Rocketing to the Top: Promotion Tournament Rewards and Innovation at NASA

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Abstract: Competitions for promotion among knowledge workers are ubiquitous in modern organizations, yet we know little about their implications for knowledge creation. This paper investigates the effect of promotion tournament rewards on innovation and teamwork at the National Aeronautics and Space Administration (NASA) utilizing original, employee-level panel data and qualitative interviews. Results indicate that larger promotion tournament rewards correlate with an increase in innovation – measured by publications and patents – despite a decrease in internal collaboration – measured by coauthoring with NASA employees. Additional results suggest that promotion tournament rewards also correlate with increases in external collaboration outside of NASA. These results indicate that extrinsic promotion rewards can be effective in promoting innovation despite the risk of crowding out intrinsic motivation, though the long-term nature of these rewards is likely important. Given recent trends in the flattening of firms and increasing use of promotion rewards, managers can benefit from taking into account the complex tradeoffs based on the nature of the firm’s knowledge and innovation strategy when designing promotion tournaments.
“We live and die on innovation. If they are innovating and coming up with solutions that lead to better missions then I will put them at the front of the promotion line.” –NASA Engineering Manager

Understanding knowledge workers’ motivations to innovate is important for any organization’s innovation governance strategy (Cohen and Sauermann, 2007). Research shows that extrinsic rewards can motivate knowledge workers (Azoulay, Graff Zivin, and Manso, 2011; Ederer and Manso, 2013; Manso, 2011; Sauermann and Cohen, 2010) yet debate about the effect of such rewards on intrinsic motivation to create and innovate still exists (Amabile, 1983; Collins and Amabile, 1999; Deci and Ryan, 1985; Erat and Gneezy, 2016). In light of this debate, surprisingly little research has investigated the effect of extrinsic rewards on individual innovation outcomes in organizations. This paper explores the effect of one such reward, promotion tournament rewards1, on individual innovation. Two general phenomenon make this exploration important. First, promotion tournament rewards are among the most ubiquitous and consequential rewards available to employees in modern organizations (Cowgill, 2014). Second, firms are in a period of flattening hierarchies (Acemoglu et al., 2007; Guadalupe and Wulf, 2010; Rajan and Wulf, 2006) which not only alters the span of control but also indicates a dynamic shift in individual promotion rewards.

This paper utilizes original employee-level data from the National Aeronautics and Space Administration (NASA) to investigate the effect of promotion tournament rewards on innovation. To my knowledge, the paper is the first to empirically show a positive relationship of promotion tournament rewards to knowledge worker innovation in a field setting. Qualitative interviews with NASA scientists, engineers, and managers complement the empirical results by exploring NASA’s innovation process and the paper’s proposed mechanism. Overall, results reveal that managers can potentially affect the prevalence, collaborative process, external access, and external dissemination of innovation through changes in the organizational promotion structure.

A complication for promotion tournament rewards with innovation is that more is not necessarily better. Individuals are likely to increase effort and risk taking to separate performance from peers while decreasing

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1 Competition between workers for promotion within an organization likely resulting in an increase in salary, responsibility, and prestige (Lazear and Rosen, 1981; Moldovanu, Sela, and Shi, 2007)
peer collaboration in an effort to isolate their contribution (Hvide, 2002; Lazear, 1989; Lazear and Rosen, 1981; Lazear and Shaw, 2007; Prendergast, 1999). Despite the prevalence of promotion tournaments and the important theoretical innovation implications, few studies exist on promotion tournaments for knowledge workers largely due to difficulty in gaining combined access to detailed data on firm level organizational promotion structure and individual level innovation outcomes.

This paper investigates the individual-level effects of promotion tournament rewards on innovation, and overcomes data barriers by utilizing NASA employee data obtained through a freedom of information act (FOIA) request and connecting individual innovation outcomes from publicly available data for publications and patents. The dataset covers the period from 2004-2016 and contains employee name, location, occupation, job level, and salary for 30,750 unique employees and over 245K employee-year observations across 10 NASA locations. The individual-level salary records allow for the construction of a standard measure of the promotion tournament reward, which is defined as the difference between salaries across job levels (Becker and Huselid, 1992; Lazear, 1991; Messersmith et al., 2011). The identifying information on NASA employees allow us to measure innovation by matching these individuals to 12,481 publications as well as 991 patents over this time period.

NASA provides a setting that is appropriate – and even advantageous – for the study of promotion rewards for multiple reasons. First, the federal government controls promotion rewards and NASA has little control over establishing the promotion rewards structure. However, NASA does control the actual employee promotions. This separation of policy and management alleviates the concern that NASA endogenously designs promotion tournaments based on differences in innovation across groups. Second, only ~1% of employees switch locations in a given year, which reveals little endogenous sorting across tournaments and locations by NASA employees. Third, NASA operates at 10 sites across the United States with simultaneous promotion tournaments that have significant variation in the number of employees and rates of innovation yet are very similar on other dimensions such as occupation type, job level, and promotion criteria. This creates similar yet relatively autonomous promotion structures across sites. Fourth, NASA is not a typical public
sector organization in that it is internationally recognized as one of the most innovative organizations in history (Dick, 2012). Finally, NASA employees are highly intrinsically motivated which provides a base case for the effect of extrinsic promotion tournament rewards on knowledge worker innovation.

Empirical results testing the relationship of promotion tournament rewards to innovation and teamwork reveal an increase in innovation in conjunction with a corresponding decrease in internal collaboration as promotion rewards increase. Employee fixed effects models additionally reveal that promotion tournament rewards may lead to an increase in external collaboration, which has implications for knowledge search. For instance, firms may be able to encourage different types and levels of collaboration (e.g. collaboration outside the organization) with heterogeneous promotion rewards. Finally, local housing price is utilized to instrument promotion tournament rewards, providing results consistent with the basic results and additional evidence to alleviate endogeneity concerns.

This paper makes multiple contributions to the innovation management literature with respect to the characterization and outcomes of innovation with promotion reward structure heterogeneity. To my knowledge, this research is the first to show the positive relationship of promotion incentives to individual innovation outcomes despite a decrease in internal collaboration. More broadly, this paper connects to the knowledge-based view of the firm by showing how internal organization of promotion structure and incentives can shape the way in which the firm generates knowledge (Grant, 1996; Nickerson and Zenger, 2004). Prior literature has focused on span of control (Acemoglu et al., 2007; Guadalupe and Wulf, 2010; Rajan and Wulf, 2006) or formal R&D structure (Argyres and Silverman, 2004; Arora, Belenzon, and Rios, 2014) where this paper focuses on the individual incentives associated with structure decisions. In addition, the paper contributes to recent literature investigating the effect of vertical wage dispersion on employee behavior (Kacperczyk and Balachandran, 2018; Obloj and Zenger, 2017), firm hierarchical structure on innovation outcomes (Keum and See, 2017), and performance incentives on innovative behavior (Lee and Meyer-Doyle, 2017). The paper also places emphasis on the microfoundations of innovation in organizations (Barney and Felin, 2013; Felin, Foss, and Ployhart, 2015) by investigating ways in which individual
innovators can be governed and shows important implications of individual aggregation. The paper also reveals information that is managerially relevant. Most importantly, managers can affect innovation by structuring promotion tournaments differently. The optimal promotion tournament is likely to differ with the characteristics of the organization’s problems and knowledge set because the importance of collaboration differs across these dimensions.

**Background**

This paper draws heavily upon two literature streams to develop a framework of the motivations and incentives of knowledge workers to innovate. Although these two streams have largely progressed in a disparate manner, this paper will point out the importance of their connections in understanding the effect of promotion rewards on innovation. The first stream investigates knowledge worker’ motivations. Research has shown that many knowledge workers are intrinsically motivated by the “taste for science” (Roach and Sauermann, 2010; Sauermann and Roach, 2014; Stern, 2004) yet are also motivated by extrinsic rewards such as salary (Azoulay et al., 2011; Ederer and Manso, 2013; Manso, 2011; Sauermann and Cohen, 2010). In particular, extrinsic incentives that tolerate short-term failure but reward long-term success may encourage innovation (Azoulay et al., 2011; Ederer and Manso, 2013; Manso, 2011).

The second literature stream investigates what are termed “promotion tournaments”. Risk taking, effort, and collaboration are all important for innovation and promotion tournament rewards create a motivational tension between these three actions. Individuals are likely to increase risk taking and effort to separate their performance from peers (Hvide, 2002; Lazear and Rosen, 1981; Lazear and Shaw, 2007; Prendergast, 1999). They are also likely to decrease collaboration with promotion competitors for the same reason (Lazear, 1989). The link between these two literature streams is in the structure of the rewards. Promotion tournament rewards are likely to tolerate short-term failure, as there is a salary safety net. However, long-term success leads to a higher likelihood of significant promotion rewards.

**Knowledge Worker Motivations**

Research in the last 15 years has begun to unwrap the complex motivations of knowledge workers. Stern (2004) utilized a survey of biology PhD students on the job market to pit two competing views of
knowledge workers’ contribution within a firm. The first view is that scientists “prefer” the ability to pursue basic science and are willing to accept a lower salary to do so. The second view is that employing knowledge workers engaged in scientific activity will increase the firm’s ability to create or absorb valuable knowledge (Cohen and Levinthal, 1990). Stern finds support for the preference effect where firms that offer scientific freedom also offer lower salaries. Therefore, scientists may pay a salary price to pursue science. The implication is that knowledge workers have an intrinsic “taste for science” that may motivate them to forgo other types of incentives. Follow-on research investigated heterogeneity in this taste for science. Utilizing a survey of science and engineering PhD students, Sauermann and Roach (2014) found significant heterogeneity in the price these students were willing to pay to pursue science. Those with a strong “taste for science” preferred academic jobs while students motivated by salary preferred industry jobs (Roach and Sauermann, 2010). Thus, the motivation is less intrinsic for industrial scientists compared to those pursuing academic positions.

Given this heterogeneity in motivations, it is unclear if pecuniary and/or non-pecuniary incentives will lead to increases in knowledge production and innovation. Sauermann and Cohen (2010) look deeper at the correlation of knowledge worker motivations and innovation outcomes. Utilizing a large survey of professional scientists and engineers, the authors find a strong positive relationship between innovation outcomes and the desire for income, independence, and intellectual challenge while also showing a negative relationship between innovation and the desire for job security and responsibility. Thus, both pecuniary (income) and non-pecuniary (independence and intellectual challenge) incentives are correlated with higher innovation outcomes.

Lastly, it is theorized that innovation requires a different type of incentive structure (Manso, 2011). In particular, innovation will increase with the combination of early failure acceptance and incentives for long-term success (Azoulay et al., 2011; Ederer and Manso, 2013; Manso, 2011). Empirical research shows external research grants with longer life cycles lead to higher publication output (Azoulay et al., 2011). An
interpretation is that a mixed pay for performance system might be optimal with guaranteed fixed pay combined with a long-term incentive.

In summary, this stream of research indicates that knowledge workers may need to accept lower wages to increase their scientific freedom. However, they are heterogeneous in their taste for science and sort into academic and industrial jobs based on their heterogeneous preferences. Given these preferences, both extrinsic and intrinsic motivations likely correlate with higher innovation output. Therefore, the structure of any extrinsic rewards is important in promoting rather than destroying innovation.

Creativity scholars have multiple views on the effect of extrinsic incentives on creativity. The first view is that creativity is inherently an intrinsically motivated activity and extrinsic incentives will take away from that motivation to decrease creativity (Amabile, 1983; Collins and Amabile, 1999; Deci and Ryan, 1985; Erat and Gneezy, 2016) while the second view is that creativity is dependent on freedom, self-determination, and empowerment leading to certain extrinsic incentives that will both bolster these attributes and increase creativity (Eisenberger and Rhoades, 2001; Eisenberger and Shanock, 2003). With respect to innovation, the latter viewpoint may be more relevant. For example, NASA employees are self-determined and rewards likely re-inforce the importance of their self-determination. It is also worth noting that these studies largely do not involve knowledge workers and typically offer incentives of much lower power and shorter in time horizon compared to career incentives for promotion.

Promotion Tournaments

An interesting result from the previously discussed research on knowledge worker motivations is the correlation of extrinsic incentives to innovation (Azoulay et al., 2011; Ederer and Manso, 2013; Sauermann and Cohen, 2010). The following paragraphs provide an overview of one such extrinsic incentive, promotion tournament rewards, which are present for over ¾ of all workers (Cowgill, 2014) and have profound theoretical implications for innovation. The theoretical concept of promotion tournaments (also called employee tournaments, rank-order tournaments, etc.) was crystallized by Lazear and Rosen (1981) and virtually all theoretical predictions descend from their constructs. Their theory holds that monitoring the
effort of employees is costly and promotion rewards based on relative rank to peers have the potential to lower monitoring costs while incentivizing certain employee behaviors (Lazear and Rosen, 1981).

Promotion-based tournaments pool a small portion of wages from all employees in a job rank or level to the salaries of higher ranks and the promotion provides a clear winner of that salary pool. This potential for a discrete jump in compensation as well as increases in responsibility and prestige elicits certain behavioral effects from employees. First, they act to increase employee effort (Lazear and Rosen, 1981; Lazear and Shaw, 2007; Prendergast, 1999) in hopes of winning the tournament prize (Lazear and Shaw, 2007). Second, promotion tournaments may increase the risk taking of innovative employees in an effort to outshine their peers competing for the same promotion (Hvide, 2002).

Similar to the incentives that encourage individual risk taking, employees may engage in less optimal behaviors to separate themselves from peers. One way in which this could occur is through a decrease in teamwork and cooperation (Lazear, 1989). Employees compete in tournaments alongside fellow employees with whom they need to work together for overall organizational success. In an attempt to provide separation from others in the tournament, employees may block competitor’ successes through decreased teamwork. This potentially negative effect of promotion tournament rewards on cooperation may offset the potential positives of effort and risk taking. Workers must make a determination of the benefit of collaboration to the innovation’s outcome, the cost of coordinating, and the cost of sharing rewards with the team (Deichmann and Jensen, 2018). Teamwork effects may be especially pertinent in innovative organizations where information exchange and cooperation are necessary to innovate (Siegel and Hambrick, 2005).

Matching the organization’s strategy to individual compensation incentives is non-trivial yet important for performance (Tenhiälä and Laamanen, 2018). Firms face a challenge in designing promotion tournaments based on their specific capabilities and objectives. If the tournament prize is too small, there may be suboptimal effort and innovative risk taking; however, if the tournament prize is too large, there may be suboptimal teamwork to combine knowledge across individuals in order to innovate. These competing effects of promotion tournaments pose an organizational design challenge for firms: how to design the
organization’s levels of hierarchy and span of control that optimizes the tension between individual effort and collaboration. Interestingly, there has been little consideration of tournaments in organizational design. The recent focus on hierarchical span of control rather than incentive considerations may be a contributing factor (Rajan and Wulf, 2006).

The promotion tournament literature has begun empirically testing theoretical predictions but detailed employee level data has been a significant barrier. Firms are reluctant to provide employee information which initially led to promotion tournament research in contexts such as sporting events where the size of a tournament prize has been shown to increase effort (Becker and Huselid, 1992; Ehrenberg and Bognanno, 1990). However, research investigating the variety of effects from promotion tournaments is accumulating and there has recently been a growing number of studies that use firm data to investigate the predictions of greater effort as envisioned through performance outcomes (Brown, Sturman, and Simmering, 2003; DeVaro, 2006; Pfeffer and Langton, 1993; Ridge, Aime, and White, 2015; Shaw, Gupta, and Delery, 2002), higher risk taking and innovativeness (Kini and Williams, 2012), and higher turnover (Bloom and Michel, 2002; Kacperczyk and Balachandran, 2018; Shaw and Gupta, 2007). Studies that utilize firm data largely investigate public firm CEO tournaments where data is readily available (e.g., Kini and Williams, 2012).

In summary, theory predicts that promotion tournaments will increase effort and risk taking while decreasing collaboration. Given that knowledge creation can rely on all three of these attributes to varying degrees, it is important to understand the effect of promotion tournaments on knowledge worker innovation because it has the potential to be an important tool for firms in their innovation governance strategy. Thus, it is peculiar that promotion tournament empirical research has done little investigation of innovation at the employee level. This is likely due to difficulty in obtaining the promotion tournament structure for an organization as well as difficulty in measuring innovation.

Research Setting

The setting for this study is the United States National Aeronautics and Space Administration (NASA), which is responsible for the civilian space program as well as aeronautics and aerospace research. NASA’s primary value to society “is as an engine of innovation” (Pyle, 2014: vii). NASA had 17,239 employees as of
September 2016 dispersed across 10 nation-wide sites, each site categorized as “Mission”, “Research”, or “Headquarters” based on their primary objective and purpose. Figure 1 shows the geographic distribution, relative size, and category of these sites across the United States.

The public largely knows NASA by the organization’s major accomplishments such as safely landing men on the moon with the Apollo space program, building a re-usable space shuttle, and exploring the outer reaches of our solar system with the Hubble telescope. However, many less-heralded innovations made these larger accomplishments possible and NASA also innovates in many peripheral areas. For instance, NASA inventions include memory foam, scratch resistant lenses, adjustable smoke detectors, and ear thermometers (Tushman, Lifshitz-Assaf, and Herman, 2014). NASA must ensure that their knowledge workers innovate broadly to fulfill the overall mission of the organization.

NASA also has a long history of collaboration with academia and private industry. Their partnership with Cal Tech at the Jet Propulsion Laboratory exemplifies this collaborative spirit, as do the long-standing relationships with contractors that build NASA products. More recently, budget cuts have made this relationship even more important with NASA’s focus on accessing and disseminating knowledge through methods such as open innovation (Tushman et al., 2014). NASA innovation has been the focus of multiple prior studies. Most recently, research has focused on the benefits of open innovation at NASA by showing the power of utilizing crowdsourcing platforms to solve complex coding problems such as modeling encounters with unexpected solar flares in space (Boudreau and Lakhani, 2011, 2016; Lakhani, Lifshitz-Assaf, and Tushman, 2013).

The setting is highly conducive for studying the effect of promotion tournament rewards for multiple reasons. First, it is imperative for NASA to attract and retain employees of the highest quality and they must compete with private organizations for that human capital. Second, innovation is key for the success of the organization. NASA has solved innovation problems throughout its history that no private sector firms would
have the market incentives to solve. Third, NASA is an organization where employees are likely intrinsically motivated with many dreaming of working at the agency from a young age. Thus, the effect of tournament incentives at NASA is likely a low estimate in comparison to firms in the private sector with less intrinsically motivated employees.

NASA Employee Interviews

The author administered qualitative interviews with about a dozen NASA employees to explore the paper’s underlying assumptions about NASA’s innovation process, promotion process, and innovation incentives. One goal of these informal interviews was to get the perspective of a broad spectrum of employees including engineers, scientists, front-line managers, and senior managers. The paper’s premise that the promotion reward affects the innovation and teamwork of NASA employees relies on multiple assumptions about the employee’s knowledge as well as NASA’s innovation and promotion process. First, employees must be generally aware of the promotion reward. Second, employees must believe that innovation will positively affect their probability of promotion. Third, employees must have some autonomy in choosing projects and collaborators. The interviews explored these assumptions and other peripheral topics with a broad set of questions tailored to each occupation type. Interviews broadly indicated that employees were aware of the promotion reward available to them. Promotion reward knowledge was consistent across occupations and levels given that federal employee salaries are public information.

Employee perceptions and actual practices associated with the role of innovation in the promotion process were less obvious ex ante. Interviews indicated that innovation performance is part of the formal employee review process at year’s end. A scientist noted, “Innovative performance with patents and publications is one of the questions that are asked during the annual reviews” and that “the annual review rating highly impacts your promotion probability”. Individual contributors and managers echoed this important connection between innovation and promotion. For instance, a technical manager noted that “if you can demonstrate creativity and innovation, that gives you an edge over others for promotion”. Another manager bluntly stated, “We live and die on innovation. If they are innovating and coming up with solutions that lead to better missions then I will put them at the front of the promotion line”. More generally, one
engineer noted, “[Innovation] is important for salary and promotion”. In fact, every interviewee stated that innovation does and should play a significant part in promotion.

Interviewees provided detail on the actual promotion and hiring process at NASA. Promotions occur through two separate processes. First is promoting without the need to apply. For instance, an employee can be promoted to the next level without the need for him or her to formally submit for the job. Employees indicated that this is the least prevalent method of promotion and rarely occurs at middle and senior levels. The most prevalent method for promotion is a competitive posting on USAJobs.gov. The process involves applying online to a job where any potential applicant (internally or externally) can apply. Promotion (or hiring) is evaluated through a combination of general aptitude and specific education, training, and experience related to the needs of the job. Managers indicated that NASA experience in the occupation provides applicants a significant advantage and most internal hires come from within the occupation and location of the job posting.

Employees indicated that endogenous team formation is very common although not the only way in which NASA teams form. In some instances, management forms the team to solve a problem. However, a technical fellow indicated, “teams are formed more so naturally than directed by management”. Another technical manager stated, “I have seen more failure with directed innovation than organic innovation”. This theme of employee autonomy in forming teams was consistent across occupations and levels.

In summary, these informal interviews served to corroborate assumptions that underlie the proposed mechanism in this paper. First, employees are aware of the promotion reward available to them. Thus, the reward magnitude has the potential to affect employee behavior. Second, individual contributors believe that innovation positively influences their promotion chance while managers indicated they promote and hire based on innovative performance. Therefore, employees may want to increase innovative output to increase their chance of promotion. Third, employees have autonomy in forming teams. Thus, individual incentives may affect an employee’s likelihood of teaming with others. Lastly, the author asked what managers can do
to motivate employees to innovate. One employee lamented, “bonuses are very tiny” while a manager noted, “there’s not a whole lot of carrots I can offer”. One carrot that NASA managers can offer is promotion.

Data and Measures
Federal employees’ non-executive job levels are classified by a system called “general schedule” (GS) ranging from 01 to 15. Each GS category has an associated median salary set by the federal government, which is adjusted depending on the location of the job. Senior positions with more responsibility are on the top end of the scale (e.g., 14 or 15) while entry level and non-skilled positions are toward the lower end. Most job positions within NASA where employees generate significant innovation are associated with grades (NASA’s term for job level) 11 through 15. Multiple occupation types (e.g. various types of engineers, scientists, etc.) generate a variety of innovations (e.g. patents, publications, standards, mission enhancements, etc.) and each job type has its own GS grades within it. Interviews revealed that NASA employees generally compete for promotion with peers in their same job, location, and grade. Thus, there are many promotion tournaments occurring simultaneously within and across sites.

Although the interviews provide initial indications that innovation positively affects promotion, additional evidence that promotions are merit-based is found in an internal federal employee satisfaction survey taken in 2017. Survey statistics reveal NASA employees rated themselves the highest of all agencies on how they are rewarded for innovation and creativity and ranked third in promotions based on merit. These two survey statistics lend credence to the underlying assumption that promotion is positively related to innovation, corroborating the qualitative evidence. NASA employees believe that they will be rewarded for innovation and that promotions are merit-based compared to other federal agencies.

Although NASA innovates in many ways, this paper will focus on two consistent and measurable innovations across organizations and locations: publications and patents. Patents are relatively rare, even at NASA, and provide a measure of innovation that is both valuable and common across many literature streams. However, NASA employees innovate through peer-reviewed publications much more frequently.

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and across a wider variety of occupations. Thus, peer-reviewed publications are a second and more common way in which to measure NASA employee innovation.

Data for empirically investigating the effect of promotion rewards on innovation comes from aggregating across four sources. First, the author filed a freedom of information act (FOIA) request with NASA in June 2017 and received identifying information in March 2018 on all NASA employees including name, job level (grade), salary, location, and occupation from 2004 through 2016. This FOIA data is utilized to construct the promotion tournament measures, which are discussed in subsequent paragraphs. Second, raw data files were directly collected from the federal Office of Personnel Management website containing employee level data without names but with additional personally identifiable information (PII) not included in the first data source such as education, age range, and NASA tenure (level of service). These secondary employee attribute variables are constructed at an aggregate level for use as controls.

The third data source is the Web of Science (WoS) academic journal database, which was queried for authors affiliated with NASA. Names in the WoS may not directly match the employee name from the NASA FOIA data so the WoS and employee data are linked by author name to five variations of an employee’s name based on common ways in which the WoS authors are named in papers. For instance, the fictitious employee name of Sarah Jeanne Johnson is matched to the WoS data utilizing her full name as well as Sarah Johnson, S Johnson, S J Johnson, and Sarah J Johnson contingent on that version of the name uniquely identifying her within NASA. This strict matching criterion ensures that there are no false positive matches between an employee and innovation outcomes at the expense of false negatives. For instance, if there is a NASA publication author identified as S Johnson and employees named Sarah Johnson and Steve Johnson, there will be no employee matched to this publication.

The fourth and last data source is the United States Patent and Trademark Office (USPTO) database, which was queried by assignee for all NASA name variations. All authors on any patents containing NASA as the assignee were matched to the NASA FOIA employee data with the same methodology as the
publication data. These two innovation data sources were used to construct the main dependent variables (the number of publications or patents) linked to individual NASA employees within a given year.

The raw FOIA data itself reveals interesting information about NASA. The workforce is highly educated and skewed toward older employees. Data also reveals significant innovation heterogeneity across NASA sites in both patents and publications. Langley, the largest site, has the highest output of patents per employee while Ames, the smallest site, has the highest output of publications per employee. Heterogeneity also exists across occupations for innovative output and collaboration. Overall, the data reveals a highly educated and experienced workforce that produces significant innovation. Important variation in innovation outcomes exist across locations, occupations, and groups, which lends itself to the potential for understanding why we see these differential outcomes. The paper’s analysis will investigate how promotion tournament reward differences across locations, occupations, and individuals impact innovation.

Variables and Measures

Promotion pools are defined as the set of employees at the same location, in the same occupation, and at the same job level. These are the most likely competitors for promotion as switching occupation or geography is infrequently observed in the data. Figure 2 drills down to show a hypothetical example of an individual promotion tournament between level 12 aerospace engineers at Langley Research Center that are competing for a promotion to level 13. The paper refers to this as a “tournament” throughout.

Promotion tournaments imply competition for a finite number of promotions. One potential concern is that employees at NASA are not actually in a promotion tournament at all. In fact, it is commonly believed that government promotion is all about tenure in the job and age of the employee. However, multiple aspects of the quantitative and qualitative evidence point to NASA having limited promotions for which employees compete. First, the federal government controls the budget and NASA cannot create an unlimited amount of funding for promotions. Second, qualitative interviews indicate that employees do compete for promotion among peer groups. Third, the data itself provides circumstantial evidence for promotion competitions.
Figure 3 provides the distribution of age (panel A) and NASA tenure (panel B) within each job level. The bar within the shaded region of panel A is the median age within the job level (grades 11 through 15) while the top and bottom line of the shaded region represents the 75th and 25th percentile values, respectively. Panel A reveals that age is certainly not the only determining factor in climbing the promotion ladder. In fact, the median age for levels 12, 13, and 14 are almost identical. In addition, there is a very significant overlap in the distribution of age across each level. Panel B provides similar information for NASA tenure. This raw data provides clear evidence that tenure and age alone do not explain NASA promotions.

Finally, panel C shows NASA promotion rates by job level over time. If unlimited promotions were available (not a competition/tournament), the expectation is that there would be significant fluctuation in this rate over time. In other words, a stable number of promotions is indicative of a tournament rather than unlimited employee promotions. Panel C reveals promotion rates remain relatively stable over time, which is interpreted as an indication that an unlimited number of promotions are not available and that competition for scarce promotions is likely. When paired with the qualitative evidence mentioned above, there is clear circumstantial evidence that NASA employees do compete with each other for promotion, rather than having a promotion created when they pass a certain threshold.

The main analysis utilizes the promotion tournament reward as the independent variable which is the difference between the mean salary of the employee’s current job level and the next higher job level within the same location and occupation. For example, the promotion tournament reward for a level 12 aerospace engineer at Langley Research Center is the mean salary of all level 13 aerospace engineers at Langley minus the mean salary of all level 12 aerospace engineers at Langley. Horizontal tournament size is the number of employees in any given tournament. For the same example, it is the number of level 12 aerospace engineers at Langley. This measure is largely utilized as a control variable. Although the FOIA data does contain executive positions, it does not specify the executive level, which prohibits the ability to construct executive promotion tournaments. Therefore, the analysis will focus on non-executive positions, which comprise the
vast majority of observations. Moreover, executive tournaments are more prevalent in the literature since this
data is readily available for public companies. The dependent variable for examining innovation is a count
variable indicating the number of publications or patents for an employee in a given year. This is constructed
from the matched WoS/USPTO and employee data. The dependent variable for examining collaboration is
the count of NASA publication co-authors on a paper. A decrease in this number indicates a decrease in
internal collaboration.

Control variables are constructed at both the individual and group levels depending on the availability of
the data. Controls for location, occupation type, and job level are utilized from the FOIA data linked to
employee names. Group level controls are aggregated from the publicly available anonymous employee level
data including controls for mean level of service, age, education, and supervisory presence that are
generated at the year-location-occupation-grade level. These controls help to parse out the effect of the
promotion tournament from the effect of differences in the attributes of employees across groups. Horizontal
tournament size is also utilized to control for the potential that promotion tournament rewards may correlate
with differences in the number of peers, which could subsequently affect innovation.

Summary statistics for the data are shown in Table 1: Panel A is at the employee-year observation level,
Panel B at the group-year observation level, and Panel C at the innovation observation level. The 236,354
observations in panel A represents 30,750 unique employees over the period from 2004 to 2016. Table 1
reveals that there is significant variation in the promotion tournament reward. Employee-year observations
have a mean publication frequency of 0.08 in any given year and they frequently work with external authors.
On the patent side, employee-year observations have a mean of 0.01 patents, which underscores both the
innovativeness of NASA employees and the relative frequency of publications to patents.

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**Analysis and Results**

The paper’s preliminary empirical analysis is a verification of the underlying assumption of innovation’s importance to promotion. More explicitly, if a positive relationship between successful innovation and promotion does not exist, the proposed mechanism is in doubt. Table 2 investigates this relationship for publications in panel A with basic controls for job level and year while panel B mirrors this analysis for patents. Job level dummy variables are necessary because successful innovations are more likely to occur at high job levels while promotions are less likely to occur. Columns 1 through 3 show the relationship between a publication in the base year and promotion in each of the subsequent three years with errors clustered at the site-occupation level. NASA interviews revealed autonomy in the promotion process across location (site) and occupation. For instance, human resource representatives generally represent an occupation type rather than an entire site and the actual hiring manager has control over the attributes desired for promotion. Thus, it can be reasonably assumed that correlation of errors will occur within the same location and job. Columns 4 through 6 add employee fixed effects. The analysis utilizes a logit specification because of the binary nature of the dependent variable, promotion, which is equal to one in a year when the employee moves up a job grade (receives a promotion).

Columns 1 through 3 in panel A reveal a robust positive relationship between the presence of a publication in the base year and a lagged promotion in any of the next three years. Columns 4 through 6 show the robustness of that relationship when controlling for invariant individual characteristics with the largest magnitude occurring in the year after a publication. The employee fixed effects isolate the effect of successful innovation (rather than ability) on promotion. Thus, the only reason for the strong relationship in Columns 1 through 3 is not that more innovative or intelligent employees are more likely to both publish and be promoted. Panel B repeats this analysis for patents to show that the impact of patents on promotion is

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3 The assumption is supported by employee interviews indicating innovation’s importance in the promotion process.
4 An alternative assumption is that site level human resource policies affecting promotion will lead to site level error correlation. Unreported analyses reveal clustering differences do not affect the statistical significance of results.
statistically robust in the subsequent year and less so in future years. This is likely because the higher likelihood of promotion in year t+1 makes it much less likely to see a promotion in future years. The employee fixed effects coefficients in the subsequent year (t+1) shows a 15.1% and 21.7% increase in promotions when the employee has a publication or patent, respectively. These results show that the presence of an innovation corresponds to a significantly higher likelihood of promotion, which is circumstantial evidence for the promotion tournament’s anticipated mechanism.

There are two key aspects of the data that must be taken into account when generating a model specification. First, the dependent variable is a count variable. Second, an administrative employee with zero publications has the potential to be fundamentally different from a physical scientist with zero publications. Therefore, it is likely that the data has an excess of zeros from employees that are not trying to produce publications and patents. The combination of these two factors makes a zero inflated negative binomial (ZINB) model an appropriate specification (Greene, 2012). The ZINB first weights the probability that each employee attempts to innovate by utilizing a logit model based on covariates, which most importantly includes occupation but also age, tenure, etc. Next, a negative binomial is utilized to model the count dependent variable based on both the weighting that the employee attempts any innovation as well as the independent variable and controls.

Data variation to empirically exploit comes from a variety of sources. First, there is variation in the promotion reward across occupations. For instance, physicists and aerospace engineers have heterogeneous tournament rewards yet innovation increases the probability of promotion in either occupation. Therefore, we can exploit and understand the differences across occupations. We can also control for any invariant differences in occupations using occupation fixed effects. Second, NASA has ten locations that produce innovation as shown in Figure 1. Thus, we can exploit similar tournaments occurring at multiple locations, which have differences in the promotion reward. We can also control for any invariant differences (e.g.

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5 A classic example is estimating the fish caught by visitors to national parks. Not all visitors fish so the covariates (age, length of stay, type of stay, etc.) are utilized to estimate the probability of fishing. Next, the negative binomial model is utilized to estimate the number of fish caught.
mission versus research site) with location fixed effects. Lastly, there are group differences across time. Therefore, we can exploit this variation even when utilizing both occupation and location fixed effects.

The relationship between promotion tournament rewards and publication count for a given employee-year observation is investigated utilizing a ZINB model to generate the results reported in Columns 1 through 5 of Table 3. All errors are clustered at the site-occupation level\(^6\) and all specifications have dummy variables for year and job grade (job level).

Columns 1 through 4 vary the type of dummy variables while column 5 integrates the full set of group control variables. A consistent positive and statistically significant relationship of promotion tournament rewards to publications is observed across all specifications. Column 1 tests the basic relationship of promotion tournament reward (in thousands of dollars) to the count of publications while utilizing dummy variables for grade and year. The interpretation of the coefficient on promotion tournament reward is that an increase of $1K in tournament size correlates with an increase in the log of publication count by 0.1420. This translates to a $1K increase in tournament size correlating to a 15.3% increase in publications for employees in each tournament revealing a strong basic relationship between promotion tournament reward and publications. One concern is that differences across sites account for a large part of the variation and the results in column 1 are driven by these differences. An example is differences across sites in how they manage innovation. Location dummy variables are added in column 2 to control for invariant differences across NASA sites, which reduces the coefficient by 17%. This is interpreted to show that the relationship between tournament size and publications is still robust when controlling for unobserved and invariant differences in NASA sites. Horizontal tournament size is added as a control to the basic regression in column 3, which reveals a continued positive relationship between promotion tournament reward and publications.

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\(^6\) The assumption of clustering at the site-occupation level is based on employee statements that promotion decisions are reasonably independent outside of location and occupation. An alternative and more conservative assumption is that site policies will lead to correlation among errors, leading to the potential that errors should be clustered at the site level. Unreported alternative specifications with site clusters do not materially affect the statistical significance of results.
but a negative relationship with horizontal tournament size. Column 4 removes the location dummy variables and adds occupation dummy variables to aid in understanding the effect of controlling for variation across occupations versus locations. The addition of occupation controls reveals that a significant portion of the magnitude in model 1 is driven by invariant differences across occupations. However, the relationship is still positive and statistically significant after controlling for these differences. Finally, the group controls are added in column 5 to control for group attributes such as tenure and education in addition to all dummy variables. The results are not just statistically but economically significant with one standard deviation increase in tournament size ($5.9K) being associated with a 17.4% increase in publications. Unreported specifications with OLS, Poisson, and negative binomial models as well as lagged outcome variables show consistent results with the ZINB specification in Table 3. In addition, utilizing the actual individual gap (rather than mean gap) from current salary to the next job level results in similar yet even more robust results. However, the concern with utilizing actual gap is the likelihood that the promotion reward measure may also be picking up individual experience and probability of promotion in addition to the actual promotion reward. Overall, the results show statistically strong correlational support for the positive effect of promotion tournament rewards on publications.

Table 4 repeats a similar analysis but utilizes patents as the dependent variable rather than publications. Errors are clustered at the site-occupation level for all specifications.7

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Insert Table 4 about Here

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Similar to the results with publications in Table 3, all models show a positive and statistically significant relationship between promotion tournament reward and patents. Controlling for invariant differences across occupations provides a less dramatic impact for patents compared with publications. The relationship is also economically significant as the estimate in column 5 correlates to an 18.6% increase in patenting for a one standard deviation increase in promotion tournament reward ($5.9K). The results in Table 4 again show strong correlational support for the positive effect of promotion rewards on innovation.

7 Results remain statistically significant in unreported analyses clustering errors at the site level.
The relationship between tournament size and collaboration is investigated for a given employee-year-publication observation because the DV is only available when an innovation is present. There is no zero inflation occurring in this subsample so a negative binomial model is utilized to generate the results reported in Table 5 and all errors are clustered at the site-occupation level.7

Column 1 tests the basic relationship of promotion tournament reward to NASA publication co-authors while column 2 adds the horizontal tournament control. Column 3 includes occupation dummy variables while column 4 integrates the group controls. All results show a negative and statistically significant relationship between promotion tournament reward and internal NASA collaboration. Similar to the results in Table 3, controlling for invariant differences across occupations has a large effect on the magnitude yet all results are robust and statistically significant. It is also economically significant as the coefficient in column 4 reveals that a one standard deviation increase in tournament size ($5.9K) is correlated with a 7.1% decrease in internal NASA collaboration. Potential implications of the search for additional co-authors outside the organization is analyzed in the robustness section and discussed in the discussion section.

Robustness

A key alternative hypothesis for an increase in innovation with promotion incentives is that employees are more willing to draw upon the human capital resources in the group through co-authorships or that increasing the number of NASA collaborators artificially increases innovation. Importantly, the combined publication results from Tables 3 and 5 alleviate this alternative hypothesis. In fact, the results reveal that publications increase in lieu of a decrease in collaboration with NASA employees.

The panel data with 13 years of data and over 30K employees provides the opportunity to use employee fixed effects for additional robustness. In particular, employee fixed effects can help us understand how much of the magnitude is from differences across employees versus within-employee changes in promotion reward. Table 6 utilizes a negative binomial specification with the publications data using employee fixed effects. Column 1 utilizes publications as the DV (similar to Table 3) while column 2 utilizes NASA co-
authors as the DV (similar to Table 5) and column 3 utilizes external co-authors as the DV. Finally, the WoS co-author data is parsed into general categories. If the external affiliation had any form of the word “university” or “college”, it was denoted as an academic co-author while all other external co-authors were lumped into the “other” category. This is because it is much more difficult to create an algorithm to determine if a co-author is from industry versus the public sector. Thus, column 4 uses external academic co-authors and column 5 uses all external non-academic co-authors as the DV.

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Insert Table 6 about Here

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Column 1 provides qualitatively similar results to the basic results in Table 3. The model shows a positive and statistically significant relationship between promotion tournament reward and publications. Column 2 reveals a negative and statistically significant relationship between tournament reward and NASA co-authors similar to the results in Table 5. Meanwhile, column 3 reveals a positive and statistically significant relationship between promotion tournament reward and external co-authors. Given the result of a positive relationship between promotion rewards and external co-authors, columns 4 and 5 further investigate the type of outside co-author. Column 4 shows that the increase is not coming from more academic co-authors while Column 5 indicates the increase is coming from the “other” category made up of both industry and other public organizations.

Two interesting results come from the analysis in Table 6. First, the coefficients for promotion tournament reward in column 1 represent approximately 40% the magnitude of the corresponding coefficients in Table 3. This indicates that both within and across employee variation in tournament size can explain a significant amount of the relationship. Second, columns 3 through 5 reveal that employees may co-author more externally and with non-academic co-authors in the presence of larger promotion rewards. Implications of this potential relationship are discussed in the following section.

Finally, I instrument promotion tournament reward with local housing price to further mitigate endogeneity concerns. Yearly location-based job-level salary adjustments for federal employees are
generated through a formula taking into account cost of living as well as wages of similar occupations in each region. NASA has 10 different sites, which vary in their location adjustment based on this calculation. Figure 4 shows how the federal cost of living adjustment differs across NASA sites in 2018 (where shading is indicative of higher cost of living adjustment). A key driver of the adjustment difference across locations is housing price in each individual location. This provides significant variation in salary adjustments and the gap between job levels - promotion tournament reward.

The first step is to address multiple potential arguments that housing prices violate the instrumental variable exclusion restriction. First, the methodology for adjusting salaries based on local housing prices (and other goods) is not a NASA policy but rather a federal government policy. Thus, NASA cannot alter the policy nor local housing prices to select which tournament rewards will receive relative increases from year to year. A second and more realistic alternative explanation is that areas with higher housing prices attract more innovative employees (e.g. Silicon Valley). However, the argument made in this paper is that relative year-to-year changes in housing prices will lead to differences in promotion tournament rewards across sites. If the alternative explanation around selection is true, we would expect to see a large number of employees transferring to other sites. However, the raw data reveals exactly the opposite. NASA employees switch sites in only ~1% of observations which lends credence to the potential that more innovative employees are not selecting into locations that happen to have higher housing prices. A third explanation is that housing wealth shocks could directly affect the innovativeness of employees (Bernstein, Townsend, and McQuade, 2017). Although the data does cover the Great Recession period, the vast majority of the employees in the sample are unlikely to experience extreme shocks in wealth.

The paper uses housing price to instrument promotion tournament reward based on the argument that housing prices will not directly or indirectly affect innovation through any means other than promotion tournament rewards. Therefore, we expect to see an increase in innovation at sites that have larger tournaments due to a relatively high increase in housing price from year to year. Housing price is constructed
using two data sets. First, the federal government releases the yearly housing price index for major cities across the US.\( ^8 \) However, each city’s index has a baseline of one for the year 1995, which allows us to look only at within city change over time. This generates the need to establish a relative magnitude difference across cities with a second database. A dataset provided by Zillow.com\(^9 \) is utilized to establish average selling price in 2017 for the closest city to each of the NASA sites. This 2017 housing price for each site is adjusted with the federal index to generate an estimated housing price in each year of the data sample. Table 7 provides the results utilizing housing price as an instrument for promotion tournament rewards. For ease of convergence, the paper utilizes an OLS instrumental variable specification. All standard errors are clustered at the site-occupation level.

Results corroborate the basic results from Table 3 (column 5) with a slightly smaller yet statistically indistinguishable magnitude. The results of the IV analysis give additional confidence that tournament size is causing the increased innovation that we see in the basic results. The results also provide additional evidence against the alternative selection hypothesis with respect to housing prices. An expectation with this view is that housing prices are associated with higher innovation due to the increase in innovative human capital brought to the area. However, controlling for the group’s traits does not materially alter the results.

Discussion

Motivation, risk taking, and collaboration each contribute to the innovation process and the incentives associated with promotion tournaments create important behaviors. Results show that while motivation and/or risk taking may increase innovation due to the promotion incentives, collaboration within the organization decreases. Therefore, promotion incentives create tradeoffs for managers in designing such systems to increase and manage the creation of new knowledge. This has real implications for managers due to the heterogeneity of size, knowledge, employees, and organizational mission.


\( ^9 \) https://www.zillow.com/research/data/
Indications that promotion incentives may change the location of co-authors and knowledge sourced for innovation is a novel yet intuitive concept. A natural extension of the promotion reward prediction that individuals will cooperate less with peer competitors is the potential that they will seek out replacements for those peers when knowledge gaps are present. This shift in the locus of knowledge may represent a new avenue for open innovation, which is generally envisioned as the “use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” (Chesbrough, Vanhaverbeke, and West, 2006: 1). Extant literature has largely focused on firm level motivations to pursue open innovation with much of the focus on external contests and other similar forms of external knowledge sourcing (Lakhani et al., 2013). Researchers have also theorized that attributes of the organization’s problems affect the comparative advantage of various open versus closed organizational forms. In particular, problems that can be modularized or with unknown knowledge locations are more aligned with open innovation governance (Felin and Zenger, 2014; Lakhani et al., 2013). However, these theories largely ignore the motivation of individual innovators within the firm in lieu of the organization’s incentives or prizes for external innovators to divulge knowledge and tend to ignore collaborative yet temporary internal-external innovative arrangements. This paper opens the discussion and calls upon future theoretical research to further investigate the role of individual incentives of internal employees (e.g. promotion rewards) in facilitating open innovation. In particular, prior theories can largely be viewed as “push” open innovation whereby the organization attempts to push both internal and external innovators to share knowledge. However, this paper opens the door for “pull” open innovation whereby the organization creates incentives for internal employees to pursue external knowledge sources when they see fit.

A counterintuitive implication of promotion rewards is the potential benefit of organizational scale. Results indicate that managers may be able to affect innovation through changes in promotion tournaments and larger organizations give managers more control over the number and size of promotion tournaments. Prior research has shown that organizational size may increase comparison costs (largely with respect to compensation) across employees which detracts from performance (Larkin, Pierce, and Gino, 2012; Nickerson and Zenger, 2008). This paper offers a compensation-based advantage for larger firms in
generating greater performance, at least with respect to innovation. This advantage may be a factor (among many others) to help explain why larger firms are more productive with their R&D spending (Knott, 2017).

The ability of management to structure promotion rewards creates strategic implications for firms similar to other structure decisions (e.g., formal R&D structure - see (Argyres and Silverman, 2004; Arora et al., 2014)). For instance, an organization similar to NASA can decide to condense knowledge worker job levels (11 through 15) from five to four without changing the average pay of individuals in the organization. According to the paper’s results, this decision could have a material impact not only on the prevalence and collaboration characteristics of innovation but also the internal versus external knowledge location.

An issue with utilizing a public sector organization is the potential for external validity concerns. A prevalent view is that public sector workers may be more intrinsically motivated based on internal rewards rather than through external rewards which may lead to pro-social behaviors such as accepting lower wages (Francois, 2000). Intrinsic motivation also leads to less effective extrinsic reward systems such as compensation incentives. In fact, extrinsic rewards may not just be ineffective but may have the potential to crowd out intrinsic motivation (Benabou and Tirole, 2003; Gubler, Larkin, and Pierce, 2016; Huffman and Bognanno, 2017). However, research on extrinsic rewards among public sector employees has also found positive performance effects. Empirically, pay for performance effectiveness is shown to be dependent on the organizational setting (Perry, 1986) and specific studies have detected a positive effect with teachers, civil servants, and health care workers (Prentice, Burgess, and Propper, 2007). Extant research has also shown that there are similarities between public sector organizations and private sector firms and employees. First, the effectiveness of public sector organizations is built upon the resources and capabilities of that organization which may contribute to performance in complex ways (Garicano and Heaton, 2010). Second, similar to private sector firms, public sector firms must attract and retain human resources with the capabilities to perform the required tasks.

It is also possible the increase in innovation exhibited by NASA employees is the result of gaming the system by directing their effort and resources to tasks that will increase rewards while shirking on other
important tasks for which they are not as heavily rewarded. Employees have been shown to be proficient in
learning how to maximize their incentive pay, which can result in suboptimal outcomes for the organization
(Frank and Obloj, 2014; Obloj and Sengul, 2012). For example, NASA scientists and engineers may direct
their effort toward publishing rather than completing mission-oriented tasks critical to NASA’s success.
However, NASA promotion rewards are much less salient compared to other forms of incentive pay that
induce gaming (e.g. sales bonuses) (Larkin, 2014). The criteria for promotion is also ambiguous compared to
more specific pay-for-performance criteria such as sales targets. Finally, employee interviews did not reveal
any indications of gaming. The combination of these factors reduce gaming concerns in this context.

Conclusion
Promotion rewards are one of the most common and important extrinsic incentives available to
employees (Cowgill, 2014). Recent research has also documented that firms are flattening (Rajan and Wulf,
2006), which changes the nature of these rewards because flatter firms are more likely to have larger
promotion rewards. This paper explored the relationship of promotion tournament rewards to innovation and
collaboration at NASA, a highly innovative public organization. Results reveal a robust positive relationship
between promotion tournament rewards and the probability an employee publishes in an academic journal or
generates a patent, which provides circumstantial evidence for the theoretical effect of promotion
tournaments on innovation. Additionally, results reveal a robust negative relationship between promotion
tournament size and the presence of NASA publication co-authors. Results are generally supported when
using employee fixed effects and instrumenting promotion tournament rewards with local housing price. In
combination, this is the first known research to provide empirical results in support of the effect of promotion
tournament rewards on individual innovation outcomes.

There are limitations to the inferences we can draw from the results. First, this analysis is within a single
public sector organization, which limits the external validity of the results. However, NASA is a unique and
innovative public sector organization and the results take into account activity from ten different NASA
locations that span across the US as well as many different occupations that patent and publish in peer-
reviewed journals. Second, we cannot rule out endogeneity in the results and caution must be taken in
interpreting the results as causal. However, care was taken in choosing an appropriate setting, utilizing fixed
effects and controls to rule out many potential alternative hypotheses, and increasing the causal case by
instrumenting promotion tournament rewards with local housing price.

The paper contributes to multiple aspects of the innovation governance literature. First, it is novel in
embarking on the analysis of promotion tournaments on individual knowledge worker innovation. The paper
opens the black box of promotion tournaments as a source of heterogeneity in organizational innovation and
complements previous work on knowledge worker motivations (Roach and Sauermann, 2010; Sauermann
and Cohen, 2010; Sauermann and Roach, 2014; Stern, 2004) as well as the structure of extrinsic rewards
(Azoulay et al., 2011; Ederer and Manso, 2013; Manso, 2011). Second, the results point to a non-obvious
benefit of organizational scale: increased freedom to structure promotion tournaments. This likely provides
innovative returns to scale where most of the literature’s discussion of large organizations is based on their
inability to match the compensation incentives of smaller firms.

Third, the paper has implications for knowledge transfer. It reveals that employees may be more likely
to rely on outside co-authors as promotion tournament rewards increase, which may provide the benefit of
access to external knowledge while also disseminating valuable knowledge to outside entities (Wadhwa,
Bodas Freitas, and Sarkar, 2017). With respect to NASA, it has the potential to provide multiple benefits
toward their mission. It implies that larger promotion tournaments for NASA employees may result in
combining more disparate information that could lead to more break through innovation (Fleming, 2001;
Murray and O’Mahony, 2007). Likewise, it also provides an avenue for more knowledge transfer from
NASA to other academic and private sector organizations, which has the potential to generate novel
scientific and commercial combinations (Bikard, Vakili, and Teodoridis, 2018). However, this may not be
beneficial for all private firms.

Lastly, the paper connects to two broad literatures. It shows the value of investigating the
microfoundations of strategy by focusing on the interaction between levels of the organization with a focus
on the individual level (Barney and Felin, 2013; Felin et al., 2015). This paper reveals interesting
implications for the interaction of organizational promotion structure and individual motivations. It also contributes to the literature on the knowledge based view of the firm in that it recognizes that knowledge generation occurs at the individual level (Grant, 1996) and an important function of the organization is to efficiently organize to create new knowledge (Nickerson and Zenger, 2004). The paper explores an underdeveloped internal structure tool, promotion tournament rewards, that affects knowledge generation. Overall, the paper represents a step forward in understanding how promotion tournaments may be effectively utilized to generate innovation in organizations.

References


**Figures and Tables**

**Figure 1: NASA Sites Across US**

**Figure 2: Example of Hypothetical Level 12 Promotion Tournament**

*Hypothetical example of employees within the same location (e.g. Langley) and job (e.g. Aerospace Engineering)*

*Shaded region signifies the hypothetical GS level 12 tournament competitors*

*GS Level 12 tournament is for promotion to GS Level 13*
Figure 3: Raw Data Support for NASA Promotion Tournaments


Panel B: Distribution of Tenure by Job Levels at NASA: 2004-2016

Source: Federal Office of Personnel Management (OPM) Data

Figure 4: Heterogeneity in 2018 Location Salary Adjustments across NASA Sites

Panel C: NASA Promotion Rates by Job Level Over Time

-- Grade 11 -- Grade 12 -- Grade 13 -- Grade 14 -- Grade 15

Source: Federal Office of Personnel Management (OPM) Data

This map contains shading associated with 2018 adjustments from the base rate from https://www.fedguide.gov/salary

Darker shading is indicative of larger adjustments and the adjustments for each NASA site are in parentheses.

Adjustments take into account the cost of living in each region which includes housing price.
## Table 1: Summary Statistics

### Panel A: Employee-Year Observation Level

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### Panel B: Group-Year Observation Level

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### Panel C: Innovation Observation Level

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Table 2: Relationship of Innovation to Employee Promotion

Panel A: Relationship of Publishing to Employee Promotion

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All errors clustered at the site-occupation level; standard errors in parenthesis
***p < 0.01, **p < 0.05, *p < 0.10

Panel B: Relationship of Patenting to Employee Promotion

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<tr>
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<th>(1) Promotion ( t+1 )</th>
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All errors clustered at the site-occupation level; standard errors in parenthesis
***p < 0.01, **p < 0.05, *p < 0.10

Table 3: Relationship of Promotion Reward to Publications

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<td>0.1044*** (0.0129)</td>
<td>0.0362*** (0.0105)</td>
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All errors clustered at the site-occupation level; standard errors in parenthesis
Group level controls include average tenure, mean group highest education received, and supervisory presence
***p < 0.01, **p < 0.05, *p < 0.10
### Table 4: Relationship of Promotion Reward to Patents

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All errors clustered at the site-occupation level; standard errors in parenthesis.
Group level controls include average tenure, mean group highest education received, and supervisory presence.
***p < 0.01, **p < 0.05, * p < 0.10

### Table 5: Relationship of Promotion Reward to Internal Collaboration

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<tr>
<th>DV: Count of internal NASA Co-authors</th>
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All errors clustered at the site-occupation level; standard errors in parenthesis.
Group level controls include average tenure, mean group highest education received, and supervisory presence.
***p < 0.01, **p < 0.05, * p < 0.10
### Table 6: Fixed Effects Relationship of Promotion Reward to Innovation & Collaboration

<table>
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<tr>
<th>Dependent Variable</th>
<th>(3) Publications</th>
<th>(2) NASA Publication Internal Coauthors</th>
<th>(3) Publication External Coauthors</th>
<th>(4) Publication Academic Coauthors</th>
<th>(5) Publication &quot;Other&quot; Coauthors</th>
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</thead>
<tbody>
<tr>
<td>Promotion Tournament Reward (SK)</td>
<td>0.015** (0.006)</td>
<td>-0.011* (0.006)</td>
<td>0.017*** (0.006)</td>
<td>0.007 (0.008)</td>
<td>0.020*** (0.007)</td>
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<td>Horizontal Tournament Size (No. Employees)</td>
<td>-0.002** (0.001)</td>
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<td>0.001 (0.001)</td>
<td>0.001 (0.001)</td>
<td>0.001 (0.001)</td>
</tr>
</tbody>
</table>

- N: 12230, 2464, 2429, 2242, 2367
- Group Controls: Y, Y, Y, Y, Y
- Employee Fixed Effects: Y, Y, Y, Y, Y
- Grade Dummy Variables: Y, Y, Y, Y, Y
- Year Dummy Variables: Y, Y, Y, Y, Y

All errors clustered at the site-occupation level; standard errors in parentheses
Group level controls include average tenure, mean group highest education received, and supervisory presence

***p < 0.01, **p < 0.05, * p < 0.10

### Table 7: IV Analysis: Impact of Promotion Reward on Innovation

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<th>Dependent Variable: Publications</th>
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<tr>
<td>Promotion Tournament Reward (SK)</td>
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- N: 150610
- N Clusters: 534
- Group Controls: Y
- Grade Dummy Variables: Y
- Year Dummy Variables: Y
- First Stage F Test: 11.2

All errors clustered at the site-occupation level; standard errors in parentheses
Group level controls include average tenure, mean group highest education received, and supervisory presence

***p < 0.01, **p < 0.05, * p < 0.10