

Short-Term versus Long-Term Incentives^{*}

Stanimir Morfov[†]

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Abstract

This paper considers the provision of long-term incentives in a principal-agent model with effort persistence. We analyze how the degree of substitutability between short- and long-term tasks affects compensation and the optimal contract. We demonstrate that a long-term contract with no threat of interim replacement can focus on short-term incentives because of an interaction between agent's effort choice and the value of his outside option.

Journal of Economic Literature Classification Numbers: D82, G30, M52

Keywords: principal-agent problem, effort persistence, long-term incentives, outside options

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[†]National Research University - Higher School of Economics, International College of Economics and Finance, 26 Shabolovka St., building 3, Moscow 119049, Russian Federation, Phone: +7 495 7729590 Ext. 026092, Fax: +7 495 5808915, E-mail: smorfov@hse.ru

Краткосрочная и долгосрочная управленческая мотивация*

(на английском языке)

Морфов Станимир

Работа принята к публикации в серии научных докладов НИУ-ВШЭ «Исследования по экономике и финансам» (WP9) в мае 2013 г.

Данная работа рассматривает предоставление долгосрочных стимулов в модели принципал-агент, где менеджерские усилия имеют персистентный эффект на прибыли компании. Мы анализируем, как уровень взаимозаменяемости между краткосрочными и долгосрочными управленческими задачами влияет на оптимальный контракт и, в частности, на вознаграждение менеджера. Мы демонстрируем, что долгосрочный договор, даже без возможности промежуточной замены агента, может быть ориентирован на краткосрочные стимулы из-за взаимодействия между усилиями менеджера и стоимостью его внешних альтернатив.

Коды JEL: D82, G30, M52

Ключевые слова: модель принципал-агент, персистентность усилий, долгосрочные стимулы, внешние альтернативы

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1 Introduction

In the aftermath of the financial crisis, there has been a strong criticism of existing executive compensation practices (e.g., Clementi et al [2009]). An important aspect of the criticism is the focus on short-term performance (Bhagat and Romano [2010] and Bebchuk [2010]). While most of the literature is pre-occupied with finding a remedy for managerial short-termism (e.g., Manso [2011]), the related cost of an emphasis on long-term performance has largely been overlooked. In particular, the manager should make an optimal choice between activities that boost firm’s short- and respectively long-term performance. If the manager is frequently evaluated based on some noise measure, he or she may favor short-term performance and so motivating him/her to focus on long-term performance may prove suboptimal. While replacement is an issue, we show it is not the only mechanism that increases the cost of long-term incentives. The substitutability of long- and short-term tasks together with an outside option that decreases in long-term activities raises the cost of long-term incentives.

Under risk-neutrality and competitive labor markets, Narayanan (1985) has shown that career concerns may induce the manager to take suboptimal decisions favoring short-term over long-term performance. This result, however, is not robust as shown by Darrough (1987). Barcena-Ruiz and Espinosa (1996) investigate the duration of incentive contracts arising in a duopoly. Their model, however, focuses on the product market and completely ignores the agency problem involved. Therefore, their results are inapplicable in a principal-agent framework.

Holmstrom and Milgrom (1991) analyze optimal allocation of tasks. While the current paper deals with two “kinds” of effort, we choose a different, two-outcome framework¹ that allows us to solve the model explicitly instead of relying on linearity assumptions.

There has been some work on explaining managerial short-termism² and the wide use of short-term incentives by career concerns (e.g., Holmstrom [2010]), overoptimistic investors in a speculative stock market (Bolton et al [2006]), price manipulation and reporting bias (Fischer and Verrecchia [2000]), early project termination (e.g., Von Thadden [1995] and Edmans [2011]), replacement (Laux [2012]). However, there has not been any analysis of the relation between long-term projects and managerial outside options. We propose such a link and investigate its implication for incentives and optimal contracting in general.

The current paper considers a two-period agency model. A principal (she) hires an agent (him) to operate a stochastic technology mapping effort into outcomes. Effort is persistent, in the sense that second-period outcome depends on the effort exerted by the agent in both periods. To simplify things, we assume that there is neither production nor consumption in the first period, so first-period effort only affects the second-period outcome. Moreover, first-period effort is fully observable by the principal. Second-period wages are then a function of first-period effort, but are still contingent

¹The model can easily be structured as repeated agency.

²See, for example, Edmans (2009) for a review.

on second-period outcome since the principal cannot observe agent's second-period effort. In such a setting, compensation depends on the relative contribution of first period effort to the distribution of second-period outcomes. If first period effort contributes more than second period effort, high effort in the first period will decrease the incentives to implement high effort in the second period and the respective wage scheme will be flatter. If the contribution of second period effort is higher, high effort in the first period leads to a second-period compensation scheme that provides stronger incentives by introducing more variation in pay across outcomes. When both efforts contribute equally, the wage scheme does not depend on first-period effort.

In such a setting, neither discounting nor interim replacement are an issue. However, there may be an additional cost related to exerting effort in the first period. Assume that the agent possesses some stock of general human capital which fully determines the value of his outside option. When he starts working for the firm, he can transform part or all of his general human capital into firm-specific human capital. The firm specific human capital positively affects the productivity of the manager or alternatively the stochastic technology he operates, thus inducing a stochastically dominating distribution of profits/returns. Given weak conditions, this would also raise managerial pay. However, the accumulation of firm-specific capital is costly. It depletes manager's general capital, thus decreasing the value of his outside option. Then, in the end of the second period, the agent would be worse off compared to the situation where he has kept his general human capital and not used it to accumulate firm-specific human capital. In a fully dynamic model, the decrease in the outside option would matter if the agent could be fired or if his contract could be revised to match his lower reservation utility. While we have concentrated on one type of effort within a period, the problem can be exacerbated if accumulating firm specific capital comes at the cost of short term effort.

A fully rational agent will require a utility premium for the loss of reservation utility. Therefore, the agent should be promised more utility than his ex ante reservation level. In a symmetric setting, we show that this utility premium may lead to a raise in both low- and high-outcome wages raising the cost of implementing long-term effort. Such an upward shift happens when, for example, both efforts contribute equally to the second period outcome distribution.

Section 2 considers a simple model that highlights the cost of providing long-term incentives to the agent. Section 3 analyzes how the interaction between firm's technology and agent's outside options affects incentives. Section 4 discusses further extensions of the model. Section 5 concludes. All proofs are contained in the Appendix.

2 A simple model

We start by a simple model that illustrates the cost associated with long term incentives. Consider a two-period set-up where a principal (she) hires an agent (him) to operate a stochastic technology

mapping effort into outcomes. There are two possible effort levels each period $a_L < a_H$ and two possible outcomes in the second period $y_L < y_H$. High first-period effort induces stochastically dominating distribution in the second period $\pi(\cdot, a_H, a_2)$, but is costlier in terms of agent's utility. Conditional on first-period effort a_1 , high effort in the second period induces a stochastically dominating second-period distribution $\pi(\cdot, a_1, a_H)$. For simplicity, we assume that neither the agent nor the principal discount future consumption, there is neither asymmetric information nor production in the first period, second-period effort is not observed by the principal, and the conditional probabilities are as follows: π_H is the probability of bad outcome conditional on high effort in both periods, π_L is the probability of bad outcome conditional on low effort in both periods and π_M is the probability of bad outcome conditional on different levels of effort in each period. Stochastic dominance requires that $\pi_H < \pi_M < \pi_L$. Observing the effort exerted in the first period, the principal offers the agent a compensation scheme $w(\cdot)$ contingent on second-period outcomes. Principal's utility is $y - w$. Agent's utility is $v(w) - a$, where v is twice continuously differentiable, strictly increasing, and strictly concave. His outside option is worth V . The principal is maximizing expected utility over agent's effort and compensation such that the agent does not have a strictly profitable deviation in the second period (incentive compatibility) and receives no less than the value of his outside option (individual rationality).

[PP]

$$\begin{aligned} \max_{a_1, a_2, w(\cdot)} \sum_y (y - w) \pi(y, a_1, a_2) \text{ s.t.:} \\ a_1, a_2 \text{ feasible} \end{aligned} \quad (1)$$

$$\sum_y v(w) \pi(y, a_1, a_2) - a_1 - a_2 \geq V \quad (2)$$

$$a_2 \in \arg \max_{a \text{ feasible}} \sum_y v(w) \pi(y, a_1, a) - a_1 - a \quad (3)$$

The first constraint simply restricts effort to the feasible set $\{a_L, a_H\}$, the second is individual rationality and the third is incentive compatibility.

Lemma 1 *Low second-period effort is implemented by a fixed wage $w(V + a_L + a_1)$, while high second-period effort is implemented by a compensation scheme that offers $w(V + a_L + a_1 - (1 - \underline{\pi}(a_1))k(a_1))$ after a bad outcome and $w(V + a_L + a_1 + \underline{\pi}(a_1)k(a_1))$ after a good outcome, where w is the inverse of v , $\underline{\pi}(a_L) = \pi_L$, $\underline{\pi}(a_H) = \pi_M$, $k(a_L) = (a_H - a_L)/(\pi_L - \pi_M)$ and $k(a_H) = (a_H - a_L)/(\pi_M - \pi_H)$.*

Given the stochastic dominance of high effort, the compensation scheme implementing it in the second period is monotonic. How does first-period effort affect second period wages? As long as π_M is smaller/greater than $(\pi_L + \pi_H)/2$, higher first-period effort increases/decreases the good outcome wage and decreases/increases the bad outcome wage implementing high effort in the second period. The reason is that first and second period effort are substitutes: high contribution of first period effort to the probability of success decreases the contribution of second period effort. When first period effort contributes more than second period effort (π_M closer to π_H than to π_L), high effort in the first period will decrease the incentives to implement high effort in the second period and the respective wage scheme will be flatter. If the contribution of second period effort is higher (π_M closer to π_L than to π_H), working hard in the first period leads to a second-period compensation scheme that provides stronger incentives by introducing more variation in pay across outcomes.

It is interesting to see whether the principal can focus only on second-period incentives by allowing the agent to shirk in the first period. Assume that high effort is optimal in the second period for any first-period effort. This requires that

$$E_{a_H, a_H}(y - w) - E_{a_H, a_L}(y - w) \geq 0, \text{ and} \quad (4)$$

$$E_{a_L, a_H}(y - w) - E_{a_L, a_L}(y - w) \geq 0, \quad (5)$$

where $E_{a_1, a_2}(\cdot)$ denotes expectation conditional on effort a_1 in the first period and effort a_2 in the second period, and wages w are as in Lemma 1. Then, high/low effort is optimal in the first period if

$$E_{a_H, a_H}(y - w) \gtrless E_{a_L, a_H}(y - w) \quad (6)$$

When π_M is the midpoint of π_L and π_H , low- and bad-outcome wages do not depend on first-period effort. Then, (6) can be simplified as follows.

Proposition 1 *If (4) and (5) hold and $\pi_M = (\pi_L + \pi_H)/2$, then high/low effort is optimal in the first period if the difference between the good and bad outcome is greater/smaller than the difference between the respective wages:*

$$y_H - y_L \gtrless w(v_H) - w(v_L), \quad (7)$$

where $v_H := V + 2 \frac{\pi_L a_H - \pi_H a_L}{\pi_L - \pi_H}$ and $v_L := V + 2 \frac{(1 - \pi_H) a_L - (1 - \pi_L) a_H}{\pi_L - \pi_H}$.

The principal weights the expected outcome gain of high first-period effort against the cost of its implementation which given observability takes the form of a positive shift in the value of

agent's outside option. When first and second period effort contribute equally to the probability of success, she compares the wedge between outcomes with the wedge between wages. When the latter dominates the former, implementing high effort in the first period proves suboptimal.

Next, we analyze how the optimality of first period effort is affected by model primitives. Assume that (4) and (5) hold and let D be the principal's gain from implementing high instead of low first-period effort. In other words, $D := E_{a_H, a_H}(y-w) - E_{a_L, a_H}(y-w)$. Table 1 below contains the effects of marginal changes in parameter values on D . The derivatives are evaluated at $\pi_M = (\pi_L + \pi_H)/2$ and $D = 0$, where the contribution of effort to the probability of success is (initially) split evenly between both periods and the principal is (initially) indifferent between implementing low or high effort in the first period. Positive effect (+) means that increasing the value of the parameter increases the dominance of high over low effort in the first period.

Parameter	Local effect on D
y_H	+
y_L	−
V	−
a_H	−
a_L	+
π_H	−
π_M	+
π_L	−

Table 1. Working hard versus shirking in the first period

Decreasing the wedge between outcomes makes shirking more attractive in the first period. Indeed, with probabilities and costs fixed, this would decrease the expected gain from working hard in the first period. The derivative of D with respect to V equals $(\pi_L - \pi_H)(w'(v_L) - w'(v_H))/2$ which is negative given the monotonicity of the wage scheme and the convexity of w . An increase in V would raise the cost of implementing high effort in the first period and would therefore promote shirking. The derivatives of D with respect to effort disutility are as follows:

$$\frac{\partial D}{\partial a_H} = -(\pi_L w'(v_H) + (1 - \pi_L) w'(v_L)), \quad (8)$$

$$\frac{\partial D}{\partial a_L} = \pi_H w'(v_H) + (1 - \pi_H) w'(v_L). \quad (9)$$

Intuitively, increasing the disutility of high relative to low effort raises the relative cost of implementing hard work versus shirking in the first period.

The derivatives of Δ with respect to failure probabilities are given below:

$$\begin{aligned} \frac{\partial D}{\partial \pi_H} = & -4 \frac{a_H - a_L}{(\pi_L - \pi_H)^2} \left((1 - \pi_H) \frac{\pi_L + \pi_H}{2} w'(v_H) - \left(1 - \frac{\pi_L + \pi_H}{2} \right) \pi_H w'(v_L) \right) \\ & - (\bar{y} - \underline{y}) - (w(v_H) - w(v_L)), \end{aligned} \quad (10)$$

$$\frac{\partial D}{\partial \pi_L} = -4 \frac{a_H - a_L}{(\pi_L - \pi_H)^2} \left(1 - \frac{\pi_L + \pi_H}{2} \right) \frac{\pi_L + \pi_H}{2} (w'(v_H) - w'(v_L)). \quad (11)$$

$$\begin{aligned} \frac{\partial D}{\partial \pi_M} = & 4 \frac{a_H - a_L}{(\pi_L - \pi_H)^2} \left(\left(1 - \frac{\pi_L + \pi_H}{2} \right) \pi_L w'(v_H) - \frac{\pi_L + \pi_H}{2} (1 - \pi_L) w'(v_L) \right) + \\ & 4 \frac{a_H - a_L}{(\pi_L - \pi_H)^2} \pi_H (1 - \pi_H) (w'(v_H) - w'(v_L)) + \\ & (\bar{y} - \underline{y}) - (w(v_H) - w(v_L)) \end{aligned} \quad (12)$$

Given that the contribution to the probability of success is split evenly between first and second-period effort and the principal is indifferent between inducing hard work or letting the agent shirk in the first period, probabilities affect principal's first-period effort recommendation only through the wage gap between outcomes.

A decrease in the probability of success conditional on shirking in both periods, i.e., an increase in the probability of failure π_L , relaxes the incentive compatibility constraint of a principal who allows the agent to shirk in the first period but motivates him to work hard in the second. Such a principal would set a smaller gap between v_H and v_L , which would weaken incentives and decrease average compensation. Hence, D would decrease, so an initially indifferent principal would find it optimal to allow for shirking in the first period.

A decrease in the probability of success conditional on working hard in both periods, i.e., an increase in the probability of failure π_H , would have three effects on D . The first comes from the higher gap between v_H and v_L required to satisfy incentive compatibility and individual rationality of an agent motivated to work hard in both periods. Since the agent is risk-averse, he would require a higher average wage to compensate for the increased variation in pay. The second effect acts in the opposite direction: if both good and bad outcome wages of an agent working hard in both periods were fixed, the increase in the probability of failure would decrease his respective

average compensation. The third effect comes through the rise in the average outcome (and so the average principal’s utility gross of wages) conditional on high effort in both periods. The second and third effects would cancel for a principal who implements high effort in the second period, but is indifferent between implementing low or high effort in the first period. Therefore, when $\Delta = 0$, an increase in π_H makes high first period effort suboptimal.

A decrease in the probability of success conditional on shirking in one period and working hard in another, i.e., an increase in the probability of failure π_M , would affect D positively if the third effect described above is dominated by the second. Hence, when $D = 0$, an increase in π_M makes shirking in the first period suboptimal to working hard. Since high effort is assumed optimal in the second period, the principal should compare π_M with π_H when deciding about first-period effort. A decrease in π_M would then have a similar effect to an increase in π_H , which as we saw earlier promotes first-period shirking.

So far we have focused on the implementation of first-period effort and have not discussed the provision of short and long-term incentives. As a matter of fact, it may seem that there is no place for such a discussion in the current framework. Note, however, that we can view first-period effort as long-term and second-period effort as short-term. While we have ignored short-term effort in the first period, we can innocuously assume that its provision would decrease the utility of the agent, and so would diminish the exerted level of long-term effort. Therefore, first-period shirking in our model should be understood as using short and not long term incentives.

3 The role of outside options

In the previous section, we build a simple framework to analyze the cost of providing long-term versus short-term incentives. A main feature of the model is effort persistence in the sense that current effort contributes to the performance of the company next period. The resulting substitutability of efforts from different periods allows us to talk about optimal effort mix and its implementation. The simplicity of the model allows us to solve for managerial compensation and analyze how firm, managerial, and environmental characteristics affect the optimal effort mix.

Now, we consider an extension of the model intended to capture a link between effort and managerial outside options. This link is of interest because it will distort the optimal effort mix by raising the cost of providing long term incentives. The idea is that when the manager invests in long-term tasks or, alternatively, exerts long-term effort, he directly decreases his outside option. While we do not model the specifics of this process, we can refer to a setting of firm-specific capital accumulation. Consider, for example, a manager who enters the firm as “generalist”. His stock of general human capital determines his outside option in an environment of highly specialized firms. Working for the firm, the manager accumulates firm-specific human capital that increases his productivity inside the firm. The accumulation, however, is costly and comes at the expense of his

general human capital. We can think of the manager as over-specializing: increasing his productivity inside the firm, but decreasing his productivity outside the firm. In other words, the manager decreases the value of his outside option. If we further associate firm-specific capital accumulation with longer-term projects that affect company's future rather than current performance, we would observe that long-term effort decreases manager's outside option. A rational agent would therefore require a utility premium for exerting long-term versus short-term effort to compensate for the related fall in his outside option.

In our model, where we have two possible levels of long-term effort, we treat the effect on the manager's outside option as symmetric: working hard in the first period would decrease manager's outside option by ΔV , while shirking would increase it by ΔV .³ We assume that ΔV is non-negative. If $\Delta V = 0$, there are no outside option effects and all the results of the previous section hold. If $\Delta V = \Delta a/2$, the difference between the required reservation levels for high and low effort amounts to the full rise in effort disutility Δa .

The only difference with the principal's problem presented in the previous section is that V in the individual rationality constraint (2) is now a function of a_1 , such that $V(a_L) = \underline{V} - \Delta V$ and $V(a_H) = \underline{V} + \Delta V$, where \underline{V} is the ex-ante value of the outside option.

With this definition of V , Lemma 1 applies to the current environment. Interestingly, however, first-period effort may move good- and bad-outcome wages in the same direction. When first- and second-period efforts have similar contribution to the probability of success, a principal who decides to implement high effort in the first period needs to raise both good- and bad-outcome wages to compensate the agent for the decrease in his outside option. We illustrate this through the following example.

Let the probability of failure conditional on high effort in both periods be 0.50 while the probability of failure conditional on shirking in both periods is 0.90. Assume that the loss of reservation utility is severe and equals $\Delta a/2$. Now, let's consider π_M , the probability of failure conditional on working hard in one of the periods and shirking in the other. For π_M between 0.50 and 0.65, high first-period effort will raise the good outcome wage and decrease the bad outcome wage. If there were no outside option effects, this would have been the case for π_M below 0.70. For π_M between 0.73 and 0.90, high first-period effort will decrease the good outcome wage and increase the bad outcome wage. With no outside option effects, this would have happened for π_M above 0.70. Note that for π_M between 0.65 and 0.73, high first-period effort raises both good and bad-outcome wages. In particular, this is the case for $\pi_M = 0.70$ when first- and second-period efforts contribute equally to the probability of success. Note that had there been no outside option effects, first-period effort would not have affected the wage scheme at $\pi_M = 0.70$.

Before formalizing the result in the following proposition, we introduce some notation. Let $\Delta V = \frac{\delta}{2}(a_H - a_L)$, where $\delta \geq 0$. Define $\pi_1 := \frac{(\delta+1)(\pi_L+\pi_H)+2-\sqrt{((\delta+1)(\pi_L+\pi_H)+2)^2-4(\delta+2)(\pi_L+\pi_H+\delta\pi_L\pi_H)}}{2(\delta+2)}$

³Shirking in the first period can be a proxy for obtaining more "marketable" versus firm-specific skills.

and $\pi_2 := \frac{(\delta+1)(\pi_L + \pi_H) + \sqrt{(\delta+1)^2(\pi_L + \pi_H)^2 - 4\delta(\delta+2)\pi_L\pi_H}}{2(\delta+2)}$.

Proposition 2 *Let (4) and (5) hold and $\delta > 0$. For $\pi_M \in [\pi_H, \pi_1]$, the good outcome wage increases with first period effort, while the bad outcome wage decreases with first period effort. For $\pi_M \in [\pi_1, \pi_2]$, both the good outcome wage and the bad outcome wage increase with first period effort. For $\pi_M \in [\pi_2, \pi_L]$, the good outcome wage decreases with first period effort, while the bad outcome wage increases with first period effort.*

Note that π_1 decreases with δ , while π_2 increases with δ . Also note that $\max_{\delta>0} \pi_1 = \min_{\delta>0} \pi_2 = (\pi_L + \pi_H)/2$.

Corollary 1 *Let (4) and (5) hold and $\pi_M = (\pi_L + \pi_H)/2$. For $\Delta V > 0$, the good-outcome and bad-outcome wage implementing high effort in the second period grow in first period effort. For $\Delta V = 0$, the wage scheme implementing high effort in the second period is not affected by first period effort.*

Because the wage scheme is history dependent, Proposition 1 does not hold in this environment.

Nevertheless, most results in Table 1 are still valid. To confirm the sign for effort effects, however, we need some stronger assumptions. A sufficient condition is that ΔV does not exceed $\frac{a_H - a_L}{\pi_H - \pi_L}$ and the convexity of w' .⁴ The convexity of w' is equivalent to $3(v'')^2 - v'''v' \geq 0$ which is satisfied as long as v''' is not too positive. In particular, it will hold for utility functions with constant absolute risk aversion and for utility functions with constant relative risk aversion above 0.5.

An increase in ΔV raises the average wage of an agent who is motivated to work hard in the first period and decreases the average wage of agent who is allowed to shirk in the first period. Therefore, a rise in ΔV makes first-period shirking more attractive.

4 Discussion

While the model described above is very simple, it can easily be extended to an environment with full information asymmetry (no effort is observable by the principal) and possibility of contract terminations. In such a setting, providing long-term incentives would be more costly because substituting long-term effort for short-term effort may lead to poor performance and firing the agent in the short run. Moreover, the agent may require that the utility premium comes in the form of more current and less deferred pay. On the other hand, in case of commitment issues, the principal may want to defer the premium and use it as a retention device.

An implication of the model is that firms that require a high extent of firm-specific capital accumulation should pay the agent a higher premium above his reservation utility. Testing for that,

⁴The local effects and their signs are discussed in detail in the Appendix.

however, is not innocuous since higher utility promises may not be directly observable due to the possible deference of compensation.

Another prediction is related to the growing importance of “generalists” leading to an increase in the opportunity cost of firm-specific capital accumulation.

5 Conclusion

The paper considers a moral hazard problem marked by effort persistence. Long- and short-term tasks compete in their contribution to firm’s performance and determine the strength of incentives. Effort targeting long-term performance, however, may impose additional costs to the agent. In particular, due to firm-specific capital accumulation, it may deplete agent’s outside option. Then, the principal would need to compensate the agent providing him with a premium above his reservation utility.

Our analysis suggests that in the presence of frictions, long-term incentives may be suboptimal to short-term incentives. Therefore, advocating compensation packages oriented towards long-term performance should be taken with caution.

APPENDIX

Proof of Lemma 1. Following Mas-Colell, Whinston and Green (1995), low second-period effort is implemented by a fixed wage such that individual rationality binds, while high second-period effort is implemented by a compensation scheme for which both individual rationality and incentive compatibility bind. ■

Proof of Proposition 1. When $\pi_M = (\pi_L + \pi_H)/2$, the good- and bad-outcome wages obtained in Lemma 1 do not depend on first-period effort and equal $w(v_H)$ and $w(v_L)$ respectively. Then, plugging $\pi_M = (\pi_L + \pi_H)/2$ into (6) results in (7). ■

Let $w(v_H^{\bar{a}})$ and $w(v_L^{\bar{a}})$ be agent’s good- and bad-outcome wages implementing high second-period effort conditional on high first-period effort. Let $w(v_H^a)$ and $w(v_L^a)$ be agent’s good- and bad-outcome wages implementing high second-period effort conditional on low first-period effort.

Proof of Proposition 2. Since w is increasing as an inverse of v , we will work with agent’s utility of consuming his wage (i.e., his utility gross of effort). By Lemma 1 with $V = V(e_1)$, $v_H^{\bar{a}} \geq v_H^a$ is equivalent to $f(\pi_M) \leq 0$, where $f(\pi_M) := (\delta + 2)\pi_M^2 - (\delta + 1)\pi_M + \delta\pi_L\pi_H$. The

bigger root of $f(\pi_M) = 0$ is π_2 , while the smaller is below π_H . Analogously, $v_L^{\bar{a}} \gtrless v_L^a$ is equivalent to $g(\pi_M) \lesseqgtr 0$, where $g(\pi_M) := (\delta + 2)\pi_M^2 - ((\delta + 1)(\pi_L + \pi_H) + 2)\pi_M + \pi_L + \pi_H + \delta\pi_L\pi_H$. The smaller root of $f(\pi_M) = 0$ is π_1 , while the bigger is greater than π_L . Then, the result follows from $\pi_H < \pi_1 < \pi_2 < \pi_L$. ■

Proof of Corollary 1. For $\Delta V > 0$, we have $\pi_1 < (\pi_L + \pi_H)/2 < \pi_2$, while for $\Delta V = 0$, $\pi_1 = \pi_2 = (\pi_L + \pi_H)/2$. ■

Deriving the local effects for $\Delta V > 0$. Assume that high effort is always optimal in the second period. D was defined as the gain in principal's utility from implementing high instead of low effort in the first period. We have $D = (\pi_M - \pi_H)(y_H - y_L) - (1 - \pi_H)w(v_H^{\bar{a}}) - \pi_H w(v_L^{\bar{a}}) + (1 - \pi_M)w(v_H^a) + \pi_M w(v_L^a)$.

$$\frac{\partial D}{\partial(y_H - y_L)} = \frac{\partial D}{\partial y_H} = -\frac{\partial D}{\partial y_L} = \pi_M - \pi_H > 0.$$

$\frac{\partial D}{\partial V} = -(1 - \pi_H)w'(v_H^{\bar{a}}) - \pi_H w'(v_L^{\bar{a}}) + (1 - \pi_M)w'(v_H^a) + \pi_M w'(v_L^a)$. For π_M close to $(\pi_L + \pi_H)/2$ or, more formally, for $\pi_M \in [\pi_1, \pi_2]$, we have $v_H^{\bar{a}} \geq v_H^a$ and $v_L^{\bar{a}} \geq v_L^a$, where the equalities cannot hold simultaneously. Then, since $w' > 0$, $\partial D / \partial V < (\pi_M - \pi_H)(w'(v_L^{\bar{a}}) - w'(v_H^{\bar{a}})) < 0$.

$$\frac{\partial D}{\partial \Delta V} = -(1 - \pi_H)w'(v_H^{\bar{a}}) - \pi_H w'(v_L^{\bar{a}}) - (1 - \pi_M)w'(v_H^a) - \pi_M w'(v_L^a) < 0.$$

The derivative of D with respect to a_H evaluated at $\pi_M = (\pi_L + \pi_H)/2$ equals $\frac{2}{\pi_L - \pi_H}A$, where $A := \pi_L((1 - \pi_M)w'(v_H^a) - (1 - \pi_H)w'(v_H^{\bar{a}})) + (1 - \pi_L)(\pi_H w'(v_L^{\bar{a}}) - \pi_M w'(v_L^a))$. It can be shown that $A = (\pi_H - \pi_M)(\pi_L w'(v_H^{\bar{a}}) + (1 - \pi_L)w'(v_L^{\bar{a}})) + 2\Delta V((1 - \pi_L)\pi_H w''(\tilde{v}_L) - \pi_L(1 - \pi_H)w''(\tilde{v}_H))$, where $\tilde{v}_L \in [v_L^a, v_L^{\bar{a}} + 2\Delta V]$ and $\tilde{v}_H \in [v_L^a + 2\frac{a_H - a_L}{\pi_L - \pi_H}, v_L^{\bar{a}} + 2\frac{a_H - a_L}{\pi_L - \pi_H} + 2\Delta V]$. The first term in A is negative. A sufficient condition for the second to be non-positive is $w''' \geq 0$ and $\Delta V \leq \frac{a_H - a_L}{\pi_L - \pi_H}$.

Analogously, we can show that $\frac{\partial D}{\partial a_L}$ is positive if $w''' \geq 0$ and $\Delta V \leq \frac{a_H - a_L}{\pi_L - \pi_H}$.

$$\frac{\partial D}{\partial \pi_L} = -\frac{(1 - \pi_M)(a_H - a_L)\pi_M}{(\pi_L - \pi_M)^2}(w'(v_H^a) - w'(v_L^a)) < 0.$$

$\frac{\partial D}{\partial \pi_H} = -(B + C)$, where $B := y_H - y_L - w(v_H^{\bar{a}}) + w(v_L^{\bar{a}})$ and $C := \frac{a_H - a_L}{(\pi_M - \pi_H)^2}((1 - \pi_H)\pi_M w'(v_H^{\bar{a}}) - (1 - \pi_M)\pi_H w'(v_L^{\bar{a}})) > 0$. Note that for $\pi_M \in [\pi_1, \pi_2]$, $(\pi_M - \pi_H)B > D$. So, when evaluated at π_M close to $(\pi_L + \pi_H)/2$ and at $D = 0$, $\frac{\partial D}{\partial \pi_H} < 0$.

$\frac{\partial D}{\partial \pi_M} = F + G + H$, where $F := y_H - y_L - w(v_H^a) + w(v_L^a)$, $G := \frac{a_H - a_L}{(\pi_M - \pi_H)^2}((1 - \pi_H)\pi_H w'(v_H^{\bar{a}}) - (1 - \pi_H)\pi_H w'(v_L^{\bar{a}})) > 0$, and $H := \frac{a_H - a_L}{(\pi_L - \pi_M)^2}((1 - \pi_M)\pi_L w'(v_H^a) - (1 - \pi_L)\pi_M w'(v_L^a)) > 0$. Note that for $\pi_M \in [\pi_1, \pi_2]$, $(\pi_M - \pi_H)F > D$. Then, when evaluated at π_M close to $(\pi_L + \pi_H)/2$ and at $D = 0$, $\frac{\partial D}{\partial \pi_M} > 0$.

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