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Promotion Tournaments in Market Equilibrium

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Abstract

Standard models of promotion tournaments assume that firms can commit to arbitrary tournament prizes. In this paper, a firm's ability to adjust tournament prizes is constrained by the outside labor market, through the wages other firms are willing to offer to the promoted and unpromoted workers. The paper shows that sufficiently patient firms may be able to retain some control over the tournament prizes through a relational contract, but if the firms are competitive, full efficiency does not obtain in equilibrium even for discount factors arbitrarily close to one. Full efficiency, however, may be feasible in firms with supranormal profits (monopolistic firms). The paper also shows that a minimum wage regulation distorts the workers' investments in human capital by restricting the firms' abilities to design efficient promotion tournaments. A minimum wage thus leads to underinvestment in competitive firms, but could lead to excessive human capital accumulation in monopolistic firms.

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1 Introduction

Evidence on careers and wages within firms suggests that, while pay does grow within job grades, higher wages tend to be attained mainly through job changes. Consequently, incentives in most organizations seem to derive primarily from the prospect of future promotions (Baker, Jensen, and Murphy, 1988; Baker, Gibbs, and Holmström, 1994a,b). Furthermore, a typical firm tends to promote its workers for relative rather than absolute performance (DeVaro, 2006). In sum, most workers appear to be engaged in a promotion tournament—a competition for a limited number of higher level jobs.

From the previous work by Lazear and Rosen (1981), Nalebuff and Stiglitz (1983), Malcomson (1984), Rosen (1986), and others, we have a good understanding of how firms can use promotions and tournaments to motivate employees.[1] However, the prevalent approach in this literature has been to focus on a single firm that (i) is assumed to be able to commit to arbitrary future wages and (ii) does not face ex post competition for its workers. These are restrictive assumptions. First, as stressed for example by Prendergast (1993), firms may have an incentive to renege on their future wage promises, a consideration left out of the standard promotion models, in which the source of the firm's commitment power is usually not specified. Second, most real world firms have to compete for their employees with other firms, which means that the wages they can promise to tournament winners and losers are constrained by the outside labor markets. Specifically, because individuals are free to change employers any time they wish, no firm can afford to pay its employees less than what other firms are willing to offer. Thus, the wage increase a worker receives upon promotion is determined at least as much by the outside labor market as by the firm's desire to provide optimal incentives.[2] This view is consistent with the evidence provided by Baker, Gibbs, and Holmström (1994a) and by Lazear and Oyer (2004). Baker et al note that the firm they study does not employ tournaments as traditionally modeled: "The scheme is not tailored to individual preferences or traits; for instance, there is no adjustment of the contest for common prizes" (p. 953). Similarly, Lazear and Oyer examine detailed personnel records data from Sweden and conclude that "in the

[1] For more recent contributions, see, for example, Fairburn and Malcomson (2001), Moldovanu and Sela (2001), and Hvide (2002).

[2] One early paper that recognizes this point is Gibbs (1995), who studies how incentives from promotions interact with explicit performance contracts.

long run, the wages paid by the typical firm are determined by prevailing wages in the market, not by conditions in the firm."

This paper studies promotion tournaments in which the firms' abilities to design tournament prizes are constrained by outside labor markets and in which the firms' commitment power comes from repeated interaction in the labor market. The starting point is the static framework developed in Zabojnik and Bernhardt (2001), in which promotion tournaments motivate workers to accumulate human capital because a promotion serves as a signal that the worker has a high level of skills. This framework combines the standard tournament model of Lazear and Rosen (1981) with the information view of promotions suggested by Waldman (1984). Following Waldman, I assume that a current employer has private information about the skills of its employees, while the firm's competitors can only infer a worker's skill from observing whether the worker was promoted or not.[3] In particular, the competing firms use Bayesian updating to conclude that the expected productivity of the promoted worker is higher than the expected productivity of those not promoted. Correspondingly, they bid the wage of a promoted worker above the wages of those not promoted and this determines the workers' spot market wages and hence the spot market tournaments. This approach is in line with the empirical evidence in Gibbons and Katz (1991), Acemoglu and Pischke (1998), DeVaro and Waldman (2005), Kahn (2007), and Pinkston (forthcoming), who document that asymmetric information plays an important role in firms' hiring, training, job assignment, and wage setting decisions.[4]

In the static model of Zabojnik and Bernhardt (2001), firms have no control over their tournament prizes and the market determined tournaments are generically inefficient. The static setting, however, is not entirely realistic. As argued by Baker, Gibbons, and Murphy (2002), firms are riddled with relational contracts that govern numerous aspects of their internal labor markets, including promotions. The present paper explicitly examines how relational contracts – i.e., informal agreements supported by reputational concerns in a repeated game setting – allow firms to overcome the constraints imposed on promotion tournaments by the outside labor markets.[5]

[3] Many other theoretical papers have highlighted asymmetric information as a key feature of labour markets, e.g., Lazear (1986), Greenwald (1986), Gibbons and Katz (1991), Bernhardt (1995), and Chang and Wang (1996).

[4] Schönberg (2007) is another recent paper that tests for asymmetric employer learning. She concludes that learning appears to be mostly symmetric, although in the case of college graduates the evidence is also consistent with asymmetric learning.

[5] MacLeod and Malcomson (1988) also model promotions in a repeated game setting in which wages are constrained by an outside labor market. Their focus, however, is on explaining how a hierarchy can arise endogenously in an organization. Also, the workers in MacLeod and Malcomson (1988) are infinitely lived, which makes them easier to

The model yields several insights about the efficiency and the optimal design of promotion tournaments and about the workers' incentives to acquire human capital:

1) First, when relational contracts are feasible, firms have an incentive to use them to commit to future wages that differ from the spot market wages. Furthermore, the wages supported by the relational contracts always weakly exceed the spot market wages. Nevertheless, the equilibrium wages under the relational tournaments could be lower than those under spot market tournaments. This would be the case when spot wages provide incentives that lead to wastefully large investments in human capital, as in the winner-take-all professions described by Frank and Cook (1995). In such winner-take-all industries, relational tournaments optimally mute incentives and therefore suppress average wages.

2) Contrary to the intuition one might have based on the Folk Theorems for repeated games, full efficiency is never achieved in a market equilibrium if firms are perfectly competitive, even if the discount factor is arbitrarily close to one. This also contrasts with the conclusions of the standard tournament models in which firms can commit to arbitrary future wages, such as Lazear and Rosen (1981), Green and Stokey (1983), and Nalebuff and Stiglitz (1983). In these standard models, promotion tournaments can be designed to provide fully efficient incentives, as long as workers are risk neutral. Relational tournaments in competitive firms do not restore full efficiency because firms must earn equilibrium profits in order to be willing to maintain a reputation for paying above spot market wages. Consequently, unlike in static models, perfect competition in labor markets does not lead to maximization of social surplus.

3) More productive firms (e.g., firms with product market power, or monopolistic firms for short) pay higher wages, because they find it easier to sustain reputation for paying wages that exceed the spot market level. Promotion tournaments in monopolistic firms therefore provide more efficient incentives to accumulate human capital than the tournaments in competitive firms. Moreover, unlike competitive firms, monopolistic firms do have an incentive to design fully efficient tournaments when the discount factor is sufficiently large. This may help explain a recent finding by DeVaro and Morita (2008), whose data on British employers show that various types of training are positively correlated with higher profitability.

4) Finally, monopolistic and competitive firms also differ in how their promotion tournaments depend on minimum wage regulations. In particular, when applied to the workers at the bottom of the corporate hierarchy, the model confirms the standard prediction that a wage floor always

motivate than the two period lived workers that populate the current model.

suppresses human capital accumulation in competitive firms. In contrast, a wage floor could lead to excessive human capital investment in monopolistic firms.

Related literature

Apart from the work on promotions and tournaments discussed above and represented by Lazear and Rosen (1981) and Waldman (1984), this paper is related to the literature on human capital investment, especially to the papers that highlight the role of promotions and of asymmetric information. In the former strand are the papers by Carmichael (1983) and Prendergast (1993), as well as Zabojnik and Bernhardt (2001) on which this model builds most directly. Similar to the present paper, both Carmichael (1983) and Prendergast (1993) investigate how firms can use promotions to induce workers to accumulate human capital, but their focus is on firm-specific rather than general human capital, and they assume that firms can fully commit to wages attached to different jobs.

Among the papers that study how asymmetric information in labor markets affects investments in human capital, the closest papers are probably Katz and Ziderman (1990), Waldman (1990), Chang and Wang (1996), and Acemoglu and Pischke (1998). They all share with the present paper the idea that a worker's current employer is better informed about the worker's skills than the outside labor market. Katz and Ziderman (1990) argue that this kind of asymmetric information makes a worker's general training less valuable to an outside firm than to his current employer, who may therefore be willing to share with the worker the cost of the training. Waldman (1990) shows how under spot market contracts asymmetric learning about workers' skills can destroy the workers' incentives to accumulate general human capital and how these incentives can be restored through up-or-out contracts. Chang and Wang (1996) and Acemoglu and Pischke (1998) also derive the result that asymmetric information about a worker's skills leads to underinvestment in human capital and they investigate how the investment depends on worker turnover, on credit constraints (Acemoglu and Pischke) and on the specificity of the training (Chang and Wang). Neither of these papers considers the role of promotions and of the firm's ability to commit to future wages.

Finally, this paper also contributes to the small literature on the relationship between the degree of competition in a firm's product market and the efficiency of incentives within the firm (e.g., Hart, 1983; Schmidt, 1997; and Raith, 2003). First, while the existing literature typically concentrates on the incentives of the firms' managers, the present paper yields insights about the interaction between a firm's market power and the incentives of the employees *below the CEO level*. Second, although the theoretical models in this literature do not yield a clear-cut prediction, most authors appear to conclude that competition in the product market tends to improve incentives within firms. This paper identifies a setting in which product market competition unambiguously worsens incentives within firms. In fact, as already noted, perfectly competitive firms never achieve full efficiency in the present framework.

The paper proceeds as follows. The next section introduces the basic tournament model and the key assumptions. Section 3 provides a preliminary analyses of promotion tournaments for the case of no commitment and for the case of full commitment, which will serve as benchmarks for the subsequent analysis. Section 4 embeds the tournaments in a relational contract setting and derives the main results for the case of markets with unconstrained wages. Section 5 examines the effects of a wage floor on tournament incentives in both competitive and monopolistic firms. Section 6 concludes.

2 The Model

Consider an infinitely lived economy with overlapping generations of risk-neutral workers. In every period, a measure one of young workers are born and a measure one of old workers retire. Each worker lives for two periods. The firms that compete for the workers' services are infinitely lived and risk-neutral, and they differ according to the production technology to which they have access, as detailed below. Time is discrete and all agents in the economy discount the future using a common discount factor $\delta < 1$. As is common in repeated games, but unlike in standard one-period tournament models, this discount factor will play an important role in the subsequent analysis.

Investment in human capital

In contrast to the conventional models in which tournaments motivate workers to provide effort, the focus here will be on the workers' incentives to accumulate costly human capital. The main reason is that promotions have two goals: to motivate workers and to assign workers to the jobs in which they are most productive. While in general these two goals could conflict with each other (Baker, Jensen, and Murphy, 1988), they are more likely to be aligned in the case of human capital investments than in the case of effort, because promoting the highest skilled worker fits well with both goals. In line with this argument, the importance of promotions in motivating human capital accumulation was stressed by Carmichael (1983) and by Prendergast (1993) and has recently received empirical support in Campbell's (2008) study of promotions in a major U.S.-based fast-food retailer. From the modeling perspective, focusing on human capital investment rather than effort choice simplifies things. In particular, unlike effort, human capital has long term productivity effects and therefore affects future wages, which leads to a natural spread between the wages of promoted and unpromoted workers. In contrast, a model based on effort would need some additional ingredient to generate a wage spread. For example, in a related model in which workers compete for promotions through their effort choices, Ghosh and Waldman (2006) assume that there is initial uncertainty about the workers' innate abilities. This introduces into the wage setting process elements of the Holmstrom's (1982) career concerns model and restores Zabojnik and Bernhardt's (2001) result that promotions provide incentives due to their signaling effects.[6] I expect such an alternative model to deliver the same qualitative results as the present model with human capital investments.

Motivated by the prospect of a future promotion, during the first period of their working life the workers invest an amount $h_i \in [0, \bar{h}]$ in accumulation of human capital, at private cost $c(h_i)$. An old worker's productivity then depends upon his accumulated human capital, $\tilde{h}_i = h_i + \epsilon_i$, where ϵ_i are i.i.d. random variables drawn from $[\alpha, \beta]$ according to a common cumulative distribution function $F(.)$ with density $f(.)$ and zero mean. The cost function $c(.)$ is twice continuously differentiable, with $c(0) = 0$, $c'(0) = 0$, and c', $c'' > 0$ for all $h > 0$. The level of human capital possessed by young workers is normalized to zero.

Production technology

In every period, each firm has n training positions for young workers, where n is exogenously given.[7] The firms have an unlimited number of laborer positions in which they can employ old workers, but only one old worker can be employed as manager.[8] A firm's revenue from a young worker is zero in the managerial position and $V\mu$ in a laborer position, where $\mu \geq 0$ is a constant and V is the firm's productivity parameter, which can be high, $V = V_H$, or low, $V = V_L$, $V_H > V_L > 0$. An old worker's productivity does not depend upon his job assignment; it only depends upon his tenure with the firm and his human capital. Specifically, the output of an old worker who has developed human capital $\tilde{h}$ is $V\gamma\tilde{h}$ if the worker remains with his first-period employer and $V\tilde{h}$ if the worker switches employers. The parameter $\gamma > 1$ reflects the fact that part of the worker's

[6] Ghosh and Waldman (2006) apply their model to explain why some firms employ up-or-out contracts, while others use standard promotion practices.

[7] In Zabojnik and Bernhardt (2001), the number of young workers a firm chooses to train is determined endogenously. Since in the present model firm size plays no important role, making n endogenous would only introduce unnecessary complications.

[8] Consequently, the model does not exhibit the promotion distortion whereby firms promote too few workers, which is a focus of much of the literature that builds on Waldman (1984).

human capital is firm specific and is lost if the worker leaves his first-period employer.

Assumption 1. (a) $\gamma \geq \frac{V_H(\bar{h}+\beta)}{V_L(\bar{h}+\alpha)}$; (b) $\alpha \geq -c'^{-1}(\delta V_H g(0)(\beta - \alpha))$.

Under the parameter restrictions of Assumption 1(a), firm specific human capital is sufficiently important so that the prospective employers can never outbid a worker's first period employer. This eliminates from the wage setting process the winner's curse that tends to plague this kind of models. It also implies that no turnover is observed in equilibrium. Assumption 1(b) guarantees that the realization of a worker's human capital is always non-negative. This condition could be easily made less restrictive at the cost of complicating the exposition, by adding a fixed component to each worker's accumulated human capital.

The difference $V_H - V_L$ can be thought of as the degree of market power enjoyed by the V_H-type firms in their respective product markets. The number of the V_H firms is fixed and limited by a measure $\phi < 1/(2n-1)$, while the number of the V_L firms is endogenously determined by free entry conditions. This setup is meant to capture in a reduced form the fact that some firms enjoy persistent competitive advantages, whether due to barriers to entry, due to their superior technology (protected, say, by trade secrets), or due to economies of scale. As we will see, the two types of firms will differ in their abilities to sustain relational contracts.

Information structure

As in Waldman (1984), the human capital developed by a young worker is not directly observed by the market. The actual level of a worker's human capital can only be observed by the worker's first period employer. At the end of a period, each employer promotes the most able worker to the managerial position, a decision that can be observed by competing firms. Based on this observation, the market forms expectations about the productivity of the promoted worker (the winner of the promotion tournament), as well as about the productivity of the unpromoted workers. In addition to observing the firms' promotion decisions, the market (including all workers) can observe the past wage offers made by the firms.

Wage determination

Formal contracts contingent on the level of accumulated human capital or on a worker's output are not feasible. Similarly, long-term wage contracts cannot be written, which means that an old worker's wage is constrained by the competitive wage that would prevail in the spot market at the beginning of a given period. The spot market wage is determined by simultaneous wage offers made at the beginning of each period by both the initial employer and the competing firms, who first observe the old workers' job assignments by their initial employers.[9] Each worker accepts the highest wage offer. A worker accepts an outside offer only if it strictly dominates the offer made by his first period employer. If there are multiple highest outside offers, the worker decides among them randomly. The details of the competition among firms for workers when the wages depend on relational contracts will be described in Section 4.

3 Preliminary analysis: Two benchmarks

This section contains an analysis of two benchmark settings. In the first one, firms have no commitment power regarding the future wages, which means that the tournaments are completely determined by the static, spot market wages. In the second benchmark setting, the firms can costlessly commit to arbitrary second period wages, constrained only by the workers' freedom to quit after learning the outcome of the first period contest and seek employment elsewhere.

3.1 Promotion tournaments with spot market wages

Let $h^*(V)$ be the equilibrium human capital investment by a worker i initially employed in a firm with technology V. Further, let $h^k(V)$ denote the expectation about an old worker's level of human capital that the market forms after observing the worker's job assignment at his initial employer with technology V, where $k = m$ if the worker was promoted to the managerial position and $k = \ell$ if the worker was not promoted and remains a laborer. If the outside market believes that the firm always promotes its best worker, then $h^k(V) = h^*(V) + \epsilon^k$, where $\epsilon^m = E(\epsilon_i \mid i$ best of n contestants) and $\epsilon^\ell = E(\epsilon_i \mid i$ not best of n contestants).[10]

The equilibrium concept used here is that of a Perfect Bayesian Equilibrium and to ensure unique wages, I use Myerson's (1978) Proper Equilibrium refinement. Proposition 1 below characterizes

[9] Some related papers have used a wage setting process in which a worker's current employer is allowed to make a final counter-offer (see, e.g., Greenwald, 1986, and Ghosh and Waldman, 2006). In the present model, this would lead to an extreme case of adverse selection, in which the outside firms would always offer the wage equal to the expected productivity of the lowest ability worker, regardless of the worker's assignment. However, as in Greenwald (1986) and Gibbons and Katz (1991), this adverse selection could be mitigated by assuming some exogenous turnover.

[10] The firm is always willing to promote the worker with the highest realized level of skills because a worker's productivity does not depend on his job assignment. To ensure that the firm strictly prefers to promote the best contestant, it would be enough to assume that instead of $V\gamma\tilde{h}$, a worker's productivity in the managerial job is $(V + \varepsilon)\gamma\tilde{h}$, where ε is arbitrarily small.

the equilibrium spot market wage $W^m(V)$ of an old worker promoted to the managerial position in a firm with technology V, as well as the spot market wage of an unpromoted worker, $W^\ell(V)$.[11]

Proposition 1. *In equilibrium, the spot market tournament is characterized by the second period wages $W^m(V) = V_H h^m(V)$ for the promoted worker and $W^\ell(V) = V_H h^\ell(V)$ for the unpromoted workers.*

Thus, in a one-shot game with no commitment, the tournament is beyond the control of the workers' employer. Instead, the workers compete for prizes that are fully determined by the outside labor market — the prizes are equal to the workers' expected productivities in a (competing) V_H firm, conditional on their job assignments at their first period employer. These wages determine the workers' incentives to accumulate human capital and the efficiency of the promotion tournament.

The wages of young workers, w_y, are determined by the zero profit condition for the V_L firms: $w_y = \mu V_L + \delta(\gamma V_L - V_H)h^*$. These wages do not affect the workers' incentives to accumulate human capital and are only relevant for the analysis of the effects of wage floors in Section 5.

Consider now a worker i who invests h_i in accumulation of human capital and, focusing on a symmetric equilibrium, let h denote the investment level of the other workers in the firm. The probability that worker i wins the promotion is

$$G(x) = \int_{\alpha}^{\beta - x} f(\epsilon)F^{n-1}(\epsilon + x)d\epsilon + \int_{\beta - x}^{\beta} f(\epsilon)d\epsilon,$$

where $x = h_i - h$.[12] Using this probability function, worker i chooses his investment level to maximize his expected payoff

$$\delta[G(x)W^m + (1 - G(x))W^\ell] - c(h_i).$$

Since all workers share the same objective function, in a symmetric pure strategy equilibrium it must be $x = 0$. Using $W^m - W^\ell = V_H(\epsilon^m - \epsilon^\ell)$ and defining $g(0) \equiv \frac{dG(x)}{dx}|_{x=0} = (n-1)\int_\alpha^\beta f^2(\epsilon)F^{n-2}(\epsilon)d\epsilon$, a representative worker's unconstrained first order condition[13] is

$$\delta V_H g(0)(\epsilon^m - \epsilon^\ell) = c'(\hat{h}). \tag{1}$$

[11] All proofs are in the Appendix.

[12] The implicit assumption here is that α and β are finite and $x \geq 0$. If α or β or both were infinite, or if $x < 0$, the expression for $G(x)$ would require a slight modification. However, this has no bearing on the results that follow.

[13] The second order conditions for rank-order tournaments are discussed in Lazear and Rosen (1981) and Nalebuff and Stiglitz (1983). In general, what is needed is that the dispersion in abilities (variance of ϵ) is sufficiently high, so that there is enough noise in the tournament. Otherwise, the workers' reaction functions may be discontinuous and no pure strategy equilibrium may exist.

Each worker's equilibrium level of investment is then given by $h^* = \hat{h}$ if $\hat{h} \leq \bar{h}$ and by $h^* = \bar{h}$ otherwise.

Because the first best level of investment, h_X^{FB}, $X = L, H$, is determined by

$$\delta\gamma V_X = c'(h_X^{FB}), \quad \text{if } h_X^{FB} \leq \bar{h}$$

and by $h_X^{FB} = \bar{h}$ otherwise, it immediately follows that when firms cannot commit to future wages, promotion tournaments generically do not provide efficient incentives. Both under- and over-investment is possible, depending upon the underlying distribution of the noise term ϵ. For example, when $F(\epsilon)$ is uniform, the first order condition (1) reduces to

$$c'(\hat{h}) = \frac{\delta V_H n}{2(n+1)}.$$

In this case, the workers always (weakly) underinvest in accumulation of human capital, because Assumption 1(a) implies that $\frac{nV_H}{2(n+1)} < \gamma V_L$ for all n. On the other hand, when $n = 2$ and $F(\epsilon)$ is normal with zero mean and variance σ^2, the first order condition (1) becomes

$$c'(\hat{h}) = \frac{1}{4\sigma^2\sqrt{\pi}} \int_0^\infty \epsilon e^{-\epsilon^2/4\sigma^2} d\epsilon.$$

Because the right hand side approaches infinity as $\sigma^2 \to 0$[14] whereas the efficient investment is independent of σ^2, the workers overinvest if σ^2 is sufficiently small.[15,16]

While overinvestment is a theoretical possibility, underinvestment appears most descriptive.[17] In the interest of reducing the number of cases that need to be analyzed, I will therefore focus on the case where the investment incentives provided by the spot market tournaments are too weak in both types of firms, that is, $h^* < h_L^{FB}$. In terms of parameter values, this requires

Assumption 2. $\gamma > \frac{V_H}{V_L} g(0)(\epsilon^m - \epsilon^\ell)$.

Under the above assumption (which for some distributions, including the uniform distribution, is implied by Assumption 1(a)), both types of firms would like to increase the wage of the *promoted*

[14] To see this, let $z \equiv \epsilon/2\sigma$. The right hand side can then be written as M/σ, where $M \equiv \frac{1}{2\sqrt{\pi}} \int_0^\infty z e^{-z^2} dz$ is a constant.

[15] Related to the discussion of the second order conditions in footnote 15, note that σ^2 cannot be too small. Otherwise, overinvestment would be so severe that the workers would prefer not to invest at all, in which case a symmetric pure strategy equilibrium would not exist.

[16] The normal distribution violates Assumption 1. However, for σ^2 small, a truncation on a finite interval $[\alpha, \beta]$ can provide a reasonably good approximation and also satisfy the assumption.

[17] For example, Rosen (1996) has argued that there are few labor markets that seem to be plagued by a wastefully fierce competition.

worker above the spot market level, thus increasing the promotion premium and strengthening the incentives provided by the tournament. The analysis of the case where the spot market tournaments in both types of firms provide incentives that are stronger than efficient would be similar, except that the firms would now want to commit to a higher-than-the-market wage for the *unpromoted* workers.[18] This would reduce the promotion premium and weaken the incentives provided by the tournaments, making them more efficient.

3.2 Promotion tournaments under full commitment

For the second benchmark, suppose now the firms have full commitment power, i.e., they can specify the wages of old workers in binding long-term (two-period) contracts. Clearly, even with commitment power, no firm can afford to offer a future wage that is lower than the spot market wage determined in Proposition 1, because the workers always have the option of leaving their current employer for another firm. This simple observation reveals quite a lot about the economics of the model and leads to the first insight discussed in the Introduction: If a firm is able to commit to future wages and decides to deviate from the spot market wage, it offers a wage that *exceeds* the spot market level.

It is straightforward that despite the market imposed lower bound on the wages they can offer, full commitment leads firms to provide efficient tournaments. The argument follows the standard surplus maximization logic — any increase in total surplus allows a firm to improve its profit by lowering the wages of young workers, while holding constant the workers' expected utilities. Thus, under full commitment, an old worker will receive the spot market wage $W^{\ell}(V)$ in the laborer position and the wage $W^{FB}(V) > W^{m}(V)$ in the managerial position, where $W^{FB}(V)$ is such that the workers invest efficiently, i.e., $h_L^* = h_L^{FB}$ and $h_H^* = h_H^{FB}$.

4 The promotion tournament as a relational contract

The above benchmark cases highlight the key role of commitment power, stressed by Prendergast (1993), Fairburn and Malcomson (2001), and others, for the efficiency results obtained in the previous literature on promotion tournaments: Once the workers have invested, the firms no longer

[18] This would be the case when $\gamma < g(0)(\epsilon^m - \epsilon^{\ell})$. There is a third case, which applies when $\frac{V_H}{V_L} g(0)(\epsilon^m - \epsilon^{\ell}) \geq \gamma \geq g(0)(\epsilon^m - \epsilon^{\ell})$. In this case, the V_H firms would like to strengthen and the V_L firms would like to mute the incentives provided by their respective tournaments. These cases may require that Assumption 1(a) is relaxed.

have an incentive to pay them more than the spot market wages. But as we have seen above, spot market tournaments are generically inefficient. The firms would therefore like to be able to commit to tournament prizes that exceed the spot market wages. Moreover, if commitment were costless, each firm would design its tournament so as to maximize the surplus from the employment relationship, which requires that the workers invest at the first best level. The focus of this section will be on investigating under what conditions and to what extent this is feasible when the commitment works through repeated interaction. It will turn out that there is a fundamental difference between how this commitment mechanism works in the low technology (V_L) and in the high technology (V_H) firms.

4.1 Relational tournaments in competitive firms

Consider a V_L firm that promises to pay its managers an amount D_L above the spot market wage. This promise can be credible only if the firm has something to lose by breaking it, that is, in equilibrium the firm has to make a positive profit. Denote a V_L firm's per period profit from a relational contract as π_L^R. I will assume that if the firm reneges on its promise and does not pay the wage premium D_L to the promoted worker, the relationship between the firm and its workers reverts to spot market contracting from that point on.[19] This yields the following incentive compatibility constraint for the V_L firms:

$$D_L \leq \frac{\delta \pi_L^R}{1-\delta}. \tag{IC$_L$}$$

Constraint (IC$_L$) will determine the set of the Perfect Public Equilibria of the repeated game (PPE) of this game.

It is a standard result in static models of competitive labor markets that free entry of firms forces them to maximize the workers' lifetime utilities. As is well known, however, repeated games can generate multiple perfect public equilibria. Following MacLeod and Malcomson (1988), Che and Yoo (2001), and others, I will focus on an equilibrium that is the equivalent of the static free

[19] This is a fairly standard assumption in models of relational contracts (see, e.g. Baker, Gibbons, and Murphy, 1994). In general, a more severe punishment might work better. In the present setting, the worst possible punishment that the workers can inflict on a firm is that, from that period on, no worker ever accepts an employment offer from this firm. However, in the case of a V_H firm, this punishment strategy may not be individually rational for the workers, because a V_H firm, being more profitable than a V_L firm, might be able to offer its young workers wages so high that even under spot contracting the workers' lifetime expected utility exceeds what they would get in a V_L firm under a relational contract. In the case of a V_L firm, the above punishment strategy is equivalent to reverting to spot contracting – in either case, the firm earns zero profit.

entry equilibrium, i.e. the PPE in which the V_L firms design their contracts so as to maximize the workers' utilities. I will discuss later the role of this equilibrium selection concept.

In the equilibrium in which the V_L firms attempt to maximize the workers' utilities, condition (IC_L) must hold with equality. Unlike in the static models, however, the firms earn profits, but only enough to have sufficient incentives to abide with the relational contracts. Denote as h_L^R the equilibrium level of human capital investment in the V_L firms when wages are determined by PPE of relational contracts. The efficiency of investment in these competitive firms is described in Proposition 2.

Proposition 2. *There exist δ^* and δ^{**} from $(0,1)$ such that the equilibrium level of investment in the V_L firms is characterized as follows:*

(i) If $\delta \leq \delta^*$, then $h_L^R = h^*$, i.e., the tournament prizes in the V_L firms are equal to the spot market wages and the workers' human capital investment in these firms is given by (1).

(ii) If $\delta > \delta^{**}$, then $h_L^R > h^*$, i.e., the firms offer relational contracts in which the workers in the V_L firms invest more efficiently than under spot market contracts.

(iii) However, $h_L^R < h_L^{FB}$ for all $\delta < 1$, that is, full efficiency is never achieved in the V_L firms.

As one might expect based on the standard folk theorems for repeated games, relational contracts allow firms to improve upon the efficiency of corporate tournaments. However, they never lead to full efficiency, which is the main result of this section. The logic behind Proposition 2 is as follows. As indicated in the discussion preceding the proposition, in any equilibrium in which a firm pays its managers more than the spot market wage, this firm must earn a positive expected profit in every period, in order to have an incentive not to renege on its wage promises. Knowing this, young workers are willing to accept a first-period wage that is less than their marginal product, because they realize that this will help the firm to maintain a relational contract that improves the efficiency of their human capital investment and they will capture this efficiency improvement through higher second period wages.

Thus, a V_L firm is able both to credibly commit to an above-spot market managerial wage and to attract young workers only if the efficiency gain from stronger investment incentives, measured by $S_L = \delta V\gamma h_L^R - c(h_L^R) - [\delta V\gamma h^* - c(h^*)]$, is such that (a) the workers' lifetime expected utilities are at least as high as what they would get in a firm who pays the spot market wages, while at the same time, (b) the present value of the firm's future profits is sufficiently high in every period to satisfy the firm's incentive compatibility constraint (IC_L). These two conditions can hold simultaneously only if the firm is sufficiently patient, i.e., δ is close to one, which yields parts (i) and (ii) in the proposition.

To see what drives the result in part (iii), note that stronger incentives require a higher managerial wage, which in turn means that the firm must receive more profit if its incentive compatibility constraint is to be satisfied. This implies that the residual surplus, which accrues to the workers, increases at a lower rate than the total surplus and therefore is maximized at a lower level of investment than the first best level. Because labor market competition forces the firms to offer the relational contracts that maximize the surplus received by the workers, the V_L firms choose this lower investment level.

In addition to the above main result, the proposition says that a higher discount rate will lead to higher wages. For example, to the extent that a firm's financial situation and its ease of access to external funds can proxy for the firm's perceived interest rate, the model predicts higher wages and more human capital investment in financially sound firms and in firms with easy access to external funds. On the other hand, firms that face the threat of bankruptcy (and therefore heavily discount the future relationships with their workers) should pay spot market wages equal to the workers' average productivities.

Finally, it is worth noting here that the firms with relational tournaments are consistently overpaying their managers, as they pay them wages greater than the managers' average productivity. Contrary to the conclusions of the theories of executive compensation that stress managerial power (e.g., Bebchuk, Fried, and Walker, 2002), this overpayment serves to improve efficiency.

The current paper's focus on an equilibrium that maximizes the workers' utilities seems natural in the present setting and, as discussed above, follows both the conventional approach in static models as well as the equilibrium selection approach in previous work on relational contracts. However, the existence of other perfect public equilibria makes it possible to better highlight the forces behind part (iii) of Proposition 2. In particular, the next proposition demonstrates that the failure to achieve full efficiency in the market equilibrium is *not* driven by the usual reason that the combined surplus is too small to sustain a relational contract. Rather, the inefficiency stems from the requirement that free entry forces the firms to maximize the workers' lifetime utilities. Without this requirement, full efficiency would always be feasible for sufficiently large discount factors.

Proposition 3. *Suppose the firms do not maximize the workers' utilities. Then there is a* $\hat{\delta} \in$

$(0,1)$ *such that for all* $\delta > \hat{\delta}$, *there exists a PPE in which the workers in the* V_L *firms invest at the first best level, i.e.,* $h_L^R = h_L^{FB}$.

4.2 Relational tournaments in high technology firms

When the workers' wages are determined by the spot labor markets, the V_L firms earn zero expected profit, due to free entry. On the other hand, the V_H firms' superior technology commands a rent – because under spot market tournaments the workers in both types of firms invest equally, each V_H firm makes a per period expected profit of $\mu n(V_H - V_L) + \gamma h^* n(V_H - V_L) > 0$. This section shows that due to their greater profitability, the V_H firms will have both the ability and the incentive to design more efficient promotion tournaments than the competitive, V_L firms.

Their profitability provides the V_H firms with an advantage when competing for workers with the V_L firms. Specifically, they do not need to design their contracts so as to maximize the workers' expected lifetime utilities; they only need to offer the utility the workers would get in a V_L firm. However, as in the case of the V_L firms, the V_H firms must have an incentive to abide with the relational contract. In particular, let π_H^S be the per-period profit made by a V_H firm that offers a tournament with the spot market wages. Note that this profit could be zero if the V_L firms' relational contracts are relatively efficient, because in such a case a V_H firm offering the spot market wages might not be able to attract any workers. Similarly, let π_H^R be the profit a V_H firm makes under a relational contract in which the wage of the promoted worker exceeds the spot market wage by an amount D_H. A V_H firm's incentive compatibility constraint can then be written as

$$D_H \leq \frac{\delta(\pi_H^R - \pi_H^S)}{1-\delta}. \tag{IC$_H$}$$

Denote as U_L the lifetime expected utility of a young worker in a V_L firm and let w_H be the first period wage paid by the V_H firms. The V_H firms set the workers' wages in the relational contract to maximize

$$\mu V_H - w_H + \delta(\gamma - 1)V_H h(D_H) - \delta D_H/n,$$

subject to

$$\delta D_H g(0) + \delta V_H g(0)(\epsilon^m - \epsilon^\ell) = c'(h(D_H)), \tag{4}$$

$$w_H + \delta V_H h(D_H) + \delta D_H/n - c(h(D_H)) \geq U_L, \tag{5}$$

and subject to (IC$_H$). Here, (4) is the workers' first order condition for human capital accumulation under the relational contract in a V_H firm (same as in a V_L firm) and (5) is the workers' individual rationality constraint.

Let h_H^R be the level of human capital investment corresponding to the relational promotion tournament that solves the above program. This investment level is characterized as follows.

Proposition 4.

(i) In the high technology (V_H) firms, relational contracts are feasible for a strictly greater set of discount factors δ than in the competitive (V_L) firms.

(ii) For any δ, $h_H^{FB} \geq h_H^R \geq h_L^R$. If $h_L^R > h^*$, then $h_H^R > h_L^R$. That is, the high technology firms provide stronger investment incentives than competitive firms. They provide strictly stronger incentives whenever the competitive firms are able to sustain a relational contract that improves upon spot market contracting.

(iii) There exists a $\delta^{FB} < 1$ such that $h_H^R = h_H^{FB}$ for all $\delta \geq \delta^{FB}$. That is, if they are sufficiently patient, the high technology firms offer relational contracts in which the workers' investment incentives are fully efficient.

Thus, technological efficiency breeds incentive efficiency: Proposition 4 says that profitable firms have both the ability and the motivation to provide at least weakly stronger incentives for human capital accumulation than competitive firms. The greater *ability* of the V_H firms to provide stronger incentives stems from their greater productivity, which implies that any given increase in the workers' investments generates more surplus in a V_H firm than in a V_L firm. Since the amount of surplus is critical for a firm's ability to sustain a relational contract, the V_H firms are able to implement relational contracts for a greater set of parameter values.

To see why the V_H firms have an *incentive* to design more efficient tournaments than the competitive firms, recall that the reason why the V_L firms never offer fully efficient tournaments, no matter how patient they are, is that these firms need to share the additional surplus with their workers, balancing the desire to attract the workers with the need to make sure that the relational contract is incentive compatible. The V_H firms do not face the former constraint: being more productive, they can always outbid the V_L firms in the labor market and they get to keep any additional surplus they create by improving the efficiency of their tournaments. Therefore, they behave as residual claimants when designing their relational contracts and their sole binding constraint is their incentive compatibility constraint which determines which relational contracts are feasible. Thus, a V_H firm always has an incentive to offer the most efficient contract that can be sustained. When the interest rate is low, fully efficient tournaments become feasible and, unlike the competitive firms, the V_H firms adopt them.

The main empirical implication of the above results is that both wages and investment in human capital should be related to a firm's profitability/market power and to its perceived interest rate. In particular, in normal labor markets (i.e., in markets in which the winner-take-all aspect of the spot market competition does not lead to excessive incentives), more profitable firms should pay higher wages, which is a well established empirical regularity (Dickens and Katz, 1987; Krueger and Summers, 1987). Moreover, this should be true mainly for managerial positions, again in accord with the available evidence. More profitable firms should also provide their workers with stronger incentives to accumulate human capital. This is consistent with the evidence in DeVaro and Morita (2008), who examine data from a large-scale cross section survey of British employers and find that higher levels of various types of training are associated with higher profitability. Similarly, firms with easy access to external funds and financially sound firms (which both proxy for low perceived interest rates) should pay higher wages and provide stronger investment incentives. Finally, firms that face high interest rates (as proxied, for example, by the threat of bankruptcy), and especially those with little market power in their product markets, should pay spot market wages equal to the workers' average productivities.

As mentioned in the Introduction, the results of Propositions 2 and 4 also contribute to the literature on the relationship between product market competition and the efficiency of incentives within firms. The past debate on the topic has focused mainly on the effects of product market competition on the incentives of the firms' top managers and tended to favor the conclusion that product market competition leads to better managerial incentives.[20] In the present framework, product market competition affects the incentives of junior employees rather than those of the top managers; moreover, the effect of product market competition on incentives is unambiguously negative.

[20] More competitive markets provide better information about the managers' actions, which allows the firms to provide more efficient incentives (Hart, 1983). A more fierce competition also means that a firm with an under-performing manager is more likely to go bankrupt, which again strengthens the manager's incentives (Schmidt, 1997). On the other hand, a firm's profits are smaller in a more competitive industry, which can decrease the marginal value of the manager's effort and hence weaken his incentives (Schmidt, 1997; Raith, 2003).

5 The effects of minimum wages

Most labor markets in developed economies have institutional features, such as minimum wage legislation and union contracts, that effectively impose a floor on feasible wages. In this section, I apply the model developed in the first part of the paper to the workers at the lowest levels of the hierarchy, with the aim of informing the debate about the effects of such wage floors on the workers' incentives to invest in human capital. Note that although much of the literature on tournaments focuses on upper level managers, the theory applies equally well to the workers at the bottom rang of the corporate hierarchy. For example, DeVaro (2006) provides empirical support for the tournament theory using a data set that includes low paid production workers and laborers, such as handlers, equipment cleaners, and helpers.

As in the standard labor theory (Rosen, 1972), a wage floor in the present model restricts the firms' abilities to extract surplus from their young workers. In Rosen's argument, this has a negative effect on human capital investment because it prevents the workers from compensating the firm for the costs of training; in effect, the wage floor makes it harder for the firms to "sell learning opportunities" to the workers.

In the present model, workers always finance their own training. Instead, a wage floor distorts the prizes in promotion tournaments. From the empirical point of view, the implication of this difference is that a wage floor may have important effects on human capital accumulation even if this is not reflected in the amount of formal training provided by the firms. Moreover, the results of the previous section suggest that the effects of a wage floor should depend on the market conditions in which the firms operate. Indeed, the analysis below shows that in competitive firms, a wage floor always reduces human capital accumulation. On the other hand, in monopolistic firms, a wage floor can lead to excessive human capital investment, in stark contrast to the standard conclusions.

To introduce a wage floor into the present framework, assume that the firms have to pay at least the wage $\bar{w}$. I assume that $\bar{w}$ is lower than the equilibrium wages under the spot market tournament but constrains the wages of young workers under the full commitment (first best) tournament investigated in Section 3.2.[21] Denote as w_L^{FB} (w_H^{FB}) the wage of young workers in the V_L (V_H) firms under the full commitment tournament and recall that the young workers' wage under the spot market tournament was denoted as w_y. The wage floor constraint is then written

[21] If the wage floor constraint were also binding under the spot market tournament, then the V_L firms would make negative profits and would be forced to exit.

as follows:

ASSUMPTION 3. $w_L^{FB} < \bar{w} < w_y$.

5.1 The effects of a wage floor on competitive firms

Consider first the V_L firms in the static setting with full commitment. By imposing a lower bound on the wages of young workers, a wage floor hampers the firms' ability to recoup in the first period their second period losses due to managerial wages that exceed the spot market wage. When the wage of young workers is w, a V_L firm's expected profit from a given worker is

$$\pi_L(D, w) = \mu V_L - w + \delta h_D(\gamma V_L - V_H) - \delta D/n,$$

where, as before, $h_D \equiv h(D)$ is given by the first order condition (2) and represents the investment level in a V_L firm when the managerial wage is $W^m + D$ and when the wage of a laborer is W^ℓ. Labor market competition forces the V_L firms to choose the wage premium D that maximizes the workers' expected lifetime utilities

$$u(D, w) = w + \delta V_H h_D + \delta D/n - c(h_D),$$

subject to the break-even condition $\pi_L(D, \bar{w}) \geq 0$ and subject to the wage floor constraint $w \geq \bar{w}$. Assuming that both $\pi_L(D, w)$ and $u(D, w)$ are quasi-concave in D, the solution to this problem is characterized by the following proposition.

Proposition 5. *Suppose firms can commit to future wages. Then a wage floor constrains the equilibrium investment in the V_L firms, $h_L^*(\bar{w})$, to be lower than the first best level h_L^{FB}. Moreover, $h_L^*(\bar{w})$ strictly decreases in $\bar{w}$.*

Thus, despite full commitment, a wage floor makes the first best level of investment infeasible in the V_L firms. This further curbs the workers' incentives and distorts their human capital investments away from the efficient level. The above result assumes full commitment, but it should be clear from the analysis in the previous section that when commitment comes from repeated interaction, the firms' incentives to design efficient tournaments are even weaker than under full commitment.

Note that the decreased level of human capital accumulation decreases the productivity of both laborers and managers and therefore leads to lower wages, as well as to a smaller difference between managerial wages and the wages of laborers. This is consistent with the observation that the differences between managerial wages and the wages of lower level workers tend to be smaller, while minimum wages tend to be higher, in the countries of continental Europe than in the United Sates.

5.2 The effects of a wage floor on high technology firms

The next two results show that in the V_H firms, a wage floor can either suppress or encourage human capital investment.

Proposition 6. *Suppose firms can commit to future wages. There exists a $V_H^* > V_L$ such that for all $V_H \in [V_L, V_H^*]$, a wage floor causes the equilibrium investment to be the same in the V_H firms as in the V_L firms: $h_H^*(\bar{w}) = h_L^*(\bar{w})$.*

Proposition 6 demonstrates that a wage floor can suppress human capital investment also in the high technology firms — in fact, it can eliminate any difference that would be observed in the absence of the constraint between the investments in the V_L and in the V_H firms. The logic behind this result is as follows: As demonstrated by Proposition 5, even under perfect commitment, a wage floor prevents the V_L firms from providing fully efficient tournaments, because it constrains their ability to recoup through lower first period wages the second period losses due to an above market prize for the tournament winner. This means that in equilibrium, a V_L firm's profit must be strictly decreasing in the managerial wage, because otherwise the firm would have an incentive to improve efficiency by increasing the managerial wage. But if an increase in the managerial wage would strictly lower the profit of a V_L firm, this must also be true for a V_H firm if V_H is only slightly higher than V_L. Consequently, when V_H is close to V_L, the V_H firms have no incentive to offer stronger tournaments than the V_L firms. As before, because this result was obtained under the assumption of full commitment, repeated interaction would not help here.

Proposition 7. *Suppose firms can commit to future wages and let $c''(h) = C$, where C is a constant. Then for any $V_H > V_L$ there exist C^* and C^{**}, $0 < C^* < C^{**}$, such that when $C \in (C^*, C^{**})$, a wage floor causes the equilibrium investment in the high technology firms to exceed the first best level: $h_H^*(\bar{w}) > h_H^{FB}$. This is also true when commitment comes from repeated interaction, as long as δ is sufficiently large.*

The above result shows that, contrary to the received wisdom, a minimum wage can encourage human capital accumulation, as long as the firms are not perfectly competitive. This, however, does not necessarily mean that wage floors improve welfare, because the resulting human capital investment could be inefficiently high.

The intuition behind Proposition 7 is that when the workers' human capital investment is sufficiently responsive to more powerful tournaments (i.e., C is relatively small), an increase in the managerial wage above the first best level induces a relatively large increase in the workers' productivities. In the absence of a wage floor, the firms would not want to induce investment in excess of the first best level, because they would ultimately bear the cost of this investment through the workers' binding participation constraints. However, a wage floor makes it impossible for the V_H firms to always hold their workers down to their reservation utilities. Consequently, the firms do not internalize all of the investment costs — they can induce more investment without compensating the workers for the additional investment costs and they find it optimal to do so when a small increase in the managerial wage induces a large increase in the workers' investments.

6 Conclusion

Internal promotions to scarce managerial positions are a salient feature of hierarchical organizations. This paper has argued that the standard theory of promotion tournaments, in which a firm is assumed to have unlimited commitment power when designing the tournament prizes, has important limitations. Firms compete for their employees with other firms and therefore cannot promise arbitrary wages — not only do the wages have to induce ex ante participation, as in the standard models, but also ex post participation, because unpromoted workers could simply quit rather than toil on under the low wages offered to the tournament losers. This in turn constrains the wages that the firms can offer to the tournament winners.

Some of the firms' ability to control the tournament prizes is regained when firms are long lived and build a reputation for paying wages that are greater than the spot market wage. This ability, however, depends critically on the market structure in which the firms operate. While profitable (monopolistic) firms design fully efficient tournaments when they are sufficiently patient, competitive firms never achieve full efficiency. Thus, in the present framework, technological efficiency breeds incentive efficiency. Similarly, competitive and monopolistic firms differ in how the human capital investment induced by their tournaments depends on minimum wage regulations and other wage floors. While a wage floor always suppresses human capital investment in competitive firms, it could lead to excessive human capital accumulation in monopolistic firms.

More generally, the fundamental difference between the view of promotion tournaments here and in the standard theory is that in the present paper promotions provide incentives "accidentally." Promoted workers are perceived by the labor market to be of higher productivity than unpromoted workers and therefore command higher wages. Thus, whether firms intend it or not, promotions are valued by the workers and motivate them to improve their productivity. The firms may try and shape the tournaments away from the labor market default, but this may not always be possible. At least to some extent, the tournament and the resulting investment in human capital will always bear the imprint of the firm's technology and of the market conditions in which the firm operates, such as the degree of product and labor market competition, market interest rates, the firm's access to credit, and so on. This could be exploited in empirical tests and it also suggests an interesting direction for future research: As pointed out by Gibbs (1995), if firms cannot rely on promotions to always provide efficient incentives, they may need to complement them by additional performance contracts (as many firms do). This establishes a link between market conditions and formal incentive contracts that has not been sufficiently explored in the existing literature.

Appendix

Proof of Proposition 1: The proof follows similar logic as the proof of Proposition 1 in Zabojnik and Bernhardt (2001). Consider a firm with technology V and suppose that the outside firms expect this firms' workers to choose an investment level $h(V)$. If a worker stays with his initial employer, his productivity is at least $V\gamma(h(V)+\alpha)$. If the worker changes employers, then his expected productivity is at most equal to $V_H(h(V)+\epsilon^m)$, which is less than $V\gamma(h(V)+\alpha)$, by Assumption 1(a). The worker's first period employer can therefore always outbid any outside firm, which means that all the workers remain with their first period employers.

Now consider the wage bids. A promoted worker's expected productivity in an outside firm with technology V_H is equal to $V_H(h(V)+\epsilon^m)$. Thus, such an outside firm is willing to bid $V_H(h(V)+\epsilon^m)$ if it expects the incumbent firm to also bid this amount. For the incumbent firm, in turn, it is the best response to bid $V_H(h(V)+\epsilon^m)$ if it expects all outside V_H firms to bid this much, because this is the minimum bid that allows it to retain the worker (and earn positive profit from him). The same argument applies to the wage bids for an unpromoted worker. Therefore, the wage offers that are equal to the workers' expected productivities in V_H firms, i.e., $W^m(V) = V_H h^m(V)$ and $W^\ell(V) = V_H h^\ell(V)$, constitute a Perfect Bayesian Equilibrium.

To see that this equilibrium is the unique proper equilibrium, notice first that it cannot be that $W^m(V) < V_H h^m(V)$ or $W^\ell(V) < V_H h^\ell(V)$. Otherwise, an outside V_H firm would find it profitable to deviate and offer a slightly higher wage, which would allow this firm to attract the worker and make positive profit. Now suppose that both the incumbent and the outside V_H firms play totally mixed strategy profiles when bidding for the promoted worker. Then with a positive probability, each outside firm outbids all the other firms (including the incumbent) and hires the promoted worker at a wage strictly greater than the worker's expected productivity $V_H h^m(V)$. Thus, each outside firm has an incentive to deviate to a strategy that places zero probability on wages greater than $V_H h^m(V)$. This means that no wage greater than $V_H h^m(V)$ can be a proper equilibrium, i.e. a limit point of a sequence of equilibria in totally mixed strategies. The argument for the wage of an unpromoted worker follows the same steps. ■

Proof of Proposition 2: (i) Consider a V_L firm offering a managerial wage $W^m + D$, where $D \geq 0$ and W^m is given by Proposition 1, and let $h_D \equiv h(D)$ be the equilibrium level of human capital investment in this firm when the wage of unpromoted workers is W^ℓ (again given by Proposition

1). The investment level h_D is thus given by the first order condition

$$\delta D g(0) + \delta V_H g(0)(\epsilon^m - \epsilon^\ell) = c'(h_D). \tag{2}$$

Note that $h_D = h^*$ when $D = 0$ and that $\frac{\partial h_D}{\partial D} > 0$.

Now, let $\hat{\pi}_L \equiv \hat{\pi}_L(\delta, D)$ be the minimum per period profit such that the firm's incentive compatibility condition (IC$_L$) is satisfied for a given D, i.e.,

$$\hat{\pi}_L = \frac{(1-\delta)D}{\delta}, \tag{IC$'_L$}$$

and let $\hat{w}_L \equiv \hat{\pi}_L(\delta, D)$ be the young workers' wage that in expectation allows the firm to earn $\hat{\pi}_L$ per period if it does not deviate from the promised wages, i.e., $\hat{w}_L = \mu V_L - \delta \frac{D}{n} - \frac{\hat{\pi}_L}{n}$. Next, denote by $S_L \equiv S_L(\delta, D)$ the expected increase in surplus *per worker* that is due to the stronger investment incentives induced by the higher managerial wage:

$$S_L \equiv \delta\gamma V_L h_D - c(h_D) - [\delta\gamma V_L h^* - c(h^*)].$$

The amount $\hat{\pi}_L/n$ of this efficiency increase must go to the firm in order to satisfy its incentive compatibility condition (IC$_L$). The wage $W^m + D$ can then be sustained as part of an equilibrium if and only if

$$S_L - \hat{\pi}_L/n \geq 0.$$

As will be shown below, if the above condition is satisfied, one can construct perfect public equilibrium strategies that support the wage $W^m + D$, while if the condition does not hold, the workers prefer working for the firms that pay the spot market wages W^m and W^ℓ (due to free entry, such firms are readily available). After substituting for $\hat{\pi}_L$ from (IC$'_L$), the above condition becomes

$$S_L - \frac{D(1-\delta)}{n\delta} \geq 0. \tag{3}$$

Now, $\lim_{\delta\to 0} h_D = \lim_{\delta \to 0} h^* = 0$, so that as $\delta \to 0$, the left hand side of (3) approaches $-\infty$ for any $D > 0$. Consequently, there must exist a $\delta^* > 0$ such that (3) cannot hold when $\delta \leq \delta^*$. For these parameter values, there cannot exist a relational contract in which a V_L firm pays other than the spot market wages. This proves part (i) of the proposition.

(ii) and (iii). Let δ go to 1. Then (3) becomes $\gamma V_L h_D - c(h_D) - [\gamma V_L h^* - c(h^*)] \geq 0$. Because $h^* < h_L^{FB}$ and $\gamma V_L h - c(h)$ is concave in h and maximized at h_L^{FB}, this inequality holds for all $h \in [h^*, h^+]$, where $h^+ > h_L^{FB}$. Hence, there exists a $\delta^{**} < 1$ such that (3) holds for all $\delta \geq \delta^{**}$. A positive $D(\delta)$ can therefore be supported by a repeated game equilibrium for any $\delta \geq \delta^{**}$, which means that $h_L^R > h^*$, as claimed in part (ii).

Now, competition for workers forces the V_L firms to choose D so as to maximize the workers' expected lifetime utilities. This is equivalent to maximizing $S_L - \hat{\pi}_L/n = \delta\gamma V_L h_D - c(h_D) - [\delta\gamma V_L h^* - c(h^*)] - \hat{\pi}_L/n$, which is transferred to the workers in the form of higher managerial wages. The first order condition for this maximization problem yields

$$[\delta V_L \gamma - c'(h_D)]\frac{\partial h_D}{\partial D} - \frac{(1-\delta)}{\delta n} = 0,$$

which implies $\delta V_L \gamma - c'(h_D) > 0$ because $\frac{\partial h_D}{\partial D} > 0$. Thus, $h_L^R < h_L^{FB}$, as claimed in part (iii).

Let D_L^R denote the managerial wage increase that induces the workers to invest h_L^R in accumulation of human capital. To complete the proof of parts (ii) and (iii), it remains to specify the firm's and the workers' strategies that sustain D_L^R and h_L^R as part of a perfect public equilibrium when $\delta \geq \delta^{**}$. Consider the following strategies:

Firm: Offer the wage W^ℓ to unpromoted old workers, $W^m + D_L^R$ to the promoted worker, and $\hat{w}_L < \mu V$ to young workers, where $\hat{w}_L$ is as constructed above. Continue to pay these wages as long as they were also paid in all previous periods. If in some period t the firm deviates by offering a first period wage $w \neq \hat{w}_L$ or by paying its tournament winner other than $W^m + D_L^R$, switch from period $t+1$ on to offering $w_L = \mu V_L$ to young workers and W^ℓ and W^m to old workers.

Workers: Accept no first period wage $w < \mu V$, unless it is equal to $\hat{w}_L$. If some worker in a period t deviates, switch from period $t+1$ on to not accepting any wage lower than μV. Invest h_L^R as given by (2).

I will now show that the above strategies constitute a perfect public equilibrium of the repeated game, that is, given that other players stick to their strategies, no player has an incentive to deviate for one period and then return back to the original strategy.

Firms: If the firm follows the equilibrium strategy, it gets expected profit equal to $\frac{\hat{\pi}_L}{1-\delta} > 0$. If the firm deviates by offering a higher first period wage, it gets an expected profit lower than $\hat{\pi}_L < \frac{\hat{\pi}_L}{1-\delta}$ this period and zero in all subsequent periods. Similarly, cheating the tournament winner is not profitable by construction of the wage $\hat{w}_L$ and of the profit $\hat{\pi}_L$. If a firm deviates in the punishment phase by offering a first period wage less than μV, it does not attract any workers, so its profit is zero as when it does not deviate. If it offers more than μV, it earns a negative expected profit. Thus, the firm has no incentive to deviate from the proposed strategy.

Workers: Suppose that in period t, a young worker accepts a first period wage $w' \neq \hat{w}_L$ such that $w' < \mu V$. Given that the firm follows its equilibrium strategy and switches to offering spot market wages from period $t+1$ on, this worker's expected lifetime utility is $w' + \delta\gamma V_L h^* - c(h^*) < \mu V_L + \delta\gamma V_L h^* - c(h^*)$, which makes the worker worse off than if he had accepted a job in a firm that only pays spot market wages. In the punishment phase, suppose a young worker accepts a wage $w' < \mu V$. Because this does not affect his second period expected wage (again, given the firm's strategy), he is worse off than if he rejected w' and accepted μV from some other firm. ■

Proof of Proposition 3: From the proof of Proposition 2, for any $h \in [h^*, h^+]$, where $h^+ > h_L^{FB}$, there exists a $\delta^{**} < 1$ such that the firms' (IC$_L$) constraints are satisfied for all $\delta \geq \delta^{**}$. Then $\hat{\delta}$ is the δ^{**} that corresponds to $h = h_L^{FB}$. To see that for $\delta \geq \hat{\delta}$, h_L^{FB} can be supported by a *PPE* of the repeated game, let D_L^{FB} denote the managerial wage increase such that, based on (2), the workers invest h_L^{FB}. It should be clear that a PPE with D_L^{FB} and h_L^{FB} can be supported by the same strategies as those in the proof of Proposition 2, with D_L^R replaced by D_L^{FB} and h_L^R replaced by h_L^{FB}. Moreover, standard reasoning implies that if the workers believe that each firm plays these equilibrium strategies, then no firm can profitably deviate by offering different wages. ■

Proof of Proposition 4: (i) Analogous to the case of a V_L firm, the surplus per worker, S_H, created in a V_H firm through a relational contract that increases the managerial wage by an amount D above its spot market level, is given by

$$S_H(D) \equiv \delta\gamma V_H h_D - c(h_D) - [\delta\gamma V_H h^* - c(h^*)].$$

Again, a relational contract is feasible only if $S_H(D)$ is sufficiently large so that (a) the V_H firm's incentive compatibility constraint (IC$_H$) holds and (b) the firm can attract workers. Let $\hat{\pi}_H^R$ be the minimum profit the firm must earn in every period in order to satisfy (IC$_H$) and let $\triangle U_L^R$ denote the extra expected lifetime utility (compared to the spot market) that the workers receive under the relational contracts in the V_L firms. A relational contract in a V_H firm is then feasible if

$$S_H(D) - \frac{\hat{\pi}_H^R - \pi_H^S}{n} - \triangle U_L^R \geq 0. \tag{6}$$

Recall from the proof of Proposition 3 that D_L^R denotes the equilibrium increase in the managerial wage in the V_L firms such that the workers' utility maximizing investment level is h_L^R. Also from the proof of Proposition 3, $\triangle U_L^R = S_L(D_L^R) - \frac{D_L^R(1-\delta)}{n\delta}$ for $D_L^R > 0$ (and $\triangle U_L^R = 0$ otherwise). Substituting this, together with $\frac{\hat{\pi}_H^R - \pi_H^S}{n} = \frac{D(1-\delta)}{n\delta}$ from (IC$_H$), into condition (6), this condition becomes

$$S_H(D) - S_L(D_L^R) + \left[\frac{D_L^R(1-\delta)}{n\delta} - \frac{D(1-\delta)}{n\delta}\right] \geq 0. \tag{7}$$

Now, for any $D > 0$, $V_H > V_L$ implies

$$\begin{aligned} S_H(D) &= \delta\gamma V_H(h_D - h^*) - [c(h_D) - c(h^*)] \\ &> \delta\gamma V_L(h_D - h^*) - [c(h_D) - c(h^*)] = S_L(D). \end{aligned} \tag{8}$$

Consequently, for any given δ, (7) holds when $D = D_L^R$. That is, any relational contract that is feasible and offered in equilibrium by the V_L firms is also feasible in the V_H firms. Moreover, if $D_L^R = 0$, (7) reduces to

$$S_H(D) - \frac{D(1-\delta)}{n\delta} \geq 0,$$

which is a strictly weaker condition than (3). Therefore, it must be that in the V_H firms relational contracts are feasible for a strictly greater set of discount factors δ than in the V_L firms, which concludes the proof of part (i).

(ii) Suppose now that δ is such that a relational contract is feasible in the V_H firms. Profit maximization implies that the workers' participation constraint (5) holds with equality. Substituting this constraint to the firm's objective function, the firm's maximization problem becomes

$$\max_{D \geq 0} \mu V_H + \delta\gamma V_H h_D - c(h_D) - U_L, \tag{MAX}$$

subject to (4) and (7).

Differentiating the objective function with respect to D yields

$$\frac{\partial(MAX)}{\partial D} = \frac{\partial h_D}{\partial D}\left[\delta\gamma V_H - c'(h_D)\right].$$

Because $\frac{\partial h_D}{\partial D} > 0$, it follows that $\frac{\partial(MAX)}{\partial D} > 0$ for all $h_D < h_H^{FB}$ and $\frac{\partial(MAX)}{\partial D} < 0$ for all $h_D > h_H^{FB}$. This means that if D_H^{FB} (i.e., the D that induces $h_D = h_H^{FB}$) satisfies (7), the firm chooses $D = D_H^{FB}$ and the workers invest $h_H^R = h_H^{FB}$. Otherwise, the firm chooses the maximum feasible D. Since, by continuity, (8) implies that if $D_L^R > 0$ then (7) must hold for some $D > D_L^R$, it follows that $h_H^R > h_L^R$ whenever $h_L^R > h^*$. Moreover, because a relational contract that is feasible in the V_L firms is also feasible in the V_H firms, it must be that $h_H^R \geq h_L^R$, which concludes the proof of part (ii).

(iii) Let $\delta \to 1$. Then (7) becomes $S_H(D) - S_L(D_L^R) \geq 0$, or

$$\gamma V_H h_D - c(h_D) - \gamma(V_H - V_L)h^* - \left[\gamma V_L h_L^R - c(h_L^R)\right] \geq 0.$$

Because the left hand side decreases in h^* and $h^* \leq h_L^R$, the above condition holds if it holds when h^* is replaced by h_L^R , i.e., if

$$\gamma V_H h_D - c(h_D) - \left[\gamma V_H h_L^R - c(h_L^R)\right] \geq 0. \tag{9}$$

Now, $\gamma V_H h_D - c(h_D)$ is concave and maximized at $h_H^{FB} > h_L^R$. The term $\gamma V_H h_D - c(h_D)$ thus increases in h_D for all $h_D < h_H^{FB}$, and therefore also increases in D for all $D < D^{FB}$. Consequently, (9) holds for all $D \in [D_L^R, D_H^{FB}]$. Hence, by continuity of (7) in δ, there must exist a $\delta^{FB} < 1$ such that (7) holds at $D = D_H^{FB}$ (so that $h_H^R = h_H^{FB}$) for all $\delta \geq \delta^{FB}$. ■

Proof of Proposition 5: First, notice that the constraint $\pi_L(D, w) \geq 0$ must bind in equilibrium. Otherwise, new V_L firms could enter the market and attract young workers away from the existing V_L firms by offering a slightly higher wage. Similarly, the constraint $w \geq \bar{w}$ must bind. Otherwise, we would be back in the unconstrained full commitment setting. As argued in subsection 3.2, the workers invest at the the first best level in such a setting. But the first best outcome is not feasible here because $\pi_L(D_L^{FB}, \bar{w}) < \pi_L(D_L^{FB}, w_L^{FB}) = 0$, where $D_L^{FB} \equiv W^{FB}(V_L) - W^m(h_L^{FB})$ is the managerial wage premium that elicits the first best level of investment in the V_L firms.

The above arguments imply that the equilibrium level of investment is given by the wage premium $D_L(\bar{w})$ that is implicitly defined by

$$\pi_L(D_L(\bar{w}), \bar{w}) = 0. \tag{10}$$

Because, by assumption, $\bar{w}$ does not bind under the spot market tournament (when $D_L = 0$ and $\pi_L = 0$), (10) has at least one solution.

Suppose that $D_L(\bar{w}) \geq D_L^{FB}$. Then it must be

$$u_L(D_L(\bar{w}), \bar{w}) \geq u_L(D_L^{FB}, \bar{w}), \tag{11}$$

because only the firms that maximize the workers' lifetime utilities can attract young workers. Now, writing $\pi_L(D, \bar{w}) = \mu V_L + \delta h_D \gamma V_L - c(h_D) - u_L(D, \bar{w})$ and using (11), the V_L firms' equilibrium profits are constrained by

$$\pi_L(D_L(\bar{w}), \bar{w}) \leq \mu V_L + \delta h_D \gamma V_L - c(h_D) - u_L(D_L^{FB}, \bar{w}). \tag{12}$$

But the right hand side of (12) is maximized at h_L^{FB}, i.e., it must be that $\pi_L(D_L(\bar{w}), \bar{w}) \leq \pi_L(D_L^{FB}, \bar{w}) < 0$, where the strict inequality follows from $\pi_L(D_L^{FB}, w_L^{FB}) = 0$ and from $w_L^{FB} < \bar{w}$. This proves that it cannot be that $D_L(\bar{w}) \geq D_L^{FB}$.

To see that $h_L^*(\bar{w})$ decreases in $\bar{w}$, differentiate (10) implicitly with respect to $\bar{w}$ to get

$$\frac{\partial h_L^*}{\partial \bar{w}} \frac{\partial \pi_L(D, \bar{w})}{\partial D}|_{D=D_L(\bar{w})} = 1.$$

Hence, $\frac{\partial h_L^*}{\partial \bar{w}} < 0$, because $\frac{\partial \pi_L(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} = [\delta\gamma V_L - c'(h_L^*)] \frac{\partial h_L^*}{\partial D}|_{D=D_L(\bar{w})} - \frac{\partial u_L(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} < 0$, which follows from $\frac{\partial h_L^*}{\partial D} > 0$, from $\delta\gamma V_L - c'(h_L^*) > 0$ (implied by $h_L^* < h_L^{FB}$), and from $\frac{\partial u_L(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} > 0$ (implied by $D_L(\bar{w}) < D_L^{FB}$). ■

Proof of Proposition 6: Because $h_H^{FB} > h_L^{FB}$, it must be that $w_H^{FB} < w_L^{FB}$, which means that $w_H^{FB} < \bar{w}$. From the proof of Proposition 5, $D_L(\bar{w}) < D_L^{FB}$ and $\frac{\partial u(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} > 0$. Suppose $\frac{\partial \pi_L(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} \geq 0$. Then the V_L firms could increase the workers' lifetime utilities by increasing D_L slightly and still break even. Due to the free entry of V_L firms, they would have an incentive to do so, which means that $D_L(\bar{w})$ could not be the equilibrium wage premium – a contradiction. It must therefore be that $\frac{\partial \pi_L(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} < 0$. Because $\pi_H(D, \bar{w})|_{V_H=V_L} = \pi_L(D, \bar{w})$ and by continuity, this implies that there exists a $V_H^* > V_L$ such that $\frac{\partial \pi_H(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} \leq 0$ for all $V_H \in [V_L, V_H^*]$. Hence, quasi-concavity of $\pi_H(D, \bar{w})$ implies that $\arg\max_D \pi_H(D, \bar{w}) \leq D_L(\bar{w})$. Because the V_H firms must offer their workers at least the lifetime utility $u_L(D_L(\bar{w}), \bar{w})$ and because $\frac{\partial u(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} > 0$, the V_H firms' constrained optimum is obtained at $D_L(\bar{w})$ for all $V_H \in [V_L, V_H^*]$. This implies $h_H^*(\bar{w}) = h_L^*(\bar{w})$ for all $V_H \in [V_L, V_H^*]$. ■

Proof of Proposition 7: Assume full commitment and let $C_1 \equiv \delta(\gamma V_L - V_H)ng(0)$ and $C_2 \equiv \delta(\gamma - 1)V_H ng(0)$. Clearly, $0 < C_1 < C_2$. Moreover, $\frac{\partial \pi_L(D,\bar{w})}{\partial D} = \delta^2(\gamma V_L - V_H)\frac{g(0)}{C} - \frac{\delta}{n} < 0$ and $\frac{\partial \pi_H(D,\bar{w})}{\partial D} = \delta^2(\gamma - 1)V_H \frac{g(0)}{C} - \frac{\delta}{n} > 0$ for all $C \in (C_1, C_2)$. The first inequality is required by Assumption 3 (from the proof of Proposition 6, Assumption 3 implies that $\frac{\partial \pi_L(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})}$ has to be negative). The second inequality implies that the V_H firms will choose the maximum feasible D, i.e., they will choose $D = D^{\max}$, where $D^{\max} \equiv \max_D\{D : u(D, \bar{w}) \geq u_L(D_L(\bar{w}), \bar{w})\}$. Because $\frac{\partial u(D,\bar{w})}{\partial D}|_{D=D_L(\bar{w})} > 0$ (from the proof of Proposition 5), it must be that $D^{\max} > D_L(\bar{w})$. Moreover, because $c(.)$ is quadratic and convex, it must be that $\lim_{h\to\infty} c'(h) = \infty$ and, from (4), $\lim_{D\to\infty} h_D = \infty$. From this, $\lim_{D\to\infty} \frac{\partial u(D,\bar{w})}{\partial D} = \lim_{D\to\infty}\{[\delta V_H - c'(h_D)]\frac{\delta g(0)}{C} + \delta/n\} = -\infty$. Hence, $D^{\max}$ is finite and given by $u(D^{\max}, \bar{w}) = u_L(D_L(\bar{w}), \bar{w})$, or

$$\bar{w} + \delta V_H h_{D^{\max}} + \delta D^{\max}/n - c(h_{D^{\max}}) = \bar{w} + \delta V_H h_L^*(\bar{w}) + \delta D_L(\bar{w})/n - c(h_L^*(\bar{w})), \quad (13)$$

where $h_{D^{\max}}$ is the level of investment induced by the managerial wage premium $D^{\max}$.

Now, the first best level of investment in the V_H firms is given by $\delta\gamma V_H = c'(h_H^{FB})$, whereas the left hand side of (13) is maximized at $\hat{D}$ given by $\delta V_H + \frac{C}{g(0)n} = c'(h_{\hat{D}})$. Let $C = C_2$, so that $\delta(\gamma-1)V_H\frac{g(0)}{C_2}=\frac{1}{n}$. This implies $\delta\gamma V_H=\delta V_H+\frac{C_2}{g(0)n}$, which means that $h_{\hat{D}}=h_H^{FB}$ for $C=C_2$. Therefore, $D^{\max}>\hat{D}$ for $C=C_2$, and because $\hat{D}=D_H^{FB}$ for this parameter value, it must be $h_H^*(\bar{w})>h_H^{FB}$ when $C=C_2$. Continuity of $u(D,\bar{w})$ in C then implies that there exists a $C^+\in(C_1,C_2)$ such that $D^{\max}>\hat{D}$ (and hence $h_H^*(\bar{w})>h_H^{FB}$) for all $C\in(C^+,C_2)$. Setting $C^*\equiv C^+$ and $C^{**}\equiv C_2$ concludes the proof of the first claim in the proposition.

Now suppose that commitment comes from repeated interaction. Then the only change in the V_H firms' optimization problem compared to the first part of the proof is that the D they choose has to satisfy their incentive compatibility constraint. This constraint is similar to (IC_H) in the analysis without minimum wages, except that the profit per period, π_H^R, is obtained using the minimum wage $\bar{w}$ for young workers: $\pi_H^R=\mu V_H-\bar{w}+\delta(\gamma-1)V_H h_D-\delta D/n$. Thus, the firm again chooses $D^{\max}$, as long as

$$D^{\max}\leq\frac{\delta(\pi_H^R(D^{\max})-\pi_H^S)}{1-\delta}. \qquad (\mathrm{IC}'_H)$$

Now, the arguments in the first part of the proof hold for any δ, including $\delta=1$. Thus, let $\delta\to 1$. Then the right hand side of (IC'_H) approaches infinity, because $\pi_H^R(D^{\max})>\pi_H^S$ (otherwise, the firm would prefer $D=0$ to $D=D^{\max}$). Because $D^{\max}$ is finite (as shown in the first part of the proof), (IC'_H) must hold for δ sufficiently close to 1. ■

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