible for external parties to link a firm's technical developments to the specific individuals who contributed most to its creation. Publishing allows the public observation of a firm's productive workers, and efforts by competitors to poach talent may be an inevitable result. Internally, publishing may increase employee mobility and bargaining power.

What, then, are the compensatory benefits that offset these costs, and what do they imply for how the organization behaves? In our interviews at BTCO, interviewees underscored a number of points. First, publishing allows BTCO's researchers to be more embedded in the external ecosystem, within which entrepreneurial activities are embedded (Liu and Stuart, 2011). Publishers, as active participants in the invisible colleges of the scientific community, acquire access to unpublished results. Over time, the organization hopes to utilize this privileged access to accelerate their future, for-profit endeavors (Cockburn and Henderson, 1998).

Second, pegging rewards to publications potentially helps firms to resolve a perennial dilemma: how to evaluate and reward researchers who work on very long-term and highly uncertain projects, the vast majority of which will fail to deliver revenues for the firm (and none will do so in the proximate future)? Under these circumstances, peer-reviewed publications provide a semi-objective method of evaluating performance to allocate discretionary compensation in a context in which the quality of research is difficult to assess, and effort is challenging to measure. Moreover, in our interviews as well as reported elsewhere (e.g., Cockburn and Henderson, 1998) managers emphasized the belief that, while costly, publishing raised the quality of the research itself, pushing BTCO employees to think harder and more creatively about their problems at hand.

Lastly, and this was a point repeatedly underscored by BTCO management, a permissive publication policy is an essential component of any strategy to recruit and retain the highest quality researchers, especially individuals who hold doctoral degrees. If potential employees, the vast majority of whom have spent many years in academia, do not perceive the ability to engage in open science activities, they may look for employment elsewhere. A record of publication success by BTCO scientists, especially in prominent journals, is a tangible illustration of the organization's commitment to fostering a pro-scientific environment.

Recently, there has been both theoretical (Lacetera and Zirulia, 2012) and empirical (Stern, 2004; Roach and Sauermann, 2010) interest in the relationship between a for-profit firm's decision to engage in (or refrain from) scientific publishing, and the implications of this decision on the firm's recruitment strategies in the scientific labor market. Broadly, the conclusion is that scientists will accept lower wages in exchange for employment in a firm that embraces scientific publishing (Stern, 2004), although the willingness to accept this differential varies across individual members within the scientific community (Sauermann and Cohen, 2010). We extend this literature by examining not BTCO's employment strategies, but rather the varied tributaries through which a pro-publication orientation permeates the entirety of the organization.

3. Organizational context and incentives to publish

The motivating concerns of this paper are two-fold. First, we seek to provide a descriptive account of how BTCO's decision to encourage publishing influences resource allocation and a variety

of other policies within the organization itself. Second, we present a quantitative analysis of the allocation of rewards that tangibly links the organization's actions to employee behavior. In particular, we examine the link between compensation and the allocation of organizational resources to publication success, and the conditions under which this link is most salient.

The first consequence of BTCO's open publication orientation, or "pro-pub" strategy, is its recruitment efforts. BTCO chooses to compete for new hires not just with other research-based firms, but also with universities. They, and other prominent biopharmaceutical firms, regularly hire university professors into scientific leadership positions. A pro-pub orientation also affects the geography of their research operations. To recruit and retain employees who readily traverse the boundary between academia and industry, BTCO has chosen to maintain research campuses in major biotechnology hubs. Indeed, many pharmaceutical companies, traditionally located in the mid-Atlantic states (e.g., New Jersey), have mirrored BTCO's decision; they have established physical footprints in Boston and the San Francisco Bay Area (Furman and MacGarvie, 2007).

A pro-pub orientation also may influence the company's internal organization and practices, including its formal and informal bases for allocating rewards. To the extent possible, the firm creates a university-like milieu to cater to the preferences held by their researchers. For biologists, who have almost all spent many years training at universities, BTCO's research division will seem a relatively familiar place. Individuals at BTCO are organized into broad groups of disciplinary departments, such as immunology or biochemistry, but the elemental organizational unit is a laboratory, led and named by a single individual.[1] If the laboratory head (BTCO's equivalent of a university professor) departs the organization, the laboratory disbands and its members are reassigned to other laboratories. Thus, the laboratory, as well as the laboratory head, is the primary affiliation through which individuals identify and relate to one another.

Nonetheless, there remain substantive differences between BTCO's research division and a university department. In addition to the most obvious point of difference, that the ultimate aim of BTCO's R& arm is to develop new medicines rather than to advance the frontier of scientific knowledge, pre- and post-doctoral training also are not central to BTCO's mission: the vast majority of individuals at BTCO are employees who expect to remain at the company for long periods of time. Rather than trainees, technicians primarily staff laboratories, and these technicians are assigned to individual, or small-group, projects. When we examine the authorship structure of papers arising from BTCO research, for example, only a minority of laboratory members (i.e., technicians) is listed as authors, and these inscriptions change from paper to paper.

Another critical difference between a for-profit firm and an academic laboratory is the division of labor. As training (and self-sufficiency) is not the primary goal of a for-profit firm, BTCO can capitalize upon the division of labor, and the gains in efficiency that result from specialization. Within BTCO research, nearly half of the individuals are not situated in laboratories, but in core support functions and facilities. These centralized functions generate a number of tools that are essential for scientific research, including monoclonal antibodies and proteins for assay development, recombinant DNA constructs, and genetically modified mice, to name a few (cf., Clarke and Fujimura, 1992). With the support of these functions, individual scientists may specialize and limit the scope of their activities.

What are the rewards that senior managers can bestow upon productive workers? Naturally, monetary compensation (e.g., salary, bonuses, stock options) is the most-discussed form of incentive in the literature. Consistent with the notion that firms that adopt a pro-pub policy attract higher-quality scientists, BTCO benchmarks their base salary compensation to comparable firms in the region. BTCO's human resource managers also explicitly speak of non-monetary compensating differentials, such as the firm's culture and its legacy of successful drug development, to attract individuals who intrinsically value employment at BTCO.

In addition to base salary, all BTCO employees are eligible to receive two additional forms of compensation. Each year, individuals receive a "forward" looking set of stock options, which is used as a retention device. Second, individuals also receive a backward-looking, end-of-year bonus, which is designed to reward prior performance. For these discretionary bonuses, human resources software first provides each manager with a "target" bonus based upon standard practices (i.e., salary-band, band-penetration, tenure, et cetera). This target bonus is then adjusted, up or down, according to the direct report's performance. BTCO also has a secondary bonus pool with funds that are only allocated to star performers, who have been identified as the top 5–10% employees within a given year. In the quantitative analysis to follow, we merge both the primary and secondary bonus pools to generate a measure of discretionary compensation: percent of target bonus-received.

Senior managers also have a number of non-monetary levers through which they can reward productive workers. As we alluded to, BTCO research scientists heavily depend on a set of extra-laboratory support from "core" facilities. As one would expect, there is often a waiting list for these services and, at times, senior management allows favored individuals to jump the queue.

Lastly, and perhaps most visibly, is the allocation of human capital resources, often referred to as full-time equivalents (FTEs). At BTCO and peer organizations, expenses associated with scientific labor vastly exceed one-time payouts, such as discretionary compensation. A skilled technician costs the organization roughly half a million dollars in direct and indirect costs. Moreover, these are highly visible resources, which contribute to the status hierarchy within the firm. Just as university professors compete for (limited) laboratory space and large offices, the allocation of direct reports is a proxy for how much authority, status, and tangible resources the organization is willing to commit to an individual. Once committed, inertial forces are strong and human capital resources are not easily revoked or redeployed.

Although we have illustrated an array of internal channels through which senior management may choose to reward its employees, it remains unclear if BTCO actually needs to peg these rewards to publication outcomes. As outlined in Section 2, there are significant costs, to the firm, of publishing their scientific discoveries. Across firms in the biopharmaceutical industry, some firms publish prolifically while others refrain from this activity. If publication success is merely a perquisite that adds little to the financial prospects of the firm, there may be no need to augment this non-productive perk with additional (monetary) compensation.

Moreover, non-monetary rewards for publication already exist. As one example, BTCO practices a ritual, common in academic departments, of having a public celebration when papers are accepted for publication in prominent journals. Specifically, a special bottle of champagne or wine is procured and signed by the authors. After consumption, the bottle is then placed around the periphery of a common conference room, to be displayed as a trophy for posterity. Moreover, through numerous interviews at multiple levels of BTCO's organization, we were reassured that monetary compensation is not discussed or revealed to an

[1] Alternatively, laboratories may be named for an area of research (e.g., molecular electrophysiology) rather than an individual. This is common practice for European laboratories, as well as a limited number of US universities (e.g., Rockefeller University).

individual's peers. It is considered to be gauche to discuss salary or bonus levels at BTCO.

Nonetheless, given the pervasive nature of BTCO's policy to promote scientific publications, we suspect that rewards within the organization are tied to an individual's publication success. As a consequence, we make the following first hypothesis:

H1. Resources and rewards within BTCO, as measured by monetary compensation and the allocation of human capital, are awarded in greater amounts to prolific publishers.

Although we have argued for a positive correlation between rewards and publishing success, this incentive system may not be uniformly applied throughout the organization. In our argument, we have emphasized that although publishing may create a number of benefits for the firm, this scientific activity also is associated with a set of costs. For occupants of job roles in which the organization perceives that the benefits to publishing outweigh the activity's costs, the organization may choose to enact an incentive system to promote the pursuit of science-based entrepreneurial activities. For organizational roles in which the costs loom larger than the gains, we suspect that the organization may opt to not reward publishing. What conditions might affect the relative costs and benefits of publishing?

The most obvious condition is simply when the organization has pledged to allow the employee to publish his or her research findings. Although the organization may delay journal submission to allow for the filing of intellectual property rights, completely reneging on an implicit understanding that scientific discoveries will be cleared for publication could cause employees who have been given this promise to seek employment elsewhere. So which individuals have not been pledged pro-pub rights, and what positions do they hold in BTCO Research? Within the company, assurance of the right to publish is much weaker for technicians. Typically, technicians are hired through the human resources department and, for these individuals, BTCO's emphasis on a pro-pub orientation is likely to be less salient. By contrast, laboratory heads, at both the junior and the senior level, are typically hired from university positions. Each laboratory head is recruited on a case-by-case basis and imports a specific set of skills to BTCO Research. Over the course of this recruitment process, there is little doubt that the scientific culture, and pro-pub orientation at BTCO, is a point of emphasis.

Consistent with BTCO's individualized recruitment process for laboratory heads, these individuals consume much of the resources of the R&D organization. Each laboratory head is likely to have a relatively unique scientific expertise, and the replacement of these skills is non-trivial. By contrast, technicians are far more interchangeable with one another. Unlike laboratory heads, technicians are not "critical" individuals: if a technician departs BTCO, the laboratory will look for a replacement, and another may be readily reassigned within the organization. If the laboratory head leaves, the laboratory disbands and ceases to exist (for similarities in an academic laboratory, see Owen-Smith, 2001).

Moreover, relational theories suggest that as non-managers, technicians are poorly positioned to capitalize upon the benefits of publishing activities (e.g., Carroll and Teo, 1996). Consider two of the cited organizational benefits for publishing: prolific authors are likely to build networks in the external scientific community (Liu and Stuart, 2011) and the firm gains objective feedback on the quality of publishing scientists. BTCO may have less to gain from promoting technicians to the external scientific community because these individuals lack the internal communication networks to act upon the acquired knowledge, or the scientific gravitas to attract a following. Although technicians often consult with one another on the mechanistic aspects of the job, they are less involved with crafting the strategic direction of research projects. Even if a technician was privy to critical external knowledge, acquired as a byproduct of publishing activity, the dissemination of this knowledge may be far slower than dissemination by a laboratory head. As a consequence, the organization may value publishing activities less for individuals in these roles.

Lastly, the literature on control systems also emphasizes that incentives should be more high-powered (i.e., a stronger correlation between rewards and desired actions) when production is harder to monitor (Wulf, 2007). As technical work often is standardized, the organization may have less need to develop "objective" measures of performance for individuals in these roles (Barley, 1996). Thus, success at scientific publishing is less necessary as a basis to allocate awards to technicians. And given the well-known propensity to attribute scientific output to the higher status individuals in scientific teams, the use of publication as a gauge of productivity, and the rewards that parallel this productive output, may appear to be more pertinent for laboratory heads (Merton, 1968).

Consistent with our theorizing that the allocation of rewards may vary across different roles within the organization, we make the following hypothesis about financial compensation within the firm:

H2. Within BTCO, the relationship between discretionary compensation and publishing will be strongest for laboratory heads.

Closely related to the rewarding of monetary compensation is the allocation of human capital resources within the firm. Although compensation and pay is the more commonly studied intra-organizational reward, as we have noted, staff resources often represent a stickier, more-costly, longer-term commitment on the part of the organization, and may be worth theorizing separately.

Notably, there are reasons *not* to peg human capital resources to scientific output. First, doing good science is not necessarily correlated to being a good manager (Zuckerman, 1977). As a scientist has more direct reports, this individual inevitably spends more time managing the work of others, rather than directly engaging in the scientific enterprise. It is also possible that allocating human resources solely on publication success could have negative consequences in the organization. Larger laboratories have a greater probability of publishing scientific articles (Conti and Liu, 2013). Thus, a direct link between the rewarding of human capital resources and publication success could result in a self-perpetuating cycle: large labs result in more publications, which then result in larger laboratories. Over time, this policy would result in stratification across laboratories by size, and large labs would both disrupt the decentralized structure highly valued by BTCO, as well as decrease interdependencies between laboratories.

By contrast, larger laboratories may benefit from economies of scale. Assigning employees to individuals who are successful at producing new science may be a worthy reward for innovative output. However, this reward may vary with the authority an individual wields within the organization. For technicians conducting routinized work, there may be little benefit to the organization to place employees under their supervision. By contrast, for scientific leaders whose daily work largely consists of managing the workflow of others, there may be significant benefits to a greater span of control.

Consistent with our theorizing that the allocation of rewards may vary across different roles within the organization, we make the following hypothesis:

H3. Within BTCO, the relationship between direct reports and publishing will be strongest for laboratory heads.

4. Data and methods

4.1. Context

We set our quantitative case study in the biopharmaceutical industry. This industry has served as a fertile testing ground for many of the topics in entrepreneurship, including the examination of venture-capital funding (Sorenson and Stuart, 2001), orientation toward scientific publishing (Cockburn and Henderson, 1998), university-industry relationships (Zucker et al., 1998; Furman and MacGarvie, 2007) the effects of status (Stuart et al., 1999), compensation structures (Stern, 2004), the formation of entrepreneurial ventures (Stuart and Sorenson, 2003; Stuart and Ding, 2006) and the establishment of interorganizational relationships (Powell et al., 1996). The company that we study, BTCO, is a first-generation biotechnology firm, founded more than 25 years ago. Since its inception, BTCO has continuously dedicated significant resources to in-house research, and today its research division employs hundreds of scientists. The mandate of the firm's research group, which is organizationally separate from its development arm, is to conduct basic and applied research to identify molecules that supply the company's drug development pipeline.

In line with the firm's historical origins and strong ties to the academic community, the internal organization of BTCO's research division resembles a university biology department. Researchers are subdivided into groups that map to scientific specializations, such as immunology, neurobiology, molecular biology, and oncology. These groups are then further divided into the firm's core organizational units, which are laboratories led by (and named after) individual scientists (Latour and Woolgar, 1979; Owen-Smith and Powell, 2001). To conduct these analyses, the company provided us with current and some historical data on all members of the research division.

4.2. Publications

BTCO scientists have published extensively—in recent years, the firm's staff has produced well over 100 papers per year—and they have succeeded in placing some of their work in the preeminent outlets in life science publication, including *Science*, *Nature*, and *Cell*.

To measure the publication outputs of the individuals in the firm's research department, we collected all articles by BTCO authors that were indexed in the ISI *Web of Science*. We then hand matched the roster of research division employees to the list of authors on papers to correct for spelling discrepancies. In the results we will report, we considered all contributors to a paper to be equivalent, regardless of their position within the author list.

4.3. Compensation and rewards structure

At BTCO, scientists are eligible for three forms of merit compensation. First, all members of the research division receive stock option grants. Second, the firm dispenses end-of-year bonuses that recognize employees' contributions to the company during the prior year. Over the course of the year, the department's total research bonus pool increases as pre-set milestones are met. At year-end, scientific leaders are allocated a customized target bonus for each of their reports, which is determined by the size of the total bonus pool, the individual's salary band, and other responsibilities. After receiving a target bonus, managers adjust the target up or down to reflect perceived performance. Importantly, each laboratory is not forced to follow a normal distribution, although BTCO's research division as a whole approaches one. Finally, a distinct bonus pool is distributed to "top contributors", who are the individuals judged to be in the top 5% of the performance distribution.

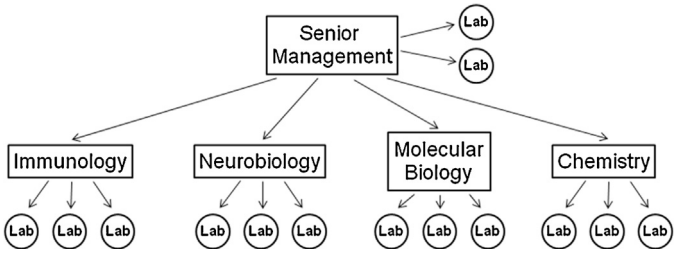

Fig. 1. Schematic of formal organizational chart. *Note*: Schematic of the formal organization of BTCO. Divisions are indicated in squares. Laboratories are indicated with circles. The number of laboratories is representative and does not reflect the distribution of laboratories across the organization.

We combined the latter two numbers to create a "proportion of target bonus-received" for each scientist, which we use to test our baseline hypothesis and hypothesis 1a, that publication success will influence bonus allocations. For the median individual in the dataset, end-of-year bonus is approximately 20% of their base salary.[2]

4.4. Organizational structure

To examine the allocation of human resources (i.e., direct reports) within BTCO, the company provided us with a full roster of personnel within the research division, and the organization's formal reporting structure. Consistent with BTCO's dedication to a flat organizational structure, a significant percentage of employees were technicians, and only a minority of technicians has any direct reports (Fig. 1). For the timeframe of the dataset, 2001–2008, each employee has a single, identifiable supervisor, which was matched to other data sources. For each individual-year observation, we created a measure of the individual's span-of-control (i.e., number of direct reports) and use this measure to test our hypothesis that publication success will influence the allocation of direct reports. We label this measure, "number of direct reports."

4.5. Control variables

We also collected a number of control variables, many of which are omitted from the regressions due to the inclusion of person fixed effects (see Section 4.6, below). For each employee, we know: gender, age, and highest educational degree. We use these variables to provide a descriptive overview of the data in Table 1. In the regressions, we include time-changing salary band and firm tenure variables.

4.6. Empirical strategy

To test the hypotheses that relate compensation at BTCO to success in publications, we use a within-person model. We estimate a linear regression of the form:

$$E[y_{it}|X_{it}] = \beta_0 + \beta_1 \text{PUBLICATION\_OUTPUT}_{it} + \beta_2 X_{it} + \delta_t + \gamma_i + \varepsilon_{it},$$

[2] We can also decompose the two components of the annual bonus and separately analyze, (a) percent of target bonus, and (b) the probability of receiving a top contributor award in a given year. We find a generally similar effect of publication count on both outcome variables, although the latter cannot be reliably estimated with the inclusion of scientist-specific fixed effects.

Table 1
Descriptive stats on yearly publishing (limited to individuals who appear in this dataset).

Year	# of patents	# of papers	Average paper impact factor	Papers in cell/nature/science
2001	83[a]	210	6.87	5
2002	76[a]	156	6.79	4
2003	77	150	8.39	6
2004	63	164	7.95	12
2005	77	149	7.6	5
2006	92	136	8.78	9
2007	26[b]	161	9.15	10

[a] Human genome patents were excluded from this count.
[b] Incomplete data collection.

where y_{it} is either an individual's "proportion of target bonus-received" or "number of direct reports".[3] For PUBLICATION_OUTPUT, we generate a dichotomous indicator of whether (or not) an individual has authored a paper. Using a spline to indicate low pubcount (i.e., 1) or high pubcount (i.e., >1), with no publication output as the reference category in the year t yielded similar results, with typically monotonic effects across the three-category specification. X is a vector of control variables, the δ's represent a complete set of year indicators, and the γ's correspond to a full set of individual fixed effects. In this model, all attributes of an individual that are time invariant will be absorbed in the person-specific intercept.

To examine the allocation of human capital resources, we run similar regressions with an individual's number of direct reports as the dependent variable. The number of FTEs reporting to researcher(i) is a non-negative count. Therefore, we run conditional fixed effects Poisson regressions, with the fixed effects entered at the researcher-level. In one set of regressions in which there is relatively limited within-person variation in the dependent variable, we encountered converge issues with conditional count models and instead report coefficients in which the conditioning is done at the laboratory level, rather than at the person level.

Our first hypothesis, that resources accrue to successful publishers, suggests that β_1 is positive for either dependent variable: compensation and the number of direct reports is higher for individuals who are successful at publishing. However, hypotheses 2 and 3 anticipate that this positive relationship is contingent on the authority an individual wields in the organization. To test these hypotheses, we will split our sample across three categories of employees in BTCO R&D: (a) technicians without PhDs, (b) technicians with PhDs, and (c) laboratory heads. We will run separate regression analyses for each subsample.

5. Results

We begin our discussion of results with a set of descriptive statistics. Table 1 reports the recent history of publishing at BTCO. These statistics provide interesting insight into the scientific strategy of the firm. Over time, BTCO has refined its publishing strategy to emphasize higher profile papers, rather than quantity. Through interviews with senior management, this change in strategy was due to the awareness of the time-costs associated with publishing in even low-profile venues. This drop in publication numbers, from 210 papers in 2001 to 136 in 2006 is particularly striking as the research department nearly doubled in size over the course of our dataset.

[3] For ease of interpretation, we have opted to run linear regressions. The use of count models (e.g., the conditional Poisson) does not significantly alter the results that are presented here.

Table 2
Descriptive statistics panel a: pooled cross-section descriptive statistics (n = scientist-years = 1963).

	Mean	SD	Min	Max
Age	39.21	8.704	22	69
Male	0.462	0.499	0	1
Highest Education-BA	0.368	0.482	0	1
Highest Education-MA	0.233	0.423	0	1
Highest Education-PhD	0.399	0.490	0	1
Firm Tenure	5.964	6.543	0	30
Lab Head	0.240	0.427	0	1
No Publications	0.768	0.422	0	1
Low Publications	0.136	0.343	0	1
High Publication	0.096	0.295	0	1
Is an author	0.232	0.422	0	1
% of Target Bonus Received	1.058	0.254	0	2.47
# of Direct Reports	1.239	2.552	0	23

Although the overall number of published papers decreased over time, quality, as measured by the quantity of papers in Cell, Nature, or Science, did not (see Table 1). Repeatedly, senior management emphasized that publishing in these three journals was a core metric for productivity. In fact, we see evidence of Senior Management's emphasis on quality over quantity; while the annual paper count declines, the mean Journal Impact Factor of the a BTCO research papers increased from 6.87 in 2001 to 8.78 in 2006. In light of these trends, we interpret publication success as the discovery of a substantive piece of research, worthy of dissemination in a quality journal. The "lumpy" publication rate in Cell, Nature, and Science reinforces the idiosyncratic nature of the scientific discovery process.

Table 2 presents descriptive statistics for members of BTCO's research staff in the full panel. The typical individual in our dataset is 39 years of age and has been with BTCO for about 6 years. The employees in the dataset are diverse: there are 53% women in the research division, and 50% of the population is non-Caucasian. Consistent with the nature of work in biotechnology, almost 40% of individuals hold a doctorate, while another 23% have a Master's level degree. One out of 4 individuals is designated as a laboratory-head and, in the context of this paper, holds a position of scientific leadership. In a typical year, 77% of individuals are not listed as a publication author. Ten percent of observed employee-years pertain to a BTCO employee who published two or more papers in that year

Recall that researchers' target bonus payouts are centered on 1.06 to reflect the addition of compensation from the "key contributors" pool. Given the range in Panel A, from 0 to 2.47, it is clear that managers' perceive significant variation in their reports' performance. Fig. 2 illustrates the overall distribution of target bonus, which is approximately normal for the research division.

The number of direct reports ranges from zero (for a front-line worker) to 23 and is right skewed (Table 2 and Fig. 3). For 66% of the person-year observations, individuals do not have any direct reports, consistent with BTCO's flat organizational structure. For individuals who do have FTEs, the median number of direct reports is three.

Table 3 presents regressions that examine the overall effect of publication on researchers' bonuses and number of direct reports for all employees. At this point, we do not discriminate between individuals in different positions within the organization.

We present baseline models in Table 3, Models 1 and 3. In the baseline models, we see that as organizational tenure increases, employees receive a greater share of bonus (Model 1) as well as resources and responsibility within the organization (Model 3). As we discuss below, the increase in bonus and FTE allocation with tenure is consistent with the notion that employees who have been

Table 3
Fixed effects (panel) model on share of discretionary bonus or # of direct reports.

	(1)	(2)	(3)	(4)
Dependent variable	Proportion of target bonus-received		Number of direct reports	
Model	OLS		Poisson	
Is an author		0.022+		0.076+
		(0.013)		(0.044)
Tenure	0.017**	0.016**	0.410**	0.393**
	(0.005)	(0.005)	(0.080)	(0.078)
Tenure-Squared	−0.000*	−0.000+	−0.003**	−0.003**
	(0.000)	(0.000)	(0.001)	(0.001)
Constant	0.941**	0.931**	−4.883**	−4.685**
	(0.056)	(0.056)	(1.413)	(1.386)
Observations	1963	1963	1963	1963
R-Squared	0.03	0.03		
rho	1	1		
F-Test	5	5		
Log-Pseudolikelihood			−1079	−1078
# of employees	543	543	543	543

Note: Estimates are displayed as raw coefficients. Columns (1) and (2) are OLS; columns (3) and (4) are conditional Poisson regressions. Is an author, is a binary (i.e., 0/1) indicators. All models include unreported person-specific fixed effects, salary-band and year dummies. Robust standard errors in parentheses below.
* Significant at 5%.
** Significant at 1%.
+ Significant at 10%.

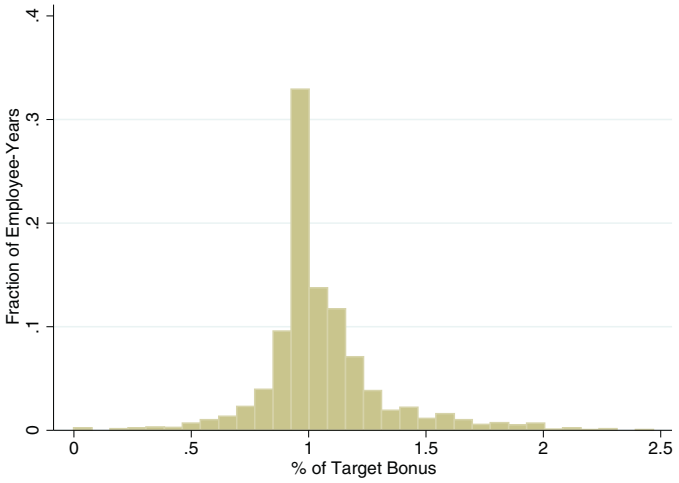

Fig. 2. Share of discretionary bonus. *Note*: Managers are provided a customized target bonus for each of their direct reports. This target is then adjusted to reflect performance. We present received/target bonus to reflect a weighted measure of performance in each year for 1964 person-years.

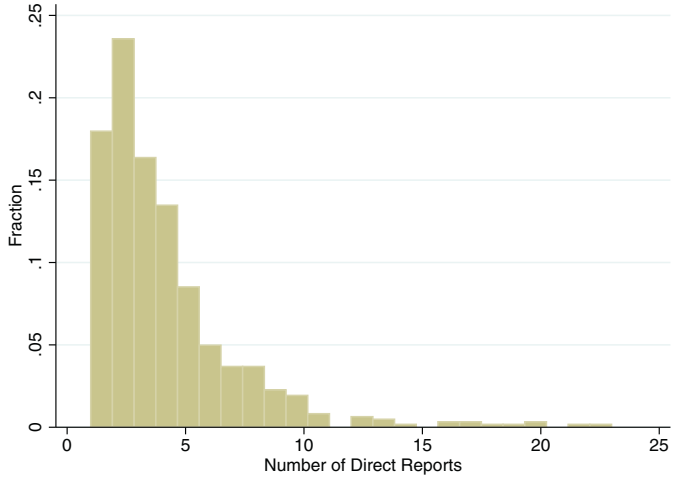

Fig. 3. Number of Direct Reports. *Note*: We show the number of direct reports for supervisors across 624 person-years in our dataset. Not shown are the 1300 (66.2%) person-years where individuals did not have a direct report.

at the organization longer are entrusted with a greater share of resources.

We find marginal evidence for hypothesis 1, which states that rewards accrue to individuals who are prolific publishers. If an individual produces one or more papers in a given year, this correlates with a 2.2% increase in bonus, although this effect is only marginally significant at the 8.6% level. Across all individuals, we observe a positive correlation between FTEs and publication success (Table 3, Model 4). Individuals who are authors have 7.9% more direct reports than their non-publishing peers.

In the following regressions, we discriminate between employees with different positions and/or human capital within the firm. In columns labeled "Labheads", the data are limited to members of the research organization that lead independent research groups. Both hypothesis 2 and hypothesis 3 suggest a positive correlation between rewards and publication success for individuals in positions of scientific leadership. We further divided the dataset into "Technicians (without PhDs)" and "Technicians (with PhDs)" to distinguish between two categories of educational attainment.

When we separately analyze the effect of publication for employees in different positions in the firm, we find support for hypothesis 2. In Table 4, we examine the effect of publishing success on an individual's share of discretionary bonus, separating out employees according to their positions within BTCO research. For technicians (i.e., non-labheads), regardless of their educational attainment, there is no correlation between publication success and bonus (Models 1–4). In contrast, we observe a positive relationship between publication success and bonus for labheads. Publishing one or more papers increases an individual's share of bonus by 6.2% (Table 4, Model 6). Interestingly too, a positive correlation between organizational tenure and bonus is observed only for individuals with PhDs, although this relationship is of greater magnitude for labheads than for technicians. We see no evidence of a relationship between discretionary bonus and publishing for technicians without PhDs (see Section 6).

We observe similar results when we turn our attention to the relationship between an individual's number of direct reports and publishing (Table 5). In this case, only labheads who publish receive a greater number of direct reports (Model 6). Technicians who publish do not receive a boost, whether or not they hold a PhD. Lastly, we see that the managerial responsibilities of labheads increase

Table 4
Fixed effects (panel) linear model on share of discretionary bonus.

	(1)	(2)	(3)	(4)	(5)	(6)
Dataset	Technicians (without-PhDs)		Technicians (with-PhDs)		Labheads	
Is an author		−0.008		0.031		0.062*
		(0.015)		(0.030)		(0.028)
Tenure	0.004	0.004	0.032*	0.029*	0.041**	0.042**
	(0.005)	(0.005)	(0.013)	(0.013)	(0.011)	(0.011)
Tenure-Squared	−0.000	−0.000	−0.002**	−0.002*	−0.001*	−0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Constant	1.086**	1.087**	0.870**	0.867**	0.914**	0.848**
	(0.086)	(0.087)	(0.100)	(0.100)	(0.105)	(0.109)
Observations	1118	1118	375	375	470	470
R-Squared	0.03	0.03	0.14	0.14	0.10	0.11
rho	1	1	1	1	1	1
F-Test	3	3	5	5	8	8
# of employees	325	325	126	126	92	92

Note: Estimates are displayed as raw coefficients. Is an author, is a binary (i.e., 0/1) indicators. All models include unreported person-specific, salary-band, year dummies. Robust standard errors in parentheses below; + significant at 10%.
* Significant at 5%.
** Significant at 1%.

Table 5
Conditional fixed effects poisson regressions: # of direct reports.

	(1)	(2)	(3)	(4)	(5)	(6)
Dataset	Technicians (without-PhDs)		Technicians (with-PhDs)		Labheads	
Is an author		0.326		0.104		0.102*
		(0.239)		(0.097)		(0.049)
Tenure	0.009	0.006	0.072	0.050	0.862**	0.853**
	(0.099)	(0.098)	(0.076)	(0.071)	(0.065)	(0.063)
Tenure-Squared	0.000	0.001	−0.003	−0.003	−0.002**	−0.002*
	(0.005)	(0.005)	(0.004)	(0.004)	(0.001)	(0.001)
Constant	3.117**	3.344**	0.692+	0.622	−13.585**	−13.575**
	(0.965)	(0.974)	(0.411)	(0.406)	(1.134)	(1.124)
Observations	1118	1118	375	375	470	470
# of employees	325	325	126	126	92	92
Log-pseudolikelihood	−178	−177	−229	−227	−789	−788
Fixed Effects	Lab		Individual		Individual	

Note: Estimates are displayed as raw coefficients. Is an author, is a binary (i.e., 0/1) indicators. All models include unreported salary-band and year dummies. Due to model convergence issues, we are unable to condition at the individual level in Columns 1 and 2. In these regressions, we include laboratory-level (rather than person-level) fixed-effects. Robust standard errors in parentheses below.
* Significant at 5%.
** Significant at 1%.
\+ Significant at 10%.

over organizational tenure (Models 5–6). This increase in direct reports over time is not observed for technicians, with or without PhDs (Models 1–4). Taken together, Tables 4 and 5 provide support for hypotheses 2 and 3, respectively.

6. Discussion

This paper has examined the relationship between the allocation of resources and publication success within a science-based firm. We utilize a rich dataset, bringing together a range of resources from compensation to the formal organization of human capital resources, to provide evidence that an employee's publication success is positively linked to the allocation of the organization's rewards. Moreover, we theorize and provide evidence that this correlation exists only for a limited set of positions within the organization. Employees who hold scientific leadership roles within the organization are rewarded for publication success, but rank-and-file members are not. These results extend the body of empirical evidence on the link between intra-organizational contexts and entrepreneurial activities within established, science-based firms.

However, this study is not without limitations. One concern is causality. It is possible that publication success itself may be a consequence of the allocation of rewards, rather than the reverse. For example, individuals who receive a payout in the form of discretionary bonus may increase their (future) motivation and effort to publish. Likewise, individuals who receive a greater number of human capital resources will have the ability to simultaneously handle more projects, resulting in an increased likelihood of publication success. And, it is possible that an omitted variable drives the findings.

We have attempted to address these issues in a variety ways, but none are fully satisfying. First, we have included person fixed effects to purge the estimates of unobserved, time-stationary attributes. Second, we provide support for the allocation of rewards to successful publishers across two very different types of organizational resources: short-run monetary compensation as well as less-reversible human capital resources. Third, our key explanatory variable, one or more accepted publications within a given year, is somewhat idiosyncratic. Due to the nature of the editorial and review process, it is difficult for authors to control the timing of their output (i.e., accelerating or retarding the publication process). We doubt that many individuals would risk a significant delay in publication that is not required for intellectual property reasons, as this action might jeopardize the establishment of priority that is of central importance within the scientific community.

A second concern is the generalizability of our results. As noted in Cockburn and Henderson (1998), there is variability in the extent to which pro-pub strategies permeate the biopharmaceutical industry: some firms readily disseminate their scientific findings, while others hold their discoveries close to their chests. By definition, firms that choose not to adopt a pro-pub strategy will not benchmark their allocation of internal resources to publication success. Nonetheless, for these firms, we suspect that the internal incentive structure will be conditioned upon an individual's position within the organization. Using whatever metric of productivity this firm might value (e.g., patenting), our findings would suggest a tighter link between innovative output and rewards for individuals in positions of authority.

Likewise, what about science-based entrepreneurial firms that are "dictatorial" (e.g., Henderson and Cockburn, 1994) where authority is held by a small minority of individuals, rather than the distributed, university-like structure of BTCO research? For organizations that adopt a much more vertical structure, we would expect that incentive structures would be much less high-powered. Specifically, there will be fewer benefits to benchmarking internal rewards and resources to an external evaluation system. As a consequence, we would expect the magnitudes of our effects to decrease. Nonetheless, we predict that as we descend the "pyramid" structure of the organizational hierarchy for these organizations, the effect of productivity on rewards will decrease for these lower positions.

The findings in this study speak, most clearly, to the literature on incentive structures in entrepreneurial industries. Recently, a burgeoning set of literature has examined the labor market for scientific talent, with an emphasis on compensating differentials (Stern, 2004). As a complement to this body of work, we extend the examination of individuals who readily traverse the public/private boundary (e.g., Stuart and Ding, 2006; Azoulay. et al., 2007) into the organization itself.

Our findings have implications not only for academic research, but also for managers of science-based firms. In this paper, we have provided an illustration of one large, yet entrepreneurial science-based firm and the internal policies and context that promote entrepreneurial activities. In doing so, a number of potential lessons for managers arise. First, entrepreneurial contexts do not need to be uniform across all members of the organization. To the extent that individuals occupy different roles and functions within the organization, the incentives and rewards for entrepreneurship may be lower- or higher-powered. Second, we illustrate that multiple types of rewards (e.g., monetary, human capital) can be allocated to productive individuals. One particularly intriguing notion, which we are not able to untangle in this paper, is to consider the interplay between award type, an individual's role, and the type of entrepreneurial activity. For example, one might imagine a division of research staff into two types: those that attend to the direct needs of the organization, and a second type which act as liasons (i.e., boundary-spanners) to the external ecosystem within which the organization is embedded. Both individuals might be monetarily rewarded for entrepreneurial activities but, with regards to human capital resources, only the first group may be rewarded to induce boundary spanners to engage more broadly throughout the internal organization.

Although speculative, this notion of differential links between rewards and roles emphasizes the intimate relationship between incentive structures and the design of the organization itself. For entrepreneurial firms, choosing an intra-organizational context that encompasses formal structure and chains of command, geographic locations, as well as the short- and long-term allocation of organizational resources are critical factors that shape the firm's innovative trajectory.

Although the focus of this paper has been on intra-organizational positions and the contingent effect these positions have on the allocation of organizational resources, the role of tenure within the firm is worth commenting upon. As individuals spend more time in the organization, the organization learns more about each individual's ability and fit, and resources accrue accordingly. It is intriguing, then, to imagine the extra-organizational publication process as a complementary system to the intra-organizational one; and both systems are used by the organization to learn about an individual's talents and abilities. From the organization's perspective, allowing their research employees to engage in the broader scientific community allows the organization to better sort employee quality. As a consequence, this external engagement has long-run implications for the management of the organization, including possibly permeating strategic decision ranging from the allocation of "sticky" internal resources, to structuring of lines of authority within the formal organization, and to patterning of the informal status hierarchy.

Ultimately, the contribution of this paper is to illustrate the central importance of organizational positions on shaping the incentive structures within the organization. This paper reaffirms the need to consider the context within which entrepreneurial activities are promoted and, at a minimum, our hope is that this paper serves as an impetus to future theoretical and empirical work on context within science-based entrepreneurial firms.

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