Online Appendix
A Theory of Fair CEO Pay

Pierre Chaigneau, Alex Edmans, Daniel Gottlieb

1 Nonlinear model

The agent's utility function is:

$$u(w,q)=\begin{cases} v(w) & \text{if } w(q)\geq w^*(q) \\ v(w^*(q))-(1+\gamma)\xi\left(w^*(q)-w\right) & \text{if } w(q)<w^*(q) \end{cases}, \tag{34}$$

where $v'>0$, $v''\leq 0$, $\xi'>0$, $\xi''\leq 0$, and $\gamma\geq 0$ parametrizes fairness concerns. If the wage is fair ($w\geq w^*(q)$), the agent's utility is $v(w)$. If the wage is unfair ($w<w^*(q)$), the agent suffers disutility which is increasing in both the discrepancy $w^*(q)-w$ and his fairness concerns γ. We assume $\lim_{w\searrow 0} v'(w)<1+\gamma$ and $\lim_{x\nearrow \overline{q}}\xi'(x)\geq 1$, so that the utility function is always steeper below the fair wage than above it. The kink at the fair wage means that the agent is loss-averse: his sensitivity to losses exceeds his sensitivity to gains, consistent with empirical and experimental evidence that the disutility from unfair wages exceed the utility from above-fair wages (see the survey of Fehr, Goette, and Zehnder (2009)). The function $\xi(\cdot)$ means that the agent's utility is weakly convex below the fair wage, as in prospect theory. The unique feature of our model is that the fair wage depends on output and is thus endogenously determined ex post, in contrast to loss aversion models where the reference point is independent of output and thus known ex ante. The main paper studies a special case of (34) is where the agent's utility is piecewise linear ($v(w)=w$ and $\xi(x)=x$).

Figure 2 displays the agent's utility as a function of w for various output realizations and two different utility functions.

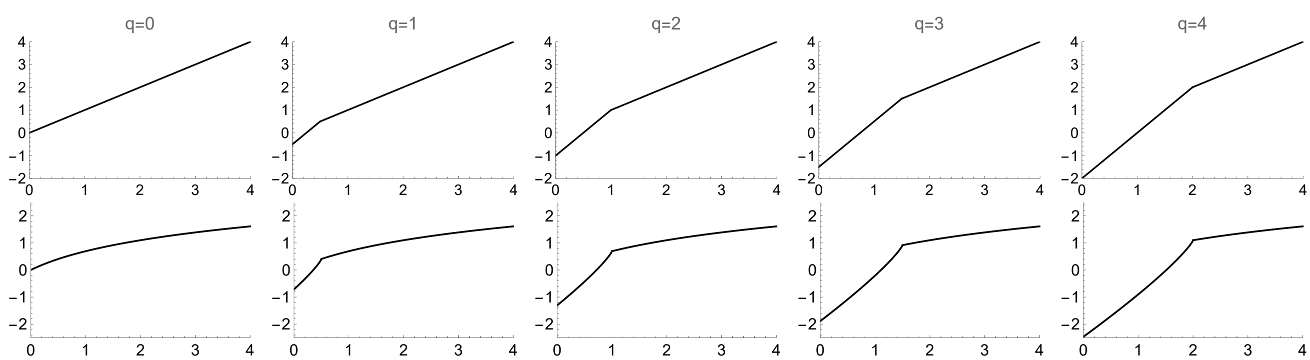

Figure 2: Function $u(w,q)$ as defined in equation (34) as a function of w for $\gamma=1$, $\rho=\frac{1}{2}$, and output $q\in\{0,1,2,3,4\}$. Top row: $v(w)=w$. Bottom row: $v(w)=\ln(w+1)$, $\xi(x)=x^{1/1.2}$.

To simplify the analysis, we assume:

$$\int_0^{q_0^{e^T}} u(0,q)\frac{\partial \phi}{\partial e}(q|e^T)dq + \int_{q_0^{e^T}}^{\overline{q}} u(\rho q,q)\frac{\partial \phi}{\partial e}(q|e^T)dq \geq C'(e^T) \tag{35}$$

$$\int_0^{\overline{q}} u(0,q)\phi(q|0)dq - C(0) < \overline{U} \tag{36}$$

$$\int_0^{\overline{q}} u(\rho q,q)\phi(q|\hat{e})dq - C(\hat{e}) \geq \overline{U}, \text{ where } \hat{e} = e^* \text{ as defined in (3) with } w(q) = w^*(q)\ \forall q. \tag{37}$$

Proposition 3 *(Zero target effort level): Fix $e^T = 0$. The contract has pay-for-performance: $w(q) > w(q')$ for some $q > q'$.*

Define $q_m^{\min}$ as the highest value that satisfies the following:

$$\int_0^{q_m^{\min}} u(0,q)\frac{\partial \phi}{\partial e}(q|e^T)dq + \int_{q_m^{\min}}^{\overline{q}} v(\rho q)\frac{\partial \phi}{\partial e}(q|e^T)dq = C'(e^T). \tag{38}$$

Proposition 4 *(Binding incentive constraint): Fix e^T sufficiently high. The principal implements $e^* = e^T$ and offers the following contract:*

$$\frac{1}{u'_w(w(q),q)} = \begin{cases} \frac{1}{u'_w(0,q)} & \text{for } q < q_m \\ \frac{1}{v'(w^*(q))} & \text{for } q \geq q_m \text{ and } \lambda_{IR} + \lambda_{IC}LR(q|e^*) < \frac{1}{v'(w^*(q))} \\ \lambda_{IR} + \lambda_{IC}LR(q|e^*) & \text{for } q \geq q_m \text{ and } \frac{1}{v'(w^*(q))} \leq \lambda_{IR} + \lambda_{IC}LR(q|e^*) \leq \frac{1}{v'(q)} \\ \frac{1}{v'(q)} & \text{for } q \geq q_m \text{ and } \frac{1}{v'(q)} < \lambda_{IR} + \lambda_{IC}LR(q|e^*) \end{cases} \tag{39}$$

Moreover, if $v'(0) \leq 1$, $\gamma > \frac{LR(\overline{q}|e^T)}{LR(q_m^{min}|e^T)} - 1$, and $\overline{U}$ is sufficiently low that IR is nonbinding, then $w(q) = 0$ for $q < q_m$ and $w(q) = w^*(q)$ for $q \geq q_m$.

The optimal contract is now given by (up to) four regions. As with $v'' = 0$, there are three regions in which the agent is paid zero, the fair wage, and the entire output. However, there is an additional region where output is sufficiently high that the principal pays more than the fair wage. It is inefficient to pay the entire output, since the agent exhibits diminishing marginal utility and so does not value this additional reward highly. Thus, unlike in the model with $v'' = 0$, the optimal contract is only discontinuous at q_m. As output rises, the likelihood ratio increases further and so the actual wage exceeds the fair wage by more. The contract will generally be convex in this region.[10] When the likelihood ratio is very high, the principal pays the entire output. If fairness concerns are sufficiently high, then as in the linear model, the contract comprises only the first two regions and corresponds to performance-vesting equity.

[10] However, the contract will be concave if the likelihood ratio is concave, so that very high output is only slightly more indicative of effort, and if risk aversion is sufficiently important compared to prudence (see Chaigneau, Sahuguet and Sinclair-Desgagné, 2017). The latter condition will typically not be satisfied for CEOs who have low absolute risk aversion due to their wealth.

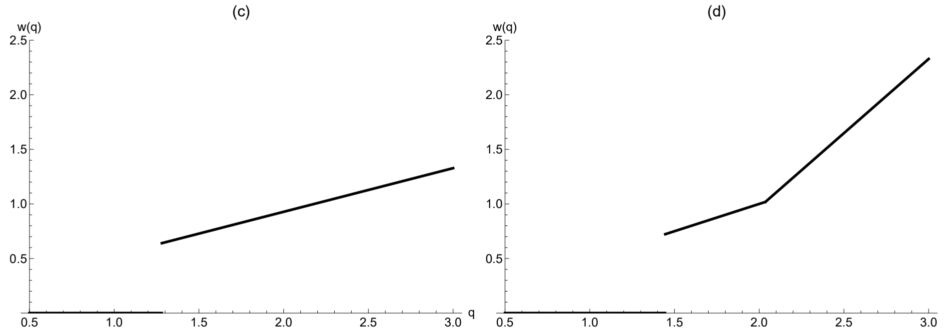

Figure 3: The contract $w(q)$ as a function of q for parameter values described in Example 1.

Example 1 illustrates how the optimal contract is affected by the underlying parameters. When $v'' < 0$, the contract resembles performance shares, where the number of shares that vest increase with performance, in contrast to performance-vesting equity where the number of shares is fixed as long as performance exceeds a threshold. Performance shares, like performance-vesting equity, are widely used in practice (see Figure 2 in Bettis et al. (2018)).

Example 1 *The agent's preferences are given by* $\gamma = 2$, $\rho = \frac{1}{2}$, *and* $v(w) = \ln(w+1)$, $\xi(x) = x$, *and output follows a truncated normal distribution on* $[0, 10]$ *with parameters* $e^* = 1$ *and* $\sigma = 1$. *Optimal contract for (c)* $\overline{U} = -0.5$ *and* $C(1) = C'(1) = 0.4$*; (d)* $\overline{U} = -1$ *and* $C(1) = C'(1) = 0.45$.

2 Proofs

Proof of Proposition 3:

We show by contradiction that an optimal contract is characterized by $w(q) > w(q')$ for some $q > q'$. Suppose that it is not. Due to the monotonicity constraint, this implies that $w(q) = \bar{w}$, which is a constant, for all $q \in [0, \overline{q}]$. A fixed wage induces $e^* = 0$ and IR binds in the optimal contract:

$$\int u(\bar{w}, q) \frac{\partial \phi}{\partial e}(q|0) dq < C'(0) \quad \text{and} \quad \int u(\bar{w}, q) \phi(q|0) dq - C(0) = \overline{U}$$

Consider the following perturbation which does not change the corner solution $e^* = 0$. Let $\check{q}$ be such that $\bar{w} = w^*(\check{q})$. For arbitrarily small ϵ and ε, let the new contract be described as:

$$w(q) = \begin{cases} \bar{w} - \rho\epsilon & \text{if } q < \check{q} - \epsilon \\ w^*(q) & \text{if } q \in [\check{q} - \epsilon, \check{q} + \varepsilon] \\ \bar{w} + \rho\varepsilon & \text{if } q \geq \check{q} + \varepsilon \end{cases}, \tag{40}$$

such that the agent's expected utility is unchanged:

$$\begin{aligned}
& \int_0^{\check{q}-\epsilon} v(\bar{w}-\rho\epsilon)\phi(q|0)dq + \int_{\check{q}-\epsilon}^{\check{q}+\varepsilon} v(w^*(q))\phi(q|0)dq + \int_{\check{q}+\varepsilon}^{\overline{q}} u(\bar{w}+\rho\varepsilon, q)\phi(q|0)dq \\
= \; & \int_0^{\check{q}} v(\bar{w})\phi(q|0)dq + \int_{\check{q}}^{\overline{q}} u(\bar{w}, q)\phi(q|0)dq
\end{aligned}$$

Since ϵ and ε are arbitrarily small, this implies:

$$\int_0^{\check{q}} \rho\epsilon v'(\bar{w})\phi(q|0)dq \approx \rho\varepsilon \int_{\check{q}}^{\overline{q}} u_w(\bar{w}, q)\phi(q|0)dq \tag{41}$$

Likewise, the change in the cost of compensation is approximately:

$$-\int_0^{\check{q}} \rho\epsilon\phi(q|0)dq + \int_{\check{q}}^{\overline{q}} \rho\varepsilon\phi(q|0)dq,$$

which is strictly negative by equation (41) with the assumption $v'(w) < u_w(w, q)$ for any w. ■

Proof of Proposition 4:

With the FOA, the IC (3) can be replaced by the first-order condition ("FOC") for interior solutions:

$$\int_0^{\overline{q}} u(w(q), q)\frac{\partial \phi}{\partial e}(q|e^*)dq = C'(e^*) \tag{42}$$

with $e^* = e^T > 0$.

We derive the optimal contract while ignoring the monotonicity constraint $\dot{w}(q) \geq 0$, and we verify later that the optimal contract thus derived is monotonic.

In the first step, we take as given the payment $w(q)$ on the subset Q_b of outputs s.t. $w(q) \in (w^*(q), q]$, and we consider the subset Q_a of outputs s.t. $w(q) \in [0, w^*(q)]$. We have:

$$\max_{w(q)\ s.t.\ q\in Q_a} \int (-w(q))\,\phi(q|e^T)dq \qquad \text{s.t.} \qquad \begin{aligned} & \int u(w(q), q)\frac{\partial \phi}{\partial e}(q|e^T)dq = C'(e^T) \\ & \int u(w(q), q)\phi(q|e^T)dq - C(e^T) \geq \overline{U} \\ & 0 \leq w(q) \leq w^*(q)\ \forall q \in Q_a \end{aligned} \tag{43}$$

The first-order necessary condition ("FONC") for an interior solution $w(q) \in (0, w^*(q))$ is:

$$-\phi(q|e^T) + \mu u_w(w(q), q)\frac{\partial \phi}{\partial e}(q|e^T) + \lambda u_w(w(q), q)\phi(q|e^T) = 0$$

where λ and μ are respectively the Lagrange multipliers associated with the participation constraint and the incentive constraint, and, since $0 \leq w(q) \leq w^*(q)$, we have $u_w(w(q), q) = (1+\gamma)\xi'(w^*(q) - w) > 0$.

In the case $\xi'' = 0$, the FONC is satisfied only if the likelihood ratio $\frac{\frac{\partial \phi}{\partial e}(q|e^T)}{\phi(q|e^T)}$ is constant, which is impossible by MLRP. In the case $\xi'' < 0$, the second-order condition with respect to $w(q)$ is not satisfied at any $w(q)$ that satisfies the FONC. Indeed, the FONC can be rewritten as:

$$\frac{1}{u_w(w(q), q)} = \lambda + \mu \frac{\frac{\partial \phi}{\partial e}(q|e^T)}{\phi(q|e^T)} \tag{44}$$

where the LHS is strictly positive, so that the RHS must be strictly positive for any $w(q)$ that satisfies the FONC. The second-order condition is satisfied if and only if:

$$\mu u_{ww}(w(q), q) \frac{\partial \phi}{\partial e}(q|e^T) + \lambda u_{ww}(w(q), q)\phi(q|e^T) < 0 \tag{45}$$

which given $u_{ww}(w(q), q) > 0$ (due to $\xi'' < 0$ in this case) can be rewritten as: $\frac{\frac{\partial \phi}{\partial e}(q|e^T)}{\phi(q|e^T)} < -\frac{\lambda}{\mu}$, where $\lambda \geq 0$ and $\mu > 0$. Thus, for $\xi'' < 0$, the optimum cannot be an interior solution, i.e. it cannot be $w(q) \in (0, w^*(q))$. We conclude that, for $w(q) \in [0, w^*(q)]$, the optimum is not characterized by an interior solution.

Thus, for some $Q_- \subseteq [0, \overline{q}]$ we have $w(q) = 0$, and for $q \in Q_+ \subseteq [0, \overline{q}]$ we have $w(q) \in [w^*(q), q]$. This implies $u(w, q) = v(w)$ for $q \in Q_+$. In sum, for a given Q_-, the relaxed optimization problem that induces $e^* = e^T$ can be rewritten:

$$\min_{w(q)} \int_{Q_+} w(q)\phi(q|e^T)dq \tag{46}$$

$$\text{s.t.} \quad \int_{Q_-} u(0, q)\frac{\partial \phi}{\partial e}(q|e^T)dq + \int_{Q_+} v(w(q))\frac{\partial \phi}{\partial e}(q|e^T)dq = C'(e^T) \tag{47}$$

$$\int_{Q_-} u(0, q)\phi(q|e^T)dq + \int_{Q_+} v(w(q))\phi(q|e^T)dq \geq \overline{U} \tag{48}$$

$$w(q) \in [w^*(q), q] \ \forall q \tag{49}$$

The program in equations (46)-(49) has a solution because of the assumptions in equations (35) and (37)). Using the notation in Jewitt, Kadan, and Swinkels (2008), we have $\underline{m}(q) = w^*(q)$ and $\overline{m}(q) = q$. We apply their Proposition 1 to derive the optimal contract on Q_+ given that $w(q) = 0$ for $q \in Q_-$ (the first terms on the LHS of equations (47) and (48) are independent of $w(q)$ and can therefore be treated as constants in the program (46)-(49)). Thus, for some Q_-, the optimal contract is defined implicitly by:

$$\frac{1}{u'_w(w(q), q)} = \begin{cases} \frac{1}{u'_w(0,q)} & \text{for } q \in Q_- \\ \frac{1}{v'(w^*(q))} & \text{for } q \in Q_+ \text{ and } \lambda_{IR} + \lambda_{IC} LR(q|e^*) < \frac{1}{v'(w^*(q))} \\ \lambda_{IR} + \lambda_{IC} LR(q|e^*) & \text{for } q \in Q_+ \text{ and } \frac{1}{v'(w^*(q))} \leq \lambda_{IR} + \lambda_{IC} LR(q|e^*) \leq \frac{1}{v'(q)} \\ \frac{1}{v'(q)} & \text{for } q \in Q_+ \text{ and } \frac{1}{v'(q)} < \lambda_{IR} + \lambda_{IC} LR(q|e^*) \end{cases}$$

Finally, with a binding IC and MLRP, standard arguments show that we must have $w(q) = 0$ if and only if $q \leq q_m$ for some $q_m \in [0, \overline{q}]$, so that the optimal contract is defined implicitly by:

$$\frac{1}{u'_w(w(q), q)} = \begin{cases} \frac{1}{u'_w(0,q)} & \text{for } q < q_m \\ \frac{1}{v'(w^*(q))} & \text{for } q \geq q_m \text{ and } \lambda_{IR} + \lambda_{IC} LR(q|e^*) < \frac{1}{v'(w^*(q))} \\ \lambda_{IR} + \lambda_{IC} LR(q|e^*) & \text{for } q \geq q_m \text{ and } \frac{1}{v'(w^*(q))} \leq \lambda_{IR} + \lambda_{IC} LR(q|e^*) \leq \frac{1}{v'(q)} \\ \frac{1}{v'(q)} & \text{for } q \geq q_m \text{ and } \frac{1}{v'(q)} < \lambda_{IR} + \lambda_{IC} LR(q|e^*) \end{cases}$$

where $\lambda_{IC} > 0$ and $\lambda_{IR} \geq 0$ are the Lagrange multipliers associated with the constraints (47) and (48), and which therefore depend on q_m.

We now establish the second part of the proof. The optimal contract is described in equation (39). Under the conditions stated in the second part of the Proposition, we will show that any contract as in equation (39) which is not such that $w(q) = 0$ for $q < q_m$ and $w(q) = w^*(q)$ for $q \geq q_m$ is dominated. Consider a given incentive-compatible "contract A" as in equation (39) such that $w(q) > w^*(q)$ for a non-empty interval of outputs. We will show that this contract is dominated by an incentive-compatible "contract B" such that $w(q) = 0$ for $q < q_m$ and $w(q) = w^*(q)$ for $q \geq q_m$.

First of all, we cannot have $w_A(q) = w^*(q)$ for $q < q_m^{\min}$ since then contract A as in equation (39) would involve a strictly higher cost than contract B, i.e. it would be dominated. The other possibility is that these two contracts differ on two (possibly empty) subintervals: $(q_m^{\min}, q_1)$ where $w_A(q) = 0 < w^*(q) = w_B(q)$, and $(q_2, \overline{q})$ where $w_A(q) > w^*(q) = w_B(q)$. The subintervals must be such that $q_m^{\min} \leq q_1 \leq q_2 \leq \overline{q}$ because of the monotonicity assumption.

Then, consider a switch from contract A to contract B. The implied change in the LHS of the IC, which must be zero by incentive compatibility, is:

$$\begin{aligned} 0 &= \int_{q_m^{\min}}^{q_1} (v(w^*(q)) - (v(w^*(q)) - (1+\gamma)w^*(q))) \frac{d\phi}{de}(q|e^T)dq + \int_{q_2}^{\overline{q}} (v(w^*(q)) - v(w_A(q))) \frac{d\phi}{de}(q|e^T)dq \\ &= (1+\gamma) \int_{q_m^{\min}}^{q_1} w^*(q) \frac{d\phi}{de}(q|e^T)dq + \int_{q_2}^{\overline{q}} (v(w^*(q)) - v(w_A(q))) \frac{d\phi}{de}(q|e^T)dq \end{aligned}$$

where, with $v'' \leq 0$: $v(w_A(q)) \leq v(w^*(q)) + v'(w^*(q))\,(w_A(q) - w^*(q))$ for $q \in (q_2, \overline{q})$, and

$v'(w^*(q)) \leq v'(0) \leq 1$, so that:

$$\begin{aligned}
0 &= (1+\gamma)\int_{q_m^{\min}}^{q_1} w^*(q)\frac{d\phi}{de}(q|e^T)dq + \int_{q_2}^{\overline{q}} \left(v(w^*(q)) - v(w_A(q))\right)\frac{d\phi}{de}(q|e^T)dq \\
&\geq (1+\gamma)\int_{q_m^{\min}}^{q_1} w^*(q)\frac{d\phi}{de}(q|e^T)dq + \int_{q_2}^{\overline{q}} \left(\left(v(w^*(q)) - v(w^*(q)) - v'\left(w^*(q)\right)\left(w_A(q) - w^*(q)\right)\right)\right)\frac{d\phi}{de}(q|e^T)dq \\
&\geq (1+\gamma)\int_{q_m^{\min}}^{q_1} w^*(q)\frac{d\phi}{de}(q|e^T)dq - v'(0)\int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\frac{d\phi}{de}(q|e^T)dq \\
&> (1+\gamma)\int_{q_m^{\min}}^{q_1} w^*(q)\frac{d\phi}{de}(q|e^T)dq - \int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\frac{d\phi}{de}(q|e^T)dq \\
&= (1+\gamma)\int_{q_m^{\min}}^{q_1} w^*(q)\frac{\frac{d\phi}{de}(q|e^T)}{\phi(q|e^T)}\phi(q|e^T)dq - \int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\frac{\frac{d\phi}{de}(q|e^T)}{\phi(q|e^T)}\phi(q|e^T)dq
\end{aligned}$$

where:

$$\begin{aligned}
\int_{q_m^{\min}}^{q_1} w^*(q)\frac{\frac{d\phi}{de}(q|e^T)}{\phi(q|e^T)}\phi(q|e^T)dq &> \frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_m^{\min}}^{q_1} w^*(q)\phi(q|e^T)dq \\
\int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\frac{\frac{d\phi}{de}(q|e^T)}{\phi(q|e^T)}\phi(q|e^T)dq &< \frac{\frac{d\phi}{de}(\overline{q}|e^T)}{\phi(\overline{q}|e^T)}\int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\phi(q|e^T)dq
\end{aligned}$$

Overall:

$$\begin{aligned}
0 &> (1+\gamma)\int_{q_m^{\min}}^{q_1} w^*(q)\frac{\frac{d\phi}{de}(q|e^T)}{\phi(q|e^T)}\phi(q|e^T)dq - \int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\frac{\frac{d\phi}{de}(q|e^T)}{\phi(q|e^T)}\phi(q|e^T)dq \\
&> (1+\gamma)\frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_m^{\min}}^{q_1} w^*(q)\phi(q|e^T)dq - \frac{\frac{d\phi}{de}(\overline{q}|e^T)}{\phi(\overline{q}|e^T)}\int_{q_2}^{\overline{q}} \left(w_A(q) - w^*(q)\right)\phi(q|e^T)dq \quad (50)
\end{aligned}$$

The implied change in contract cost is:

$$\int_{q_m^{\min}}^{q_1} w^*(q)\phi(q|e^T)dq + \int_{q_2}^{\overline{q}} \left(w^*(q) - w_A(q)\right)\phi(q|e^T)dq$$

Because of $q_m^{\min} \geq q_0^{e^T}$ (see equations (35) and (38)) and MLRP, the change in cost has the same sign as:

$$\begin{aligned}
&\frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_m^{\min}}^{q_1} w^*(q)\phi(q|e^T)dq + \frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_2}^{\overline{q}} \left(w^*(q) - w_A(q)\right)\phi(q|e^T)dq \\
<\ & (1+\gamma)\frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_m^{\min}}^{q_1} w^*(q)\phi(q|e^T)dq + \frac{\frac{\frac{d\phi}{de}(\overline{q}|e^T)}{\phi(\overline{q}|e^T)}}{\frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}}\frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_2}^{\overline{q}} \left(w^*(q) - w_A(q)\right)\phi(q|e^T)dq \\
=\ & (1+\gamma)\frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}\int_{q_m^{\min}}^{q_1} w^*(q)\phi(q|e^T)dq + \frac{\frac{d\phi}{de}(\overline{q}|e^T)}{\phi(\overline{q}|e^T)}\int_{q_2}^{\overline{q}} \left(w^*(q) - w_A(q)\right)\phi(q|e^T)dq
\end{aligned}$$

where the inequality follows from $1+\gamma > \frac{\frac{d\phi}{de}(\overline{q}|e^T)}{\phi(\overline{q}|e^T)} \Big/ \frac{\frac{d\phi}{de}(q_m^{\min}|e^T)}{\phi(q_m^{\min}|e^T)}$. The RHS is negative because of equation (50). Thus, under the conditions stated in the second part of Proposition 4, the change in the contract is incentive compatible and it involves a negative change in cost, which establishes that the initial contract is dominated since IR is nonbinding. ■

References

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