Benefits of Broad-Based Option Pay*

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Abstract

This paper examines the optimal structure of a firm's aggregate wage bill. Rents promised to employees drive a wedge between total firm output and the share received by the firm's owners, thus distorting the owners' exit (i.e., liquidation, sale) decisions. In an optimal contracting framework, we show that the unique optimal aggregate wage structure is to grant all employees an option on the firm's cash flow. Broad-based option pay minimizes the firm's total wage cost in states where the firm is only marginally profitable, thus minimizing the wedge between total output and the owners' share of it in exactly those states where, e.g., a fixed wage would lead the firm's owners to (inefficiently) exit. If there is a subsistence requirement, employees additionally receive a base wage.

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1 Introduction

What is the optimal structure of a firm's aggregate wage bill? This paper shows that the structure of wage contracts matters even if there is no moral hazard or private information on the part of employees. Wage payments drive a wedge between total firm output and the output share received by the firm's owners, thus distorting strategic decisions made by the firm's owners such as, e.g., whether to continue the firm, shut it down, or sell it. In an optimal contracting framework, we show that the unique optimal aggregate wage structure from this perspective is a broad-based option plan. If there is a subsistence requirement, employees additionally obtain a base wage.

The intuition is conceivably simple. Broad-based option pay minimizes the firm's total wage cost in exactly those states of nature where the firm is only marginally profitable, and where, e.g., a fixed wage would lead the firm's owners to (inefficiently) exit. While any form of indexed wage (e.g., stock grant) does better than a fixed wage, broad option grants are *uniquely optimal* as they shift more wage costs from low into high states of nature (where wage costs do not matter for the owners' decision) than any other type of wage contract.

Our argument might help explain why firms use option grants to compensate middle- and lower-level employees. Hall and Murphy (2003), for instance, find that in 2002 more than 90 percent of total company stock option grants in the United States have been awarded to managers and employees below the top-five executive level.[1] They conclude that "given the increasing prevalence of broad-based plans, a compelling theory of employee stock options must explain not only executive stock options, but also options granted to the rank and file" (p. 54). As far as such a "theory" is concerned, the question is not so much what are the costs of broad-based option grants? It is well understood, we believe, that paying employees with options subjects them to considerable risk. Rather, the interesting question is what are the offsetting *benefits* that might warrant these costs? (Oyer and Schaefer (2003)).

This question has spurred a considerable amount of research, both empirical and theoretical, which we will review in the following section. We do not view our argument as exclusive,

[1] For further evidence on the prevalence of broad-based option grants, see Mehran and Tracy (2001) and Oyer and Schaefer (2003).

although we do take a stand—along with certain other papers—that efficiency considerations may play an important role in understanding broad-based option pay. Rather, we view our argument as complementary to arguments focusing on the decisions of individual *employees*, such as, e.g., retention and sorting arguments. Our argument, by contrast, focuses on decisions made by the firm's owners. While our argument appears to be particularly relevant for smaller firms with active founder-CEOs, we believe it is also relevant for larger firms in which founders have significant ownership stakes, or firms in which the board maximizes shareholder value.[2]

In our model, the owner of a firm must decide whether or not to continue his business.[3] The owner's optimal decision depends on the "state of nature", which generates a probability distribution over future firm cash flows. Higher states of nature are associated with "better" cash-flow distributions in the usual sense. The state of nature indicates how successful the owner's business strategy has been. It captures, for instance, how successful the owner was in finding buyers, striking good deals with suppliers and vendors, developing ideas for follow-up products, and establishing a sales and distribution network. All these factors determine the firm's future profitability if the owner continues.

The state of nature is ex ante uncertain, which captures the typical entrepreneurial risk that the owner does not know in advance how successful he will be. At an interim date, the owner privately observes the state of nature and decides whether to continue. The first-best decision is to continue if the expected cash flow from continuation exceeds the (opportunity) cost of continuation, which holds if and only if the state of nature is sufficiently high. The cost of continuation includes forgone profits from not liquidating or selling the firm, but also any effort or investment by the owner required for the firm's continuation.

Since the owner privately observes the state of nature, his decision whether to continue is fully discretionary. Due to a standard efficiency-wage type argument, the firm's employees must

[2]Oyer and Schaefer (2003) and Ittner, Lambert, and Larcker (2003) find that broad-based option plans are particularly prevalent in new-economy firms, which tend to be smaller on average. But also larger firms in which founders have significant ownership stakes, such as Microsoft and Oracle, frequently tend to have broad-based option plans. Oyer and Schaefer, like this paper, thus take as their "starting point the assertion that broad-based stock option plans are in shareholders' interests" (p.16).

[3]The continuation decision plays a key role in corporate finance models, but also in models of investment under uncertainty. For respective surveys, see, e.g., Hart (2001) and Dixit and Pindyck (1994).

earn a rent if the firm is continued. This rent drives a wedge between the first-best exit decision and the owner's privately optimal exit decision. In particular, in marginally profitable states where the expected cash flow from continuation barely exceeds the cost of continuation, the owner will nevertheless find it optimal to exit as he only receives the expected cash flow *minus* the rent promised to the employees.

The question is therefore—holding expected wage payments constant—what form of aggregate wage structure minimizes the distortions in the owner's exit decision? In an optimal contracting framework with continuous firm cash flows, we show that the unique optimal wage structure from this perspective is to grant all employees an option on the firm's cash flow.[4] If there is a subsistence requirement, employees additionally obtain a base wage. Intuitively, broad-based option pay minimizes the firm's total wage cost in low, and hence marginally profitable states of nature, thus minimizing the wedge between the first-best exit decision and the owner's privately optimal exit decision. By contrast, a fixed wage, or any other form of wage contract (e.g., stock grants), would imply a higher wage cost—and thus a more severe "wage overhang" problem—in marginal states of nature, thus making continuation unprofitable in situations where it would be profitable under broad-based option pay.

On the other hand, broad-based option pay implies a relatively high wage cost in profitable states of nature. This is inconsequential for the owner's decision though, as in these states he would continue anyway, i.e., despite the high wage cost. This confirms a basic intuition from incentive theory that incentives matter only at the margin (here: in marginal states of nature).

In an extension of our model, we allow for the possibility that the employees additionally receive a severance payment, i.e., the wage contract stipulates both a payment if the firm is continued and a (possibly different) payment if the owner exits (e.g., the employees receive a fraction of the sales price or liquidation value). As it turns out, introducing severance pay has no qualitative effects on our results. In another extension, we allow for the possibility that the owner receives private benefits from continuing (e.g., he gains additional experience as an

[4] We use the term "option" in the classic (i.e., finance) sense. In the labor contracting literature, it is sometimes used differently. For instance, Holmström and Ricart I Costa (1986) use the term "option on the manager's human capital" to denote a sequence of downward rigid wage contracts that protects the manager from a decline in the value of his human capital.

entrepreneur). Since these private benefits also enter into the first best, the inefficiency that the owner exits too often *relative to the first best* remains exactly the same, and so does our main result. If the private benefits are sufficiently large, however, it may now be the case that the owner continues even though the firm's continuation value (excluding private benefits) is less than the liquidation value or sales price. For an outside observer who does not know the owner's private benefits, it may then appear as if the owner exits too little.

The driving force underlying our model is the owner's inability to commit to a particular decision rule due to his private information. If the owner could commit to a decision rule based on the (true) state of nature, the choice of optimal wage contract would be trivial. Precisely, there would be an infinite number of optimal wage contracts (including a fixed wage) that leave the employees the required rent and implement the first best. In this regard, our basic setting is related to Grossman and Hart (1983) and other models of implicit labor contracting under asymmetric information.[5] In Grossman and Hart's model, the owner of a firm must decide whether to lay off workers after privately observing the state of nature. Unlike our model, however, Grossman and Hart *assume* that workers receive a fixed wage. This generates excessive unemployment, which is the primary focus of that literature.[6]

The rest of this paper is organized as follows. Section 2 reviews the literature on broad-based option pay. Section 3 lays out the basic model. Section 4 contains our main results. In particular, this section shows that the unique optimal form of wage contract is to grant all employees an option on the firm's cash flows, coupled with a base wage if there is also a subsistence requirement. Section 5 contains extensions and robustness checks. In particular, it considers the possibility of severance pay as well as private benefits on the part of the owner. It also examines renegotiations, which is important as the owner's exit decision is inefficient in marginal states of nature. As renegotiations take place under private information, however, the optimal wage contract is not renegotiated in equilibrium. Section 6 concludes.

[5] Rosen (1985) contains an excellent overview of the implicit labor contracting literature.

[6] Weitzman (1985) and Nordhaus (1988) discuss a similar point from a macroeconomic perspective.

2 Literature Review

"Traditional" arguments for incentive pay like effort provision and sorting—while potentially relevant for CEO compensation—are unlikely to be able to explain the widespread use of broad option grants. The reason is that an individual worker's effort or ability has at best only a small impact on firm profits (Hall and Murphy (2003), Lazear (1999), Oyer and Schaefer (2003)). Even in relatively small firms with few employees, this can quickly lead to an "enormous free-rider problem" (Hall and Murphy, p. 58).[7]

Two arguments for broad-based option pay that have been advanced in the literature are the favorable tax and accounting treatment of options (Hall and Murphy (2003)) and cash constraints (Core and Guay (2001), Kedia and Mozumdar (2002)). However, Oyer and Schaefer's (2004) analysis casts doubt on the accounting hypothesis, while Ittner, Lambert, and Larcker (2003) and Bergman and Jenter (2003) find that cash constraints are unlikely to be able to explain broad-based option pay. In our model, cash constraints play no role.

While incentive or sorting arguments are unlikely to play a major role, it is still possible to motivate broad-based option pay on the basis of economic efficiency. Indeed, Oyer (2003) shows that firms can use equity-based pay as a way to retain employees. The idea is that, if a firm's stock price is positively correlated with the employees' outside opportunities, the value of the employees' compensation package is high precisely when his outside opportunities are good, and vice versa. Empirical support for the retention hypothesis is provided by Oyer and Schaefer (2003, 2004) and Kedia and Mozumdar (2002). In addition, Oyer and Schaefer find that options are a less costly way to retain employees than either cash or restricted stock. Our paper also suggests an efficiency rationale for broad-based option pay, although we focus on the incentives of firm owners to make optimal exit decisions, not on the incentives of employees

[7] The economic arguments for incentive pay—and, more generally, incentive provision in firms—are discussed in, e.g., Prendergast (1999), Gibbons (1998), and Lazear (1999a). Innes (1990) examines the use of stock options in a moral hazard setting, while Lazear (1986, 1999b) shows that incentive pay can be used to sort workers according to their ability. As Lazear (1999b, p. 0) points out, however, this "does not explain why some firms give stock options even to very low-level workers". On the other hand, broad-based option pay *may* be an effective sorting device if sorting is with respect to risk aversion or optimism about the firm's prospects rather than ability (Oyer and Schaefer (2003, 2004), Bergman and Jenter (2003)).

to stay. Besides, we endogenously derive broad option pay from first principles as an optimal contract between the firm's owner and its employees.

Finally, Hall and Murphy (2003) and Bergman and Jenter (2003) provide behavioral explanations for broad-based option plans.[8] Hall and Murphy argue that boards and firm owners erroneously perceive option plans as "cheap to grant because there is no accounting cost and no cash outlay, and granting decisions are based on this inaccurate "perceived cost" rather than the much-higher economic cost of options" (p. 61). Bergman and Jenter, by contrast, assume irrationality on the part of the employees. In particular, they argue that overoptimistic employees are willing to overpay for option grants because they (irrationally) prefer the stock option to its market value in cash. Firms, in turn, take advantage of this by paying employees in the form of option grants.

3 The Model

We examine the decision of a firm's owner whether or not to continue his business. For simplicity, we assume that the firm has a single employee. As there is no (strategic) interaction among employees, we can think of this employee as representing all employees in the firm. We denote the firm's owner by P (for principal) and the employee by A (for agent).

If the firm is continued, it generates a stochastic cash flow $x \in X = [\underline{x}, \overline{x}]$, where $0 \leq \underline{x} < \overline{x}$, and where $\overline{x}$ can be either finite or infinite. For convenience, we set $\underline{x} = 0$, although our results straightforwardly extend to $\underline{x} > 0$. The cash-flow distribution $G_\theta(x)$ depends on the underlying state of nature $\theta \in \Theta := [\underline{\theta}, \overline{\theta}]$. We assume that $G_\theta(x)$ is atomless and the density $g_\theta(x)$ is positive everywhere and continuous in both x and θ. The expected cash flow conditional on the state of nature is denoted by $E[x \mid \theta] := \int_X x g_\theta(x) dx$.[9]

We also assume that in case of continuation the owner receives private benefits of $B \geq 0$. While this has interesting implications for the owner's exit decision, it does not affect our qualitative results. For expositional clarity, we therefore initially set $B = 0$ in our analysis. The

[8] See also Weitzman and Kruse (1990, p. 100), who argue that stock-based compensation creates a "corporate culture that emphasizes company spirit."

[9] If $\overline{x}$ is infinite, we assume that $E[x \mid \theta]$ exists.

case where $B > 0$ is formally considered in Section 5.

As argued in the Introduction, the state of nature indicates how successful the owner is (or was) in running the firm. In a certain sense, it is a measure of the owner's (idiosyncratic) entrepreneurial talent. Specifically, we assume that higher states of nature imply a more favorable cash-flow distribution in the following sense:

Assumption 1. *The hazard rate* $g_\theta(x)/[1 - G_\theta(x)]$ *is strictly decreasing in* θ *for all* $x \leq \overline{x}$.

Assumption 1 is relatively standard in contracting models and known as monotone hazard rate property (MHRP), or log-concavity.[10]

Only the owner observes the true state of nature θ, and therefore the true cash-flow distribution. While employees (and courts) may realistically have *some* notion of how well the firm is doing, it appears plausible to us that there are certain issues which the owner knows more about (see the Introduction for examples). It is this difference in information what we are trying to capture here.

The alternative to continuation is exit, i.e., to shut the firm down or sell its assets, property, and patents on the market. We denote the owner's (opportunity) cost of continuation by L. This includes any forgone revenues from not liquidating or selling the firm, any effort or investment by the owner required for the firm's continuation, but also any profit which the owner forgoes by not pursuing another business activity. The employee's opportunity cost of continuation includes forgone unemployment benefits. For simplicity, we assume that these unemployment benefits provide the employee with a minimum subsistence level of J, which implies the total opportunity cost of continuation is $L + J$. While introducing opportunity costs on the part of the employee adds realism to our model, it is unrelated to our basic argument for why options are optimal. It is straightforward to extend our model to include unemployment benefits exceeding J, or (forgone) wages from alternative employment, which would then realistically also exceed J. By the same token, any extension along these lines provides only limited additional insight.

Benchmark: First-Best Decision Rule. As a benchmark, let us derive the first-best decision rule. By Assumption 1 and continuity of $g_\theta(x)$, the conditional expected cash flow $E[x \mid \theta]$ is

[10] For an economic interpretation, see Laffont and Tirole (1993). MHRP is implied by, and hence weaker than, the monotone likelihood ratio property, which is satisfied by many standard distributions (Milgrom (1981)).

continuous and increasing in θ. To rule out trivial cases where continuation is either always (i.e., in all states of nature) or never optimal, we assume that $E[x \mid \overline{\theta}] > L + J$ and $E[x \mid \underline{\theta}] < L + J$. Consequently, there exists a unique cutoff $\theta_{FB} \in (\underline{\theta}, \overline{\theta})$ given by $E[x \mid \theta_{FB}] = L + J$ such that $E[x \mid \theta] \geq L+J$ if and only if $\theta \geq \theta_{FB}$. The first-best decision rule is then to continue if $\theta \geq \theta_{FB}$ and to exit if $\theta < \theta_{FB}$. $\square$

There are three dates: $t = 0$, $t = 0.5$, and $t = 1$. At $t = 0$ the employee obtains a wage contract. At this stage, the state of nature is uncertain and represented by the distribution function $F(\theta)$, which is common knowledge. We assume that $F(\theta)$ has no atoms and the density $f(\theta)$ is positive everywhere. At $t = 0.5$ the owner privately observes the state of nature and decides whether to continue or exit. At $t = 1$—provided the firm is continued—the cash flow x is realized, and the employee receives the contractually stipulated wage payment $w(x)$.[11] We impose the following restriction on $w(x)$:

Assumption 2. *Both $w(x)$ and $x - w(x)$ are nondecreasing everywhere.*

This sort of restriction is common in contracting models. It implies, among other things, that neither the employee nor the owner has an incentive to destroy output (Innes (1990), DeMarzo and Duffie (1999)).

We furthermore require that the wage contract guarantees the employee a minimum subsistence level, implying that $w(x) \geq J$.[12] (For instance, we might assume that if $w(x) < J$ the employee's utility is infinitely negative.) As in the case of the employee's unemployment benefit, this constraint—while adding realism to our model—is unrelated to our economic argument for why options are optimal. To illustrate this, we first present the basic intuition for our results for the case where $J = 0$. Subsequently, we show that this intuition straightforwardly extends to the case where $J > 0$.

Any wages that are paid regardless of whether or not the firm is continued do not affect the

[11] While the wage contract $w(x)$ cannot directly condition on the state of nature θ, one could—in principle—make the wage payment indirectly contingent on θ by allowing the owner to choose a contract from a prespecified menu of contracts after observing the state of nature. Absent any sorting variable, introducing such a menu has no benefits, however. In fact, one can show that offering a menu of wage contracts at $t = 0$ is strictly suboptimal.

[12] This is possible as we do not assume that the firm is cash constrained. Alternatively, we could have assumed that $\underline{x} \geq J$, in which case the subsistence wage could be paid out of the firm's cash flow at $t = 1$.

owner's decision, and are therefore irrelevant. We could thus easily introduce an interim wage at $t = 0.5 - \varepsilon$ that is paid independently of the subsequent exit decision. Payments that are due *only* when the owner exits, on the other hand, may affect the owner's decision. In Section 5, we allow that the wage contract additionally stipulates a (severance) payment S if the firm is discontinued, e.g., the employee might receive a fraction of the sales price or liquidation value. As it turns out, this does not affect our qualitative results. For expositional clarity, we therefore initially set $S = 0$ in our analysis.

Finally, we assume that between $t = 0$ and $t = 0.5$ the employee can make an unobservable human capital investment at private cost Δ. The details of this human capital investment are of secondary importance, which is why we relegate them to Section 5. At this point, what matters is only that the employee's investment problem imposes an efficiency-wage type constraint on the wage contract $w(x)$: to induce the employee to undertake his human capital investment, the expected wage payment if the firm is continued must exceed the employee's outside income J by a sufficiently large margin. In other words, if the firm is continued, the employee must earn a rent.[13]

We formally introduce this efficiency-wage constraint in Section 4. There, we also show that—besides creating a rent for the employee—this constraint alone has no implications for the optimal wage contract. In particular, if the owner could commit to a particular decision rule based on the true state of nature, there would be an infinite number of wage contracts that satisfy the efficiency-wage constraint and implement the first best. Rather, it is the combination of (i) leaving the employee a rent if the firm is continued and (ii) the inability of the owner to commit to a decision rule which is driving our results.

4 Optimality of Broad-Based Option Pay

We proceed in two steps. We first derive the owner's optimal continuation decision at $t = 0.5$ as a function of the state of nature. In a second step, we derive the wage contract that maximizes the owner's expected payoff at $t = 0$ taking into account the effect on his subsequent decision,

[13] Any other (efficiency-wage type) argument that leaves the employee a rent would work equally well. For an overview of efficiency-wage models, see Weiss (1991) and Yellen (1994).

subject to the relevant constraints.

Generally, the owner will find it optimal to continue if and only if the expected cash flow minus wage payments exceeds his opportunity cost of continuation, i.e., if $E[x - w(x) \mid \theta] \geq L$. We ignore trivial cases where the owner either always (i.e., for all θ) or never continues. Given our earlier assumptions, it is straightforward to provide sufficient conditions ruling these cases out. If continuation and exit are both sometimes optimal, the question is what is the owner's (privately) optimal decision rule? The following lemma shows that the optimal decision rule takes a simple form: continue if and only if the state of nature is sufficiently high.

The intuition for this result is straightforward. By Assumption 2, $x - w(x)$ is nondecreasing everywhere. Moreover, it cannot be the case that $x - w(x) = 0$ for all x, or else the owner would always exit. Consequently, $x - w(x)$ must be strictly increasing for *some* x (on a set of positive measure). In conjunction with Assumption 1 and continuity of $g_\theta(x)$ in θ, this in turn implies that the owner's expected payoff $E[x - w(x) \mid \theta]$ is continuous and strictly increasing in θ. There consequently exists a cutoff state $\theta_P \in (\underline{\theta}, \overline{\theta})$ such that the owner optimally continues if $\theta \geq \theta_P$ and exits if $\theta < \theta_P$.[14]

Lemma 1. *There exists a unique state of nature $\theta_P = \theta_P(w(x)) \in (\underline{\theta}, \overline{\theta})$ given by $E[x - w(x) \mid \theta_P] = L$ such that the owner continues if and only if $\theta \geq \theta_P$.*

While the owner's privately optimal cutoff $\theta_P(w(x))$ depends on the wage contract, we omit the argument in what follows for convenience and simply write θ_P.

Equipped with Lemma 1, we can determine the optimal wage contract $w(x)$ offered at $t = 0$. The optimal wage contract maximizes the owner's expected payoff

$$\int_{\theta_P}^{\overline{\theta}} E[x - w(x) \mid \theta] f(\theta) d\theta + LF(\theta_P), \tag{1}$$

subject to (i) the employee's *subsistence constraint* $w(x) \geq J$ for all x, and (ii) the *efficiency-wage* (or incentive-compatibility) constraint

$$\int_{\theta_P}^{\overline{\theta}} [E[w(x) \mid \theta] - J] f(\theta) d\theta \geq \Delta. \tag{2}$$

[14] Without loss of generality, we assume that the owner continues if he is indifferent.

We can rewrite (2) more conveniently as

$$\int_{\theta_P}^{\overline{\theta}} E[w(x) \mid \theta] \frac{f(\theta)}{1-F(\theta_P)} d\theta \geq J + \frac{\Delta}{1-F(\theta_P)}, \tag{3}$$

which states that the employee's expected wage if the firm is continued (left-hand side) must exceed his outside income J by at least $\Delta/[1-F(\theta_P)]$.[15] As noted earlier, it is straightforward to extend our model to the case where the employee's outside income exceeds J. Such an extension provides no additional insight, however. Since the employee's investment cost is already sunk at $t = 0.5$ (in equilibrium), $\Delta/[1-F(\theta_P)]$ constitutes the employee's *rent* if the firm is continued: the higher the owner's cutoff θ_P, the lower is the probability of continuation $1-F(\theta_P)$, and the higher must be the employee's rent *if* the firm is continued. In Section 5, we derive this constraint from first principles based on the employee's human-capital investment problem.[16]

By standard arguments, (2) must bind at the optimal solution.

Lemma 2. *The efficiency-wage constraint* (2) *must bind at the optimum.*

Proof. See Appendix.

Substituting the binding efficiency-wage constraint (2) into the owner's objective function (1), we obtain that the owner chooses $w(x)$ to maximize

$$\int_{\theta_P}^{\overline{\theta}} [E[x \mid \theta] - J - L] f(\theta) d\theta + L - \Delta, \tag{4}$$

subject to $w(x) \geq J$, where θ_P is a function of $w(x)$. Precisely, by Lemma 1 it holds that $E[x - w(x) \mid \theta_P] = L$. By inspection, (4) attains its maximum at $\theta_P = \theta_{FB}$. Intuitively, as the owner is the residual claimant to all cash flows, he would like to commit to the (first-best) efficient decision rule. Indeed, if such commitment was possible, the choice of the optimal wage contract would be trivial, as the following benchmark illustrates.

[15] While the employee can rationally infer the owner's privately optimal cutoff θ_P, he does not know the true state of nature. All he knows is that $\theta \geq \theta_P$, where $f(\theta)/[1-F(\theta_P)]$ is the posterior probability of θ given that the firm is continued, i.e., given that $\theta \geq \theta_P$.

[16] Note that the subsistence constraint $w(x) \geq J$ does not generate any additional rents for the employee on top of $\Delta/[1-F(\theta_P)]$. Moreover, if (2) is satisfied, the employee's ex-ante participation constraint is also satisfied, while the employee's interim participation constraint is slack.

Benchmark: Observable States of Nature. If the owner could commit to a particular decision rule, say, $\theta_P = \hat{\theta}$, there is an infinite number of optimal wage contracts satisfying the relevant constraints. In particular, under the fixed-wage contract $w(x) = B := J + \Delta/[1 - F(\hat{\theta})]$ the efficiency-wage constraint (2) holds with equality, while the employee's subsistence constraint $w(x) \geq J$ is slack. Hence, if the owner could commit to the decision rule $\theta_P = \theta_{FB}$, he could trivially implement the first best with a "flat" wage.

This shows that—unlike a "standard" moral hazard problem—the efficiency-wage constraint has no immediate implications for the optimal wage contract: the fact that with probability $1 - F(\hat{\theta})$ the employee earns a rent is enough to make him indifferent between undertaking and not undertaking his investment. How this rent is divided across cash flows $x \in [\underline{x}, \overline{x}]$ or continuation states $\theta \geq \theta_P$ is—from the employee's perspective—quite irrelevant, which is why, e.g., a "flat" wage $w(x) = B$ can implement the first best. The division of the employee's rent across cash flows or continuation states does, however, matter for the *owner's* incentives if he *cannot* commit to a decision rule, as we will now show. □

Returning to our basic setting where θ is private information, we now derive the solution to the owner's maximization problem. For expositional clarity, we first consider the case where $J = 0$. We show that (i) under any (arbitrary) wage contract $w(x)$, the owner exits in too many states of nature, and (ii) the wage contract minimizing this inefficiency is an option. Subsequently, we show that the same intuition also holds if $J > 0$. To satisfy the employee's subsistence constraint, however, the wage contract must then additionally include a base wage. Hence, the only effect of $J > 0$ is that it adds a base wage.

Let us begin with the case where $J = 0$. In this case, the first-best cutoff is given by $E[x \mid \theta_{FB}] = L$. The efficiency-wage constraint (2), on the other hand, requires that $w(x) > 0$ on a set of positive measure. This immediately implies that $E[x - w(x) \mid \theta] < E[x \mid \theta]$ for all θ, which in turn implies that $\theta_P \neq \theta_{FB}$. Hence, the owner's privately optimal exit decision is inefficient. In fact, we can say more about this inefficiency: since $E[x \mid \theta]$ and $E[x - w(x) \mid \theta]$ are both continuous and strictly increasing in θ (see above), and since $E[x - w(x) \mid \theta] < E[x \mid \theta]$ for all θ, it must be true that $E[x - w(x) \mid \theta_{FB}] < E[x \mid \theta_{FB}] = L$, and therefore that $\theta_P > \theta_{FB}$.

Intuitively, the fact that the employee must earn a rent (in the form of $w(x) > 0$) drives a wedge between the expected cash flow $E[x \mid \theta]$ and the owner's share of this cash flow,

$E[x - w(x) \mid \theta]$. As a result, the owner exits in marginally profitable states $\theta \in [\theta_{FB}, \theta_P)$ where the first-best decision rule would prescribe to continue.[17]

As the owner exits too much relative to the first best, the optimal contract design problem is one-sided: the optimal wage contract $w(x)$ minimizes the owner's incentives to exit. Precisely, the optimal wage contract minimizes the owner's privately optimal cutoff θ_P, thereby bringing it closer to the first-best cutoff θ_{FB}. We now argue that the unique solution to this problem is to give the employee an option on the firm's cash flow.

An option minimizes $w(x)$ when x is low. Since low values of x are relatively more likely after low states of nature by Assumption 1, an option minimizes the employee's expected wage $E[w(x) \mid \theta]$ in low states of nature.[18] The flip side is that it maximizes the owner's expected payoff $E[x - w(x) \mid \theta]$ in low states, which pushes the cutoff state where the owner is indifferent between continuation and exit, θ_P, as far down as possible. (It cannot be the case that θ_P is being pushed down "too far", since we have shown above that $\theta_P > \theta_{FB}$ for any wage contract $w(x)$.) Put simply, paying the employee with an option minimizes the firm's wage cost in low states of nature, thus making continuation relatively attractive for the owner in these states. This in turn minimizes the owner's privately optimal cutoff θ_P, thereby minimizing the gap between θ_P and θ_{FB}.

There is a more general principle at work here. If the owner continues in state θ_P, he also continues in all higher states $\theta \geq \theta_P$. Hence, we only need to look at the owner's incentives in marginally profitable—i.e., relatively low—states of nature. The owner's expected payoff in inframarginal states $\theta > \theta_P$, on the other hand, is irrelevant. Accordingly, the optimal wage contract must make continuation as attractive as possible in low states of nature. This is precisely what an option does: it shifts more wage costs from low into high states of nature (where wage costs do not matter for the owner's decision) than any other form of wage contract, thus maximizing the owner's expected payoff in low states.

[17] The fact that the owner exits in too many states of nature (compared to the first best) holds for *any* wage contract $w(x)$, irrespective of whether or not Assumption 2 is satisfied. If Assumption 2 holds, however, we can characterize the owner's privately optimal decision rule by a unique cutoff state θ_P, which makes the comparison with the first-best decision rule particularly simple as we then have that $\theta_P > \theta_{FB}$.

[18] This is subject to the efficiency-wage constraint (2) and Assumption 2 that $x - w(x)$ be nondecreasing.

Let us now turn to the case where $J > 0$. The inefficiency is exactly the same: due to the efficiency-wage constraint (2), the employee must earn a rent if the firm is continued, which is now given by the employee's expected wage *in excess* of his outside income J.[19] Again, the existence of a rent drives a wedge between the first-best cutoff and the owner's privately optimal cutoff, with the consequence that the owner exits too often. Like above, the employee only cares about his expected rent, while the owner cares about how this rent is divided across cash flows $x \in [\underline{x}, \overline{x}]$, and thus across continuation states $\theta \geq \theta_P$. The solution is, again, to shift as much of this rent as possible into high states of nature, thus maximizing the owner's expected payoff in marginal states. This implies that the subsistence constraint $w(x) \geq J$ must bind, which in turn implies that the optimal solution is an option plus a base wage equal to J.

Proposition 1. *The unique optimal wage contract is to pay all employees a base wage* J *and an option on the firm's cash flow, i.e.,* $w(x) = J + \max\{x - s, 0\}$ *for some* $s \in (\underline{x}, \overline{x})$. *And yet, under the optimal wage contract the owner exits too often relative to the first best.*

Proof. See Appendix.

We have assumed that the owner can commit to the wage contract $w(x)$ despite the fact that it leads to inefficient exit decisions in marginal states of nature. As it turns out, such a strong assumption is not necessary. In the following section, we show that the optimal wage contract given in Proposition 1 is the unique optimal renegotiation-proof contract if new wage offers can be made after the state of nature has materialized. The reason, in short, is that renegotiations take place under asymmetric information, which means the owner will use his informational advantage to obtain wage concessions from the employee even in states $\theta > \theta_P$ where he would have ordinarily continued. As the employee anticipates this, he is better off not renegotiating the original wage contract.

[19] By (3) we have that

$$\int_{\theta_P}^{\overline{\theta}} [E[w(x) - J \mid \theta] \frac{f(\theta)}{1 - F(\theta_P)} d\theta \geq \frac{\Delta}{1 - F(\theta_P)}.$$

The left-hand side denotes the employee's expected *excess* wage if the firm is continued, while the right-hand side denotes the employee's rent.

5 Extensions and Robustness

5.1 Private Benefits of Continuation

The decisions of owners and entrepreneurs to continue their firms may not always be guided exclusively by profit maximization. In addition to profits, owners and entrepreneurs may also receive private benefits if the firm is continued, i.e., they may gain additional entrepreneurial experience, build up a reputation vis-à-vis employees and customers, or simply derive utility from running their firms.

Suppose continuation entails nonpecuniary private benefits $B > 0$ for the owner. To rule out again trivial cases where continuation is either always or never (first-best) efficient, we assume that $E[x \mid \overline{\theta}] + B > L + J$ and $E[x \mid \underline{\theta}] + B < L + J$. Introducing private benefits changes the optimal continuation decision(s). The first-best decision rule is now to continue if and only if $\theta \geq \theta_{FB}$, where θ_{FB} is given by

$$E[x \mid \theta_{FB}] + B = L + J. \tag{5}$$

By the same token, the owner's privately optimal decision rule is to continue if and only if $\theta \geq \theta_P$, where his optimal cutoff θ_P is given by

$$E[x - w(x) \mid \theta_P] + B = L. \tag{6}$$

Denote by $\widehat{L} := L - B$ the owner's opportunity cost of continuation net of his private benefits. Given this transformation, it is immediate that all our results continue to hold, except that now $\widehat{L}$ instead of L. In particular, it again holds that $\theta_P > \theta_{FB}$, while the unique optimal wage contract is again to pay all employees a base wage J plus an option. The crux is that the private benefits enter both into the first-best decision rule and the owner's privately optimal decision rule. From an efficieny standpoint, the owner thus again exits too often (relative to the first best, that is).

Interestingly, if B is sufficiently large it is possible that $E[x \mid \theta_P] < L$.[20] In this case, there exist states of nature where the owner continues even though the firm's continuation value (i.e.,

[20] It must then also hold that $E[x \mid \theta_{FB}] < L$, i.e., (first-best) efficiency requires that the firm is sometimes continued even though its expected cash flow from continuation is less than its liquidation or sales value.

the expected cash flow from continuation) is less that the liquidation or sales value. From the perspective of an outsider who does not know the owner's private benefits, it might then appear as if the owner exits too little. Since $\theta_P > \theta_{FB}$, the opposite is actually true, however.

5.2 Severance Pay

We now consider the possibility that the wage contract specifies both a payment $w(x)$ if the firm is continued and a (severance) payment S if the firm is shut down or sold. The latter could, e.g., take the form of a fixed payment plus a fraction of the liquidation or sales value, i.e., $S = a+bL$, although we shall not impose any such formal restrictions on S. From the owner's perspective, introducing severance pay has both costs and benefits.

Severance pay is costly for two reasons: first, the owner incurs a cost of S if he exits. Second—because of this—the employee's "outside income" at $t = 0.5$ is now $J + S$ instead of J. As the employee's expected wage if the firm is continued must exceed his outside income by $\Delta/[1 - F(\theta_P)]$, this implies that his expected wage in case of continuation must also increase by S. Formally, if $S > 0$ the efficiency-wage constraint (2) becomes

$$\int_{\theta_P}^{\overline{\theta}} [E[w(x) \mid \theta] - J - S] f(\theta) d\theta \geq \Delta, \tag{7}$$

which we can rewrite more conveniently as

$$\int_{\theta_P}^{\overline{\theta}} E[w(x) \mid \theta] \frac{f(\theta)}{1 - F(\theta_P)} d\theta \geq J + S + \frac{\Delta}{1 - F(\theta_P)}.$$

Hence, if $S > 0$ (right-hand side) the expected wage payment if the firm is continued (left-hand side) must increase by the same amount.

Introducing $S > 0$ also entails benefits. While the employee only cares about the fact that his expected wage under continuation increases by S, the owner cares about how this increase is divided across different cash flows $x \in [\underline{x}, \overline{x}]$, and thus across different continuation states $\theta \geq \theta_P$. Specifically, if $w(x)$ is an option (plus a base wage), the entire wage increase is paid at high cash flows, and thus—by Assumption 1—primarily in high states of nature. While overall the employee's expected wage must increase by S, it will increase by more than S in high states and by (much) less than S in low states. The flip side is that the owner's expected payoff from continuing decreases by less than S in low states. His payoff from exit, however, decreases by the full amount S from L to $L-S$. Consequently, continuation may now be profitable for the owner in (marginal) states where it was previously unprofitable. In short, increasing S lowers the owner's privately optimal cutoff θ_P.[21]

The next question is whether the owner should increase S so much to push θ_P all the way down to θ_{FB}, thus fully eliminating the inefficiency. The answer is no. At the first-best cutoff $\theta_P = \theta_{FB}$, the efficiency loss from a marginal increase in θ_P caused by a small decrease in S is zero. The benefit (i.e., cost saving) of reducing S is of first-order magnitude, however. Formally, the owner's objective function if $S > 0$ is

$$\int_{\theta_P}^{\overline{\theta}} E[x - w(x) \mid \theta] f(\theta) d\theta + (L - S)F(\theta_P).$$

Inserting the (binding) efficiency-wage constraint (7), this transforms to

$$\int_{\theta_P}^{\overline{\theta}} \left[E[x \mid \theta] - J - L\right] f(\theta) d\theta + L - S - \Delta. \tag{8}$$

By inspection, reducing S affects the owner's expected payoff both directly (positive effect) as well as indirectly via θ_P (negative effect). The total derivative of (8) with respect to S is

$$-\frac{\partial \theta_P}{\partial S}[E[x \mid \theta_P] - J - L] - 1.$$

At the first-best cutoff θ_{FB}, it holds that $E[x \mid \theta_{FB}] = J + L$. Hence, if $\theta_P = \theta_{FB}$ the total derivative is -1, implying that a reduction in S is strictly profitable.

Whether the benefit of introducing $S > 0$ outweighs the cost depends on the probability distributions $F(\theta)$ and $G_\theta(x)$. What is unambiguously clear, however, is that it does not pay the owner to increase S by so much that $\theta_P = \theta_{FB}$, which implies his exit decision remains inefficient. As a consequence, the optimal wage contract $w(x)$ remains the same as in Proposition 1, namely, an option plus a base wage equal to J.[22]

[21] While this monotonic relation between S and θ_P holds if $w(x)$ is an option (plus a base wage), it does not hold for arbitrary wage contracts.

[22] Another way of viewing this is that there are two ways to improve the owner's exit decision: (i) switching from a non-option wage contract to an option contract, and (ii) increasing S. As the second method is costly, the owner will always first exploit the "costless route" of switching to an option contract. Only then—and only if the benefits outweight the costs—might he reduce θ_P even further by raising S.

Proposition 2. *Proposition 1 continues to hold if the wage contract can additionally stipulate a (severance) payment to the employee if the firm is shut down.*

Proof. See Appendix.

5.3 The Efficiency-Wage Constraint

We now derive the efficiency-wage constraint (2) from first principles based on the employee's human capital investment problem. For the sake of brevity, we only consider the case where $S > 0$. The analysis if $S > 0$ is—subject to some modifications—similar.[23]

As laid out in Section 3, the employee can make an unobservable human capital investment between $t = 0$ and $t = 0.5$ at private cost Δ. Whether or not the employee undertakes his investment is fully revealed at $t = 1$. For instance, the investment may involve the acquisition of skills and knowledge that are needed at $t = 1$. If the employee lacks the required skills, everybody (including the courts) notices it. On the other hand, if the firm is liquidated at $t = 0.5$, the truth never comes out.

The precise details of how exactly the employee's investment affects output are of secondary importance. Also, we need not assume that the employee has a big impact on firm output. In fact, his impact can be quite small, as might be realistically the case. All we need is that the benefits of the employee's human capital investment outweigh the costs, which implies it is efficient to incentivize him to undertake the investment. For instance, we might assume that if the employee undertakes his human capital investment, the output technology is as specified in Section 3. On the other hand, if he does not undertake his investment, the firm incurs a (separately measurable) cost of C. For example, the firm may loose customers because the employee lacks the skills to give them sensible advice. If C is sufficiently large relative to Δ, undertaking the human capital investment is efficient.

To derive the efficiency-wage constraint (2), we now have some degree of freedom in specifying out-of-equilibrium payoffs. One possibility is that the employee—if the firm is continued and

[23] Precisely, if S is paid both if the owner exits and if the employee quits, we straightforwardly obtain the efficiency-wage constraint (7) used in Section 5.2. On the other hand, if S is paid only if the owner exits (but not if the employee quits), we obtain our previous constraint (2). While this partly affects the analysis in Section 5.2, it does not affect our basic results.

the employee does *not* undertake his human capital investment—obtains a zero wage. (In fact, this is an optimal incentive scheme as the subsistence constraint $w(x) \geq J$ must only hold in equilibrium.) Anticipating this, the employee will then rather quit at $t = 0.5$ to secure his unemployment benefit of J.

To summarize, if the employee does not undertake his human capital investment, his payoff is simply his outside income J. By contrast, if he undertakes the human capital investment, his expected payoff is

$$\int_{\theta_P}^{\overline{\theta}} E[w(x) \mid \theta] f(\theta) d\theta + F(\theta_P) J - \Delta,$$

which implies he will undertake the investment if and only if

$$\int_{\theta_P}^{\overline{\theta}} E[w(x) \mid \theta] f(\theta) d\theta + F(\theta_P) J - \Delta \geq J.$$

Rearranging yields the efficiency-wage constraint (2).

5.4 Renegotiation

Our previous results suggest that in marginally profitable states $\theta \in (\theta_{FB}, \theta_P]$ the owner exits even though it would be efficient to continue. This provides scope for mutually beneficial renegotiations: to make continuation more attractive for the owner, the employee might be willing to take a paycut, thereby securing at least a fraction of his promised continuation rent. As we show, however, such potentially efficient renegotiations fails due to the fact that the state of nature is private information.

We consider the following model of renegotiation. After the state of nature has materialized but before the owner makes his decision, either the owner or the employee can offer a new wage contract.[24] If the owner makes the contract offer, the employee must agree. If the employee rejects the offer, the old contract remains in force. Conversely, if the employee makes the offer, the owner must agree, otherwise the old contract remains in force. As the following

[24] There is no point in renegotiating before the state of nature has materialized. By contrast, we could assume that renegotiations take place after the owner has made his decision—provided the decision is reversible. (The decision has no signalling value in this case.) If the decision is irreversible, it is too late for renegotiations.

proposition shows, irrespective of who makes the offer, the unique optimal wage contract derived in Propositions 1-2 is not renegotiated.

Proposition 3. *The unique optimal wage contract derived in Propositions 1-2 is renegotiation-proof. That is, in any (perfect Bayesian) equilibrium of the renegotiation game, the contract is not renegotiated with positive probability—irrespective of whether the owner or the employee offer a new wage contract.*

Proof. See Appendix.

Let us provide the intuition for the simpler case where $S = 0$; the case where $S \geq 0$ is covered the Appendix. Suppose the owner proposes (or accepts) to replace the optimal contract in Proposition 1, $w(x)$, with some new contract $\widetilde{w}(x)$. Since the owner knows the true state of nature, it must hold that $E[x - \widetilde{w}(x) \mid \theta] \geq E[x - w(x) \mid \theta]$, or equivalently, $E[w(x) \mid \theta] \leq E[\widetilde{w}(x) \mid \theta]$. Accordingly, in states $\theta \geq \theta_p(w)$ where the owner would have continued anyway, replacing $w(x)$ with $\widetilde{w}(x)$ only shifts rents back from the employee to the owner, thus making the employee worse off. This implies that, for replacing $w(x)$ with $\widetilde{w}(x)$ to be mutually beneficial, it *must* be the case that (i) the new contract $\widetilde{w}(x)$ induces continuation in strictly more states of nature, i.e., $\theta_p(\widetilde{w}) < \theta_p(w)$, and (ii) the employee must attach a reasonably high probability that the current state θ lies between $\theta_p(\widetilde{w})$ and $\theta_p(w)$.

Unfortunately, there is no simple way for the owner to signal that the current state is $\theta \in [\theta_p(\widetilde{w}), \theta_p(w))$, or for the employee to screen the owner's "type" θ. The reason is that, if the owner prefers $\widetilde{w}(x)$ to $w(x)$ in state θ, he will also prefer $\widetilde{w}(x)$ to $w(x)$ in all higher states $\widetilde{\theta} > \theta$.[25] Intuitively, the optimal contract $w(x)$ shifts as much as possible of the employee's compensation into high cash-flow outcomes, which implies that any other contract $\widetilde{w}(x) \neq w(x)$ makes the owner better off. Consequently, the employee will continue to hold his prior beliefs $f(\theta)$, implying that he will prefer $w(x)$ over $\widetilde{w}(x)$ if and only if

$$\int_{\theta_P(\widetilde{w})}^{\overline{\theta}} E[\widetilde{w}(x) \mid \theta] f(\theta) d\theta + F(\theta_P) J \geq \int_{\theta_P}^{\overline{\theta}} E[w(x) \mid \theta] f(\theta) d\theta + F(\theta_P) J,$$

[25] This is because $w(x)$ is an option plus a base equal to J. Any other wage contract $\widetilde{w}(x)$ satisfying Assumption 2 and $\widetilde{w}(x) \geq J$ must either (i) leave the owner strictly less for all x or (ii) satisfy $\widetilde{w}(x) \geq w(x)$ for all $x \leq \widetilde{x}$ and $\widetilde{w}(x) \leq w(x)$ for all $x > \widetilde{x}$ for some interior $\widetilde{x} \in X$, with strict inequality on sets of positive measure. In case (i) the owner never prefers $\widetilde{w}$ to w. In case (ii), the asserted statement follows directly from Assumption 1.

or

$$\int_{\theta_P(\widetilde{w})}^{\overline{\theta}} [E[\widetilde{w}(x) \mid \theta] - J]f(\theta)d\theta \geq \int_{\theta_P}^{\overline{\theta}} [E[w(x) \mid \theta] - J]f(\theta)d\theta. \tag{9}$$

By Lemma 2, the right-hand side in (9) equals Δ, which implies that the optimal wage contract $w(x)$ satisfies the employee's efficiency-wage constraint (2) with equality. By (9), this implies that the new contract $\widetilde{w}(x)$ must also satisfy (2). This cannot be true, however: if there was a contract $\widetilde{w}(x) \neq w(x)$ satisfying (2) (as well as $w(x) \geq J$) *and* implementing a lower cutoff $\theta_p(\widetilde{w}) < \theta_p(w)$, then $w(x)$ could not be the solution to the owner's original (i.e., commitment) problem. Accordingly, the employee will never find it optimal to propose (or accept) replacing $w(x)$ with $\widetilde{w}(x)$.

6 Concluding Remarks

This paper argues that broad-based option pay improves exit (i.e., liquidation, sale) decisions made by firm owners. In our model, employees obtain a rent if the firm is continued, which (inefficiently) biases the owners' decision in favor of exit. Employees may earn rents due to firm-specific human capital investments, like here, or due to a standard efficiency-wage argument. Broad-based option pay shifts most of the employees' compensation—and thus their rent—into states where expected firm profits are high, thereby leaving the firm's owners as much surplus as possible in states where expected profits are low. This mitigates the owners' bias and maximizes the efficiency of their exit decisions. While severance pay may further improve the efficiency of exit decisions, the bias never fully disappears, and broad-based option pay remains uniquely optimal even if severance pay is possible.

While our model has a representative employee, it does not insinuate that the employee has a significant impact on firm output. Neither is there any interaction or free-riding among employees. Hence, our argument extends to all employees, making it truly a theory of *broad* option pay. Our model does, however, assume that exit decisions are made by the firm's owners, or managers pursuing the owners' interest. This suggests that it is particularly relevant for smaller firms (e.g., new economy firms), as well as larger firms in which founders and directors have significant ownership stakes. Empirically, it appears that broad-based option pay is indeed more prevalent in these kinds of firms (see Introduction). Moreover, our argument rests on the notion that there is considerable uncertainty—coupled with asymmetric information—about future firm profits. This may help explain a finding in the empirical literature that broad-based option pay—and high-powered compensation in general—appears to be more pervasive in volatile industries (Prendergast (2002), Oyer and Schaefer (2003)). Again, new economy firms fit quite well into this picture.

An interesting avenue of research that we have not explored here is to examine exit decisions by managers whose interests diverge from those of the firm's owners. Given the owners' bias, it may be optimal to strategically use such managers as a commitment device to make more efficient exit decisions, which would then require a hands-off policy by the firm's owners (c.f., Aghion and Tirole (1997), Burkart, Gromb, and Panunzi (1997)). On the other hand, delegating exit decisions to managers with diverging interests may introduce problems of its own, such as inertia, empire building, and entrenchment.

The objective of this paper is to provide further insights into the benefits of broad-based option pay. To bring out the intuition for our results in the clearest possible way, we have isolated our effect from previously studied benefits and costs, such as, e.g., risk aversion. If employees are risk averse, our basic argument that broad-based option pay induces optimal exit decisions will still hold, but the question is then whether broad option pay will actually be used given the potentially high risk premium demanded by employees. While it is impossible to address this question in an optimal contracting framework, one could imagine a more limited setting in which the owner(s) can choose among standard contracts (e.g., stocks, options, fixed wage), and then estimate this model using specific utility functions and probability distributions. For a calibration exercise of this sort, see, e.g., Oyer and Schaefer (2003).[26]

7 Appendix

Proof of Lemma 2. If (2) did not bind, once could adjust $w(x)$ slightly so that (2) still holds while the owner is strictly better off. To prove this, we must first define a feasible adjustment

[26] A common way of modelling risk aversion in an optimal contracting framework is to use a CARA-normal setup and restrict wage contracts to the affince class $w(x) = a + bx$. This approach is not very helpful here, as the class of affine wage contracts does not include options. Moreover, CARA utility admits the possibility of (infinitely) negative wage payments, which is inconsistent with the notion that employees have limited wealth.

to $w(x)$ such that the employee's payoff does not fall below J for all $x \in X$ and Assumption 2 remains satisfied. By Assumption 2 $w(x)$ is continuous and almost everywhere differentiable, and it satisfies $w'(x) \geq 0$ at points of differentiability.

We can distinguish between the following two cases. In the first case $w'(x) > 0$ holds strictly for a set of positive measure. In this case, we define a new contract $\widetilde{w}(x)$ by the requirements that $\widetilde{w}(0) = w(0)$ holds that at points of differentiability it holds that $\widetilde{w}'(x) = w'(x)(1-\varepsilon)$, where $0 \leq \varepsilon < 1$. By construction, $\widetilde{w}(x)$ satisfies Assumption 2, while $\widetilde{w}(x) \geq K$ holds for all $x \in X$. Note also that $E[\widetilde{w}(x) \mid \theta]$ is continuous and strictly increasing in ε for all θ. By the latter implication the owner would be strictly better off by offering $\widetilde{w}(x)$ with $\varepsilon > 0$ if (2) was still satisfied. As (2) was originally slack by assumption, it is still satisfied for all sufficiently small values ε in case the employee's payoff is also continuous in ε. By continuity of $E[\widetilde{w} \mid \theta]$ and as $F(\theta)$ has no atoms, this holds surely if the cutoff $\theta_P(\widetilde{w})$ is continuous in ε, which follows immediately from the definition of θ_P and continuity of $E[\widetilde{w}(x) \mid \theta]$ in ε.

In the second case $w(x)$ is a fixed wage. As $w(x)$ must satisfy (2) this implies $w(0) > J$. We can now simply construct an alternative feasible contract where $\widetilde{w}(x) = w'(x) - \varepsilon$. Again, for sufficiently small $\varepsilon > 0$ (2) is still satisfied while the owner is made strictly better off. Q.E.D.

Proof of Proposition 1. We argue to a contradiction. Suppose that some other contract $w(x)$ that does not satisfy $w(x) = J + \max\{0, x - s\}$ was optimal. Recall now that the constraint (2) binds by Lemma 2, while by the arguments in the main text it follows that $\theta_P(w) > \theta_{FB}$. Moreover, it must hold that $w(x) \geq J$. We now construct a contract $\widetilde{w}(x) = J + \max\{0, x - \widetilde{s}\}$ as follows. We keep the original cutoff $\theta_P(w)$ fixed and choose $\widetilde{s}$ such that the constraint (2) is still satisfied with equality, requiring

$$\int_{\theta_P(w)}^{\overline{\theta}} \left(\int_{\widetilde{s}}^{\overline{x}} (x - \widetilde{s}) g_\theta(x) dx \right) f(\theta) d\theta = \Delta. \tag{10}$$

Existence of a unique value $0 < \widetilde{s} < \overline{x}$ solving (10) is immediate.[27] We show now that the true cutoff under the new contract, $\theta_P(\widetilde{w})$, is strictly lower than the original cutoff $\theta_P(w)$.

Claim 1. *It holds that* $\theta_P(\widetilde{w}) < \theta_P(w)$.

[27] As (2) holds at the original contract, the left-hand side of (10) surely exceeds Δ at $\widetilde{s} = 0$. At $\widetilde{s} = \overline{x}$ the left-hand side of (10) is lower than Δ. Moreover, by Assumptions 1 and 2—together with continuity of $g_\theta(x)$—the left-hand side of (10) is also continuous and strictly decreasing in $\widetilde{s}$.

Proof. It is convenient to use the following transformation. Take any function $a(x)$ that is continuous and differentiable almost everywhere on $x \in X$. Partial integration yields

$$\int_X a(x) g_\theta(x) dx = a(0) + \int_X a'(x)[1 - G_\theta(x)] dx. \tag{11}$$

Note next that the derivative of $\widetilde{w}(x)$ satisfies $\widetilde{w}'(x) = 0$ for $x < \widetilde{s}$ and $\widetilde{w}'(x) = 1$ for $x > \widetilde{s}$. Also, by Assumption 2 the original contract $w(x)$ is continuous and almost everywhere differentiable. Using the transformation (11), we then obtain for all θ

$$\begin{aligned} E[\widetilde{w}(x) - w(x) \mid \theta] = \quad & \int_{\widetilde{s}}^{\overline{x}} [1 - w'(x)] \, [1 - G_\theta(x)] \, dx - \int_0^{\widetilde{s}} w'(x) \, [1 - G_\theta(x)] \, dx \\ & + J - w(0), \end{aligned} \tag{12}$$

where we used that $\widetilde{w}(0) = J$. As both $w(x)$ and $\widetilde{w}(x)$ satisfy (2), holding $\theta_P(w)$ fixed, there must exist at least one state $\theta_P(w) < \widetilde{\theta} < \overline{\theta}$ such that

$$E[\widetilde{w}(x) - w(x) \mid \widetilde{\theta}] = 0. \tag{13}$$

We next transform (12) into

$$\begin{aligned} E[\widetilde{w}(x) - w(x) \mid \theta] \ = \ & \int_{\widetilde{s}}^{\overline{x}} [1 - w'(x)] \left[1 - G_{\widetilde{\theta}}(x)\right] \left[\frac{1 - G_\theta(x)}{1 - G_{\widetilde{\theta}}(x)}\right] dx \\ & - \int_0^{\widetilde{s}} w'(x) \left[1 - G_{\widetilde{\theta}}(x)\right] \left[\frac{1 - G_\theta(x)}{1 - G_{\widetilde{\theta}}(x)}\right] dx + J - w(0). \end{aligned} \tag{14}$$

By Assumption 2 we have $0 \leq w'(x) \leq 1$. Moreover, as $\widetilde{w}(x)$ satisfies (10) and as (2) is binding under $w(x)$, $w'(x) < 1$ holds strictly over a positive measure of values $x > \widetilde{s}$. Likewise, we must either have $w(0) > J$ or $w'(x) > 0$ must hold strictly over a positive measure of values $x < \widetilde{s}$. Note next that Assumption 1 implies for all $\underline{\theta} < \theta < \widetilde{\theta}$ that $\frac{1 - G_\theta(x)}{1 - G_{\widetilde{\theta}}(x)}$ is strictly decreasing in x.[28] Note also that this implies from $0 < \widetilde{s} < \overline{x}$ that $\frac{1 - G_\theta(\widetilde{s})}{1 - G_{\widetilde{\theta}}(\widetilde{s})} < 1$. We thus obtain from (14)

$$\begin{aligned} & E[\widetilde{w}(x) - w(x) \mid \theta] \\ < \ & \frac{1 - G_\theta(\widetilde{s})}{1 - G_{\widetilde{\theta}}(\widetilde{s})} \left[\int_{\widetilde{s}}^{\overline{x}} [1 - w'(x)] \left[1 - G_{\widetilde{\theta}}(x)\right] dx - \int_0^{\widetilde{s}} w'(x) \left[1 - G_{\widetilde{\theta}}(x)\right] dx + J - w(0) \right], \end{aligned}$$

which after substitution of (13) transforms into

[28] In fact, Assumption 1 is stronger as we require that the distribution function is everywhere absolutely continuous.

$$E[\widetilde{w}(x) - w(x) \mid \theta] < \frac{1 - G_\theta(\widetilde{s})}{1 - G_{\widetilde{\theta}}(\widetilde{s})} E[\widetilde{w}(x) - w(x) \mid \widetilde{\theta}] = 0. \tag{15}$$

This implies for all $\theta < \widetilde{\theta}$ that the owner's payoff from continuation is strictly higher under the new contract, i.e., that $E[x - \widetilde{w} \mid \theta]$ strictly exceeds $E[x - w(x) \mid \theta]$. Recall now that the original cutoff satisfies $\theta_P(w) > \theta_{FB}$ and that by Lemma 1 it is determined by the indifference condition $E[x - w(x) \mid \theta_P(w)] = L$. This together with the fact that $E[\widetilde{w}(x) \mid \theta]$ is strictly increasing in θ then implies $\theta_P(\widetilde{w}) < \theta_P(w)$. Q.E.D.

Recall now from (10) that $\widetilde{w}(x)$ satisfies (2) with equality if we apply the cutoff from the original contract, $\theta_P(w)$. Using $\theta_P(\widetilde{w}) < \theta_P(w)$ from Claim 1, inspection of (2) reveals that the constraint still holds under the new contract if we apply the true threshold, $\theta_P(\widetilde{w})$. Hence, to prove that the original contract was not optimal it only remains to show that the owner is strictly better off under $\widetilde{w}(x)$. This follows immediately from the observation that he would—by construction of $\widetilde{w}(x)$—realize the same expected payoff if he still applied the old cutoff $\theta_P(w)$, while by Claim 1 he strictly prefers a different cutoff under the new contract.

We have thus shown that an optimal contract must satisfy $w(x) = J + \max\{0, s - x\}$. Establishing that there is a unique optimal choice for s is straightforward. As the employee's payoff is continuous in s, which follows as also θ_P changes continuously in s, there exists a compact set of $s-$values for which (2) binds. As the owner's expected payoff is strictly increasing in s, the largest value in this set uniquely defines the unique optimal compensation contract. Q.E.D.

Proof of Proposition 2. We now extend the argument of Proposition 1 to the case where $S > 0$. As the cutoff now depends on both $w(x)$ and S we denote it by $\theta_P(S, w)$. (Where this is without ambiguity, we will, however, again abbreviate the cutoff by writing θ_P.) We argue now to a contradiction and assume optimality of a contract $(S, w(x))$ where $w(x)$ is not given by $w(x) = J + \min\{0, x - s\}$. Note first that the proof of Lemma 2 did not rely on the choice $S = 0$, implying that the constraint (2) must be binding irrespective of the choice of S. We now construct a new contract $(S, \widetilde{w}(x))$ where $\widetilde{w}(x) = J + \min\{0, x - \widetilde{s}\}$ and where

$$\int_{\theta_P(S,w)}^{\overline{\theta}} \left[\left(\int_{\widetilde{s}}^{\overline{x}} (x - \widetilde{s}) g_\theta(x) dx \right) - S \right] f(\theta) d\theta = \Delta. \tag{16}$$

Again, existence of a unique such value $\widetilde{s}$ is immediate. Next, the arguments of Claim 1 in Proposition 1 do not depend on the choice $S = 0$ and, therefore, extend immediately to $S > 0$. We thus have that $\theta_P(S, \widetilde{w}) < \theta_P(S, w)$.

As in the proof of Proposition 1 we are done if $\widetilde{w}(x)$ satisfies (2), once we apply the true cutoff $\theta_P(\widetilde{w})$. We distinguish now between two cases. Assume first that $\theta_P(S, \widetilde{w}) \geq \theta_{FB}$. Note next that, by definition of the optimal cutoff, we have $E[x - \widetilde{w}(x) \mid \theta_P(S, \widetilde{w})] = L - S$, while by $\theta_P(S, \widetilde{w}) \geq \theta_{FB}$ we have $E[x \mid \theta_P(S, \widetilde{w})] \geq L + J$, which together imply $E[\widetilde{w}(x) \mid \theta_P(S, \widetilde{w})] \geq S + J$. By Assumption 1 we then have for all $\theta_P(S, \widetilde{w}) \leq \theta \leq \theta_P(S, w)$, i.e., over the whole new set of states for which the owner changes her decision, that $E[\widetilde{w}(x) \mid \theta] \geq S + J$, which completes the proof.

Take now the other case where $\theta_P(S, \widetilde{w}) < \theta_{FB}$. In this case we have to adopt an intermediate step. We construct another contract $(\widehat{S}, \widehat{w}(x))$ where $\widehat{S} < S$ and where $\widehat{w}(x) = J + \min\{0, x - \widehat{s}\}$ with $\widehat{s} > \widetilde{s}$. Hence, under the new contract the employee gets less both when the firm is continued and when the owner chooses to exit. We also choose $(\widehat{S}, \widehat{w}(x))$ such that (i) the true cutoff satisfies $\theta_P(\widehat{S}, \widehat{w}) = \theta_{FB}$ and that (ii) under the original threshold, $\theta_P(S, w)$, the constraint (2) still holds with equality, i.e.,

$$\int_{\theta_P(S,w)}^{\overline{\theta}} \left[\left(\int_{\widehat{s}}^{\overline{x}} (x - \widehat{s}) g_\theta(x) dx \right) - \widehat{S} \right] f(\theta) d\theta = \Delta. \tag{17}$$

We establish first existence of a contract $(\widehat{S}, \widehat{w}(x))$ with these characteristics.

Claim 1. *In case $\theta_P(S, \widetilde{w}) < \theta_{FB}$ we can find a contract $(\widehat{S}, \widehat{w}(x))$, where $\widehat{S} < S$, $\widehat{w}(x) = J + \min\{0, x - \widehat{s}\}$ with $\widehat{s} > \widetilde{s}$, $\theta_P(\widehat{S}, \widehat{w}) = \theta_{FB}$, and (17) holds.*

Proof. We first argue that a contract with these characteristics would satisfy $\theta_P(\widehat{S}, \widehat{w}) > \theta_P(S, \widetilde{w})$. To see this, note that by (16) and (17) there exists at least one state $\theta_P(S, w) < \widetilde{\theta} < \overline{\theta}$ such that

$$E[\widetilde{w}(x) - S \mid \widetilde{\theta}] = E[\widehat{w}(x) - \widehat{S} \mid \widetilde{\theta}]. \tag{18}$$

Using again the transformation (11), we have next that

$$E[(\widetilde{w}(x)-S)-(\widehat{w}(x)-\widehat{S}) \mid \theta]=\int_{\widetilde{s}}^{\widehat{s}}[1-G_\theta(x)]\,dx-(\widehat{S}-S),$$

which by Assumption 1 is strictly increasing in θ. (Precisely, this follows from strict First-Order Stochastic Dominance, which is implied by Assumption 1.) Together with (18) this implies $E[\widetilde{w}(x)-S \mid \theta] < E[\widehat{w}(x)-\widehat{S} \mid \theta]$ for all $\theta < \widetilde{\theta}$. Using $\theta_P(S,w) < \widetilde{\theta}$ and $\theta_P(S,\widetilde{w}) < \theta_P(S,w)$, this holds also at $\theta = \theta_P(S,\widetilde{w})$. The assertion that $\theta_P(\widehat{S},\widetilde{w}) > \theta_P(S,\widetilde{w})$ follows then immediately from the definition of the cutoff θ_P.

We can now proceed by reducing $\widehat{S}$ and increasing $\widehat{s}$ until $\theta_P(\widehat{S},\widehat{w})$ becomes indeed equal to θ_{FB}. This is feasible as we already know that θ_P is continuous in both $\widehat{S}$ and $\widehat{s}$, while at $\widehat{S}=0$ it must hold that $\theta_P(\widehat{S},\widehat{w}) > \theta_{FB}$. (Note that $\widehat{s} < \overline{x}$ is needed to satisfy (17).) **Q.E.D.**

As $\theta_P(\widehat{S},\widehat{w}) = \theta_{FB}$ we already from the argument for the case with $\theta_P(S,\widetilde{w}) \leq \theta_{FB}$ that $(\widehat{S},\widehat{w}(x))$ satisfies (2) also if we apply the true threshold $\theta_P(\widehat{S},\widehat{w})$. That the owner is strictly better off follows finally again from (17) and as the owner's new optimal cutoff is strictly different from $\theta_P(S,w)$. Q.E.D.

We have thus established that in any optimal contract the compensation scheme $w(x)$ must satisfy $w(x)=J+\min\{0,x-s\}$. That $\theta_P > \theta_{FB}$ follows from the argument in the main text. Finally, for given choice of S we have again a unique corresponding choice of the strike price s. Q.E.D.

Proof of Proposition 3. Recall first from Propositions 1-2 that $w(x)=J+\min\{0,x-s\}$. Moreover, for a given choice of $S \geq 0$ the value of s is also uniquely pinned down. It is now convenient to assume that there is also a uniquely optimal level of $S \geq 0$, though the proof can be extended at the cost of adding additional notation. For brevity we refer to the unique optimal (commitment) contract just as $(S,w(x))$. The following result is now intuitive from the insights of Proposition 1.

Claim 1. *If $\widetilde{w}(x) \neq w(x)$ and $E[\widetilde{w}(x) \mid \widehat{\theta}] \geq E[w(x) \mid \widehat{\theta}]$ holds for some $\widehat{\theta} < \overline{\theta}$ then $E[\widetilde{w}(x) \mid \theta] > E[w(x) \mid \theta]$ holds for all $\theta > \widehat{\theta}$.*[29]

[29] Note that by Assumption 2 we have that if $\widetilde{w}(x) \neq w(x)$ holds for some x it must hold over a set of x of positive measure.

Proof. We argue to a contradiction and assume that $E[\widetilde{w}(x) \mid \widehat{\theta}] \geq E[w(x) \mid \widehat{\theta}]$ and that $E[\widetilde{w}(x) \mid \theta] \leq E[w(x) \mid \theta]$ for some $\theta > \widehat{\theta}$. Using continuity of $E[\widetilde{w}(x) \mid \theta]$ and $E[w(x) \mid \theta]$ this implies existence of some $\widehat{\theta} \leq \widetilde{\theta} < \widehat{\theta}$ such that $E[\widetilde{w}(x) \mid \widetilde{\theta}] = E[w(x) \mid \widetilde{\theta}]$. We can now fully apply the argument in Claim 1 of Proposition 1 to show that, by construction of $w(x)$ and Assumptions 1-2, this must imply $E[\widetilde{w}(x) \mid \theta] > E[w(x) \mid \theta]$, which yields a contradiction. Precisely, we obtain

$$E[w(x) - \widetilde{w}(x) \mid \theta] < \frac{1 - G_\theta(s)}{1 - G_{\widetilde{\theta}}(s)} E[w(x) - \widetilde{w}(x) \mid \widetilde{\theta}] = 0.$$

Q.E.D.

Consider now first the game where the employee makes some offer $(\widetilde{S}, \widetilde{w}(x))$. By optimality, the owner will then only have to pay $\min\{S, \widetilde{S}\}$ if he decides to exit, while for a given θ he will only have to pay the expected wage $\min\{E[w(x) \mid \theta], E[\widetilde{w}(x) \mid \theta]\}$ if he chooses to continue. It is thus immediate that offering $\widetilde{S} < S$ is not optimal for the employee. Moreover, in case $\widetilde{S} \geq S$ the new severance pay offer is clearly irrelevant as the owner will reject if he prefers to exit. The new offer is also only profitable for the employee if it increases the set of states for which the firm is continued, i.e., if $\theta_P(\widetilde{S}, \widetilde{w}) < \theta_P(S, w)$. As this implies at $\theta_P(\widetilde{S}, \widetilde{w})$ that $E[\widetilde{w}(x) \mid \theta_P(\widetilde{S}, \widetilde{w})] > E[w(x) \mid \theta_P(\widetilde{S}, \widetilde{w})]$, we have by Claim 1 that $E[\widetilde{w}(x) \mid \theta] > E[w(x) \mid \theta]$ holds for all θ where the owner chooses continuation. As a consequence, offering a new contract $\widetilde{w}(x)$ that reduces the cutoff is only beneficial for the employee if condition (9) from the main text holds. As we also argued in the main text, this is not possible.

Suppose next the owner makes the offer. As this occurs after he observed θ we have a game of signaling. By specifying very optimistic out-of-equilibrium beliefs, which put high probability on high states θ, it is straightforward to support an equilibrium where no acceptable new offer is made. We show next that there are no successful renegotiations in any (perfect Bayesian) equilibrium. Though the argument holds generally, for brevity's sake we restrict attention to equilibria where the employee accepts a new offer in case he is indifferent, given his beliefs about the proposing types. (Note that if the employee rejects the new offer the old contract is still in place.)

We argue again to a contradiction and suppose that, in a given equilibrium, there is a non-empty set of accepted new contracts, which we denote by Ω. By previous arguments it is straightforward that we can restrict consideration to changes in the wage paid in case of continuation: $\Omega = \{w_i(x)\}_{i \in I}$, where I is some index set. Denote $\widetilde{\Omega} = \Omega \cup \{w(x)\}$ and denote the new cutoff, given the contracts in $\widetilde{\Omega}$, by $\theta_P(\widetilde{\Omega})$.[30] We pick one of the possible contracts that are chosen at $\theta = \theta_P(\widetilde{\Omega})$ by $\widetilde{w}(x)$. From our previous arguments we know that we can restrict consideration to the case where $\theta_P(\widetilde{\Omega}) < \theta_P(w)$. Moreover, by Claim 1 we know that for all states $\theta > \theta_P(\widetilde{\Omega})$ the owner strictly prefers to offer a new contract from Ω. Moreover, in all states $\theta > \theta_P(\widetilde{\Omega})$ the owner will offer her most preferred contract in Ω, which reduces the payoff of the employee. Consequently, an upper boundary for the employee's payoff in the renegotiation game is given by the case where *only* the contract $\widetilde{w}(x)$ is offered. But we already know for this case that the employee would be strictly worse off when accepting the offer–a contradiction. Q.E.D.

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[30] Formally, the existence of such a cutoff follows as $\max_{i \in I'} E[w_i(x) \mid \theta]$, where we write $\widetilde{\Omega} = \{w_i(x)\}_{i \in I'}$, is by Assumption 2 nondecreasing and continuous in θ.

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