



Cornell University  
ILR School

Cornell University ILR School  
**DigitalCommons@ILR**

---

Articles and Chapters

ILR Collection

---

9-1-2006

## Internal Promotion Competitions in Firms

Jed DeVaro

*Cornell University*, [jed.devaro@csueastbay.edu](mailto:jed.devaro@csueastbay.edu)

Follow this and additional works at: <https://digitalcommons.ilr.cornell.edu/articles>



Part of the [Benefits and Compensation Commons](#), [Labor Relations Commons](#), and the [Organizational Behavior and Theory Commons](#)

**Thank you for downloading an article from DigitalCommons@ILR.**

**Support this valuable resource today!**

---

This Article is brought to you for free and open access by the ILR Collection at DigitalCommons@ILR. It has been accepted for inclusion in Articles and Chapters by an authorized administrator of DigitalCommons@ILR. For more information, please contact [catherwood-dig@cornell.edu](mailto:catherwood-dig@cornell.edu).

If you have a disability and are having trouble accessing information on this website or need materials in an alternate format, contact [web-accessibility@cornell.edu](mailto:web-accessibility@cornell.edu) for assistance.

---

## Internal Promotion Competitions in Firms

### Abstract

[Excerpt] Using a sample of skilled workers from a cross section of establishments in four metropolitan areas of the United States, I present evidence suggesting that promotions are determined by relative worker performance. I then estimate a structural model of promotion tournaments (treating as endogenous promotions, worker performance, and the wage spread from promotion) that simultaneously accounts for worker and firm behavior and how the interaction of these behaviors gives rise to promotions. The results are consistent with the predictions of tournament theory that employers set wage spreads to induce optimal performance levels, and that workers are motivated by larger spreads.

### Keywords

promotion, worker, performance, model, tournament, theory, spreads

### Disciplines

Benefits and Compensation | Labor Relations | Organizational Behavior and Theory

### Comments

#### Suggested Citation

DeVaro, J. (2006). Internal promotion competitions in firms [Electronic version]. *RAND Journal of Economics*, 37, 521-542.

#### Required Publisher Statement

Copyright by the RAND Corporation. Published version posted with special permission of the copyright holder.

# Internal promotion competitions in firms

Jed DeVaro\*

*Using a sample of skilled workers from a cross section of establishments in four metropolitan areas of the United States, I present evidence suggesting that promotions are determined by relative worker performance. I then estimate a structural model of promotion tournaments (treating as endogenous promotions, worker performance, and the wage spread from promotion) that simultaneously accounts for worker and firm behavior and how the interaction of these behaviors gives rise to promotions. The results are consistent with the predictions of tournament theory that employers set wage spreads to induce optimal performance levels, and that workers are motivated by larger spreads.*

## 1. Introduction

■ Since the seminal work on tournament theory by Lazear and Rosen (1981), an extensive theoretical literature has emerged on the subject of promotions as incentive mechanisms.<sup>1</sup> In the tournament model, workers of a given rank in an organization compete for promotion to the next level of the job hierarchy, with the promotion (and associated wage increase) awarded to the worker with the highest performance. The prize is the difference in wages between the post-promotion and pre-promotion jobs, and this is chosen by the employer to induce the optimal level of worker effort in the pre-promotion job. Tournament theory has important implications for the compensation structure of the firm and its relation to worker effort and performance. It provides a theory of career advancement and promotions within firms. Despite the theoretical appeal of the tournament model, its practical relevance as an explanation for promotions remains an open empirical question. Empirical tests of tournament theory have been of two main types. The first type focuses only on the behavior of workers (or agents), testing to see whether tournaments have incentive effects in that larger prizes imply higher levels of performance, usually in the context of sporting events rather than promotion decisions in typical firms. The second type focuses only on the behavior of the firm (or principal), testing to see whether compensation spreads appear to be structured to produce incentives in the manner predicted by tournament theory.

In this article I diverge from both streams of previous empirical literature by considering the behavior of workers and firms jointly rather than in isolation. I do this in the context of greatest interest, namely promotion decisions in typical firms. Using a cross-sectional employer dataset

---

\* Cornell University; [devaro@cornell.edu](mailto:devaro@cornell.edu).

I am grateful for the helpful comments of the Editor, two anonymous referees, Ron Ehrenberg, Martin Farnham, Gary Fields, Mike Gibbs, Kaj Gittings, Bob Hutchens, George Jakobson, Larry Kahn, Fidan Kurtulus, Jason Perry, Mike Waldman, and seminar participants at Cornell University, the NBER Summer Institute, and the Federal Reserve Bank of Chicago. David Rosenblum and Dana Brookshire provided outstanding research assistance.

<sup>1</sup> Representative studies include Holmström (1982), Green and Stokey (1983), Nalebuff and Stiglitz (1983), Carmichael (1983), Malcomson (1984), Mookherjee (1984), Rosen (1986), O'Keefe, Viscusi, and Zeckhauser (1984), McLaughlin (1988), Baker, Jensen, and Murphy (1988), Lazear (1989), and Zabojnik and Bernhardt (2001).

containing information on promotions, wage spreads from promotion, worker performance, and worker, firm, and job characteristics, I estimate a structural model treating performance, the wage spread, and promotions as endogenous variables. In contrast to the studies in the first branch of empirical literature that regress a measure of the agent's performance on a spread that is assumed to be exogenous, I treat this spread as endogenous in the performance equation, since it is chosen by the firm to induce the optimal worker effort choice. To my knowledge, this is the first study of tournament theory in which the empirical methodology accounts for the optimizing behavior of both workers and firms, and how these behaviors jointly determine promotion outcomes. I describe how the interaction of worker and firm behavior has testable implications that would be missed by considering only worker behavior or firm behavior individually.

Central to tournament theory is the idea that promotions are determined by relative performance. Competitions based on relative performance, with the highest performer of a given rank winning the promotion, arise when internal hiring policies are combined with fixed job hierarchies. Throughout this article I refer to such situations as internal promotion competitions. Tournament theory takes the notion of an internal promotion competition and adds stronger implications arising from the optimizing behavior of workers and firms, in particular that firms optimally set wages to create incentives. Thus, a promotion tournament is a special case of an internal promotion competition, with additional testable implications.

I present two sets of empirical results in this article. In the first, I provide evidence suggesting that promotions are determined by relative performance for workers in a cross section of establishments. In the second, I estimate a three-equation structural model, finding support for the stronger predictions of tournament theory. A distinguishing feature of the data is the presence of employer-reported worker performance ratings. Such information is rare in datasets that span many establishments. The performance data allow a test of the incentive effects of tournaments in the context of greatest interest, namely promotion decisions in conventional firms. Prendergast (1999) criticizes the empirical incentives literature for what he perceives as its excessive focus on the contracts of workers for whom objective measures of output are readily available (e.g., CEOs, golfers, mutual fund managers, tree cutters, windshield installers, etc.). As Prendergast argues, most people do not work in such jobs. Instead, most workers are evaluated on subjective criteria. Since the analysis in this article is based on a broad cross section of workers for whom the relevant output measure is a subjective performance rating, it contributes results to the empirical incentives literature on the types of "typical jobs" that are rarely studied.

A common approach in empirical analyses of promotions is to study comprehensive data on all of the workers in a single firm, the identity of which is often undisclosed. Examples of such studies include Lazear (1992), Baker, Gibbs, and Holmström (1994a, 1994b), Audas, Barmby, and Treble (2004), and DeVaro and Waldman (2005). A small number of influential studies in this vein, most notably those of Baker, Gibbs, and Holmström, have significantly shaped the development of new theory on careers, as in the recent studies by Gibbons and Waldman (1999, 2006). In addition to large sample sizes and rich sets of consistently measured variables, the great advantage of single-firm datasets is that there is only one set of firm-specific institutions and procedures operating rather than a multitude of different processes, as is the case in a cross section. Such single-firm studies are useful in identifying the empirical regularities that hold simultaneously in one environment. Their advantages notwithstanding, since case studies are based only on single firms, there is no way of knowing how representative the firm's behavior is. In addition, the single firms that are analyzed tend to be selected nonrandomly, making it difficult to draw general inferences about employer behavior even when pooling the results from multiple case studies. An alternative approach, and the one taken in this article, is to use broader cross sections or panels of employers. Examples of this approach include McCue (1996), DeVaro and Brookshire (2007), and Belzil and Boganno (2005). Empirical work based on such broader samples of workers in a range of firms provides important information that complements the more detailed case studies of individual firms. In estimating a structural model using data spanning the full spectrum of firm sizes and types, industries, and distinct geographic labor markets, I aim to shed light on how well tournament theory describes the general tendencies of employer behavior.

## 2. Background and previous literature

■ Lazear and Rosen (1981) showed that compensation schemes based on workers' ranks within an organization are attractive alternatives to output-contingent contracts, particularly when an employer cannot easily measure a worker's output. More precisely, tournaments induce the same efficient allocation of resources as output-contingent contracts such as piece rates and quotas, when the principal and agents are risk-neutral. In the model, two identical, risk-neutral workers in a firm compete in a low-level job for promotion to a high-level job.<sup>2</sup> The promotion (and its associated higher pay) is awarded to the worker who performs the best in the low-level job during some observation period. The prize from winning the promotion, commonly referred to as the "spread," is the wage difference between the two jobs. The firm chooses the spread before observing worker performance, with the knowledge that workers will then choose effort levels accordingly. Worker performance is a function of effort and a stochastic "luck" component that is independent across workers, with mean zero and variance  $\theta$ . Having observed the wage spread, the worker chooses an effort level to maximize expected utility. The resulting optimal labor supply condition states that the worker chooses the effort level that equates the marginal return of effort to its marginal cost. This optimal labor supply condition and the assumed convexity of the effort cost function give rise to two implications about the optimal effort level. First, effort is increasing in the wage spread.<sup>3</sup> Second, effort is decreasing in  $\theta$ . Intuitively, when random factors over which the worker has no control become more important determinants of the promotion probability, the marginal return to effort declines and the worker's incentives to exert effort are depressed.

The firm's problem is to choose the wage spread to maximize expected profit, given the worker's labor supply condition and a participation constraint. The resulting first-order conditions imply that the optimal wage spread chosen by the firm is increasing in  $\theta$ . Intuitively, as random factors matter more in dictating the probability of winning the promotion, a larger wage spread is required to induce the worker to exert a given amount of effort. In summary, the model has three main predictions: (i) worker effort is increasing in the wage spread, (ii) worker effort is decreasing in  $\theta$ , the variance of stochastic determinants of performance, (iii) the wage spread is increasing in  $\theta$ .

Although virtually all of the literature on tournament theory assumes that the prizes or wage spreads are chosen by firms to induce optimal worker effort levels, an exception is Zabojsnik and Bernhardt (2001). In their model, wage spreads are determined competitively via a mechanism similar to the promotion-signalling process described by Waldman (1984). Given an informational asymmetry in which the current employer knows more about an incumbent worker's ability than do outside employers, promotion of that worker signals to outside employers that the worker has high ability. Outside employers update their beliefs and bid up the wages of this worker. In my discussion of tournament theory I take the conventional interpretation that wage spreads are fixed *ex ante* by the employer to induce the optimal level of effort.

Previous empirical studies of tournament theory are of two main types: those focusing on worker behavior and those focusing on firm behavior.<sup>4</sup> Studies focusing on worker behavior ask whether tournaments have incentive effects, meaning that larger prizes imply higher levels of performance. These studies typically use data from sporting events (golf, bowling, tennis, NASCAR, etc.) rather than from the context of greatest interest, namely promotion decisions in conventional firms. Representative articles include Ehrenberg and Bognanno (1990a, 1990b),

<sup>2</sup> Most of the basic results of the two-person tournament can be generalized to the case of  $N$  contestants. See McLaughlin (1988) for a derivation of expressions for the optimal spread and effort levels in a tournament with  $N$  contestants.

<sup>3</sup> Furthermore, changes in the level of compensation that leave the spread unchanged do not affect effort. Wage levels only influence worker participation, which requires a nonnegative expected wage net of effort costs.

<sup>4</sup> One exception is an early classroom experiment by Bull, Schotter, and Weigelt (1987) that found mixed support for the predictions of tournament theory using a sample of undergraduate paid volunteers from NYU. A more recent exception is the study by Levy and Vukina (2004), which focuses on the league composition effect of tournaments using contract production data for broiler chickens. The authors find that leagues in broiler tournaments disintegrate rapidly over time, interpreting this as evidence that tournament contracts offer more welfare than piece rates.

Becker and Huselid (1992), and Knoeber and Thurman (1994).<sup>5</sup> In such studies, a performance measure is regressed on some measure of the spread, and a positive coefficient on the spread is interpreted as evidence that tournaments have incentive effects. The spread is always treated as exogenous in such regressions. Conclusions from this strand of literature generally support the prediction that performance is increasing in the compensation spread rather than in compensation levels. The recent study by Audas, Barmby, and Treble (2004) is unusual in that it uses data on promotions, based on the personnel records of a large British financial sector employer. The authors find support for the predictions of tournament theory that effort is increasing in the spread and decreasing in the importance of "luck." Like the other studies in this literature, this one focuses only on worker behavior and treats the spread as exogenous in the worker's performance equation.

The second branch of the empirical literature focuses only on the behavior of firms (or principals), testing to see whether prizes appear to be structured to produce incentives in the manner predicted by tournament theory. Representative articles include O'Reilly, Main, and Crystal (1988), Main, O'Reilly, and Wade (1993), Lambert, Larcker, and Weigelt (1993), Eriksson (1999), and Bognanno (2001). Studies in this vein typically use firm-level data on corporate executives and ask whether firms choose compensation spreads to create incentives as suggested by tournament theory. Dependent variables in these studies are generally compensation spreads between levels of a job hierarchy. Two predictions of tournament theory are generally tested, both arising from extensions to the basic Lazear and Rosen model. The first is that wage spreads from promotion to a given level should be increasing in the number of workers at the next level down.<sup>6</sup> The reason is that more workers create more competition, which has a negative effect on incentives that the principal counters by setting a larger wage spread. The second prediction, arising from Rosen (1986), is that the compensation structure is convex, meaning that the size of the wage spread increases with the level of the job.<sup>7</sup> Rosen analyzed an elimination tournament with a fixed job hierarchy and multiple rounds, finding that wage spreads increase with the level of the job because of the diminishing option value of successive promotions.

This second strand of literature finds mixed support for the tournament model. O'Reilly, Main, and Crystal (1988) found that the number of vice presidents was negatively associated with the compensation spread between CEOs and vice presidents. In contrast, Main, O'Reilly, and Wade (1993) found the opposite result in a similar regression. Lambert, Larcker, and Weigelt (1993) used data from four organizational levels (ranging from plant manager to CEO) and found support for the convexity of the pay structure. Using data on Danish executives, Eriksson (1999) found a stable convex relation between compensation and the level of jobs in a hierarchy. He also found that the wage spread is increasing in the number of contestants, as found by Main, O'Reilly, and Wade (1993) using American data. Bognanno (2001) analyzed executives over an eight-year period and found that pay rises strongly with hierarchical level, that most positions are filled through promotions, and that the winner's prize is increasing in the number of contestants though decreasing in the square of the number of contestants. He interpreted the evidence as supportive of the tournament model but noted some conflicting findings.

### 3. Data and variable definitions

■ The data for this study are from the Multi-City Study of Urban Inequality (MCSUI), a cross-sectional employer telephone survey of 3,510 establishments collected between 1992 and 1995 in four metropolitan areas: Atlanta, Boston, Detroit, and Los Angeles. The respondent was the

<sup>5</sup> Knoeber and Thurman (1994) use data not from sporting events but from competing producers of broiler chickens, with time dummies representing different payment regimes reflecting the use of tournaments. Absent a measure of the spread, they cannot establish that larger spreads have incentive effects. However, they show that changes in prize levels alone have no effect on performance.

<sup>6</sup> As explained in footnote 46 of Prendergast (1999), this result relies on the distribution of the measurement errors being single-peaked at zero.

<sup>7</sup> As noted in Gibbs (1994) and Prendergast (1999), the prediction of a convex wage structure is not unique to tournament theory and can also be generated by a hierarchy, as in Rosen (1982), where workers are allocated to jobs on the basis of comparative advantage, without incentives being relevant.

owner in 14.5% of the cases, the manager or supervisor in 42%, a personnel department official in 31.5%, and someone else in 12%. Two-thirds of the cases come from a probability sample stratified by establishment size (25% 1–19 employees, 50% 20–99 employees, 25% 100 or more employees), drawn from regional employment directories provided by Survey Sampling, Inc. (SSI), primarily based on local telephone directories. The remaining third was drawn from the current or most recent employer reported by respondents in the corresponding MCSUI household survey. Screening identified a respondent who actually carried out hiring for the relevant position, and the survey instrument took 30–45 minutes to administer, with a response rate of 67%. Sampling weights were constructed to correct for the complexities of the sampling scheme and weighted observations are a representative sample of establishments, such as would occur if a random sample of employed people was drawn from each city. Holzer (1996) describes the data in more detail.

Many of the survey questions ask about the most recently hired worker. The key variables measure whether this worker was promoted or was expected to be promoted within the next five years, the employer-reported subjective performance rating for this worker, the employer-reported subjective performance rating for the “typical” worker in that same job, the worker’s wages before and after promotion or expected promotion, and characteristics of the worker and the job. The data also include firm characteristics. The two promotion variables are defined as follows:

$$\begin{aligned}
 PROMOTE &= \begin{cases} 1 & \text{if a promotion occurred by the survey date} \\ 0 & \text{otherwise} \end{cases} \\
 PROMEXP &= \begin{cases} 1 & \text{if a promotion was expected to occur within five years of the survey date} \\ 0 & \text{otherwise.} \end{cases}
 \end{aligned}$$

Since the observations are a sample of recent hires, in many cases a promotion had not occurred by the survey date. About 8.0% of the workers had received a promotion by the survey date, and about 73.5% of the workers were expected to be promoted within the next five years.<sup>8</sup>

The performance measure,  $P$ , is the employer’s answer to the following question about the most recently hired worker’s performance in the job into which he was hired: “On a scale of 0–100 where 50 is average and 100 is the best score, how would you rate this employee’s performance in this job?” A proxy for  $P_0$ , the performance of the most recently hired worker’s competitors for promotion is provided by the following question: “On a scale of 0–100, how would you rate the typical employee’s performance in this job?”

Estimating the structural tournament model requires a measure of the wage spread,  $S$ , which is the difference in wages between the post-promotion and pre-promotion jobs. For workers who have received a promotion by the survey date, this spread is defined as the difference between their current (post-promotion) wage and their starting wage, since this is the spread that is relevant for determining their performance level in the job into which they were hired. For workers who have not been promoted by the survey date,  $S$  is defined as the difference between the wage they are expected to receive if they get promoted and their current wage. More precisely, the questions pertaining to the wages of the most recently hired worker are:  $W_0$  = “What is [this employee’s] actual starting wage/salary?”  $W_1$  = “What is his/her current wage/salary?”  $W_2$  = “If promoted, what would this employee’s wage or salary be?” The reported time frame for these wages was either hourly, weekly, monthly, or annually, and I converted all responses to hourly wages measured in 1990 dollars, deflated using the CPI-UX. From these I defined the wage spread,  $S$ :

$$S_i = \begin{cases} W_{1i} - W_{0i} & \text{if } PROMOTE_i = 1 \\ W_{2i} - W_{1i} & \text{if } PROMOTE_i = 0. \end{cases}$$

<sup>8</sup> These statistics reflect sampling weights. Missing values reduce the total MCSUI sample size of 3,510 to 3,175 for *PROMOTE* and to 2,668 for *PROMEXP*. I further omitted 350 cases for which the employer reported that no promotion was possible for the job in question, resulting in sample sizes of 2,827 for *PROMOTE* and 2,341 for *PROMEXP*. The 73.5% statistic includes both workers who have already received a promotion and those who have not. Excluding those who have already received a promotion, about 71.8% of workers were expected to be promoted within the next five years ( $N = 2,093$ ).

In principle, it is possible that a worker was promoted more than once since the hiring date. Since multiple promotions are not observable in the data, in such cases the measured wage spread would span more than two levels. However, since the sample is one of recent hires, with a relatively small fraction of observed promotions by the survey date, few workers will have had time to be promoted more than once.

Controls for worker and firm characteristics include dummies for whether the most recent hire has more than a high school degree or a college degree or more; the worker's tenure with the establishment; the fraction of high-skilled workers currently employed at the establishment; sex; age; race; establishment size; number of sites of operation for the firm; fraction of workers covered by a collective bargaining agreement at the establishment; duration of the establishment's operation at the current site (2 years or less, more than 2 years but no more than 5, more than 5 years); dummies for whether the establishment is a franchise, whether it is for-profit, whether it employs temporary workers, whether it employs contract workers, whether it has formal procedures for posting internal job openings and soliciting applications for filling them; 8 industry categories (manufacturing, services, wholesale trade, retail trade, finance, public administration, construction and mining, transportation); and the following occupation categories:<sup>9</sup>

*Managerial:* Includes executive, administrative, and managerial occupations.

*Scientists, engineers, doctors, lawyers:* Includes surveyors and architects; natural scientists and mathematicians; social scientists; religious workers; health diagnosing and treating practitioners.

*Teachers, librarians, counselors:* Also includes writers, artists, entertainers, and athletes.

*RNs, pharmacists, and dieticians:* Also includes therapists and physicians' assistants.

*Technologists and technicians:* Both "health" and "nonhealth."

*Marketing and sales occupations.*

*Administrative support occupations, including clerical.*

*Service occupations.*

*Craft, construction, and transportation occupations:* Includes mechanics and repairers; extractive occupations; precision production occupations; material-moving occupations.

*Production workers and laborers:* Includes handlers, equipment cleaners, and helpers.

The first two columns of Table 1 display summary statistics for the full sample.<sup>10</sup>

#### 4. Are promotions determined by relative performance?

■ In some firms, the combination of internal hiring policies and fixed job slots creates internal promotion competitions in which promotions depend on relative performance. There are a number of possible theoretical rationales for internal hiring policies. One possibility is that firms choose internal hiring over external hiring because of informational advantages. Hiring internally saves on the recruitment and screening costs associated with external hiring. Furthermore, incumbent workers might have valuable firm-specific knowledge that justifies filling a position through internal promotion. A second explanation, proposed by Waldman (2003), argues that internal promotions may be understood as a rational response on the part of the firm to avoid the time-inconsistency problem that arises when promotions are used for both job assignment and incentives. A third explanation is that internal hiring policies are used to motivate workers by the

<sup>9</sup> Technically there are 9 industry groups, since 2 of the observations are from the agriculture, forestry, and fishing industries. These are included in the reference group in models that include industry controls. Dropping these 2 observations from all analyses yields virtually identical results to those I report in the article.

<sup>10</sup> The sample size of 3,160 rather than 3,510 reflects the deletion of 350 cases for which the employer reported that no promotion was possible for the job in question. For many variables, the sample size is lower than 3,160 due to missing values.



prospect of a promotion tournament as described by Lazear and Rosen (1981). This idea is developed in Chan (1996), where it is argued that in the context of tournaments, internal promotion policies serve as handicapping mechanisms that preserve incentives for a firm's current workers. An alternative way to maintain incentives in the face of external hiring would be to increase the size of the wage spread, but this creates problems of moral hazard on the part of the employer and also creates problems of sabotage as described by Lazear (1989).

Internal hiring alone, however, does not imply that relative performance determines promotions. In some cases there are not fixed job hierarchies creating internal competitions for a fixed number of promotions. Instead, everyone can, in principle, be promoted for good performance. This is the model used in some consulting firms, in banks, and in research settings, where workers have job titles like "research associate," "senior research associate," "vice president," and "senior vice president," and often job tasks vary little across levels of the hierarchy. Since there is not a fixed number of vice president positions, the fact that one worker gets promoted to vice president does not adversely affect the probability that another will also be promoted. In such cases, even if all positions are filled with internal candidates, there are not internal competitions, and therefore promotions do not depend on relative performance but rather on absolute performance levels. Given the existence of both types of promotion processes, whether promotions based on relative performance occur frequently enough to be detected in the cross section is an empirical question.

Consider the following probit models for the probability of promotions and expected promotions:

$$\text{Prob}(\text{PROMOTE}_i = 1) = \Phi(a_0 + a_1 P_i + a_2 P_{0i} + \mathbf{Z}_i \mathbf{b}) \quad (1)$$

$$\text{Prob}(\text{PROMEXP}_i = 1) = \Phi(c_0 + c_1 P_i + c_2 P_{0i} + \mathbf{Z}_i \mathbf{d}) \quad (2)$$

Here  $P_i$  denotes the performance of worker  $i$  (the most recent hire) in his starting job,  $P_{0i}$  denotes the performance of the typical worker in that same job,  $\mathbf{Z}_i$  is a vector of worker and firm characteristics, and  $\Phi$  is the standard normal cumulative distribution function. If promotions were based solely on absolute performance in the cross section, we would expect to find positive estimates for  $a_1$  and  $c_1$ , but the estimates of  $a_2$  and  $c_2$  should be near zero. That is, increases in the most recently hired worker's performance should improve his chances of promotion (and expected promotion), but increases in the performance of his competitors (as measured by the performance of the typical worker in that same position) should not harm his chances. On the other hand, if promotions are based on relative performance, we should expect to find positive estimates for  $a_1$  and  $c_1$  but negative estimates for  $a_2$  and  $c_2$ , since a higher level of performance for the most recent hire's competition implies a reduction in the most recent hire's chances for promotion or expected promotion. Table 2 displays results from these probit models.<sup>11</sup> As seen in columns 1 and 3, the results suggest that relative performance matters in determining both promotions and expected promotions. A ten-point increase in  $P$  from the mean value of 78, holding constant  $P_0$ , is associated with an increase of about 2.6 percentage points in this worker's probability of promotion.<sup>12</sup> Similarly, holding  $P$  constant, an increase from 76 to 86 in  $P_0$  is associated with a decrease of nearly 1.3 percentage points in the promotion probability. For expected promotions, a ten-point increase in  $P$  is associated with an increase of nearly 4.6 percentage points in the probability of expected promotion, and a ten-point increase in  $P_0$  is associated with about a 2.5 percentage point decrease in the probability of expected promotion. These results are upheld even in the presence of controls for worker and firm characteristics. The same pattern of signs (positive on performance and negative on typical performance) is observed for both promotions

<sup>11</sup> Missing values scattered across the variables reduce the sample size to 1,516 in the probit for *PROMOTE*. In columns 3 and 4 of Table 1 I report summary statistics computed on this subsample, to be compared with those of the full sample in columns 1 and 2. For most variables, the means are roughly comparable between columns 1 and 3. The means are also roughly comparable for the sample of 1,357 used in the probit for *PROMEXP*; note that the sample size is lower for the *PROMEXP* models than for the *PROMOTE* models, because in the *PROMEXP* models I dropped those workers who had been promoted by the survey date. Throughout the article I estimate all models using listwise deletion.

<sup>12</sup> A ten-point increase in performance is roughly half of the standard deviation of performance.

TABLE 1 Descriptive Statistics

	Mean (1)	Standard Error (2)	Mean (3)	Standard Error (4)	Mean (5)	Standard Error (6)
<b>Promotion Variables</b>						
PROMOTE	.080	.006	.092	.009	.124	.015
PROMEXP	.735	.013	.726	.018	.785	.021
<b>Performance Variables</b>						
Performance (P)	78.185	.458	78.149	.625	78.062	.645
Typical performance ( $P_0$ )	75.897	.414	75.760	.549	75.757	.578
Wage spread (S)	3.34	.307	3.42	.405	2.83	.184
<b>Worker Characteristics</b>						
More than high school	.253	.011	.268	.016	.301	.020
College or more	.353	.018	.315	.023	.192	.023
Fraction high skilled	.318	.013	.308	.015	.254	.014
Tenure (in years)	.115	.005	.123	.008	.127	.010
Male	.477	.015	.474	.020	.424	.025
Age	30.486	.262	30.730	.303	29.868	.452
Black	.176	.009	.164	.012	.189	.021
Hispanic	.144	.010	.153	.016	.163	.020
Other non-white	.083	.011	.064	.009	.058	.010
<b>Firm Characteristics</b>						
For profit	.759	.016	.802	.018	.874	.018
Franchise	.062	.006	.072	.009	.070	.011
Internal hiring	.611	.014	.560	.020	.490	.025
Number of sites	63.350	8.391	69.940	11.201	65.101	11.351
Establishment size	554.010	56.836	320.040	63.223	183.143	25.975
Union (% covered in establishment)	17.553	1.119	15.905	1.605	13.347	2.015
Temporary workers	.365	.015	.320	.020	.298	.022
Contract workers	.295	.013	.263	.016	.246	.020
≤2 years in operation	.084	.007	.088	.010	.097	.019
>2 & ≤5 years in operation	.147	.010	.151	.013	.181	.017
>5 years in operation	.769	.012	.761	.016	.722	.023
<b>Occupational Categories</b>						
Managerial	.100	.011	.099	.015	—	—
Scientists, engineers, doctors, lawyers	.049	.009	.052	.015	—	—
Teachers, librarians, counselors	.071	.010	.081	.015	—	—
RNs, pharmacists, and dieticians	.032	.009	.029	.013	—	—
Technologists and technicians	.044	.007	.043	.008	.077	.015
Marketing and sales	.132	.009	.139	.011	.250	.021
Administrative support, including clerical	.268	.011	.268	.016	.503	.025
Service occupations	.106	.008	.087	.008	—	—
Craft, construction, and transportation	.102	.007	.102	.009	.170	.018
Production workers and laborers	.092	.006	.096	.008	—	—

TABLE 1  
Continued

	Mean (1)	Standard Error (2)	Mean (3)	Standard Error (4)	Mean (5)	Standard Error (6)
<b>Industry Categories</b>						
Public administration	.014	.003	.014	.004	.013	.005
Construction	.027	.004	.019	.003	.028	.006
Wholesale trade	.078	.011	.094	.013	.079	.012
Finance	.078	.006	.065	.007	.099	.013
Retail trade	.152	.009	.152	.012	.190	.020
Manufacturing	.205	.010	.220	.015	.229	.021
Services	.390	.016	.393	.021	.318	.023
Transportation	.053	.008	.039	.006	.040	.010
Number of observations	3,160		1,516		632	

Note: Summary statistics in columns 1 and 2 use all available data for each variable, excluding 350 observations for which the employer reported that no promotion was possible for the promotion in question. These 350 observations were also omitted from columns 3–6. Due to missing observations scattered throughout the variables, the actual sample size for a given variable in columns 1 and 2 is frequently less than 3,160. Columns 3 and 4 compute summary statistics only for the subsample of 1,516 observations used in the first main set of empirical results (presented in column 2 of Table 2). Columns 5 and 6 compute summary statistics only for the subsample of 632 observations on “skilled” workers used in the second main set of empirical results (presented in Table 3).

and expected promotions. This pattern of matching signs generally holds for the control variables as well, in that the signs of the marginal effects of the controls are usually the same between the promotion equation and the expected promotion equation whenever at least one of the two effects is statistically significant. This is true for each of the occupation and industry controls, even though these are unreported in Table 2. An interesting result that is new to the literature is that even in the presence of all the other controls, for-profit status is associated with significantly higher probabilities of promotion and expected promotion. This finding is explored in DeVaro and Brookshire (2007).

The evidence suggesting that relative performance matters in determining promotions does not rule out the possibility that absolute performance also matters. Rather, it is evidence that absolute performance is not all that matters. This is important because most of the literature on promotions as job assignment mechanisms, whether based on symmetric or asymmetric learning on the part of the employer, has the implication that only absolute performance matters. In other words, in such models the performance of one’s co-workers does not affect one’s probability of promotion, since promotions are determined only by the worker’s absolute level of performance as it increases over time or is revealed to the employer over time. In contrast, the evidence here suggests a role for relative performance.

A potential limitation of the analysis is suggested by the subjective nature of the performance ratings and the fact that a different rater reports these measures for each observation. The fact that the ratings are subjective measures of performance means that they are subject to measurement error in the sense that they are noisy measures of true performance. Since a different respondent provides these ratings for each establishment in the sample, the possibility of a “respondent-specific effect” in the performance ratings arises. For example, optimistic managers might report higher-than-true ratings for both the most recent hire and the typical worker, whereas more critical managers might report lower-than-true assessments. It might be expected that errors in the performance ratings are more severe for  $P$  than for  $P_0$ . The reason is that in many cases the most recent hire has had a relatively short tenure with the firm, and this short observation period implies that the employer’s assessment of performance is likely to be imperfect. In contrast, the employer is likely to have much more accurate information on the typical worker’s performance in that same position, since in many cases these “typical” workers have occupied the position for a long period. The implications of such errors in the performance ratings (due either to imperfect information on the part of the employer or to “respondent-specific effects”) for the analysis are explored in

**TABLE 2** Probabilities of Promotion and Expected Promotion

Dependent Variable	PROMOTE		PROMEXP	
Performance ( $P$ )	.263** (.057)	.194** (.045)	.458** (.096)	.542** (.103)
Typical performance ( $P_0$ )	-.126** (.056)	-.069* (.041)	-.251** (.116)	-.263** (.127)
Worker characteristics				
More than high school	-	.007 (.012)	-	-.022 (.035)
College or more	-	-.048** (.019)	-	.001 (.047)
Fraction high skilled	-	-.005 (.023)	-	.054 (.064)
Tenure (in years)	-	.148** (.033)	-	-.672** (.125)
Male	-	.015 (.012)	-	.036 (.035)
Age (in years)	-	-.0004 (.0006)	-	-.003 (.002)
Black	-	.027* (.015)	-	.001 (.039)
Hispanic	-	.014 (.015)	-	.067 (.046)
Other non-white	-	.050** (.021)	-	.099** (.063)
Firm characteristics				
For profit	-	.048** (.019)	-	.086* (.050)
Franchise	-	-.0004 (.021)	-	-.043 (.063)
Number of sites (1000s)	-	.002 (.010)	-	.133 (.083)
Establishment size (1000s)	-	-.003 (.006)	-	.046 (.035)
Union (fraction of workers covered)	-	-.039** (.017)	-	-.164** (.062)
Temporary workers	-	.007 (.011)	-	.057 (.037)
Contract workers	-	.007 (.012)	-	.026 (.037)
Internal hiring	-	-.033** (.011)	-	.099** (.034)
≤2 years in operation	-	-.004 (.017)	-	.047 (.053)
>2 & ≤5 years in operation	-	.007 (.015)	-	.011 (.041)
Occupation controls	NO	YES	NO	YES
Industry controls	NO	YES	NO	YES
$N$	2,425	1,516	2,174	1,357
Pseudo $R^2$	.025	.194	.017	.149

Note: Reported coefficients are probability derivatives ( $dF/dX$ ) evaluated at the means. Standard errors are in parentheses. \* and \*\* denote statistical significance at the 10% and 5% levels, respectively. Probits for expected promotions include only those workers who had not received a promotion by the survey date.

Section 7, where I extend the structural model of promotion tournaments to incorporate reporting errors in the performance ratings.

## 5. A structural model of promotion tournaments

■ The structural tournament model addresses the following testable propositions from Lazear and Rosen (1981).

*Testable Proposition 1.* Worker effort is increasing in the wage spread from promotion.

*Testable Proposition 2.* Effort is decreasing in  $\theta$ , the variance of the stochastic component of performance.

*Testable Proposition 3.* The wage spread is increasing in  $\theta$ .

*Testable Proposition 4.* Promotions are determined by relative performance.

The first three testable propositions are implications of the tournament model, and the fourth is a key underlying assumption.

Beginning with worker behavior, consider the first-order condition characterizing the worker's optimal labor supply, in which effort is a function of the wage spread. Substituting a linear approximation of optimal effort into the production function yields the worker's linearized optimal performance function, expressed as follows:

$$P_i = \alpha_0 + \alpha_1 S_i^* + X_i \alpha_2 + \varepsilon_{1i}, \quad (3)$$

where  $P_i$  is worker performance,  $S_i^* \equiv (W_H - W_L)$  is the wage spread that the worker receives if promoted from the low-level job paying  $W_L$  to the high-level job paying  $W_H$ ,  $X_i$  is a vector of worker characteristics, and  $\varepsilon_{1i}$  is a mean-zero disturbance representing the unobserved determinants of performance. This equation is the basis for the strand of empirical literature that focuses on the behavior of agents and asks whether tournaments have incentive effects (meaning  $\alpha_1 > 0$ ). The articles in this literature estimate regressions of the form (3), treating  $S^*$  as exogenous. Recall from Testable Proposition 3 that the optimal level of effort (and therefore performance) is increasing in  $\theta$ . Since  $\theta$  is unobserved to the econometrician, it is part of  $\varepsilon_{1i}$ .

Turning next to the firm's behavior, the optimal wage spread can be expected to vary with firm characteristics. Furthermore, anything observed by the employer that affects worker performance also affects the employer's choice of the spread, since the firm chooses the spread to induce the optimal level of performance. That is, anything that appears on the right-hand side of (3) and is observed by the employer also determines the employer's choice of wage spread, whether or not the econometrician observes these variables. A linearized version of the firm's optimal wage-spread equation can thus be expressed as follows:

$$S_i^* = \beta_0 + F_i \beta_1 + X_i \beta_2 + \varepsilon_{2i} \quad (4)$$

where  $F_i$  is a vector of firm characteristics,  $X_i$  is the vector of worker characteristics appearing in (3), and  $\varepsilon_{2i}$  is a mean-zero disturbance representing unobserved determinants of the wage spread. Recall from Testable Proposition 2 that the optimal spread is an increasing function of  $\theta$ . Since  $\theta$  is unobserved to the econometrician, it is part of  $\varepsilon_{2i}$ .

Testable Proposition 1 implies that  $\alpha_1$  in (3) should be positive. If the performance equation is estimated by OLS, as it has been in the previous literature based mostly on data from sporting events, a behavioral interpretation cannot be attached to  $\alpha_1$ . We cannot say that  $\alpha_1$  measures the amount by which worker performance increases in response to an increase in the spread unless we assume that  $\text{cov}(\varepsilon_{1i}, \varepsilon_{2i})$ , which I denote  $\sigma_{12}$ , equals zero. This assumption is clearly untenable, since both  $\varepsilon_{1i}$  and  $\varepsilon_{2i}$  include common components such as  $\theta$ . The tournament model predicts that performance is decreasing in  $\theta$  and that the wage spread is increasing in  $\theta$ . More generally, factors that depress incentives cause the employer to increase the wage spread to counter the depressed

incentives. Therefore,  $\sigma_{12} < 0$ , and consistent estimation of  $\alpha_1$  requires a simultaneous-equations estimation approach. Furthermore, since  $\sigma_{12}$  is an estimable parameter in the covariance matrix of the disturbances across equations, we can jointly address the Testable Propositions 2 and 3. Together, they imply  $\sigma_{12} < 0$ . To see this, note that the structural disturbances may be decomposed as follows:  $\varepsilon_{1i} = \tau\theta_i + \varepsilon_{1i}^*$  and  $\varepsilon_{2i} = \varphi\theta_i + \varepsilon_{2i}^*$ , where  $\theta_i$  is the variance of the stochastic component of worker  $i$ 's performance,  $\tau$  and  $\varphi$  are parameters, and  $\varepsilon_{1i}^*$  and  $\varepsilon_{2i}^*$  are disturbances that are assumed uncorrelated with  $\theta_i$ . Hence,  $\sigma_{12} \equiv \text{cov}(\varepsilon_{1i}, \varepsilon_{2i}) = \tau\varphi\text{Var}(\theta_i) + \text{cov}(\varepsilon_{1i}^*, \varepsilon_{2i}^*)$ . The optimal labor supply condition implies  $\tau < 0$ , and the employer's optimal wage-spread equation implies  $\varphi > 0$ , so the term  $\tau\varphi\text{Var}(\theta_i)$  is negative. Furthermore,  $\text{cov}(\varepsilon_{1i}^*, \varepsilon_{2i}^*)$  should also be negative, since factors that depress worker effort and thereby performance also induce the employer, other things equal, to increase the wage spread to compensate. To the extent that the structural disturbances include such factors, the prediction that  $\sigma_{12} < 0$  is strengthened.

It remains to show how the optimizing behaviors of workers and firms, represented by equations (3) and (4), interact to produce promotions. Consider a latent index,  $I_i^*$ , that can be interpreted as the amount by which the most recently hired worker's performance exceeds  $T_i^*$ , the minimum performance threshold for promotion. That is,  $I_i^* = P_i - T_i^*$ . The performance threshold depends on firm and worker characteristics and on the performance of the other workers competing with the most recently hired worker for the promotion. A linear specification of this threshold is as follows:

$$T_i^* = \gamma_0 + F_i\gamma_1 + X_i\gamma_2 + \gamma_3 P_{0i} + \varepsilon_{3i}. \quad (5)$$

where  $F_i$  and  $X_i$  are as previously defined,  $P_{0i}$  is the performance of the competition, and  $\varepsilon_{3i}$  is a mean-zero disturbance. Testable Proposition 4 implies that  $\gamma_3$  is positive, since the higher the level of  $P_{0i}$ , the higher the threshold and the lower the probability of promotion. This simply says that promotions are determined by relative performance.

A potential concern arising when the MCSUI data are used to estimate this model is measurement error in the wage spread. The relevant theoretical notion of the wage spread is the expected difference in the present discounted values of total compensation between the two positions, including such nonpecuniary factors as fringe benefits and the prestige of the higher-level job. The measured wage spread,  $S_i$ , captures only the straight wage differential (either the observed differential in the case of promoted workers or the expected differential in the case of nonpromoted workers). This measure could be afflicted by reporting errors and in any event does not reflect the potential influence of nonwage variables and the prospect for future wage increases beyond the immediate promotion. Since measurement error in the spread could potentially bias the parameters of interest, I explicitly account for it in estimation, assuming that such errors take the classical linear form. That is,  $S_i = S_i^* + \eta_i$ , where  $S_i$  denotes the observed spread,  $S_i^*$  is the true, unobserved spread, and  $\eta_i$  is a disturbance that is uncorrelated with  $\varepsilon_{1i}$ ,  $\varepsilon_{2i}$ , and  $\varepsilon_{3i}$ .

The reduced form of the structural model is as follows:

$$P_i = \omega_0 + F_i\omega_1 + X_i\omega_2 + \nu_{1i} \quad (6a)$$

$$S_i^* = \beta_0 + F_i\beta_1 + X_i\beta_2 + \nu_{2i} \quad (6b)$$

$$S_i = \beta_0 + F_i\beta_1 + X_i\beta_2 + \nu_{3i} \quad (6c)$$

$$I_i^* = \lambda_0 + F_i\lambda_1 + X_i\lambda_2 + \lambda_3 P_{0i} + \nu_i \quad (6d)$$

$$\text{PROMOTE}_i = \begin{cases} 1 & \text{if } I_i^* \geq 0 \\ 0 & \text{otherwise,} \end{cases} \quad (6e)$$

where  $\omega_0 = \alpha_0 + \alpha_1\beta_0$ ,  $\omega_1 = \alpha_1\beta_1$ ,  $\omega_2 = \alpha_1\beta_2 + \alpha_2$ ,  $\lambda_0 = \alpha_0 + \alpha_1\beta_0 - \gamma_0$ ,  $\lambda_1 = \alpha_1\beta_1 - \gamma_1$ ,  $\lambda_2 = \alpha_1\beta_2 + \alpha_2 - \gamma_2$ ,  $\lambda_3 = -\gamma_3$ ,  $\nu_{1i} = \varepsilon_{1i} + \alpha_1\varepsilon_{2i}$ ,  $\nu_{2i} = \varepsilon_{2i}$ ,  $\nu_{3i} = \varepsilon_{2i} + \eta_i$ , and  $\nu_i = \varepsilon_{1i} + \alpha_1\varepsilon_{2i} - \varepsilon_{3i}$ .

I assume that  $(\varepsilon_{1i}, \varepsilon_{2i}, \eta_i, \nu_i)$  is i.i.d. multivariate normal with mean vector zero and covariance matrix  $\Sigma$ . The identifying restrictions required on  $\Sigma$  are  $\sigma_{\nu\nu} = 1$  and  $\sigma_{1\eta} = \sigma_{2\eta} = \sigma_{\nu\eta} = 0$ . Note that the rank conditions for identification hold unless all elements of  $\beta_1$  are equal to zero. Therefore, the exclusion of firm characteristics from (3) identifies the performance equation. This identifying assumption can be justified on the grounds that employers know more about the firm

than do recently hired workers, so workers are less able to assimilate information about firm characteristics into a decision function than firms are able to about worker characteristics. This is especially so given that the typical recently hired worker has experience with only a small number of previous employers, if any at all, whereas the firm represents a wealth of historical information about how certain worker types perform in given positions. It is clear from the reduced form that the three parameters of interest (namely  $\alpha_1$ ,  $\sigma_{12}$ , and  $\gamma_3$ ) are identified. That is,  $\alpha_1$  is inferred from  $\omega_1 = \alpha_1 \beta_1$ ,  $\sigma_{12}$  is inferred from  $\text{cov}(v_1, v_2) = \sigma_{12} + \alpha_1 \text{Var}(v_2)$ , and  $\gamma_3 = -\lambda_3$ .

Let  $g$  denote the joint density function and  $G$  the cumulative distribution function.<sup>13</sup> There are two branches to the likelihood function, one for workers who have been promoted and one for workers who have not. Defining  $K_i \equiv \lambda_0 + F_i \lambda_1 + X_i \lambda_2 + \lambda_3 P_{0i}$ , we can write the first of these terms, denoted  $g_{1i}$ , as follows:

$$\begin{aligned} g_{1i} &= g(P_i, S_i \mid \text{PROMOTE}_i = 1) \times \text{Prob}(\text{PROMOTE}_i = 1) \\ &= g(P_i, S_i \mid I_i^* > 0) \times \text{Prob}(I_i^* > 0) \\ &= \int_{-\infty}^{\infty} \int_{-K_i}^{\infty} g(\varepsilon_{1i}, \varepsilon_{2i}, \eta_i, v_i) dv_i d\varepsilon_{2i} \times \mathbf{J} \\ &= \int_{-\infty}^{\infty} g(\varepsilon_{1i}, \varepsilon_{2i}) g(\eta_i) \int_{-K_i}^{\infty} g(v_i \mid \varepsilon_{1i}, \varepsilon_{2i}) dv_i d\varepsilon_{2i} \times \mathbf{J} \\ &= \int_{-\infty}^{\infty} g(\varepsilon_{1i}, \varepsilon_{2i}) g(\eta_i) \Phi\left(\frac{K_i - \mu}{\sigma}\right) d\varepsilon_{2i} \times \mathbf{J}, \end{aligned}$$

where  $\mathbf{J}$ , the Jacobian of transformation from  $(\varepsilon_{1i}, \varepsilon_{2i}, \eta_i, v_i)$  to  $(P_i, S_i^*, S_i, I_i^*)$ , is 1,  $\Phi$  is the standard normal cdf, and  $\mu$  and  $\sigma$  are the mean and standard deviation of the conditional distribution of  $v_i$  given  $\varepsilon_{1i}$  and  $\varepsilon_{2i}$ . The second of these terms, denoted  $g_{0i}$ , is defined similarly. The likelihood function,  $L$ , is as follows:

$$L = \prod_{i=1}^N g_{1i}^{\omega_i \text{PROMOTE}_i} g_{0i}^{\omega_i (1 - \text{PROMOTE}_i)},$$

where  $\omega_i$  is a sampling weight such that  $\sum \omega_i = N$ .

## 6. Estimating the structural tournament model

■ Ideally, the tournament model would be tested within a single, narrowly defined, high-skilled occupational group. The rationale for choosing a high-skilled occupation is that promotion tournaments are more likely to occur in higher-skilled jobs, such as in management, than in low-skilled jobs. The reason is that output is typically easier to measure when the work is less skilled, making output-based incentive schemes like piece rates relatively more attractive. Tournaments, on the other hand, induce effort with only the requirement that relative output be measurable and become more attractive as incentive mechanisms in skilled positions where output is often harder to measure. The MSCUI dataset is not large enough to estimate the structural model on a single narrowly defined occupation. My strategy is therefore to use the 1980 Standard Occupational Classification for the job into which the most recent worker was hired to construct a coarser occupational aggregate that is roughly homogeneous with respect to skill level but also large enough to estimate the model convincingly. I first discard some occupations that are clearly less skilled than the others. These include service occupations, operators, fabricators, laborers, and workers in farming, forestry, fishing, and hunting occupations.<sup>14</sup> The remaining

<sup>13</sup> To avoid a proliferation of notation in deriving the likelihood function, I use  $g$  and  $G$  generically to denote densities and cumulative distribution functions.

<sup>14</sup> The average hourly starting wage for these excluded jobs is \$6.73, whereas for the remaining observations it is \$10.47.

usable observations, after accounting for missing values and cases for which no promotion is reported to be possible, include a small number ( $N = 170$ ) of professional jobs (administrative, engineering, scientific, teaching, and related occupations, including creative artists) and a larger number ( $N = 632$ ) of positions I refer to as "skilled." The average hourly starting wage is \$14.21 for professionals and only \$8.61 for "skilled" workers. Given that these two groups are clearly quite different in their pay and skill levels, rather than pooling these disparate sets of jobs I estimate the model only on the larger subsample of 632 skilled workers. This group is defined as follows:

*Skilled workers:* Technical, clerical, sales, and related occupations; precision production, craft, and repair.

While this group is clearly less skilled than the professional workers, it is interesting to study in that it effectively poses a greater challenge to the tournament model if in fact the prevalence of tournaments is higher the greater the skill level of the job.<sup>15</sup> Since the occupational subgroup I analyze is still relatively broad, to mitigate concerns about heterogeneity within this group I include controls for the following occupational subgroups:

(i) *Technologists and technicians:* Both "health" and "nonhealth."

(ii) *Marketing and sales occupations.*

(iii) *Administrative support occupations, including clerical.*

(iv) *Craft, construction, and transportation occupations:* Includes mechanics and repairers; construction and extractive occupations; precision production occupations; transportation and material-moving occupations.

Summary statistics for the subsample of skilled workers are displayed in columns 5 and 6 of Table 1, and estimates of the structural parameters are reported in Table 3.<sup>16</sup> In such models there is no unique or universally reported measure of goodness of fit. One simple approach for assessing fit is to compare the average predicted values of performance, the spread, and promotions to their average sample values. The average predicted values are (.745, .294, .138) and the average sample values are (.777, .267, .131).<sup>17</sup> Among promotions, 82 out of 632 are misclassified by the structural model, which is slightly less than 13%.<sup>18</sup> An alternative approach to assessing fit is based on a pseudo- $R^2$ , defined as  $1 - L$ , where  $L$  is the ratio of the unrestricted to the restricted log-likelihood functions evaluated at the maximum-likelihood estimates. This measure was suggested by McFadden (1974) for the case of the logit model. To compute this statistic, one must decide on a restricted model to use as the benchmark. In the case of the probit or logit, the benchmark

<sup>15</sup> In fact, this model cannot even be estimated on the smaller group of professional workers without imposing further restrictions. In DeVaro (2006) I estimate a pared-down version of the model using only the sample of professional workers, finding empirical support for the model's predictions on  $\alpha_1$  and  $\gamma_3$  but not  $\sigma_{12}$ . The model in DeVaro differs in two key respects (both driven by the small sample size for professionals) from the one estimated here. First, the set of controls was less extensive. Second, the model does not allow for measurement error in the spread. For these reasons, the results on professionals are not directly comparable to those I present here.

<sup>16</sup> The summary statistics in columns 5 and 6 are based only on observations that are nonmissing for every variable included in the structural model. I also computed means that include nonmissing observations for a particular variable even if the same observation is missing for another variable in the structural model and found that these were roughly comparable to those I report in Table 1. Note that some of the control variables (race, whether the establishment is a franchise, whether the establishment employs temporary or contract workers, establishment age) had estimated effects near zero and large standard errors and could be excluded from the model on the basis of likelihood ratio tests. I dropped these to increase precision on the remaining estimates. I also aggregated the industry controls slightly (to 5 categories) compared with the analysis of Section 4 that used 8 industry categories.

<sup>17</sup> Note that I have scaled performance by dividing by 100 and the spread by dividing by 10. Also, the actual and predicted averages reported here are unweighted, which explains why the actual averages differ slightly from those displayed in column 5 of Table 1. The structural results in Table 3 are based on weighted estimation, as is the pseudo- $R^2$  soon to be discussed. Weighted versus unweighted structural estimation yields the same qualitative results of interest.

<sup>18</sup> A prediction is defined to be misclassified if either  $PROMOTE_i = 1$  and the model's predicted probability of promotion is less than 1/2 or  $PROMOTE_i = 0$  and the model's predicted probability of promotion is greater than or equal to 1/2. As noted in Amemiya (1981), this criterion is appropriate when one has an "all-or-nothing" loss function, which applies the same penalty to a prediction of .49 as to 0 when the actual observation involves  $PROMOTE_i = 1$ .



TABLE 3 Estimates from Structural Tournament Model

	<i>P</i>	<i>S</i> *	<i>T</i> *
<i>S</i> (wage spread)	.591* (.326)	—	—
Worker characteristics			
Male	-.026 (.021)	.023 (.017)	-.078 (.430)
More than high school	.014 (.016)	-.002 (.015)	-.173 (.430)
College or more	.026 (.028)	.037 (.024)	.282 (.430)
Age (divided by 10)	-.001 (.010)	.017** (.008)	.076 (.430)
Tenure (in years)	.135** (.059)	-.188** (.023)	-1.145** (.435)
Fraction high skilled	-.016 (.043)	.130** (.025)	.044 (.431)
Firm Characteristics			
Internal job postings	—	-.006 (.014)	.192 (1.192)
For profit	—	.024 (.023)	-.006 (1.193)
Number of sites (1000s)	—	-.014 (.013)	.965** (1.192)
Establishment size (1000s)	—	-.017** (.006)	-.046 (1.192)
Union (fraction of workers covered)	—	.082** (.022)	.351 (1.194)
Performance of typical employee, $P_0$	—	—	1.496** (.517)
Industry controls	—	YES	YES
Occupation controls	—	YES	YES
Constant	.588** (.083)	.212** (.060)	-.008 (.541)
$\sigma_{11}$		.075 (.060)	
$\sigma_{22}$		.145** (.039)	
$\sigma_{12}$		-.090* (.052)	
$\sigma_{1v}$		-.180** (.088)	
$\sigma_{2v}$		.249** (.065)	
$\sigma_{\eta\eta}$		.009** (.001)	

Note: Estimation is by maximum likelihood. Sampling weights are used. Asymptotic standard errors are in parentheses. \* and \*\* denote statistical significance at the 10% and 5% levels, respectively. Sample size is 632 "skilled" workers.

is typically a model that includes only a constant on the right-hand side. I define the benchmark model as one in which the three equations for worker performance, the spread, and promotions each include only constants, so that only three constants and six free covariance parameters are estimated. The resulting pseudo- $R^2$  is .90. Taken collectively, I interpret the evidence here as indicating a reasonably good fit of the model.

Recall that the tournament model has the following implications for the parameter estimates:

*Testable Proposition 1.*  $\alpha_1 > 0$ .

*Testable Propositions 2 and 3.*  $\sigma_{12} < 0$ .

*Testable Proposition 4.*  $\gamma_3 > 0$ .

As revealed in Table 3, all three parameters have the theoretically predicted signs and are statistically significant at the 10% level, providing empirical support for the tournament model. That is,  $\alpha_1 = .591$  ( $Z = 1.81$ ),  $\sigma_{12} = -.090$  ( $Z = 1.72$ ), and  $\gamma_3 = 1.496$  ( $Z = 2.89$ ).<sup>19</sup> The result that  $\gamma_3 > 0$  implies that relative performance matters for the promotion of skilled workers, just as was found in Section 4 for the entire cross section. While that result alone is suggestive of internal promotion competitions determined by relative performance, the further findings that  $\alpha_1 > 0$  and  $\sigma_{12} < 0$  suggest that, at least for skilled workers, such internal promotion competitions are consistent with the notion of a tournament in which employers strategically choose the spread to induce effort and larger spreads induce higher levels of performance.

The basic logic behind the tournament model's prediction that  $\sigma_{12} < 0$  is that factors that depress incentives (and therefore performance) cause the firm to counter by increasing the spread, thereby increasing effort and performance. An example of such a factor, as discussed earlier, is  $\theta_i$ , the variance of the stochastic component of worker performance. The results indicate that the prediction holds for the unobserved determinants of performance and the spread, since the estimated  $\sigma_{12}$  is negative. This pattern of opposing effects also appears in the observed covariates, in that five of the six worker characteristics have opposite signs between the performance equation and the spread equation. While many of these are small in magnitude and statistically insignificant, the overall pattern is noteworthy and supportive of the logic of the tournament model. The clearest and most precisely estimated example of these opposing effects is found in the tenure variable, which is positive in the performance equation and negative in the spread equation.

Since a key feature of the model is that it accounts for the full set of disturbance correlations in performance, the spread, and promotions, it is worth noting that a likelihood ratio test strongly rejects the joint restriction  $\sigma_{12} = \sigma_{1\nu} = \sigma_{2\nu} = 0$ : the test statistic is 46.5 and the critical value of the  $\chi^2$  distribution with 3 degrees of freedom is 11.34. It is also interesting to note that if this joint restriction is imposed, the theoretical prediction  $\alpha_1 > 0$  is no longer supported in the data; that is,  $\alpha_1 = -.030$  ( $Z = 1.63$ ). The prediction  $\gamma_3 > 0$  still holds, with  $\gamma_3 = .984$  ( $Z = 1.68$ ). The reason the prediction  $\alpha_1 > 0$  is lost in this model is that by imposing  $\sigma_{12} = 0$  we are mistakenly treating the endogenous wage spread as exogenous in the performance equation, yielding a biased estimate of  $\alpha_1$ . The results here suggest that, at least in the MCSUI, failure to treat the spread as endogenous would have led to quite misleading results with regard to the incentive effects of tournaments.

DeVaro and Brookshire (2007) document a new empirical result that promotions are less likely in nonprofits than for-profits. Their proposed explanation is that workers in nonprofits experience intrinsic motivation deriving from their sympathy with the organizational mission, thereby allowing nonprofit employers to rely on promotions more to achieve efficient job assignments and less to create incentives via tournaments, whereas for-profit employers rely more heavily on promotion tournaments to create incentives. This theory implies that if nonprofit organizations are dropped from the estimation sample, the empirical support for the tournament model that is found in Table 3 should strengthen even further. That is exactly what happens. Dropping the 81 nonprofits and estimating the structural model on 551 for-profits yields the following estimates:  $\alpha = 0.709$  ( $Z = 1.98$ ),  $\sigma_{12} = -0.118$  ( $Z = 1.75$ ),  $\gamma_3 = 1.633$  ( $Z = 2.85$ ), whereas the results in Table 3 were  $\alpha = 0.591$  ( $Z = 1.81$ ),  $\sigma_{12} = -0.091$  ( $Z = 1.72$ ),  $\gamma_3 = 1.496$  ( $Z = 2.89$ ).

□ **Predicting the impact of change in the production environment.** Recall that  $\theta_i$  denotes

<sup>19</sup> These estimates account for the survey sampling weights as indicated by the likelihood function of the previous section. Results based on unweighted estimation are also supportive of all three predictions of the model; these are  $\alpha_1 = 1.122$  ( $Z = 2.08$ ),  $\sigma_{12} = -.152$  ( $Z = 1.90$ ), and  $\gamma_3 = 1.031$  ( $Z = 2.07$ ).

TABLE 4

Prior value of $\sigma_{\ln\theta}$	$\Delta S^*$ (\$)	$\Delta P$
.01	3.84	-4.9
.5	5.57	-7.1
1	8.23	-10.5

the variance in the stochastic component of worker performance for observation  $i$ . Let  $f(\theta)$  be the distribution of  $\theta$  in the population of establishments, where  $\mu_\theta$  and  $\sigma_\theta$  denote the mean and variance of  $\theta$ . Given some auxiliary assumptions, it is possible to quantify the effect of an environmental change that shifts the distribution of  $\theta_i$  to the right, increasing both its mean and variance (that is,  $\Delta\mu_\theta > 0$  and  $\Delta\sigma_\theta > 0$ ), on the expected values of worker performance and the optimal wage spread.<sup>20</sup> Let  $\theta_i$  be distributed lognormal, and let  $\mu_{\ln\theta}$  and  $\sigma_{\ln\theta}$  denote the mean and variance of  $\ln\theta_i$ . Assume that  $\mu_{\ln\theta} = 0$  and that the structural disturbances for  $P$  and  $S^*$  reflect only  $\theta_i$ , in the following fashion:  $\varepsilon_{1i} = \tau \ln\theta_i$  and  $\varepsilon_{2i} = \varphi \ln\theta_i$ , where the sign restrictions  $\tau < 0$  and  $\varphi > 0$  are implied by the first-order conditions of the tournament model. Letting  $\Delta S^*$  and  $\Delta P$  denote the implied changes in the expected values of the spread and performance, it is straightforward to show that  $\Delta S^* = \varphi \Delta\mu_\theta > 0$  and that  $\Delta P = [\tau + \alpha_1\varphi]\Delta\mu_\theta$ , where  $\tau = -\varphi(\sigma_{11}/\sigma_{22})^{1/2}$ . The sign of  $\Delta P$  is ambiguous in general and depends on the relative magnitudes of  $\sigma_{11}$ ,  $\sigma_{22}$ , and  $\alpha_1$ . Given the estimates in Table 3, however, it is clear that  $\Delta P < 0$ .

Attaching empirical magnitudes to  $\Delta S^*$  and  $\Delta P$  requires choosing a magnitude for  $\Delta\mu_\theta$  and also assigning a value to  $\sigma_{\ln\theta}$  prior to the environmental change. (Given the lognormal assumption, an increase in  $\sigma_{\ln\theta}$  increases both  $\mu_\theta$  and  $\sigma_\theta$ .) I consider an increase in  $\sigma_{\ln\theta}$  that increases  $\mu_\theta$  by one standard deviation of  $\theta_i$ , given the particular prior value of  $\sigma_{\ln\theta}$ . Assigning a prior value of  $\sigma_{\ln\theta}$  implies values for  $\varphi$ ,  $\tau$ , and  $\Delta\mu_\theta$ , and therefore  $\Delta S^*$  and  $\Delta P$ .<sup>21</sup> Since the prior value of  $\sigma_{\ln\theta}$  on which these computations are based must be arbitrarily assigned, I compute  $\Delta S^*$  and  $\Delta P$  for a range of possible values of  $\sigma_{\ln\theta}$ . The results for three such values of  $\sigma_{\ln\theta}$  are shown in Table 4.

Relative to the sample means of  $S^*$  and  $P$  (\$2.67 per hour and 77.7, respectively), these magnitudes are quite substantial, which is perhaps not surprising in response to an environmental change that increases the mean of  $\theta$  by a full standard deviation and also raises its variance. One should also consider that the assumptions underlying this example attribute all of the residual variance in the  $P$  and  $S^*$  equations to variation in  $\theta$ . While  $\theta$  is clearly an important factor in the disturbances  $\varepsilon_1$  and  $\varepsilon_2$ , it is not the only factor. Thus, the responses depicted in Table 4 are likely to be somewhat overstated.

## 7. Extensions and limitations

■ The results in Table 3 are robust to various changes in the specification of controls, including using the more detailed industry controls, using multiple race dummies, including quadratics in worker age and tenure with the firm, controlling for the age of the establishment either linearly or using three dummies (less than 2 years of operation, between 2 and 5 years, greater than 5 years), and including dummies for whether the establishment employs any temporary workers and whether the establishment employs any contract workers. Across all such specifications, the results of interest are of comparable magnitudes; while their standard errors are in some cases higher than in the results I report, for the three parameters of interest, statistical significance is always achieved on a one-tailed test at the 10% significance level. I now discuss five potential concerns.

<sup>20</sup> In principle, the effect on the expected value of promotion could also be analyzed, though this would depend on the structure of the hierarchy in the establishment, and this is not directly observed in the data.

<sup>21</sup> The implied value of  $\Delta\mu_\theta$  is  $\exp[(\sigma_{\ln\theta} + \Delta\sigma_{\ln\theta})/2] - \exp[\sigma_{\ln\theta}/2]$ . In this expression, the value of  $\Delta\sigma_{\ln\theta}$  is found by solving for  $\Delta\sigma_{\ln\theta}$  as a function of  $\sigma_{\ln\theta}$  in the equation  $\Delta\mu_\theta = (\sigma_\theta)^{1/2}$  or, in its less compact form,  $\exp[(\sigma_{\ln\theta} + \Delta\sigma_{\ln\theta})/2] - \exp[\sigma_{\ln\theta}/2] = [\exp(\sigma_{\ln\theta})\{\exp(\sigma_{\ln\theta}) - 1\}]^{1/2}$ .

First, the difference in hourly wages might be too crude a proxy for the relevant theoretical notion of the spread that actually motivates workers. The relevant spread is the expected difference in the present discounted value of total compensation between the two jobs, where the term "total compensation" is broadly defined to include the value of fringe benefits and all other nonpecuniary job characteristics. While the model accounts for classical linear measurement error in the spread, other functional forms for measurement error in the spread have not been addressed and could potentially contaminate the results. It is interesting to note, however, that the magnitude of measurement error in the wage spread appears fairly modest, given the distributional assumptions and the assumption on the functional form of this measurement error. Measurement error accounts for less than 6% of the total variance in the spread. That is,  $\sigma_{\eta\eta}/(\sigma_{22} + \sigma_{\eta\eta}) = .009/(.145 + .009) = .058$ .<sup>22</sup>

Second, the tournament model predicts that performance is an increasing function of wage spreads rather than wage levels, although wage levels affect a worker's participation decision as to whether to work for the firm (see footnote 3). That is, an increase in the spread, holding the wage level constant, induces higher performance. This suggests that a test of the effect of the spread on performance necessitates controlling for wage levels. In fact, the wage level does not appear on the right-hand side of the performance equation (3). By estimating the structural model only on an occupational subgroup (albeit a fairly broad one), I roughly control for wage levels by considering a relatively homogeneous group of workers with respect to skill level. Nevertheless, I estimated the model including a measure of wage levels (in particular the average of the pre- and post-promotion wages) on the right-hand side of the performance equation. The results are quite similar in magnitude to those in Table 3 and remain significant at the 10% level using one-tailed tests:  $\alpha_1 = .531$  ( $Z = 1.37$ ),  $\sigma_{12} = -.086$  ( $Z = 1.43$ ), and  $\gamma_3 = 1.504$  ( $Z = 2.93$ ).

A third potential concern is the possibility of measurement error in the performance ratings, arising because managers are likely to have imperfect information about the true performance of an individual worker, particularly when the worker is a recent hire. While such errors are likely in the performance measures for the most recent hire, they should be much less of a problem in the performance ratings of the "typical worker" in the same position. This latter rating draws on the manager's experience with many workers that have been employed in the position over time, including some who have been observed in the position for a long time. I therefore extended the structural model to account for measurement error in  $P$ , dropping the measurement error in the wage spread to simplify the estimation. All three predictions of the model are upheld and are statistically significant at the 10% level. That is,  $\alpha_1 = .618$  ( $Z = 24.69$ ),  $\sigma_{12} = -.105$  ( $Z = 4.21$ ), and  $\gamma_3 = .993$  ( $Z = 1.75$ ). An alternative source of measurement error in performance might arise because performance is rated by a different respondent (at a different establishment) for each observation, creating a respondent-specific effect in measuring both performance ratings. For example, it might be that upbeat or optimistic managers provide higher-than-true assessments of performance, both for the most recent hire and for the typical worker in that position. Hence, both  $P$  and  $P_0$  could be measured with error, and these errors would be correlated. To account for this, I extended the structural model to account for a common measurement error (interpreted as a respondent-specific effect) in both  $P$  and  $P_0$ , dropping the measurement error in the wage spread to simplify the estimation. The theoretical predictions  $\alpha_1 > 0$  and  $\sigma_{12} < 0$  are upheld in this version of the model, and both are statistically significant. That is,  $\alpha_1 = .616$  ( $Z = 26.37$ ) and  $\sigma_{12} = -.105$  ( $Z = 4.26$ ). The prediction  $\gamma_3 > 0$  is unsupported, with  $\gamma_3 = -.181$  ( $Z = .54$ ). The likely reason this prediction is unsupported is that incorporating measurement error in  $P_0$  implies a strong restriction on  $\gamma_3$ , placing an upper bound on  $\gamma_3$  that is decreasing in the variance of the measurement error. In the Appendix I discuss both extensions of the structural model in more detail.

A fourth potential concern is the validity of the exclusion restrictions used to identify the performance equation. The model assumes that firm characteristics are absent from the performance

<sup>22</sup> The estimates for  $\sigma_{22}$  and  $\sigma_{\eta\eta}$  appear small in magnitude relative to the mean value of the spread reported in Table 1 (\$2.83 per hour) because I have scaled the spread, dividing it by ten when estimating the structural model.

equation. This could be problematic if workers perform differently in different types of firms. Another rationale for including firm characteristics in the performance equation is the possibility of a respondent-specific effect. If certain types of respondent managers work in certain types of firms, then this provides a rationale for including firm characteristics in the performance equation. I can address these concerns to some extent by partially relaxing this identifying assumption, since identification requires only that a single firm characteristic be absent from the performance equation rather than all firm characteristics. I therefore estimate the model including all firm characteristics in the performance equation except for "union," or the percent of the workforce covered by a collective bargaining agreement. The union variable is probably the closest item available in the MCSUI to an "exogenous" factor affecting the spread. While it could still be argued that unions might have a direct effect on effort, meaning this variable should also be included in the performance equation, the effects of unions on the wage structure are clear and well documented, suggesting that the presence of the union variable in the equation for the spread is of first-order importance. It is hoped that any direct effects of unions on effort are small by comparison. The three key results all hold in this version of the model and remain statistically significant at the 10% level, with  $\alpha_1 = .702$  ( $Z = 1.74$ ),  $\sigma_{12} = -.107$  ( $Z = 1.85$ ), and  $\gamma_3 = 1.533$  ( $Z = 2.95$ ). This provides some assurance that the absence of all firm characteristics from the performance equation is not driving the results.

Finally, there is considerable heterogeneity on both the worker and firm sides in the cross section of worker-establishment observations. I attempt to cope with this to the extent permitted by the data through control variables and through selection of a worker subsample that is roughly homogeneous with respect to skill but large enough to generate interesting results. Nonetheless, unmeasured heterogeneity could affect the results. In particular, tournaments might look very different in some job types as compared with others in the estimation sample. To some extent this can be addressed by re-estimating the model on a series of subsamples, each of which drops an individual narrowly defined occupation that represents a relatively small fraction of the "total" estimation sample used in the main analysis. In such tests I found that the three results of interest were largely unchanged.

## 8. Conclusion

■ I have presented evidence that promotions are determined by relative performance in a cross section of workers spanning multiple establishments. Using a structural model, I have also shown that promotions in a subsample of skilled workers are consistent with three propositions from tournament theory: (i) worker effort is increasing in the wage spread attached to promotions, (ii) worker effort is decreasing in the stochastic component of performance, whereas the wage spread is increasing in this stochastic component, and (iii) promotions are determined by relative performance. A main objective of this analysis has been to illustrate the value of recognizing the behavior of both principal and agent simultaneously when constructing empirical models for confronting theory in personnel economics with data. The fashion in the empirical literature has been to estimate descriptive regressions focusing on only one set of behaviors at a time, either the worker's or the firm's. For example, studies that test for incentive effects of tournaments treat the spread as exogenous in a single equation for performance. Such an approach would have led to quite misleading results in the present context. While estimation of the structural model yielded evidence that tournaments have incentive effects in that performance is increasing in the spread, this result would have been missed by taking the standard approach of estimating a single performance equation with an exogenous spread. Furthermore, the finding that the unobserved determinants of performance and the spread are negatively correlated was possible only because the structural model treated this correlation as a free parameter to be estimated. Increased attention to empirical models that simultaneously incorporate the behaviors of all economic agents appears to be a promising direction for future research in empirical personnel economics.

## Appendix

## ■ Incorporating measurement errors in worker performance.

*Case 1: measurement error in P.* Suppressing the subscript  $i$  that indexes observations, suppose that the performance of the most recent hire is measured with error, so that  $P = P^* + \xi$ , where  $P$  denotes observed performance,  $P^*$  denotes true performance, and  $\xi$  represents a mean-zero reporting error that is uncorrelated with the structural disturbances  $\varepsilon_1$ ,  $\varepsilon_2$ , and  $\varepsilon_3$ . This reporting error could reflect both imperfect information and respondent-specific qualities such as optimism. For simplicity, I assume that the wage spread is measured without error, yielding the following structural system:

$$P^* = \alpha_0 + \alpha_1 S + X\alpha_2 + \varepsilon_1 \quad (A1)$$

$$S = \beta_0 + F\beta_1 + X\beta_2 + \varepsilon_2 \quad (A2)$$

$$P = P^* + \xi \quad (A3)$$

$$T^* = \gamma_0 + F\gamma_1 + X\gamma_2 + \gamma_3 P_0 + \varepsilon_3 \quad (A4)$$

$$PROMOTE = \begin{cases} 1 & \text{if } I^* \geq 0 \\ 0 & \text{if } I^* < 0. \end{cases} \quad (A5)$$

where  $I^* = P^* - T^*$ .

Substituting (A1) into (A3) and substituting (A1), (A2), and (A4) into the expression for  $I^*$ , we can rewrite the system as

$$P^* = \alpha_0 + \alpha_1 S + X\alpha_2 + \varepsilon_1$$

$$S = \beta_0 + F\beta_1 + X\beta_2 + \varepsilon_2$$

$$P = \alpha_0 + \alpha_1 S + X\alpha_2 + \psi$$

$$I^* = \lambda_0 + F\lambda_1 + X\lambda_2 + \lambda_3 P_0 + \nu$$

$$PROMOTE = \begin{cases} 1 & \text{if } I^* \geq 0 \\ 0 & \text{if } I^* < 0, \end{cases}$$

where  $\psi = \varepsilon_1 + \xi$ ,  $\lambda_0 = \alpha_0 + \alpha_1 \beta_0 - \gamma_0$ ,  $\lambda_1 = \alpha_1 \beta_1 - \gamma_1$ ,  $\lambda_2 = \alpha_1 \beta_2 + \alpha_2 - \gamma_2$ ,  $\lambda_3 = -\gamma_3$ , and  $\nu = \varepsilon_1 + \alpha_1 \varepsilon_2 - \varepsilon_3$ .

I assume  $(\varepsilon_1, \varepsilon_2, \psi, \nu) \sim MVN(0, \Sigma)$  and constrain  $\nu$  to have unit variance for identification. Six parameters in  $\Sigma$  are identified:  $\sigma_{11}$  or  $\text{cov}(\varepsilon_1, \psi)$ ,  $\sigma_{12}$  or  $\text{cov}(\varepsilon_2, \psi)$ ,  $\sigma_{1\nu}$  or  $\text{cov}(\psi, \nu)$ ,  $\sigma_{\psi\psi}$  or  $\sigma_{11} + \sigma_{\xi\xi}$ ,  $\sigma_{22}$ , and  $\sigma_{2\nu}$ . The likelihood function has the same form as that expressed in the text, but with different expressions for  $g_1$  and  $g_0$ . Defining  $K \equiv \lambda_0 + F\lambda_1 + X\lambda_2 + \lambda_3 P_0$ , the expression for  $g_1$  is now as follows:

$$\begin{aligned} g_1 &= g(P, S \mid PROMOTE = 1) \times \text{Prob}(PROMOTE = 1) \\ &= \int_{-\infty}^{\infty} \int_{-K}^{\infty} g(\varepsilon_1, \varepsilon_2, \psi, \nu) d\nu d\varepsilon_1 \times J \\ &= \int_{-\infty}^{\infty} \int_{-K}^{\infty} g(\nu, \varepsilon_1 \mid \varepsilon_2, \psi) g(\varepsilon_2, \psi) d\nu d\varepsilon_1 \times J \\ &= g(\varepsilon_2, \psi) \int_{-\infty}^{\infty} \int_{-K}^{\infty} g(\nu, \varepsilon_1 \mid \varepsilon_2, \psi) d\nu d\varepsilon_0 d\varepsilon_1 \times J. \end{aligned}$$

where the Jacobian of transformation from  $(\varepsilon_1, \varepsilon_2, \psi, \nu)$  to  $(P^*, S, P, I^*)$  is 1. The expression for  $g_0$  is analogous.

*Case 2: measurement error in both P and P<sub>0</sub>.* Now suppose that both performance ratings are measured with a common error, so that  $P = P^* + \xi$  and  $P_0 = P_0^* + \xi$ , where the measurement error has mean zero and is uncorrelated with the structural disturbances  $\varepsilon_1$ ,  $\varepsilon_2$ , and  $\varepsilon_3$ . The error in this case has a natural interpretation as a respondent-specific effect, which could arise if some managers are optimistic and tend to inflate performance ratings, whereas others are pessimistic and rate too harshly. For simplicity, I assume that the wage spread is measured without error, yielding the following structural system:

$$P^* = \alpha_0 + \alpha_1 S + X\alpha_2 + \varepsilon_1 \quad (A6)$$

$$S = \beta_0 + F\beta_1 + X\beta_2 + \varepsilon_2 \quad (A7)$$

$$P = P^* + \xi \quad (A8)$$

$$P_0^* = P_0 - \xi \quad (A9)$$

$$T^* = \gamma_0 + F\gamma_1 + X\gamma_2 + \gamma_3 P_0^* + \varepsilon_3 \quad (A10)$$

$$PROMOTE = \begin{cases} 1 & \text{if } I^* \geq 0 \\ 0 & \text{if } I^* < 0, \end{cases} \quad (A11)$$

where  $I^* = P^* - T^*$ .

The reduced-form expression for  $I^*$  is as follows:

$$I^* = \lambda_0 + F\lambda_1 + X\lambda_2 + \lambda_3 P_0 + \nu,$$

where  $\lambda_0 = \alpha_0 + \alpha_1\beta_0 - \gamma_0$ ,  $\lambda_1 = \alpha_1\beta_1 - \gamma_1$ ,  $\lambda_2 = \alpha_1\beta_2 + \alpha_2 - \gamma_2$ ,  $\lambda_3 = -\gamma_3$ , and  $\nu = \varepsilon_1 + \alpha_1\varepsilon_2 - \varepsilon_3 + \gamma_3\xi$ .

I assume  $(\varepsilon_1, \varepsilon_2, \nu, \xi) \sim \text{MVN}(\mathbf{0}, \Sigma)$  and constrain  $\nu$  to have unit variance for identification. Six covariance parameters are identified:  $\sigma_{11}, \sigma_{22}, \sigma_{1\nu}, \sigma_{2\nu}, \sigma_{12}$ , and  $\sigma_{\xi\xi}$ . The likelihood function has the same form as that expressed in the text, but with different expressions for  $g_1$  and  $g_0$ . Defining  $K \equiv \lambda_0 + F\lambda_1 + X\lambda_2 + \lambda_3 P_0$ , the expression for  $g_1$  is now as follows:

$$g_1 = g(P, S \mid \text{PROMOTE} = 1) \times \text{Prob}(\text{PROMOTE} = 1) \\ = \int_{-\infty}^{\infty} \int_{-K}^{\infty} g(\varepsilon_1, \varepsilon_2, \nu, \xi) d\nu d\varepsilon_1 \times \mathbf{J} = \int_{-\infty}^{\infty} g(\xi) g(\varepsilon_1, \varepsilon_2) \int_{-K}^{\infty} g(\nu \mid \varepsilon_1, \varepsilon_2, \xi) d\nu d\varepsilon_1 \times \mathbf{J},$$

where  $\mathbf{J}$  is the Jacobian of transformation from  $(\varepsilon_1, \varepsilon_2, \nu, \xi)$  to  $(P^*, S, I^*, P)$ , and where the expression for  $g_0$  is analogous.

There is a key difference between this model and both the one in the main body of the text and in Case 1 of this Appendix. All three models are similar in structure. The main model of the text has a single measurement error  $\eta$  in the wage spread, the model in Case 1 of this Appendix has a single measurement error  $\xi$  in the worker performance rating, and the present model has a single measurement error  $\xi$  in both worker performance ratings. The key difference lies in  $\nu$ , the disturbance for the reduced-form expression for  $I^*$ . In the present context, the measurement error  $\xi$  appears in the expression for  $\nu$ , since  $\nu = \varepsilon_1 + \alpha_1\varepsilon_2 - \varepsilon_3 + \gamma_3\xi$ , whereas in the other two models there is no measurement error term in  $\nu$ . Thus, in the present context we have  $\text{cov}(\nu, \xi) = \gamma_3 \text{Var}(\xi)$ , meaning that  $\gamma_3$  appears in the disturbance covariance matrix  $\Sigma$ . The presence of  $\gamma_3$  in  $\Sigma$  implies a strong restriction on this parameter. Positive definiteness of  $\Sigma$  requires that a number of inequalities involving  $\gamma_3$  hold, including the following inequality:  $\gamma_3 < 1/\sqrt{\text{Var}(\xi)}$ . To see this, consider an arrangement of  $\Sigma$  such that its first two rows and columns pertain to  $\nu$  and  $\xi$ . Positive definiteness of  $\Sigma$  requires that all leading principal minors be positive. Requiring that the second of these minors be positive implies  $\text{Var}(\xi) - [\gamma_3 \text{Var}(\xi)]^2 > 0$ . Rearranging this expression yields  $\gamma_3 < 1/\sqrt{\text{Var}(\xi)}$ . In the limit, as the variance of measurement error becomes large, this inequality approaches  $\gamma_3 < 0$ , whereas tournament theory implies  $\gamma_3 > 0$ . Hence, in the limit the model cannot deliver the result that relative performance matters in determining promotions. A finding of  $\gamma_3 > 0$  is compatible with only very modest amounts of measurement error in  $P_0$ . This is an unfortunate by-product of assuming measurement error in  $P_0$ , and the problem exists even if there is no measurement error in  $P$ . The constraint on  $\gamma_3$  arises only as a consequence of the need to ensure that the statistical model makes sense (in that it has a positive definite covariance matrix) and not from the economics of the problem.

## References

- AMEMIYA, T. "Qualitative Response Models: A Survey." *Journal of Economic Literature*, Vol. 19 (1981), pp. 1483-1536.
- AUDAS, R., BARMBY, T., AND TREBLE, J. "Luck, Effort, and Reward in an Organizational Hierarchy." *Journal of Labor Economics*, Vol. 22 (2004), 379-395.
- BAKER, G.P., GIBBS, M., AND HOLMSTRÖM, B. "The Internal Economics of the Firm: Evidence from Personnel Data." *Quarterly Journal of Economics*, Vol. 109 (1994a), pp. 881-919.
- , ———, AND ———. "The Wage Policy of a Firm." *Quarterly Journal of Economics*, Vol. 109 (1994b), pp. 921-955.
- , JENSEN, M.C., AND MURPHY, K.J. "Compensation and Incentives: Practice vs. Theory." *Journal of Finance*, Vol. 43 (1988), pp. 593-616.
- BECKER, B. AND HUSELID, M. "The Incentive Effects of Tournament Compensation Systems." *Administrative Science Quarterly*, Vol. 37 (1992), pp. 336-350.
- BELZIL, C. AND BOGNANNO, M. "The Promotion Dynamics of American Executives." Working Paper, Tempe University, 2005.
- BOGNANNO, M.L. "Corporate Tournaments." *Journal of Labor Economics*, Vol. 19 (2001), pp. 290-315.
- BULL, C., SCHOTTER, A., AND WEIGELT, K. "Tournaments and Piece Rates: An Experimental Study." *Journal of Political Economy*, Vol. 95 (1987), pp. 1-33.
- CARMICHAEL, H.L. "The Agent-Agents Problem: Payment by Relative Output." *Journal of Labor Economics*, Vol. 1 (1983), pp. 50-65.
- CHAN, W. "External Recruitment Versus Internal Promotion." *Journal of Labor Economics*, Vol. 14 (1996), pp. 555-570.
- DEVARO, J. "Strategic Promotion Tournaments and Worker Performance." *Strategic Management Journal*, Vol. 27 (2006), pp. 721-740.
- AND BROOKSHIRE, D. "Promotions and Incentives in Nonprofit and For-Profit Organizations." *Industrial and Labor Relations Review*, Vol. 60 (2007), pp. 311-339.
- AND WALDMAN, M. "The Signaling Role of Promotions: Further Theory and Empirical Evidence." Working Paper, Cornell University, 2005.
- EHRENBERG, R.G. AND BOGNANNO, M.L. "The Incentive Effects of Tournaments Revisited: Evidence from the European PGA Tour." *Industrial and Labor Relations Review*, Vol. 43 (1990a), pp. 745-885.

- AND ———. "Do Tournaments Have Incentive Effects?" *Journal of Political Economy*, Vol. 98 (1990b), pp. 1307–1324.
- ERIKSSON, T. "Executive Compensation and Tournament Theory: Empirical Tests on Danish Data." *Journal of Labor Economics*, Vol. 17 (1999), pp. 262–280.
- GIBBONS, R. AND WALDMAN, M. "A Theory of Wage and Promotion Dynamics Inside Firms." *Quarterly Journal of Economics*, Vol. 114 (1999), pp. 1321–1358.
- AND ———. "Enriching a Theory of Wage and Promotion Dynamics Inside Firms." *Journal of Labor Economics*, Vol. 24 (2006), pp. 59–107.
- GIBBS, M. "Testing Tournaments? An Appraisal of the Theory and Evidence." *Labor Law Journal*, Vol. 45 (1994), pp. 493–500.
- GREEN, J.R. AND STOKEY, N.L. "A Comparison of Tournaments and Contracts." *Journal of Political Economy*, Vol. 91 (1983), pp. 349–364.
- HOLMSTRÖM, B. "Moral Hazard in Teams." *Bell Journal of Economics*, Vol. 13 (1982), pp. 324–340.
- HOLZER, H. *What Employers Want: Job Prospects for Less-Educated Workers*. New York: Russell Sage Foundation, 1996.
- KNOEBER, C.R. AND THURMAN, W.N. "Testing the Theory of Tournaments: An Empirical Analysis of Broiler Production." *Journal of Labor Economics*, Vol. 12 (1994), pp. 155–179.
- LAMBERT, R.A., LARCKER, D.F., AND WEIGELT, K. "The Structure of Organizational Incentives." *Administrative Science Quarterly*, Vol. 38 (1993), pp. 438–461.
- LAZEAR, E.P. "Pay Equality and Industrial Politics." *Journal of Political Economy*, Vol. 97 (1989), pp. 561–580.
- . "The Job as a Concept." In W. Bruns, ed., *Performance Measurement, Evaluation, and Incentives*. Boston: Harvard Business School Press, 1992.
- AND ROSEN, S. "Rank-Order Tournaments as Optimum Labor Contracts." *Journal of Political Economy*, Vol. 89 (1981), pp. 841–864.
- LEVY, A. AND VUKINA, T. "The League Composition Effect in Tournaments with Heterogeneous Players: An Empirical Analysis of Broiler Contracts." *Journal of Labor Economics*, Vol. 22 (2004), pp. 353–377.
- MAIN, B., O'REILLY, C., AND WADE, J. "Top Executive Pay: Tournament or Teamwork?" *Journal of Labor Economics*, Vol. 11 (1993), pp. 606–628.
- MALCOMSON, J.M. "Work Incentives, Hierarchy, and Internal Labor Markets." *Journal of Political Economy*, Vol. 92 (1984), pp. 486–507.
- MCCUE, K. "Promotions and Wage Growth." *Journal of Labor Economics*, Vol. 14 (1996), pp. 175–209.
- MCFADDEN, D. "Conditional Logit Analysis of Qualitative Choice Behavior." In P. Zarembka, ed., *Frontiers in Econometrics*. New York: Academic Press, 1974.
- MCLAUGHLIN, K. "Aspects of Tournament Models: A Survey." In R. Ehrenberg, ed., *Research in Labor Economics*, Vol. 9. Greenwich, Conn.: JAI, 1988.
- MOOKHERJEE, D. "Optimal Incentive Schemes with Many Agents." *Review of Economic Studies*, Vol. 51 (1984), pp. 433–446.
- NALEBUFF, B.J. AND STIGLITZ, J.E. "Prizes and Incentives: Towards a General Theory of Compensation and Competition." *Bell Journal of Economics*, Vol. 14 (1983), pp. 21–43.
- O'KEEFE, M., VISCUSI, K., AND ZECKHAUSER, R.J. "Economic Contests: Comparative Reward Schemes." *Journal of Labor Economics*, Vol. 2 (1984), pp. 27–56.
- O'REILLY, C.A., MAIN, B.G., AND CRYSTAL, G.S. "CEO Compensation as Tournament and Social Comparison: A Tale of Two Theories." *Administrative Science Quarterly*, Vol. 33 (1988), pp. 257–274.
- PRENDERGAST, C. "The Provision of Incentives in Firms." *Journal of Economic Literature*, Vol. 37 (1999), pp. 7–63.
- ROSEN, S. "Authority, Control, and the Distribution of Earnings." *Bell Journal of Economics*, Vol. 13 (1982), pp. 311–323.
- . "Prizes and Incentives in Elimination Tournaments." *American Economic Review*, Vol. 76 (1986), pp. 701–716.
- WALDMAN, M. "Ex Ante Versus Ex Post Optimal Promotion Rules: The Case of Internal Promotion." *Economic Inquiry*, Vol. 41 (2003), pp. 27–41.
- . "Job Assignments, Signalling and Efficiency." *RAND Journal of Economics*, Vol. 15 (1984), pp. 255–270.
- ZABOJNIK, J. AND BERNHARDT, D. "Corporate Tournaments, Human Capital Acquisition, and the Firm Size-Wage Relation." *Review of Economic Studies*, Vol. 68 (2001), pp. 693–716.