Job Perks and the Structure of Optimal Incentive Contracts

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January 10, 2006

Abstract

This paper examines the effects of work-related perks, such as corporate jets and limousines, nice offices, secretarial staff, etc., on the optimal incentive contract. Using a simple linear contracting framework, we show that such perks improve the standard trade-off between incentives and insurance that determines the optimal contract for a risk-averse agent. We identify the conditions under which the principal will find it optimal to provide the perk and show that (i) the perk may be offered even if its direct consumption and productivity benefits are offset by its cost; (ii) workers in more uncertain production environments will receive more perks; (iii) the perk will be offered for free; (iv) more productive workers receive both more perks and stronger explicit incentives; (v) better corporate governance can lead firms to award their CEOs more perks; and (vi) workers organized in teams should receive more perks. Our analysis also offers insights into the firms' decisions about how much autonomy they should grant to their workers.

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1. Introduction

In the minds of many economists and business commentators, executive perks such as chauffeured limousines, corporate jets, and plush offices typically conjure up an image of a wasteful CEO, frivolously boosting his or her pay by spending on unnecessary benefits at the expense of the company's shareholders. Among academic researchers, this view has been formalized in the seminal paper by Jensen and Meckling (1976) and, in recent years, has been vocally espoused by, e.g., Bebchuk, Fried, and Walker (2002). There is no denying that some executives misuse their power and engage in excessive consumption of perks. At the same time, many perks do have legitimate use, especially if they increase a manager's productivity. In his discussion of composition of pay, Rosen (2000) lists productivity considerations among the main reasons for why companies include in kind payments in their compensation packages. The argument is that if an employee does not internalize all the benefits from the productivity increase brought about by the perk, the employee would under-invest in the perk and, therefore, the firm needs to subsidize its consumption. The productivity view of perks finds strong support in a recent study by Rajan and Wulf (2006), who provide an empirical evaluation of existing theories of managerial perks. Rajan and Wulf conclude that the evidence for the agency driven perk consumption is at best mixed and that the patterns of perk provisions that they observe seem to be best explained by productivity considerations.

Despite the apparent importance of work-related perks in compensation packages, economists have not developed the implications of the productivity theory of perks in a formal model in which the provision of perks would arise as a part of the optimal employment contract. One exception is Oyer (2004), who tests three theories of employee benefits, among them the productivity theory. He uses a simple model to show that a benefit will be provided more frequently the more it lowers a worker's cost of effort, and he finds support for this prediction using data on company provided meals. However, Oyer does not consider formal incentive contracts, and this limits the potential insights from his model. Also, in Oyer's model, there appears to be no distinction between an "employee benefit" and the standard notion of "production capital", since the latter, too, could be thought of as decreasing a worker's cost of effort.

The purpose of this paper is to provide a richer theory of work-related perks. We focus on a special class of perks which, in Rosen's (2000) terminology, have "productive consumption" attributes and which we define as non-pecuniary compensation that has productive use and provides intrinsic motivation. To emphasize this specific nature of work-related perks, we will at times refer to them as "technological perks". Our key assumption in modelling this kind of benefit is that there are consumption complementarities between a perk and effort in the agent's utility function. This is meant to capture the perks for which a worker is likely to derive a greater utility from a given amount of the perk if he uses it in the production process longer, more frequently, or more intensively. While obviously not all perks share this feature (for instance, this is not a good description of dental insurance, pensions, or country club membership), many work-related perks do. A pleasant working environment is probably more valued by employees who spend longer hours at work, a CEO is less likely to derive utility from a corporate jet if she is not sufficiently engaged in the company's operations and does not go frequently on business trips, and so on. Such consumption complementarities between the perk and effort mean that the perk provides the agent with some incentive to exert effort, even if the agent faces no formal incentive contract.[1]

In our framework, there are two distinguishing features of a "technological perk" as opposed to standard "production capital" (such as a hammer). The first is that while both can possibly increase the agent's productivity (by decreasing his cost of effort or, equivalently, increasing his productivity of effort), the "perk" also provides the agent with consumption utility. For example,

[1] The online betting company Betfair provides an example. According to its COO, David Yu, of the incentives Betfair offers its staff (which include performance bonuses), the most important is the working environment. "We ... do more trades than the London Stock Exchange... But we are very relaxed: engineers can work from home and have flexible hours. People like working here and with each other." (Vowler, 2005).

a corporate jet increases an executive's productivity as any other capital equipment would, but the executive may also derive consumption utility from using it (say, because it increases his status among his peers). Additional examples of perks falling into this category include top of the line computers, cell phones, pleasant work environment, limousines, and plush offices. The second defining characteristic of a perk in our model is that, as in Jensen and Meckling's (1976) agency theory, the employee might want to use it in non-productive activities. For example, in the case of the corporate jet, the executive may be tempted to use it to transport himself and his family to a vacation destination. Notice, though, that in this formulation, the agency problems are less severe than those described in Jensen and Meckling (1976), because in our model, the agent can only misuse the perk once it is awarded to him by the firm, but he cannot unilaterally decide to obtain the perk without the firm's consent. This is a realistic assumption for most employees, but perhaps less so in the case of powerful top executives in firms with weak boards of directors. Our approach here is in line with recent empirical studies on executive perks (Rajan and Wulf, 2006; Yermack, forthcoming) that seem to implicitly assume that the perks enjoyed by CEOs and other top executives have been awarded to them.

The goal of our analysis is to examine the relationship between the provision of technological perks and formal incentives. We do this by incorporating perks in Holmström and Milgrom's (1987) linear version of the principal-agent model. The main economic forces that are at play in our model can be explained as follows: The incentive effect of the perk, driven by the consumption complementarities between the perk and effort described above, allows the principal to decrease the pay-performance sensitivity of the agent's explicit incentive contract. This in turn decreases the uncertainty in the agent's income. Given that the agent is risk-averse, a lower income uncertainty translates into a lower total expected pay that he must get to accept the employment contract, which increases the principal's expected profit.

Despite its simplicity, our framework is rich enough to allow us to ask questions such as: If a firm provides a technological perk, how much is the perk subsidized, that is, at what price should it be sold to the agent? How does the amount of the perk depend upon the model's exogenous parameters, such as the production technology and production uncertainty? What is the relationship between the amount of the perk and the slope of the agent's formal incentive contract? How does the possibility that the agent could use the perk in a non-productive activity affect the optimal price and quantity of the perk and the agent's formal incentives? By offering relatively clear-cut answers to these and similar questions, we are also hoping to provide some guidance for future empirical tests attempting to disentangle the agency and the productivity motives behind the observed patterns of managerial perks. Our main results are the following:

(1) In some cases, the firm will find it optimal to provide the perk even if it has no direct effect on the agent's productivity and the cost of providing the perk is greater than the monetary equivalent of the utility the agent derives from it. This surprising result highlights the fact that the complementarities between the perk and effort that are central to our model make perks valuable solely for their incentive effects and for the resulting decrease in the worker's salary that the principal needs to pay to attract the worker.

(2) The logic behind the incentive value of the perk described above implies that the more uncertain is the production process (as measured by the variance of output) and the harder it is to monitor and evaluate the workers' performance, the more valuable are the perk's incentive effects and, consequently, the more likely it is that the perk will be provided. This suggests that we should observe more technological perks in larger firms, in privately held firms, in firms in the new economy sector, in firms with many inter-dependent divisions, and in geographically dispersed firms.

(3) The existing informal discussions of the productivity theory of perks, such as the one in

Rosen (2000), suggested that productivity enhancing perks should be subsidized by companies, but were not specific about how large the subsidy should be. In our framework, we show that it is always optimal to provide the perk to the employees free of charge.[2] This result does not depend upon how much or how little the perk increases the agent's productivity. Neither is it affected by allowing for the possibility that the agent can divert the perk for personal use, such as using a corporate jet for family trips.

(4) In our theory, the firm's problem of optimal provision of technological perks is a part of a more complex problem of designing an optimal incentive package in which explicit incentives are intertwined with implicit motivation provided by perks. Consequently, the factors that affect the strength of explicit contracts also play a role in the firm's decision to provide perks, so that the two variables are correlated. For example, firms with less precise performance measures (such as large firms) should provide both weaker explicit incentives and more technological perks. Similarly, all else equal, agents with higher marginal productivities (e.g., the employees with greater skills, or the employees assigned to more productive technologies/jobs) will be offered contracts with greater pay-performance sensitivities, and these more powerful explicit incentives will be accompanied by greater amounts of technological perks.

(5) Allowing for the possibility that the perk is diverted by the workers for purely personal use introduces into our framework agency problems in perk consumption. We show that contrary to what one would expect based on Jensen and Meckling's (1976) theory, agency problems in our model lead to less equilibrium perk consumption and to greater fractional ownership by the firm's CEO. We also show that better corporate governance can actually lead firms to award their managers *more* perks. These results suggest caution in interpreting empirical evidence on CEOs'

[2] Of course, at the end, the worker is always held down to his reservation utility, which means that he pays for the perks up-front, through a lower salary, as in the standard theory of hedonic prices. When we say the perk is provided "free of charge", we mean that the worker does not pay more for the perk if he uses it more intensively; e.g., the CEO is not asked to share a part of the operation costs incurred when she uses the company aircraft.

perk consumption and on the strength of their incentives as supporting or refuting the agency theory.

(6) In addition to the above main results, our model can be extended in a straightforward way to yield additional insights. In particular, we show that workers organized in teams should receive more technological perks, and discuss an alternative interpretation of the perk as the degree of worker autonomy.

Aside from the papers mentioned earlier and from the literature on employee benefits, most of which does not deal with the specific issues considered here, this paper is related to the vast literature on optimal incentive contracts. In a way, an employee benefit as modeled in our paper has a similar effect on the optimal incentive contract as an additional performance measure. By choosing the price that she charges the agent for the perk, the principal in essence adjusts the weight that the incentive effects of the perk receive in the agent's total incentive package. Our paper is thus related to the literature examining the structure of optimal incentive contracts with multiple performance measures. Two recent papers on this topic are Baker (2002)[3] and Raith (2005). Baker (2002) argues that the measures available in organizations for evaluating the performances of individual employees are either noisy, so that their inclusion in the contract imposes risk on the workers, or they are distorted, so that they do not measure the workers' "true" contribution to the organization's value. The optimal weights on the measures in the second best contract are then determined by the trade-off between risk and distortion. Raith (2005) focuses on a different trade-off. In his model, the principal can avoid imposing risk on the agent by using an input based performance measure, but will find it optimal to include also a noisy output-based measure, in order to induce the agent to use his specific knowledge about the production process. Unlike in these two papers, there is only one explicit performance measure in our model (the worker's

[3] See also Baker (2000).

output), although the price the worker is charged for the use of the perk is akin to a weight put on a performance measure in an incentive contract based on multiple measures. This formal relation to the literature on multiple performance measures notwithstanding, our model focuses on different issues, not examined elsewhere.

The rest of the paper proceeds as follows. In Section 2, we introduce our basic model, in its linear contract form. The analysis of this model, which abstracts from agency problems in perk consumption, follows in Section 3. In Section 4, we investigate the possibility that the worker diverts the perk for personal use and relate our model to Jensen and Meckling's agency theory. In Section 5 we offer two applications and extensions of our basic framework: We consider here the effects of teamwork on perk provision and discuss the insights our model can offer into the question of the optimal degree of delegation within organizations. Section 6 concludes.

2. The Model

In this section, we introduce our basic model, which, for expositional purposes, abstracts from the possibility that the agent could misuse the perk for purely private consumption. We allow for agency problems in perk consumption in Section 4, where we also demonstrate that our basic results from this section continue to hold in this richer setting.

The model is based on the linear contract principal-agent framework of Holmström and Milgrom (1987). Consider a firm consisting of a risk neutral principal and a risk averse agent with reservation utility $\bar{u}$, which corresponds to a certainty equivalent reservation income $\bar{w}$. The agent chooses unobservable action, $a \in \mathbb{R}_+$, which affects the distribution of the firm's output. The agent receives a formal linear performance contract, which conditions his monetary pay on his output. In addition, the owner of the firm can provide the worker with a technological perk, which the worker views as a consumption good, i.e., he derives utility from its use, but it also can serve as a non-labor input in the sense that it may increase the worker's productivity (a computer, a quiet office, use of a ski lift for ski instructors, etc.). The effectiveness of the agent's action in improving the expected revenue depends upon the amount, q, of the perk provided by the firm, as specified next.

Technology. If the agent chooses action a and the firm provides an amount q of the perk, the firm's output is given by

$$y = \beta(1 + qm)(a + \varepsilon).$$

Here, β captures the agent's marginal productivity on the job. Alternatively, β could also be interpreted as the marginal productivity of the firm's technology, which could depend upon such things as the firm's market power in its product market, it's cost effectiveness, and so on. The parameter $m \geq 0$ measures the effect of the perk on the agent's productivity; if $m = 0$, the perk is a pure consumption good. Finally, ε is a normally distributed noise term, with zero mean and variance σ^2. Note that both β and q enter multiplicatively with ε. This means that the perk does not simply increase the signal to noise ratio of y as it would if q and ε were additively separable. The same goes for the agent's marginal productivity β.[4]

The perk's acquisition cost is kq, $k \geq 0$, and its operating cost is $c(q, a) = \theta qa$, $\theta > 0$.[5] Thus, while the acquisition cost does not depend upon the agent's work intensity, the operation cost does. In this sense, the acquisition cost can be thought of as a fixed cost of obtaining a given amount of the perk and the operation cost is the variable cost associated with using the perk in production and/or consumption. For example, in the case of a corporate jet, this would be any cost

[4] Arguably, the multiplicative specification is more realistic than the additive one, even though the latter has been used more frequently in the literature. If an agent becomes more productive because he is asigned to a more productive technology or receives more perks, it seems reasonable to expect that the variance of his output would increase. However, our main reason for choosing the multiplicative specification is to separate the incentive effects of β and q from their effects on the signal-to-noise ratio of the performance measure. In an additive world, β and q would increase the signal-to-noise ratio of y, which would make the perk even more valuable to the principal than in our model. This effect, though, is well understood.

[5] The assumption that the perk's cost is deterministic does not play any role in our analysis and is adopted purely to simplify exposition.

that depends upon the intensity with which the jet is used, such as the costs of fuel, maintenance, perhaps insurance, the plane's depreciation, and so on.

Preferences. The agent's utility as a function of his monetary income, w, his action, a, and his perk consumption, q, is given by

$$U(w) = -e^{-r[w+\gamma qa-g(a)]},$$

where r is the agent's coefficient of absolute risk aversion. The term γqa is his monetary equivalent of utility from consuming q units of the perk, where $\gamma > 0$ is a parameter that allows us to vary how much the agent likes the perk. Note in particular the complementarity between q and a in the agent's utility, implied by this specification. As explained in the Introduction, this complementarity is a key feature of our model, without which the perk would only affect the optimal incentive contract through the productivity parameter m. This would make the perk's effects indistinguishable from the effects of a standard production technology. In particular, our specification guarantees the perk has an incentive effect, so that unlike in the case of pure production capital, the agent is willing to work even in the absence of formal incentives.[6]

The term $g(a)$ indicates the agent's monetary equivalent of disutility from providing action a. The function g is differentiable, increasing and convex. The principal is risk neutral and maximizes expected profit.

Contracting. The firm and the agent sign a formal incentive contract, according to which (i) the agent's pay, w, is a linear function of his output and (ii) the agent is charged a portion $p \geq 0$

[6] Oyer (2004) also introduces a complementarity between perk and effort, but it is in the agent's *cost of effort function*. Such complementarity does not have the incentive effects present here, which makes his perks hard to differentiate from pure production capital.

of the perk's operating cost.[7] That is,

$$w(y) = s + by - pc(q, a),$$

where s is the agent's base salary and b is the piece-rate, measuring the strength of the formal incentives. Observe that $p = 0$ corresponds to the principal owning the perk and bearing all its costs. We do not allow for $p < 0$. This restriction is meant to capture the fact that if the agent's pay increased in c, he could game the contract by taking some unobservable action that would increase the costs incurred by the firm without imposing personal costs on himself.[8]

Note also that when $q = 0$, the problem collapses into a version of the standard principal agent model discussed in Holmström and Milgrom (1987), in which the optimal piece rate is given by

$$b_0^* = \frac{1}{1 + r\sigma^2 g''(a^*)}.$$

Observe in particular that b_0^* is independent of the agent's productivity parameter, β. This is because, as we have already explained, β increases not only the agent's productivity but also the variance of his output, and these two effects cancel out in determining the optimal piece rate. Again, we have chosen this specification purposefully, to highlight that any effect β will have on the optimal incentive contract will be driven by the presence of the perk.

[7] Since we are interested in the effects of p on the agent's incentives, we ignore the possibility that the agent could also be charged for part of the perk's acquisition cost kq. Such a payment would simply represent a transfer equivalent to a decrease in the agent's salary, s, and hence it would not affect incentives.

[8] For example, if the agent's pay increased with the electricity bill that he runs up using his computer, he would simply leave the computer turned on at all times. Formally, this could be easily incorporated in the model by assuming that there is another action, a', that the agent can take, and that a' has a similar effect on $c(q, .)$ as a, but it imposes no cost on the agent.

3. The Analysis

Standard transformation of the agent's expected utility allows us to write his certainty equivalent as

$$CE(s, b, q, p) = \gamma qa + s + b\beta(1 + qm)a - \frac{1}{2} rb^2\beta^2(1 + qm)^2\sigma^2 - pq\theta - g(a),$$

so that his optimal choice of a is given by the first order condition

$$g'(a) = \max\{0, b\beta(1 + qm) - pq\theta + \gamma q\}. \tag{1}$$

Thus, as one would expect, the higher is the price the agent is charged for the perk, the lower is the level of effort he chooses to provide given any piece rate b.

Because the principal is the residual claimant, her problem is to design for the agent a comprehensive incentive package, balancing the explicit incentives of the formal contract with the implicit incentives provided by the perk, so as to maximize the expected total surplus,

$$TS(b, q, p) \equiv \beta a + qa(\gamma + \beta m - \theta) - \frac{1}{2} rb^2\beta^2(1 + qm)^2\sigma^2 - g(a) - kq - \bar{w}.$$

This optimization problem can be written as

$$\max_{b,q,p} TS(b, q, p),$$

subject to the incentive compatibility constraint (1). We will assume that this is a concave problem.[9]

Given that our goal is to focus on the incentive benefits of perks, we will restrict our attention to parameter values such that the direct benefits due to increased productivity and consumption

[9] A sufficient, but not necessary condition, for this is that $g'''(.) \geq 0$.

utility derived from the perk are not sufficient to offset the perk's operating costs.

Assumption 1: $\theta > \beta m + \gamma$.

Under this assumption, providing the perk is clearly suboptimal, unless the perk can improve the efficiency of the optimal incentive contract. Assumption 1 also guarantees that the optimal quantity of the perk will be finite.[10]

Let $A(b,q,p) \equiv \frac{\partial TS}{\partial b}$ denote the net marginal benefit to the principal of increased effort. Substituting for $g'(a)$ from (1), we can write

$$A(b,q,p) = (1-b)\beta(1+qm) - (1-p)\theta q.$$

Differentiating the total surplus with respect to b, p, and q then yields

$$\frac{\partial TS}{\partial b} = \frac{\partial a}{\partial b} A(b,q,p) - b\beta^2(1+qm)^2 r\sigma^2, \tag{2}$$

$$\frac{\partial TS}{\partial p} = \frac{\partial a}{\partial p} A(b,q,p), \text{ and} \tag{3}$$

$$\frac{\partial TS}{\partial q} = \frac{\partial a}{\partial q} A(b,q,p) - (\theta - \beta m - \gamma)a - b^2 m\beta^2(1+qm)r\sigma^2 - k. \tag{4}$$

Also from (1), we have

$$\frac{\partial a}{\partial b} = \frac{\beta(1+qm)}{g''(a)} > 0, \quad \frac{\partial a}{\partial p} = -\frac{q\theta}{g''(a)} < 0, \quad \text{and} \quad \frac{\partial a}{\partial q} = \frac{b\beta m - p\theta + \gamma}{g''(a)}.$$

Lemma 1. *If* $A(b^*, q^*, p^*) \le 0$*, then it must be* $q^* = 0$.

The proof for this lemma is in the appendix, as are the proofs of all our subsequent results.

[10] If the inequality in Assumption 1 were reversed, it would be optimal to provide the perk not only for incentive and risk-sharing purposes, but also for its direct consumption and productivity values. Of course, in the *comparative statics* exercises, the consumption and productivity enhancement motivations are going to play a role even under Assumption 1.

According to Lemma 1, the profit-maximizing amount of the perk, q^*, can be positive only if $A(b^*, q^*, p^*) > 0$. In such a case, (3) implies that $\frac{\partial TS}{\partial p} < 0$ for all $p > 0$, so that $p^* = 0$ and $A(b^*, q^*, p^*) = (1 - b^*)\beta(1 + q^* m) - \theta q^*$. Then b^* and q^* solve (2) and (4), which together yield

$$b^* = \frac{1 - \theta q^*/\beta(1 + q^* m)}{1 + r\sigma^2 g''(a^*)} \tag{5}$$

and

$$q^* = \frac{\beta}{\theta - \beta m} - \frac{[(\theta - \beta m - \gamma)a^* + k][1 + r\sigma^2 g''(a^*)]}{(\theta - \beta m)\gamma r \sigma^2}. \tag{6}$$

Comparing expression (5) with the slope of the optimal contract when no perks are provided, b_0^*, reveals that the effect of the perk on the optimal explicit incentives is captured by the negative term $-\theta q^*/\beta(1 + q^* m)$ in the numerator of b^*. Because the perk itself has some incentive effects, this crowds out formal incentives, which is reflected in a smaller slope of the incentive contract. These results are summarized and the optimal contract is further characterized in the following proposition.

Proposition 1. *It is always optimal to set $p^* = 0$ and $b^* > 0$. Also, there exists a $\gamma^* > 0$ such that*

(i) if $\gamma > \gamma^*$, then b^* and q^* are given by (5) and (6) respectively, where $q^* > 0$ and $b_0^* > b^* > 0$;

(ii) if $\gamma \leq \gamma^*$, then $b^* = b_0^* = \frac{1}{1 + r\sigma^2 g''(a^*)} > 0$ and $q^* = 0$.

Proposition 1 provides two main insights into the optimal provision of a technological perk. First, the firm may find it optimal to provide the perk even if the perk's cost is greater than its direct benefits represented by the worker's consumption utility from the perk plus the direct increase in his productivity (i.e., even if $\theta > \gamma + \beta m$, which is Assumption 1). For these parameter values, the main motivation for providing the perk is that it improves the agent's incentives and the risk-sharing properties of the optimal contract. Since the incentive effects of the perk increase in γ, they are sufficiently high to offset the marginal cost of providing the perk (net of the perk's marginal consumption and productivity improvement values, i.e., $(\theta - \beta m - \gamma)a + k$) only if γ is relatively high. Hence the condition $\gamma > \gamma^*$ in the proposition.[11] Notice that this requires that $\gamma > 0$, that is, the good indeed needs to be a perk rather than pure production technology. On the other hand, it is not necessary for the argument that the perk improves the agent's productivity: As long as $\gamma > \gamma^*$, providing the perk is optimal even if the perk *decreases* the agent's productivity, i.e., even if $m < 0$.

The second insight offered by Proposition 1 is that the perk should always be provided to the agent for free (i.e., $p^* = 0$). This seems to be an empirically sound prediction, and one that shows that the standard explanation for providing productivity enhancing perks is incomplete. According to the standard reasoning (found, for example, in Rosen, 2000), a firm needs to subsidize a technological perk if the workers do not internalize all the benefits from the productivity increase brought about by the perk. This argument, however, does not take into account the incentive effects of the perk and their interaction with the agent's explicit incentive contract. Consequently, it only implies zero price for the perk if the agent's pay is completely unresponsive to his productivity, which is an extreme assumption. Otherwise, if the agent internalizes a part of the productivity increase through an increase in his pay, the logic of the standard argument seems to suggest that he should be charged a positive price for the use of the perk, lest he does not overuse it. In contrast, our analysis shows that once the optimal adjustment in the incentive contract is taken into account, it is always optimal to offer the perk for free. The reason is that charging the agent for the use of the perk would discourage him from using the perk and hence mute his incentives, as can be seen

[11] In order to guarantee that $\gamma^* < \theta - \beta m$, so that Assumption 1 is not violated, it also must be that the perk's fixed cost is not too high, $k < \frac{\beta r \sigma^2 (\theta - \beta m)}{1 + r\sigma^2 g''(a_0^*)}$. However, even when this condition does not hold, it is still true that the firm wants to provide the perk if $\gamma > \gamma^*$.

from the first order condition (1). Therefore, stronger incentives would have to be provided through an increase in the slope, b^*, of the explicit contract. This, however, would impose additional risk on the agent and hence decrease efficiency.[12]

We now turn our attention to how the optimal incentive contract and the optimal provision of the perk depend on the economic environment in which the firm operates. In general, the firm's decision whether or not to provide a technological perk, how much of the perk to provide, and what should be the optimal slope of the incentive contract, can all depend on the model's parameters in a complicated way, determined by the third derivative of the agent's cost of effort function $g(.)$. To avoid these complications, we will from now on assume that $g(a) = a^2/2$, so that $g'''(.) = 0$.

Proposition 2.

(i) A technological perk is more likely to be provided (γ^* is smaller) the greater are β, γ, m, r, and σ^2 and the lesser are k and θ.

(ii) The optimal amount of the perk, q^*, increases with β, m, γ, r, and σ^2 and decreases in k and θ. The optimal pay-performance sensitivity of the incentive contract, b^*, increases with β, k, and θ and decreases in γ, r, σ^2, m (and in q^*).

Along with several expected predictions, Proposition 2 yields two interesting and potentially testable comparative static results. First, it predicts that both the use of technological in-kind compensation and the amount of such compensation should be more prevalent in more uncertain economic environments. The reason is that, as we have explained earlier, the in kind good allows the firm to improve the incentives-versus-insurance trade-off that the firm has to take into account

[12] As noted in the Introduction, our maintained assumption that the perk is awarded to the agent by the firm may be less realistic in the case of very powerful CEOs. If a CEO could choose q, it might be optimal to set $p > 0$, to curb his excessive consumption of the perk. However, if the board is so weak that it cannot control q, it is not clear why it would be strong enough to control p. Thus, while this is clearly an interesting variation on our analysis, it is outside of the scope of this paper, because it would require a different model – perhaps along the lines of Hermalin and Weisbach (1998) – that would allow us to capture the relative powers of the firm's CEO and its board of directors.

when designing the agent's incentive contract. This beneficial feature of the in kind good is more valuable in more uncertain environments, because in such environments the inefficiencies caused by the trade-off are greater.[13] Similarly, companies in which monitoring and evaluating the employees' individual performance is harder should offer more technological perks. These observations allow us to suggest the types of organizations that should be more likely to provide technological perks, such as top of the line computers, generous secretarial support, nice offices, child care, and so on:

(1) Privately held firms. Since a company's stock price offers an informative measure of performance, not available in privately held firms, these firms should find it harder to evaluate their employees and should therefore find technological perks more valuable.

(2) Firms with multiple inter-dependent divisions where coordination is important and where the actions taken by the employees in one division affect the performance of the other divisions.[14]

(3) Firms that are geographically dispersed and therefore find it harder to monitor employees. Consistent with this interpretation, Rajan and Wulf (2006) show that company planes are more common in geographically dispersed firms. Since this could be also driven by planes being more useful in geographically dispersed companies (which would be captured by a greater m in our model), a more direct support for this prediction would come from technological perks that are not travel related.

(4) Large firms, as these tend to have more noisy measures of individual performance (e.g., Schaefer (1998); Baker and Hall (2004)). The existing empirical studies of non-monetary compensation typically examine benefits that are more broadly defined than our technological perks, and therefore can only provide a limited support for our theory. With this caveat in mind, the prediction

[13] Oyer (2004) presents a model in which uncertainty leads to more fringe benefits because the firms are assumed to find it less costly to adjust workers' fringe benefits than their salaries. However, in Oyer's theory it is the uncertainty about labor market conditions that is important, rather than the noise in the workers' performance measures that is the focus of our analysis.

[14] We would like to thank Julie Wulf for suggesting this and the next example.

that large firms should provide more perks appears to be consistent with available evidence: numerous studies have documented that large firms offer more non-wage compensation than small firms (e.g., Antos (1981), Mellow (1982), Brown, Hamilton, and Medoff (1990), Montgomery and Shaw (1997), Oyer (2004), and Rajan and Wulf (2006)). This prediction is similar to what one would expect in the presence of economies of scale in perk provision (Freeman, (1981), Rosen (2000)). The empirically relevant distinction between our theory and the economies of scale argument is that in our model, the decision whether to provide the perk need not depend upon the actual number of employees within the organization that receive it.

(5) New economy firms. These firms tend to be more R&D intensive, have greater market-to-book ratios, and grow more rapidly than the old economy firms (Ittner, Lambert, and Larcker (2003)). All of these characteristics could make it hard to observe a manager's marginal contribution.[15] Rajan and Wulf (2005) find that the firm's growth prospects have a significant positive effect on perk provision (although market-to-book ratio does not). This prediction also seems to be in accord with the popular belief that new economy firms offer more and better perks, especially productivity enhancing ones.[16]

In addition, because perk provision in our model is intertwined with the problem of designing the optimal incentive contract, all else equal, we would expect the greater amount of perks in the above types of companies to be accompanied by weaker explicit incentives. This is consistent, for example, with the fact that larger firms have been shown to offer weaker formal incentives, at least to their top executives (Schaefer (1998); Murphy (1999); Baker and Hall (2004)).[17] However, this

[15] Both R&D expenditures and the market-to-book ratio have been used by empirical researchers to proxy for the degree of difficulty in measuring managerial performance in a firm (e.g., Kole, 1997).

[16] For example, an article in *Salon.com* (Standen, 2001) describes how the $700 Aeron office chairs "renowned throughout the office universe for their ergonomically correct luxury" became extremely popular with technology firms. "According to the new-economy ethos," Standen writes "work would be fun; it would be comfortable and ergonomic...". According to an article in the *Christian Science Monitor* (Terry, 2001), "Dotcom companies became infamous for pioneering many ... perks, including catered lunches and free car-wash services.... At the core of all this ... is anything that focuses on time, because time is such a huge commodity."

[17] This prediction can also be obtained from the standard principal-agent model in the absence of perks, as long as

prediction may not be robust in environments where greater uncertainty is associated with greater reliance on the employee's specific knowledge, as in such environments the relationship between uncertainty and explicit incentives is typically ambiguous (see, e.g., Baker and Jorgensen (2003), Prendergast (2002), Raith (2005), and Zabojnik (1996)).

The second comparative static result worth noting concerns the effects of an employee's productivity (as measured by the parameter β) on b^* and q^*. In contrast to the case with no perk, if the perk is provided then more productive employees (say, senior managers versus rank-and-file workers) receive stronger explicit incentives.[18] In addition, more productive workers in our model are also more likely to receive technological perks and the amounts of the perks they receive are greater and/or their quality higher.[19] The perk becomes more valuable as β increases, for two reasons. First, for a given b, it magnifies the effect of the perk on the agent's incentives ($\frac{\partial^2 a}{\partial q \partial \beta} > 0$), as well as the net marginal benefit of increased effort ($\frac{\partial A(b,q,p)}{\partial \beta} > 0$). Second, it directly improves the agent's productivity, as in Oyer (2004), through the term βmqa. This prediction is in accord with the general conclusion in Rajan and Wulf (2006) that managerial perks in major U.S. public companies appear to be awarded mainly for productivity reasons. Our prediction is also consistent with Krueger and Summers' (1988) empirical finding that inter-industry wage differentials, with more capital intensive industries typically paying higher wages, are magnified when one accounts for non-wage benefits. This suggests that more capital intensive industries tend to provide more fringe benefits (again, more broadly defined than in our paper).

Finally, the prediction fits well with the common perception that senior managers receive more perks than the average employee.[20] Of course, this relationship could also be driven by a pure

one assumes that the variance of the agent's output increases faster with the firm's size than his marginal productivity. See Baker and Hall (2004) for a detailed discussion of this model.

[18] As with the relationship between firm size and the strength of formal incentives, this prediction also obtains in the standard model without perks. To get the prediction, it is enough to assume that β does not affect variance, i.e., $y = \beta a + \varepsilon$. In this case, the relationship is driven by the fact that β improves the signal to noise ratio of y.

[19] The variable q in our model can easily be interpreted as the perk's quality rather than its amount.

[20] Rajan and Wulf (2005) document that CEOs in their sample receive more perks than lower-level managers.

income effect, wherein senior managers demand more perks simply because they have greater wealth. Thus, in testing the productivity theory, one would ideally want to control for the managers' wealth. Also, the income based explanation applies to all employee benefits, whether they are work-related or not. Hence, a test that would find a stronger relationship between manager seniority and the amount of technological perks than between seniority and non-work related perks could be interpreted as lending support to the productivity theory.

4. Agency problems in perk consumption

Provision of work-related in kind compensation might induce the agent to take unproductive actions, in cases where such actions would generate personal benefit. For example the provision of a computer with high speed internet access might result in the agent wasting time surfing the web. The provision of transportation services might encourage the agent to use these services for purely personal purposes. Given that the examples of technological perks that fall into this category abound, it is important to examine how the presence of a non-productive action affects our basic results. In this section, we show that our earlier conclusions are robust to this extension. The analysis in this section will also allow us to contrast our model with the agency theory of perk consumption developed by Jensen and Meckling (1976).

Let a_1 represent a productive action and let a_2 represent a non-productive action, where the variable a_1 takes the place of a in the basic model. Action a_2 only generates a personal benefit $\gamma_2 a_2$ to the agent, while imposing the same marginal cost on the principal as activity a_1. The parameter γ_2 can be thought of as a measure of agency problems in the firm: the greater is this parameter, the more the employee likes to divert the perk for personal use or the easier it is for him to do so.

Assumption 2: $\theta > \beta m + \gamma_1 + \gamma_2$.

Assumption 2 is the analogue of Assumption 1; it says that the direct consumption and productivity benefits from the perk are not sufficiently high to offset the cost of providing the perk. Thus, it is not efficient to provide the perk unless it allows the principal to design a better incentive contract.

The agent's personal cost function is $g(a_1, a_2) = \frac{a_1^2}{2} + \frac{a_2^2}{2}$. His certainty equivalent is now written as

$$CE(a_1, a_2, s, b, q, p) = \sum_{i=1}^{2} \gamma_i a_i q + s + b\beta(1 + qm)a_1 - \frac{1}{2} r b^2 \beta^2 (1 + qm)^2 \sigma^2 - pq\theta(a_1 + a_2) - g(a_1, a_2),$$

and his first order conditions for a_i choice are

$$a_1 = \max\{0, \gamma_1 q + b\beta(1 + qm) - pq\theta\}, \tag{16}$$

$$a_2 = \max\{0, \gamma_2 q - pq\theta\}. \tag{17}$$

The principal again maximizes the total surplus, which in this case is given by

$$TS(b, q, p) = \beta(1 + qm)a_1 + \sum_{i=1}^{2} \gamma_i a_i q - \frac{1}{2} r b^2 \beta^2 (1 + qm)^2 \sigma^2 - q\theta(a_1 + a_2) - kq - g(a_1, a_2) - \bar{w}.$$

Under what conditions will the firm provide the perk in the presence of agency problems? Also, will the firm now charge for the in kind good in equilibria where it is provided? Let x^{**} denote an equilibrium variable in the present setting. We have

Proposition 3. *Suppose the worker can use the perk in a non-productive activity, i.e.* $\gamma_2 > 0$*. Then* $p^{**} = 0$ *and* $q^{**} > 0$ *if and only if* $q^* > 0$*. Moreover,* $q^{**} < q^*$ *and* $b_0^* > b^{**} > b^*$*.*

Proposition 3 demonstrates that the main conclusions of Proposition 1 remain unchanged when the agent can engage in private consumption of the perk outside of the production process, as long as his utility from using the perk in production is sufficiently high ($\gamma_1 \geq \gamma^*$). That is, it remains optimal for the firm to offer the perk to the employees free of charge[21] and to provide it under the same parameter values as when the purely private consumption was not possible. Note in particular that the possibility that the worker can divert the perk for personal use does not enter the firm's decision whether to provide the perk. When a_1 and a_2 are additively separable in the agent's cost function, as in our specification, the effect of the non-productive consumption is manifested only through the optimal amount of the perk that the firm provides and through the slope of the optimal incentive contract. More concretely, the firm optimally responds to the possibility that the worker can misuse the perk by providing it in a smaller amount and/or a lower quality and by increasing the slope of the incentive contract. This is demonstrated in the following proposition.

Proposition 4. *When the perk can be diverted for personal use, q^{**} decreases and b^{**} increases in γ_2. With respect to the rest of the parameters, the comparative statics for q^{**} and b^{**} are the same as for q^* and b^*. That is, q^{**} increases in β, m, γ_1, r, and σ^2 and decreases in k and θ, while b^{**} increases in β, k, and θ and decreases in γ, r, σ^2, m (and in q^{**}).*

Proposition 4 also shows that the comparative statics results of Proposition 2 are preserved in the present setting with unproductive effort. Thus, all of our empirical predictions discussed earlier are robust to an extension allowing for agency problems in perk consumption.

Two additional insights emerge from this extension. First, it is instructive to compare our analysis with the predictions of Jensen and Meckling's (1976) agency theory. In that theory, greater agency problems (due to, say, greater difficulties in monitoring the CEO's actions or due to an increase in the CEO's taste for perks) should lead to more equilibrium perk consumption, which Jensen and Meckling measure by expenditures on perks. In contrast, Proposition 4 says that, in our model, greater agency problems (a larger γ_2) lead to *fewer* perks if their amount is measured

[21] Our proof that $p^{**} = 0$ easily extends to more general cost functions. For example, the exact same proof continues to hold even if $g_{12}(a_1, a_2) \neq 0$, as long as $g_{11} = g_{22}$ and $g_{12} \neq g_{11}$ (where the latter is automatically met if g is strictly convex). These assumptions are satisfied, e.g., by the cost function $g(a_1, a_2) = \frac{a_1^2}{2} + \frac{a_2^2}{2} + da_1a_2$, where d is a constant.

by q^{**}, or that the relationship is ambiguous if the amount of perk consumption is measured by the total expenditures on perks, $q^{**}k + q^{**}\theta(a_1^{**} + a_2^{**})$.[22]

Another prediction that is sometimes attributed to Jensen and Meckling's theory is that there should be a negative relationship between the CEO's level of perk consumption and his fractional ownership in the firm (Yermack, forthcoming). Thus, an increase in the degree of agency problems (i.e., an increase in γ_2) should lead not only to more perk consumption but also to a smaller fractional ownership (smaller b^{**} in our model). Again, we obtain exactly the opposite prediction: in our model, b^{**} increases with γ_2. Strengthening the CEO's explicit incentives in response to greater agency problems is optimal in our framework, because this redirects the CEO's focus from non-productive (a_2) to productive (a_1) use of the perk.

The implication of the above analysis is that one needs to exercise caution when interpreting empirical evidence on CEO fractional ownership and perk consumption as supporting or refuting the presence of agency problems in perk consumption. First, our model demonstrates that in the case of technological perks (such as the use of company aircraft), greater fractional ownership can actually be associated with *more severe* agency problems. Similarly, companies with better corporate governance may be willing to award their CEOs *greater* amounts of perks, because they know that the CEO will use the perks to enhance the firm's value rather than for personal consumption.[23] Second, the presence of agency problems does not necessarily imply a negative relationship between the CEO's explicit incentives and his expenditures on perks, because the effect of agency problems on the latter is ambiguous. The reverse argument is also true — if one finds no significant relationship between a CEO's fractional ownership and his expenditures on

[22] The effect of γ_2 on total expenditures is ambiguous because a_1^{**} and a_2^{**} could go up or down with γ_2. Given that $a_2^{**} = \gamma_2 q^{**}$, an increase in γ_2 pulls it up, while the decrease in q^{**} pulls it down. As for a_1^{**}, an increase in γ_2 decreases q^{**}, which tends to decrease a_1^{**}, but it also increases b^{**}, which tends to increase a_1^{**}.

[23] Rajan and Wulf (2006) find that governance does not have a clear-cut impact on perk provision in firms they study. Consistent with our arguments, they recognize that the apparent lack of support in their data for the agency theory could be caused by endogeneity problems, much like the ones we discuss here.

perks (as Yermack, forthcoming, does for the case of corporate jets), this does not imply absence of agency problems in perk consumption. These conclusions are consistent with Rajan and Wulf's (2006, p. 4) assessment, where they reflect on the lack of empirical support for the agency theory in their data by arguing that "...we need to rethink whether perk consumption should be the canonical example of systematic forms of agency ... as has been suggested in the past."

The second point worth noting regarding the results in Proposition 4 is that they complement the conclusions found in the literature on distorted performance measures (Baker, 1992) and on multitasking (Holmström and Milgrom, 1991). These papers provide a theoretical rationale for the general absence of high-powered explicit incentives within firms, first pointed out by Williamson (1985). The absence of high-powered incentives within organizations is conspicuous both because standard principal-agent models seem to predict that workers should face elaborate incentive contracts and because relationships with independent contractors frequently are governed by such high-powered contracts. Similar to Baker (1992) and Holmström and Milgrom (1991), our model predicts weaker explicit incentives than the standard model (i.e., $b^{**} < b_0^*$), due to the fact that some incentives are provided indirectly, via work-related fringe benefits. Moreover, if one relaxes Assumption 2, which amounts to adding the usual consumption and productivity improvement motives for perk provision, then it is straightforward to verify that for γ_2 small, it is optimal to provide enough of the perk so that it completely crowds out explicit incentives. That is, $b^{**} = 0$ and the worker receives a flat wage. Finally, to the extent that firms provide fewer technological perks to independent contractors than to their own employees, and to the extent that, where such perks are awarded, preventing their misuse for personal use is easier in the case of employees than in the case of independent contractors, Proposition 4 implies that independent contractors should face stronger explicit incentives.[24]

[24] The idea that firms might want to provide technological perks to independent contractors is not as peculiar as it may sound. For example, independent consultants frequently get the use of a firm's offices and equipment for the

5. Applications and extensions

In the past two decades, many companies have started to implement innovative work practices, most notable among them being probably teamwork and worker autonomy, where the latter denotes granting to the workers flexibility in deciding how to do their job. Furthermore, these two work practices are considered to be complementary, in the sense that the beneficial effects of organizing workers in teams are believed to be greater if teamwork is coupled with greater worker autonomy (see, e.g., DeVaro, 2006, and the references therein). Should these changes in workplace organization be accompanied by complementary changes in the provision of productivity enhancing perks? A simple extension of our model allows us to shed some light on these issues. To keep the analysis simple, we will again abstract here from agency problems in perk consumption.

5.1. Perks in teams

Suppose that the workers are organized in a team consisting of $n \geq 2$ members. Analogous to the production function introduced earlier, the team's output is given by $y(n) = \beta \sum_{i=1}^{n}(1+q_i m)(a_i+\varepsilon)$, where q_i now denotes the amount of the perk offered to worker i, a_i is the action taken by worker i, and $n\varepsilon$ is a common shock affecting the team's output, with ε distributed according to the same normal distribution as before. Each individual member's explicit contract is now a linear function of the whole team's output, i.e.,

$$w_i(y(n)) = s_i + b_i y - p_i \theta q_i a_i,$$

where the term $\theta q_i a_i$ is the operating cost of the perk provided to agent i. Since all agents are identical and the production function is additively separable in the agents' individual outputs

duration of their assignment. Also, the idea makes perfect sense if the perk is interpreted as the degree of worker or contractor autonomy.

(although these are not contractible), the optimal contract will be the same for each agent. We will therefore drop the subscripts i and denote the optimal contract as $(\hat{s}(n), \hat{b}(n), \hat{p}(n), \hat{q}(n))$.

The current setting differs from the single agent setting of the previous section only in that the variance term is now given by $\sigma^2(n) = n^2\sigma^2$.[25] Since this does not affect the logic of Proposition 1, this proposition continues to hold here. That is, if offered, the perk should be provided to the workers free of charge, $\hat{p}(n) = 0$ for all n, even if the workers are organized in teams. Moreover, the slope of the optimal contract, $b^*(n)$, and the optimal amount of the perk, $q^*(n)$, are given by (5) and (6) respectively (provided that $q^*(n)$ given by (6) is positive), with σ^2 replaced by $\sigma^2(n)$. Thus, $\hat{b}(n) = b^*(n)$ and Proposition 2 immediately implies the following result.

Proposition 5. *A technological perk is more likely to be provided under team production than under individual production. Moreover, $\hat{q}(n)$ increases with the team size, n.*

Proposition 5 says that there should be a systematic positive relationship between the amount of the perk per worker and the team's size. Moreover, teams should receive some perks that would not be offered to the workers under individual production. The logic behind this result is as follows. The firm optimally reacts to an increase in the team size by weakening the workers' explicit incentives, because of the greater variance of the measurable output. These weaker explicit incentives mean that the incentive effects of the perk become more valuable, which tends to increase the optimal amount of the perk provided by the firm.

5.2. Worker autonomy

In recent years, researchers have shown considerable interest in the economics behind the firms' decisions whether to delegate decision-making authority to their workers and in the incentive ef-

[25] Note that unlike some papers in the literature on teams, we do not impose a balanced budget constraint $\hat{b}(n) \leq 1/n$. This could be justified by assuming that either the workers or the principal serve as the firm's budget breakers, as in Holmström (1982). Alternatively, we could restrict our attention to parameter values such that $r\sigma^2 > 1$, in which case the constraint would never bind because $b^*(n) \leq b_0^*(n) \leq 1/n$ for all n.

fects of this decision.[26] If workers like autonomy, or derive private benefits from being delegated decision-making authority, as in Aghion and Tirole (1997), then "worker autonomy" quite easily fits the description of a "technological perk", as formalized in our model. There are natural complementarities in a worker's consumption of the perk/autonomy and his work activity, and the perk could be also consumed by the worker in connection with non-productive activities — for example, the worker could use his autonomy to take care of personal errands during work hours. The variable q would then measure the degree of autonomy granted to the worker, the parameter m the direct productivity improvement (if any) due to the worker's greater decision-making authority, γ would capture the degree to which the worker values autonomy, and θ would be the marginal cost of delegating authority as perceived by the principal (say, the loss of control over which projects the agent pursues, as in Aghion and Tirole (1997)). Note that worker autonomy has long been viewed as a motivating benefit in the organizational behavior literature. For example, according to Hackman (1987, p. 324),[27] team members are motivated when "the task provides group members with substantial autonomy for deciding about how they do the work...".

Using this interpretation of our model, our earlier analysis yields the following four insights into the economic forces that determine the optimal degree of worker autonomy. The first three follow from Proposition 2, while the last one is obtained from Proposition 3.

(1) First, because q^* increases in γ, we confirm the finding in Aghion and Tirole (1997) that the degree of autonomy granted to a worker should be greater the greater is the benefit that the worker derives from it. In addition, we predict that in this case there should be a negative relationship between the agent's degree of autonomy and his formal incentives.

(2) More interestingly, our second prediction says that the more difficult it is to measure a

[26] Papers in this literature include Aghion and Tirole (1997), Prendergast (2002), Zabojnik (2002), Marino and Matsusaka (2005), and Raith (2005).

[27] As cited in DeVaro (2006).

worker's performance (i.e., the bigger is σ^2), the greater should be the degree of autonomy granted to the worker. This result is consistent with the finding in DeVaro (2006), who studies the effects of autonomy on financial performance of teams, and concludes that "the unobserved factors that make autonomy more likely (given that teams are in use) tend to lower financial performance in the presence of teams."[28] In our model, an increase in σ^2 not only makes team autonomy more likely, but also adversely affects the workers' overall incentives (by decreasing b^*) and ultimately the total surplus.[29]

Also, analogous to our discussion following Proposition 2, all else equal, we would expect the employees in larger organizations, privately held firms, in firms with many inter-dependent divisions, in geographically dispersed firms, and in the new economy firms to enjoy greater autonomy.

(3) Third, more productive employees (those with greater β), for example the employees higher up in an organization's hierarchical ladder, should be given more autonomy. This prediction sounds quite intuitive and in line with casual empirical observations.

(4) Finally, our model says that workers organized in teams should be given more autonomy than workers engaged in individual production. However, applying the argument discussed in point (2) above, this does not necessarily mean that teams that have more autonomy should perform better. Our model can thus reconcile the popular belief among business practitioners, that teams should be given more autonomy, with the evidence in DeVaro (2006), that there appears to be no significant difference in performance between autonomous and non-autonomous teams.

As before, these conclusions are all driven by the impact that the incentive effects of the perk/autonomy have on the trade-off between risk and incentives in the optimal contract.

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[28] DeVaro (2005) confirms this finding for labor productivity and product quality as alternative measures of team performance.

[29] This can be seen by differentiating total surplus $TS(b, q, p)$ with respect to σ^2 and applying the Envelope Theorem.

6. Conclusions

Work related perks appear to represent an important component of employment contracts, with possible consequences for the structure of observed formal incentives. Yet, their systematic treatment has been neglected in the extant literature on optimal incentive contracts. The present paper aims to fill this gap. In the spirit of Jensen and Murphy (1990), our starting point is the idea that in order to understand the incentives provided by an organization to its employees, one needs to examine all of the components of a worker's employment contract, as well as the interactions among these components. We point out that a firm's provision of a work-related perk can be understood by viewing the perk as a component of a complex incentive package, designed to optimally balance its conflicting insurance and incentive roles.

Our framework could be extended in several directions to add more realism. For example, one could incorporate in it multitasking considerations, viewed by many economists to be equally important in practice as the concerns about optimal risk-sharing. In such an augmented framework, we would expect the value of a technological perk to the principal to depend not only upon how easy it is to measure the agent's performance in the task the perk is associated with, but also upon the availability of good performance measures for the tasks that are unrelated to the perk but compete for the agent's attention.

Appendix

Proof of Lemma 1: Suppose $A(b^*, q^*, p^*) < 0$. Then (3) and $\frac{\partial a}{\partial p} < 0$ imply that $\frac{\partial TS}{\partial p} > 0$ for all $q > 0$. Hence, $p^* = \infty$. Similarly, (2) implies that $b^* = 0$, because $\frac{\partial TS}{\partial b} < 0$ for all $b \geq 0$ when $A(b^*, q^*, p^*) < 0$. Using $b^* = 0$ and $p^* = \infty$ means that $A(b^*, q^*, p^*) < 0$ only if $q^* = 0$.

Now suppose that $A(b^*, q^*, p^*) = 0$. Then (2) implies that $\frac{\partial TS}{\partial b} < 0$ for all $b \geq 0$, which means that $b^* = 0$. This, together with $A(b^*, q^*, p^*) = 0$, in turn implies that $\frac{\partial TS}{\partial q} = -(\theta - \beta m - \gamma)a - k < 0$ for all q. Hence, $q^* = 0$ in this case, too. ■

Proof of Proposition 1: (i) Because the optimization problem is concave, it must be that $\frac{\partial^2 TS}{\partial q^2} \leq 0$. Consequently, the necessary and sufficient condition for $q^* > 0$ is that $\frac{\partial TS}{\partial q}|_{q=0} > 0$. From (4), this holds if and only if[30]

$$\gamma > \gamma^* \equiv \frac{k + a_0^*(\theta - \beta m)}{a_0^* + \frac{\beta r \sigma^2}{1 + r\sigma^2 g''(a_0^*)}}, \tag{7}$$

where a_0^* is given by (1) evaluated at $q = 0$ and $b = b_0^* = \frac{1}{1 + r\sigma^2 g''(a_0^*)}$. Note that $\gamma^* > 0$. Also, a_0^* is independent of θ. Hence, if $\gamma > \gamma^*$, then $\frac{\partial TS}{\partial q}|_{q=0} > 0$ so that $q^* > 0$. Then, from (5), $b^* > 0$ iff $q^* < \frac{\beta}{\theta - \beta m}$, which always holds from (6). The analysis in the text proves that when $q^* > 0$ then $p^* = 0$.

(ii) The above argument implies that $q^* = 0$ for $\gamma \leq \gamma^*$. The expression for b^* in part (i)(b) then follows from $\frac{\partial TS}{\partial b} = 0$ evaluated at $q^* = 0$ and $p^* = 0$ (or from (5) evaluated at $q^* = 0$).

Finally, we prove that the FOC(1) has an interior solution when $q^* > 0$ and $p^* = 0$. To see this, let first $a = 0$. Then $RHS(1) = 0$, while $LHS(1) > 0$ because $b^* > 0$. On the other hand, if $a \to \infty$, then also $RHS(1) \to \infty$, while $LHS(1) < \infty$ because $b^* < 1$ always and (6) says that $q^* < \frac{\beta}{\theta - \beta m} < \infty$. The existence of a positive but finite a^* then follows from continuity of all relevant

[30] If TS were not concave in q, then (7) would be a sufficient but not always a necessary condition for $q^* > 0$.

expressions. ■

Proof of Proposition 2: (i) As shown in the proof of Proposition 1, $q^* > 0$ if and only if condition (7), reproduced here for convenience, holds:

$$\gamma > \gamma^* \equiv \frac{k + a_0^*(\theta - \beta m)}{a_0^* + \frac{\beta r \sigma^2}{1 + r\sigma^2 g''(a_0^*)}}. \tag{7}$$

This is obviously more likely to hold the higher is γ. Moreover, because a_0^* is independent of m and k, γ^* increases in k and decreases in m. For the rest of the proof, we will use the assumption that $g(a) = a^2/2$. Under this specification, (7) becomes

$$\gamma > \gamma^* \equiv \frac{k}{\beta} + \frac{\theta - \beta m}{1 + r\sigma^2},$$

which immediately implies that γ^* decreases in β, r, and σ^2, and increases in θ.

(ii) Using $g(a) = a^2/2$, the first order condition (1) yields $a^* = b\beta(1 + qm) + \gamma q$, which after substituting in b^* from (5) becomes

$$a^* = \frac{\beta + \gamma r \sigma^2 q - q(\theta - \beta m - \gamma)}{1 + r\sigma^2}.$$

Plugging this into (6) and rearranging, we get that q^* is given by $q^* = B/D$, where

$$\begin{aligned} B &\equiv \beta[\gamma r\sigma^2 - (\theta - \beta m - \gamma)] - k(1 + r\sigma^2), \text{ and} \\ D &\equiv \gamma(2\theta - 2\beta m - \gamma)(1 + r\sigma^2) - (\theta - \beta m)^2. \end{aligned} \tag{8}$$

Comparative statics on q^*. For any parameter t, we have that $\frac{\partial q^*}{\partial t} = \frac{\partial B/\partial t - q^* \partial D/\partial t}{D}$. Since $D > 0$

whenever $q^* > 0$, we have that q^* increases in parameter t if

$$\partial B/\partial t - q^* \partial D/\partial t > 0 \tag{9}$$

and decreases in t if the reverse is true. We now investigate for each of the model's parameters whether (9) or its reverse holds.

β : Differentiating (8) with respect to β, we see that (9) holds iff

$$[\gamma r \sigma^2 - (\theta - \beta m - \gamma)] + \beta m > -2mq^*[\gamma r \sigma^2 - (\theta - \beta m - \gamma)], \tag{10}$$

which always holds because the terms in the square brackets must be positive if $q^* > 0$ (since $q^* > 0$ implies $B > 0$). Therefore, we get $\frac{\partial q^*}{\partial \beta} > 0$.

m : We get $\partial B/\partial m = \beta^2 > 0$ and $\partial D/\partial m = 2\beta[(\theta - \beta m - \gamma) - \gamma r \sigma^2] < 0$, where the latter inequality follows because $B > 0$ for $q^* > 0$. Thus, (9) always holds for $t = m$, which means that $\frac{\partial q^*}{\partial m} > 0$.

θ : In this case, $\partial B/\partial \theta = -\beta < 0$ and $\partial D/\partial \theta = 2\beta[\gamma r \sigma^2 - (\theta - \beta m - \gamma)] > 0$, where the latter inequality again follows from $B > 0$. Thus, the reverse of (9) holds for $t = \theta$, so that $\frac{\partial q^*}{\partial \theta} < 0$.

k : We have $\frac{\partial q^*}{\partial k} = \frac{-(1+r\sigma^2)}{D} < 0$.

r and σ^2 : These parameters only enter through $r\sigma^2$; thus, let $t = r\sigma^2$. Differentiating B and D with respect to $r\sigma^2$, plugging in for q^* and rearranging, we see that condition (9) holds in this case iff

$$\gamma \beta (\theta - \beta m - \gamma) > -k(\theta - \beta m). \tag{11}$$

Since the left hand side is positive while the right hand side is negative, this always holds and we have that $\frac{\partial q^*}{\partial r} > 0$ and $\frac{\partial q^*}{\partial \sigma^2} > 0$.

γ : In this case, after substituting for q^*, we find that (9) is equivalent to

$$\beta(1+r\sigma^2)[2\gamma(\theta-\beta m)-\gamma^2]-\beta(\theta-\beta m)^2-2\beta(\theta-\beta m-\gamma)[\gamma r\sigma^2-(\theta-\beta m-\gamma)]+2k(\theta-\beta m-\gamma)(1+r\sigma^2)>0.$$

Since the left hand side increases in k, the condition holds for all k if it holds for $k=0$. But when $k=0$, the condition simplifies to

$$(\theta-\beta m-\gamma)^2+\gamma^2 r\sigma^2>0,$$

which always holds. Hence, $\frac{\partial q^*}{\partial \gamma}>0$.

Comparative statics on b^*. First, notice from (5) that b^* decreases in q^*. It is then straightforward to see that b^* decreases in γ, r and σ^2 and increases in k. On the other hand, θ, β, and m, all have both direct and indirect (through q^*) effects on b^* and these work in opposite directions. For example, the direct effect of θ on b is negative, while the indirect effect, through a smaller q^*, tends to increase b^*.

θ : Rewriting (5) to get

$$b^*=\frac{1-\theta q^*/\beta(1+q^*m)}{1+r\sigma^2}, \tag{5'}$$

we see that $\frac{\partial b^*}{\partial\theta}>0$ iff $\frac{\partial}{\partial\theta}\left[\frac{\theta q^*}{1+q^*m}\right]<0$, which holds iff

$$\frac{\partial q^*}{\partial\theta}<\frac{-q^*(1+q^*m)}{\theta}. \tag{12}$$

Using $q^*=B/D$, (12) can be rewritten as

$$q^*\left[(1+q^*m)D-\theta\frac{\partial D}{\partial\theta}\right]<-\theta\frac{\partial B}{\partial\theta},$$

which always holds if the term in square brackets on the left hand side is negative, because $\frac{\partial B}{\partial \theta} = -\beta$. Thus, assume that the bracketed term is positive. Then the condition holds if

$$q^* < \frac{-\theta \partial B/\partial \theta}{(1+q^*m)D - \theta \partial D/\partial \theta}, \tag{13}$$

Now, from (5) we know that $q^* < \frac{1}{\theta - \beta m}$. Hence, (13) holds if

$$\frac{1}{\theta - \beta m} < \frac{-\theta \partial B/\partial \theta}{(1+q^*m)D - \theta \partial D/\partial \theta},$$

which can be rewritten as

$$D + Bm - \theta \frac{\partial D}{\partial \theta} < \theta(\theta - \beta m).$$

Since B is the only term in this inequality that depends on k and B decreases in k, the inequality holds as long as it holds for $k = 0$. Setting $k = 0$ and plugging in for D, B, and $\frac{\partial D}{\partial \theta}$, we see that after a few algebraic manipulations the condition becomes $\gamma + \beta m > 0$, which always holds. Therefore, $\frac{\partial b^*}{\partial \theta} > 0$.

m : Form (5'), we see that $\frac{\partial b^*}{\partial m} < 0$ iff $\frac{\partial}{\partial m}\left[\frac{\theta q^*}{1+q^*m}\right] > 0$, which holds iff

$$\frac{\partial q^*}{\partial m} > (q^*)^2. \tag{14}$$

Using $q^* = B/D$, we get that (14) holds iff

$$D\frac{\partial B}{\partial m} > B(B + \frac{\partial D}{\partial m}).$$

Plugging in for B and $\frac{\partial D}{\partial m}$ from (8) and setting $k = 0$ (again, the only effect of k is to decreases the right hand side of the above inequality), it turns out that $B + \frac{\partial D}{\partial m} = -B < 0$. Since $D\frac{\partial B}{\partial m} > 0$, this means that the condition always holds. Therefore, $\frac{\partial b^*}{\partial m} < 0$.

β : In this case, (5') implies that $\frac{\partial b^*}{\partial \beta} > 0$ iff $\frac{\partial}{\partial \beta}\left[\frac{\theta q^*}{\beta(1+q^* m)}\right] < 0$, or

$$\frac{\partial q^*}{\partial \beta}\beta < 1 + q^* m.$$

Using $q^* = B/D$, this translates into

$$\frac{\partial B}{\partial \beta}\frac{1}{D} < \frac{\partial B}{\partial \beta}q^* + D(1 + q^* m). \tag{15}$$

Now, analogous to γ^*, define k^* as the cutoff level such that $q^* > 0$ if and only if $k < k^*$. From (4), k^* is given by

$$k^* \equiv \frac{\beta\gamma r\sigma^2}{1 + r\sigma^2} - (\theta - \beta m - \gamma)a_0^*.$$

Note that $k^* < \infty$. Next, observe that the left hand side of (15) is independent of k, while the right hand side decreases in k (because q^* decreases in k). Thus, (15) holds for all k if it holds for $k = k^*$. Since by definition of k^* we have $q^* = 0$ when $k = k^*$, a sufficient condition for (15) to hold is that

$$\frac{\partial B}{\partial \beta} < D^2$$

when evaluated at $q^* = 0$. Differentiating B with respect to β, we get that $\frac{\partial B}{\partial \beta} = \frac{B}{\beta} - \beta m$. Because $q^* = B/D = 0$ requires that $B = 0$, the above inequality becomes $-\beta m < D^2$, which is always satisfied. Hence, $\frac{\partial b^*}{\partial \beta} > 0$. ■

Proof of Proposition 3: Using equations (16) and (17), and assuming a_1,$a_2 > 0$, we obtain the following results:

$$\frac{\partial a_1}{\partial b} = \beta(1 + qm), \quad \frac{\partial a_1}{\partial q} = \gamma_1 + \beta bm - p\theta, \quad \frac{\partial a_1}{\partial p} = -q\theta, \tag{18}$$

$$\frac{\partial a_2}{\partial b} = 0, \quad \frac{\partial a_2}{\partial q} = \gamma_2 - p\theta, \quad \frac{\partial a_2}{\partial p} = -q\theta. \tag{19}$$

Substituting from (16) and (17), we can define

$$\partial TS/\partial a_1 \equiv A_1 = (1-b)\beta(1+qm) - (1-p)q\theta,$$

$$\partial TS/\partial a_2 \equiv A_2 = -(1-p)q\theta.$$

The derivatives of TS in the choice variables (b, p, q) can then be written as

$$\frac{\partial TS}{\partial b} = A_1 \frac{\partial a_1}{\partial b} + A_2 \frac{\partial a_2}{\partial b} - rb\beta^2(1+qm)^2\sigma^2,$$

$$\frac{\partial TS}{\partial p} = A_1 \frac{\partial a_1}{\partial p} + A_2 \frac{\partial a_2}{\partial p},$$

$$\frac{\partial TS}{\partial q} = A_1 \frac{\partial a_1}{\partial q} + A_2 \frac{\partial a_2}{\partial q} - rb^2\beta^2(1+qm)m\sigma^2 - k - (\theta - \beta m - \gamma_1)a_1 - (\theta - \gamma_2)a_2. \tag{19'}$$

Suppose $p^{**} > 0$ and $q^{**} > 0$. Then p^{**} is determined by $\frac{\partial TS}{\partial p} = 0$, which, together with $\frac{\partial a_1}{\partial p} = \frac{\partial a_2}{\partial p}$, yields $A_1 = -A_2 = \theta(1-p^{**})q^{**}$, which yields $A_1(q=0) = A_2(q=0) = 0$. Now, the concavity of TS in q implies that $\frac{\partial TS}{\partial q} > 0$ when evaluated at p^{**} and $q = 0$. But

$$\frac{\partial TS}{\partial q}|_{q=0} = -rb^2\beta^2 m\sigma^2 - k - (\theta - \beta m - \gamma_1)b\beta < 0,$$

which contradicts the requirement that $\frac{\partial TS}{\partial q} > 0$. Hence, if $q^{**} > 0$, then it must be $p^{**} = 0$.

Given that $p^{**} > 0$, the first order conditions for b^{**} and q^{**} yield

$$b^{**} = \frac{1 - \theta q^{**}/\beta(1+q^{**}m)}{1 + r\sigma^2}, \tag{20}$$

$$q^{**} = \frac{\beta[\gamma_1(1+r\sigma^2)+\beta m-\theta]-k(1+r\sigma^2)}{[(2\theta-2\beta m-\gamma_1)\gamma_1+(2\theta-\gamma_2)\gamma_2](1+r\sigma^2)-(\theta-\beta m)^2}. \tag{21}$$

The corresponding condition for b^* is identical except for the appearance of q^* in the place of q^{**} and the condition for q^* is as in (21) with $\gamma_2 = 0$. Thus, equation (21) implies that $q^* > q^{**}$ and by the fact that the right side of (20) is decreasing in q, we have that $b^{**} > b^*$. Because $q^* = q^{**}(\gamma_2 = 0)$ and the numerator of (21) does not depend upon γ_2, it must be that $q^{**} > 0$ if and only if $q^* > 0$. ■

Proof of Proposition 4: From $\theta > \gamma_2$, we have that $(2\theta - \gamma_2)\gamma_2$ increases in γ_2. Using (21), this means that q^{**} decreases in γ_2, which in turn implies that b^{**} increases in γ_2, because γ_2 only affects b^{**} through q^{**} and b^{**} decreases in q^{**}. Also, it is immediate that q^{**} decreases in k, which then implies that b^{**} increases in k because b^{**} only depends on k through q^{**}. To get the rest of the comparative statics results, write q^* as $q^* = B/D$, as in the proof of Proposition 2, and q^{**} as $q^{**} = B/D'$, where

$$\begin{aligned} B &\equiv \beta[\gamma_1(1+r\sigma^2)+\beta m-\theta]-k(1+r\sigma^2), \\ D &\equiv [(2\theta-2\beta m-\gamma_1)\gamma_1+(2\theta-\gamma_2)\gamma_2](1+r\sigma^2)-(\theta-\beta m)^2, \text{ and} \\ D' &\equiv D+\gamma_2(2\theta-\gamma_2)(1+r\sigma^2). \end{aligned}$$

Comparative statics on q^{**}. For any parameter t, we have that $\frac{\partial q^{**}}{\partial t} > 0$ if and only if

$$D'\frac{\partial B}{\partial t} - B\frac{\partial D'}{\partial t} > 0,$$

which will be useful to write as

$$D\frac{\partial B}{\partial t} - B\frac{\partial D}{\partial t} + \gamma_2(2\theta-\gamma_2)(1+r\sigma^2)\frac{\partial B}{\partial t} - B\frac{\partial}{\partial t}\left(\gamma_2(2\theta-\gamma_2)(1+r\sigma^2)\right) > 0.$$

If $\frac{\partial q^*}{\partial t} > 0$, then $D\frac{\partial B}{\partial t} - B\frac{\partial D}{\partial t} > 0$ so that to establish $\frac{\partial q^{**}}{\partial t} > 0$ it will be sufficient to show that

$$\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\frac{\partial B}{\partial t} - B\frac{\partial}{\partial t}\left(\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\right) > 0. \tag{22}$$

Similarly, if $\frac{\partial q^*}{\partial t} < 0$, then $D\frac{\partial B}{\partial t} - B\frac{\partial D}{\partial t} < 0$ and it is enough to show that

$$\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\frac{\partial B}{\partial t} - B\frac{\partial}{\partial t}\left(\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\right) < 0 \tag{23}$$

to establish that $\frac{\partial q^{**}}{\partial t} < 0$.

β : Since $\frac{\partial q^*}{\partial \beta} > 0$, we only need to show that (22) holds for $t = \beta$. In this case, (22) becomes

$$\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)[\gamma_1(1 + r\sigma^2) + 2\beta m - \theta] > 0,$$

which is always satisfied because $\theta > \gamma_2$ and because $q^{**} > 0$ requires $\gamma_1(1 + r\sigma^2) + \beta m - \theta > 0$. Therefore, we get $\frac{\partial q^{**}}{\partial \beta} > 0$.

m : Again, $\frac{\partial q^*}{\partial m} > 0$ means that we only need to check (22) for $t = m$, which in this case becomes

$$\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\beta^2 > 0,$$

which again holds. Hence, $\frac{\partial q^{**}}{\partial m} > 0$.

θ : In this case, $\frac{\partial q^*}{\partial \theta} < 0$, so we need to show that (23) holds for $t = \theta$. This condition becomes

$$-\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\beta - B\gamma_2 2\theta(1 + r\sigma^2) < 0,$$

which holds because $B > 0$. Thus, $\frac{\partial q^{**}}{\partial \theta} < 0$.

γ_1 : $\frac{\partial q^*}{\partial \gamma} > 0$ means that we only need to check that (22) is satisfied. For γ_1, this condition is

$$\gamma_2(2\theta - \gamma_2)(1 + r\sigma^2)\beta\gamma_1(1 + r\sigma^2) > 0,$$

which holds. Therefore, $\frac{\partial q^{**}}{\partial \gamma} > 0$.

$r\sigma^2$: Differentiating B and D' with respect to $r\sigma^2$ and rearranging, we see that the condition $D'\frac{\partial B}{\partial t} - B\frac{\partial D'}{\partial t} > 0$ holds iff

$$\beta\gamma_1 - k > q^{**}[(2\theta - 2\beta m - \gamma_1)\gamma_1 + (2\theta - \gamma_2)\gamma_2].$$

Plugging in $q^{**} = B/D'$, rearranging again, and cancelling out terms, this condition simplifies to $\theta - \beta m - \gamma_1 > 0$, which holds by assumption. This yields $\frac{\partial q^{**}}{\partial r} > 0$ and $\frac{\partial q^{**}}{\partial \sigma^2} > 0$.

Comparative statics on b^{**}. For convenience, we reproduce here the expression for b^{**}:

$$b^{**} = \frac{1 - \theta q^{**}/\beta(1 + q^{**}m)}{1 + r\sigma^2}. \tag{20}$$

First, notice from (5') and (20) that b^{**} is the same function of q^{**} as b^* is of q^*, and that b^{**} decreases in q^{**}. It is then immediate that b^* decreases in γ_1, r and σ^2.

On the other hand, as with the effects of θ, β and m on b^*, all of these parameters have both direct and indirect (through q^*) effects on b^{**} that work in opposite directions.

θ : The direct effect of θ on b^{**} is negative, while the indirect effect, through a smaller q^{**}, tends to increase b^{**}. From (20), we see that $\frac{\partial b^{**}}{\partial \theta} > 0$ iff $\frac{\partial}{\partial \theta}\left[\frac{\theta q^{**}}{1+q^*m}\right] < 0$, which holds iff

$$\frac{\partial q^{**}}{\partial \theta} < \frac{-q^{**}(1 + q^{**}m)}{\theta}. \tag{24}$$

Now, from the proof of Proposition 2, we know that

$$\frac{\partial q^*}{\partial \theta} < \frac{-q^*(1+q^*m)}{\theta}. \tag{25}$$

Since $q^{**} < q^*$, the right hand side of (24) is greater than the right hand side of (25). Thus, (24) holds if $\frac{\partial q^{**}}{\partial \theta} \leq \frac{\partial q^*}{\partial \theta}$, i.e. if

$$\frac{D'\frac{\partial B}{\partial \theta} - B\frac{\partial D'}{\partial \theta}}{D'^2} < \frac{D\frac{\partial B}{\partial \theta} - B\frac{\partial D}{\partial \theta}}{D'^2}.$$

Because the numerators on both sides of the inequality are positive and $D' > D$, this holds if $D'\frac{\partial B}{\partial \theta} - B\frac{\partial D'}{\partial \theta} < D\frac{\partial B}{\partial \theta} - B\frac{\partial D}{\partial \theta}$, which reduces to condition (23) for $t = \theta$. As we have shown above, this condition holds. Hence, (25) holds, which means that $\frac{\partial b^{**}}{\partial \theta} > 0$.

m : From (20), we have that $\frac{\partial b^{**}}{\partial m} < 0$ iff $\frac{\partial}{\partial m}\left[\frac{\theta q^{**}}{1+q^*m}\right] > 0$, which holds iff

$$\frac{\partial q^{**}}{\partial m} > (q^{**})^2. \tag{26}$$

Using $q^{**} = B/D'$, we get that (26) holds iff

$$D'\frac{\partial B}{\partial m} > B(B + \frac{\partial D'}{\partial m}).$$

Since from the proof of Proposition 2 we know that $D\frac{\partial B}{\partial m} > B(B + \frac{\partial D}{\partial m})$, and because $D' > D > 0$, $\frac{\partial B}{\partial m} > 0$, $B > 0$, and $\frac{\partial D'}{\partial m} = \frac{\partial D}{\partial m}$, the above condition must hold. Therefore, $\frac{\partial b^{**}}{\partial m} < 0$.

β : In this case, (20) implies that $\frac{\partial b^{**}}{\partial \beta} > 0$ iff $\frac{\partial}{\partial \beta}\left[\frac{\theta q^{**}}{\beta(1+q^*m)}\right] < 0$, or

$$\frac{\partial q^{**}}{\partial \beta}\beta < 1 + q^{**}m.$$

Using $q^{**} = B/D'$, this translates into

$$\frac{\partial B}{\partial \beta} < \frac{\partial B}{\partial \beta} B + D'(D' + Bm). \tag{27}$$

Again, from the proof of Proposition 2 we have that

$$\frac{\partial B}{\partial \beta} < \frac{\partial B}{\partial \beta} B + D(D + Bm).$$

Thus, (27) holds because $\frac{\partial B}{\partial \beta} > 0$, $B > 0$, and $D' > D > 0$. Hence, $\frac{\partial b^*}{\partial \beta} > 0$. ■

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