Online Appendix for "Effect of Guided Delegation and Information Proximity on Multi-tier Responsible Sourcing"

Proof of Proposition 1: Based on the manufacturer's best response function in §3.2 and the fact that $w_1 < w_2$, to obtain the optimal solution, the buyer compares the optimal profit from the following three sub-problems: (1) when $w \geq w_2$, $(\tilde{S}(H_M), \tilde{S}(L_M)) = (H_M, H)$.

$$\tilde{\pi}_B^1 = \max_w \; r - w$$
$$s.t. \;\; w \geq w_2, \; \tilde{\pi}_M = w - c + \eta\varphi \geq 0.$$

By the assumption that $\theta\beta\gamma < 1$, the optimal solution is achieved at $w = w_2$. So, $\tilde{\pi}_B^1 = r - w_2$.

(2) when $w \in [w_1, w_2]$, $(\tilde{S}(H_M), \tilde{S}(L_M)) = (H_M, L_M)$.

$$\tilde{\pi}_B^2 = \max_w \; r - w - (1-\eta)\tau_B$$
$$s.t. \;\; w_1 \leq w \leq w_2, \; \tilde{\pi}_M = \eta(w-c) + (1-\eta)(1-\tau_M)(w - \alpha c) + \varphi \geq 0.$$

By the assumption that $\theta\beta\gamma < 1$ and $(1-\alpha)c > \varphi$, the optimal solution is achieved at $w = w_1$. So, $\tilde{\pi}_B^2 = r - w_1 - (1-\eta)\tau_B$.

(3) when $w \leq w_1$, $(\tilde{S}(H_M), \tilde{S}(L_M)) = (L, L_M)$.

$$\tilde{\pi}_B^3 = \max_w \; r - w - \tau_B$$
$$s.t. \;\; w \leq w_1, \; \tilde{\pi}_M = (1-\tau_M)(w - \alpha c) + (1-\eta)\varphi \geq 0.$$

The optimal solution is achieved at $w = \alpha c - \frac{(1-\eta)\varphi}{1-\tau_M}$. So, $\tilde{\pi}_B^3 = r - \alpha c + \frac{(1-\eta)\varphi}{1-\tau_M} - \tau_B$.

First, comparing $\tilde{\pi}_B^1$ and $\tilde{\pi}_B^2$, we have $\tilde{\pi}_B^1 > \tilde{\pi}_B^2$ when $\tau_B > \zeta_1 := \frac{2}{(1-\eta)\tau_M}\varphi$, and $\tilde{\pi}_B^1 < \tilde{\pi}_B^2$ otherwise. When $\tau_B > \zeta_1$, we compare $\tilde{\pi}_B^1$ and $\tilde{\pi}_B^3$ and get $\tilde{\pi}_B^1 > \tilde{\pi}_B^3$ when $\tau_B > \zeta_2 := \frac{(1-\alpha)c}{\tau_M} + \frac{1-\eta\tau_M}{\tau_M(1-\tau_M)}\varphi$, and $\tilde{\pi}_B^1 < \tilde{\pi}_B^3$ otherwise. When $\tau_B < \zeta_1$, we compare $\tilde{\pi}_B^2$ and $\tilde{\pi}_B^3$ and get $\tilde{\pi}_B^2 > \tilde{\pi}_B^3$ when $\tau_B > \zeta_3 := \frac{(1-\alpha)c}{\eta\tau_M} - \frac{1-(2-\eta)\tau_M}{\eta\tau_M(1-\tau_M)}\varphi$. Proposition 1 and Figure 3 follow. ■

Proof of Lemma 1: When the manufacturer observes H_M, the manufacturer's profit function when the buyer conducts auditing ($A = 1$) is given by (1). The manufacturer will optimally choose H_B if $w > w_3$, and choose L otherwise (recall that we focus on the case where $\mu s > (1-\mu)\varphi$). The manufacturer's optimal supplier selection when $A = 0$ is the same as the full-delegation case, characterized by the threshold w_1. Since $w_3 - w_1 = \frac{(1-\mu)\varphi - \mu s}{(1-\mu)\tau_M} < 0$, part (i) follows. When the manufacturer observes L_M, the manufacturer's profit function when $A = 1$ is given by (2), the manufacturer will optimally choose H_B if $w > w_4$, and choose L_M otherwise. The manufacturer's optimal supplier selection when $A = 0$ is the same as the full-delegation case, characterized by the threshold w_2. Clearly, $w_4 < w_2$, so part (ii) follows. ■

Proof of Lemma 2: When the manufacturer always chooses a risk-free supplier, clearly it is optimal for the buyer not to conduct auditing, i.e., $A(\text{risk-free}, \text{risk-free}) = 0$. When the manufacturer always chooses a risky supplier, from (3) the buyer's profit is $r - w - \tau_B$ if auditing is not performed, and $r - w - (1-\mu)\tau_B - I$ if auditing is performed. Comparing the two cases, we obtain that $A(\text{risky}, \text{risky}) = 1$ if $I \leq \mu\tau_B$, and $A(\text{risky}, \text{risky}) = 0$ otherwise. When the manufacturer selects a risk-free supplier when observing H_M and a risky supplier when observing L_M, from (4) the buyer's profit is $r-w-(1-\eta)\tau_B$ if auditing is not performed, and $r-w-(1-\eta)(1-\mu)\tau_B-I$ if auditing is performed. Comparing the two cases, we obtain that $A(\text{risk-free}, \text{risky}) = 1$ if $I \leq (1-\eta)\mu\tau_B$, and $A(\text{risk-free}, \text{risky}) = 0$ otherwise. ■

Proof of Proposition 2: First, we have shown that $w_3 < w_1$, $w_4 < w_2$, $w_3 < w_4$, and $w_1 < w_2$. There are two possible cases: (1) $w_3 < w_1 < w_4 < w_2$, and (2) $w_3 < w_4 < w_1 < w_2$. Consider case (1) first. When $w \geq w_2$, by Lemma 1 the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (H_M, H_B)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, H_B)$ given $A = 1$. In both cases, the selected supplier is risk free. By Lemma 2 the buyer's best response is not to audit. Therefore, the fixed point is $(A^*, S^*(H_M), S^*(L_M)) = (0, H_M, H_B)$. When $w \in [w_4, w_2]$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (H_M, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, H_B)$ given $A = 1$. The latter is not a fixed point. The former is a fixed point if and only if $I \geq (1-\eta)\mu\tau_B$. When $w \in [w_1, w_4]$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (H_M, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, L_M)$ given $A = 1$. The former is a fixed point if and only if $I \geq (1-\eta)\mu\tau_B$, and the latter is a fixed point if and only if $I \leq (1-\eta)\mu\tau_B$. When $w \in [w_3, w_1]$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (L, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, L_M)$ given $A = 1$. The former is a fixed point if and only if $I \geq \mu\tau_B$, and the latter is a fixed point if and only if $I \leq (1-\eta)\mu\tau_B$. When $w \leq w_3$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (L, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (L, L_M)$ given $A = 1$. The former is a fixed point if and only if $I \geq \mu\tau_B$, and the latter is a fixed point if and only if $I \leq \mu\tau_B$. Combine the same fixed points, we have (5).

Finally, for case (2), when $w \in [w_1, w_2]$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (H_M, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, H_B)$ given $A = 1$. The latter is not a fixed point. The former is a fixed point if and only if $I \geq (1-\eta)\mu\tau_B$. When $w \in [w_4, w_1]$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (L, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, H_B)$ given $A = 1$. The latter is not a fixed point. The former is a fixed point if and only if $I \geq \mu\tau_B$. When $w \in [w_3, w_4]$, the manufacturer's supplier selection decision is $(S(H_M), S(L_M)) = (L, L_M)$ given $A = 0$, and is $(S(H_M), S(L_M)) = (H_B, L_M)$ given $A = 1$. The former is a fixed point if and only if $I \geq \mu\tau_B$, and the latter is a fixed point if and only if $I \leq (1-\eta)\mu\tau_B$. Combine the same fixed points, we get the same form as (5). ■

Proof of Proposition 3: We first solve for the optimal wholesale price for the five cases in (5).

Case 1: $(A^*, S^*(H_M), S^*(L_M))$=$(0, H_M, H_B)$ when $w \geq w_2$. The buyer solves the problem $\max_w \ \pi_B^1 = r - w$ subject to $w - c + \eta\varphi \geq 0$, $w \geq w_2$. Since $\tau_M < 1$, we have $w_2 > w - c + \eta\varphi$, and therefore $w^* = w_2$.

Case 2: $(A^*, S^*(H_M), S^*(L_M))$=$(0, H_M, L_M)$ when $w_1 \leq w \leq w_2$ and $I \geq (1-\eta)\mu\tau_B$. The buyer solves the problem $\max_w \ \pi_B^2 = r - w - (1-\eta)\tau_B$ subject to $\eta(w-c) + (1-\eta)(1-\tau_M)(w-\alpha c) + \varphi \geq 0$, $w_1 \leq w \leq w_2$, $I \geq (1-\eta)\mu\tau_B$. The first constraint is equivalent to $w \geq \alpha c + \frac{\eta(1-\alpha)c-\varphi}{1-(1-\eta)\tau_M}$. By the assumption $(1-\alpha)c > \varphi$, we have $w_1 > \alpha c + \frac{\eta(1-\alpha)c-\varphi}{1-(1-\eta)\tau_M}$, and therefore $w^* = w_1$.

Case 3: $(A^*, S^*(H_M), S^*(L_M))$=$(1, H_B, L_M)$ when $w_3 \leq w \leq w_4$ and $I \leq (1-\eta)\mu\tau_B$. The buyer solves the problem $\max_w \ \pi_B^3 = r - w - (1-\eta)(1-\mu)\tau_B - I$ subject to $w - c - (1-\eta)[\mu s + (1-\mu)(\tau_M(w-\alpha c) - (1-\alpha)c - \varphi)] \geq 0$, $w_3 \leq w \leq w_4$, $I \leq (1-\eta)\mu\tau_B$. The first constraint is equivalent to $w \geq w_{31} := \alpha c + \frac{(1-\alpha)c[1-(1-\eta)(1-\mu)]+(1-\eta)\mu s-(1-\eta)(1-\mu)\varphi}{1-(1-\eta)(1-\mu)\tau_M}$. We have $w^* = w_3$ when $(1-\alpha)c(1-\tau_M) + \varphi(1-\eta)\tau_M(1-\mu) > \frac{\mu s}{1-\mu}$ and $w^* = w_{31}$ otherwise.

Case 4: $(A^*, S^*(H_M), S^*(L_M))$=$(0, L, L_M)$ when $w < w_1$ and $I \geq \mu\tau_B$. The buyer solves the problem $\max_w \ \pi_B^4 = r - w - \tau_B$ subject to $(1-\tau_M)(w-\alpha c) + (1-\eta)\varphi \geq 0$, $w < w_1$, $I \geq \mu\tau_B$. The optimal wholesale price is $w^* = \alpha c - \frac{(1-\eta)\varphi}{1-\tau_M}$.

Case 5: $(A^*, S^*(H_M), S^*(L_M))$=$(1, L, L_M)$ when $w < w_3$ and $I \leq \mu\tau_B$. The buyer solves the problem $\max_w \ \pi_B^5 = r - w - (1-\mu)\tau_B - I$ subject to $w - c - \mu s - (1-\mu)[\tau_M(w-\alpha c) - (1-\alpha)c - (1-\eta)\varphi] \geq 0$, $w < w_3$, $I \leq \mu\tau_B$. The optimal solution exists only when $(1-\alpha)c(1-\tau_M) + \varphi(1-\eta)\tau_M(1-\mu) > \frac{\mu s}{1-\mu}$, and $w^* = \alpha c + \frac{\mu s+\mu(1-\alpha)c-(1-\eta)(1-\mu)\varphi}{1-(1-\mu)\tau_M}$.

When $I \geq \mu\tau_B$, the buyer compares Cases 1, 2, and 4 to obtain the optimal contract. The analysis is identical to the full-delegation model. See the proof of Proposition 1. The optimal solution is characterized by the boundary lines ζ_1, ζ_2, and ζ_3 defined there. This corresponds to Figure 4 (i).

When I is between $(1-\eta)\mu\tau_B$ and $\mu\tau_B$, the buyer compares Cases 1, 2, and 5 to obtain the optimal contract. Define:

$$\zeta_4 := \frac{(1-\tau_M)(1-\alpha)c - \mu s\tau_M}{(1-\mu)[1-(1-\mu)\tau_M]\tau_M} - \frac{I}{1-\mu} + \frac{1-\eta(1-\mu)\tau_M}{(1-\mu)[1-(1-\mu)\tau_M]\tau_M}\varphi$$
$$\zeta_5 := \frac{(1-\tau_M)(1-\alpha)c - \mu s\tau_M}{(\eta-\mu)[1-(1-\mu)\tau_M]\tau_M} - \frac{I}{\eta-\mu} - \frac{1-(2-\eta)(1-\mu)\tau_M}{(\eta-\mu)[1-(1-\mu)\tau_M]\tau_M}\varphi$$

When $\eta > \mu$, we have $\pi_B^{2^*} > (<)\pi_B^{5^*}$ if $\tau_B > (<)\zeta_5$. In this case, we have $\pi_B^{1^*} > \pi_B^{2^*}$ when $\tau_B > \zeta_1$, and $\pi_B^{1^*} > \pi_B^{5^*}$ when $\tau_B > \zeta_4$. We also have $\pi_B^{2^*} > \pi_B^{1^*}$ when $\tau_B < \zeta_1$, and $\pi_B^{2^*} > \pi_B^{5^*}$ when $\tau_B > \zeta_5$. Finally, we have $\pi_B^{5^*} > \pi_B^{1^*}$ when $\tau_B < \zeta_4$, and $\pi_B^{5^*} > \pi_B^{2^*}$ when $\tau_B < \zeta_5$. This corresponds to Figure 4 (ii). Similarly, when $\eta < \mu$, the intercept of ζ_5 is negative and the slope is positive. We have $\pi_B^{2^*} > (<)\pi_B^{5^*}$ if $\tau_B < (>)\zeta_5$. The equilibrium can be characterized similarly as Figure 4 (ii).

When $I \leq (1-\eta)\mu\tau_B$, the buyer compares Cases 1, 3, and 5 to obtain the optimal contract. Assuming that the optimal solution in case 5 is feasible, then the optimal wholesale price in case 3 is $w^* = w_3$. Define:

$$\zeta_6 := \frac{\mu s}{(1-\eta)(1-\mu)^2\tau_M} - \frac{I}{(1-\eta)(1-\mu)} + \frac{1}{(1-\eta)(1-\mu)\tau_M}\varphi$$
$$\zeta_7 := \frac{(1-\tau_M)(1-\alpha)c - \frac{\mu s}{1-\mu}}{(1-\mu)[1-(1-\mu)\tau_M]\eta\tau_M} + \frac{(1-\eta)(1-\mu)}{\eta(1-\mu)[1-(1-\mu)\tau_M]}\varphi$$

Then, we have $\pi_B^{1^*} > \pi_B^{3^*}$ when $\tau_B > \zeta_6$, and $\pi_B^{1^*} > \pi_B^{5^*}$ when $\tau_B > \zeta_4$. We also have $\pi_B^{3^*} > \pi_B^{1^*}$ when $\tau_B < \zeta_6$, and $\pi_B^{3^*} > \pi_B^{5^*}$ when $\tau_B > \zeta_7$. Finally, we have $\pi_B^{5^*} > \pi_B^{1^*}$ when $\tau_B < \zeta_4$, and $\pi_B^{5^*} > \pi_B^{3^*}$ when $\tau_B < \zeta_7$. This corresponds to Figure 4 (iii). ■

Proof of Corollary 1: Part (i): It can be shown that ζ_1 and ζ_6 are independent of α and c. When $(1-\alpha)c$ decreases, the intercept of ζ_2, ζ_3, ζ_4, ζ_5, ζ_7 decreases, and the slope does not change. The region for the outcome $(0, H_M, H_B)$ in all the panels of Figure 4 expands. The region for the outcome $(1, H_B, L_M)$ in panel (iii) also expands.

Part (ii): When auditing is not performed (Figure 4 panel (i), i.e., when $\tau_B < \frac{I}{\mu}$), the switching cost has no effect ($\zeta_1, \zeta_2, \zeta_3$ are all independent of s). When s increases, the intercept of ζ_4, ζ_5, ζ_7 decreases while the intercept of ζ_6 increases, and the slope does not change. The region for the outcome $(0, H_M, H_B)$ in Figure 4 panel (ii) expands. The region for the outcome $(1, L, L_M)$ in panel (iii) becomes smaller, so the combined region for $(0, H_M, H_B)$ and $(1, H_B, L_M)$ becomes bigger.

Part (iii): When γ increases, the slope of ζ_1 decreases, the intercept of ζ_2 decreases, the intercept and the absolute value of the slope of ζ_3 both decrease. So, the region for the outcome $(0, H_M, H_B)$ expands in Figure 4 panel (i). In panel (ii), when γ increases, the intercept of ζ_4 decreases, the intercept and the absolute value of the slope of ζ_5 both decrease. Together with the fact that the slope of ζ_1 decreases, we have the result that the region for the outcome $(0, H_M, H_B)$ expands. Finally, in panel (iii), when γ increases, the intercept and slope of ζ_6 both decrease. Together with the fact that the intercept of ζ_4 decreases, we have the result that the region for the outcome $(0, H_M, H_B)$ also expands. ■

Proof of Corollary 2: First, recall that in the component procurement stage, the manufacturer's optimal supplier choice is given by Lemma 1(ii). The buyer's optimal auditing decision for given manufacturer's supplier choice are: $A(\text{risk-free}) = 0$, $A(\text{risky}) = 1$ if $I \leq \mu\tau_B$, and $A(\text{risky}) = 0$ if $I \geq \mu\tau_B$. The equilibrium in (5) reduces to three cases: $(A^*, S^*) = (0, H_B)$ if $w \geq w_2$, $(A^*, S^*) = (0, L_M)$ if $w < w_2$ and $I \geq \mu\tau_B$, and $(A^*, S^*) = (1, L_M)$ if $w \leq w_4$ and $I \leq \mu\tau_B$. Next, we derive the optimal wholesale price in each case.

Case 1: $(A^*, S^*) = (0, H_B)$ when $w \geq w_2$. The buyer solves the following problem: $\max_w \ \pi_B^1 = r - w$ subject to $w \geq w_2$, $w \geq c$. By the assumption $\tau_M < 1$, we have $w_2 > c$. So, $w^* = w_2$.

Case 2: $(A^*, S^*) = (0, L_M)$ when $w < w_2$ and $I \geq \mu\tau_B$. The buyer solves the following problem: $\max_w \ \pi_B^2 = r - w - \tau_B$ subject to $w < w_2$, $(1-\tau_M)(w - \alpha c) + \varphi \geq 0$, $I \geq \mu\tau_B$. We have $w^* = \alpha c - \frac{\varphi}{1-\tau_M}$.

Case 3: $(A^*, S^*) = (1, L_M)$ when $w \leq w_4$ and $I < \mu\tau_B$. The buyer solves the following problem: $\max_w \ \pi_B^3 = r - w - (1-\mu)\tau_B - I$ subject to $w \geq \alpha c + \frac{\mu(1-\alpha)c + \mu s - (1-\mu)\varphi}{1-(1-\mu)\tau_M}$, $w \leq w_4$, $I < \mu\tau_B$. The optimal wholesale price is $w^* = \alpha c + \frac{\mu(1-\alpha)c + \mu s - (1-\mu)\varphi}{1-(1-\mu)\tau_M}$ and is feasible only when $(1-\alpha)c(1-\tau_M) + \varphi > \frac{\mu s}{1-\mu}$.

Define:

$$
\begin{aligned}
\ell_1 &: \tau_B = \frac{(1-\alpha)(1-\tau_M)c + \varphi}{\tau_M(1-\tau_M)} \\
\ell_2 &: \tau_B = \frac{I}{\mu} \\
\ell_3 &: \tau_B = \frac{(1-\alpha)c(1-\tau_M) + \varphi - \mu s \tau_M}{\tau_M(1-\mu)[1-(1-\mu)\tau_M]} - \frac{I}{1-\mu}
\end{aligned}
$$

First, consider the case when τ_B is below the line ℓ_2 or equivalently $I > \mu\tau_B$, the buyer compares Cases 1 and 2. We have $\pi_B^{1*} > \pi_B^{2*}$ when τ_B is above ℓ_1 (Region $A_a(1)$), and $\pi_B^{1*} < \pi_B^{2*}$ when τ_B is below ℓ_1 (Region B_a). Now, consider the case when τ_B is above the line ℓ_2 or equivalently $I < \mu\tau_B$, the buyer compares Cases 1 and 3. We have $\pi_B^{1*} > \pi_B^{3*}$ when τ_B is above ℓ_3 (Region $A_a(2)$), and $\pi_B^{1*} < \pi_B^{3*}$ when τ_B is below ℓ_3 (Region C_a). See Figure A.1. Combine Region $A_a(1)$

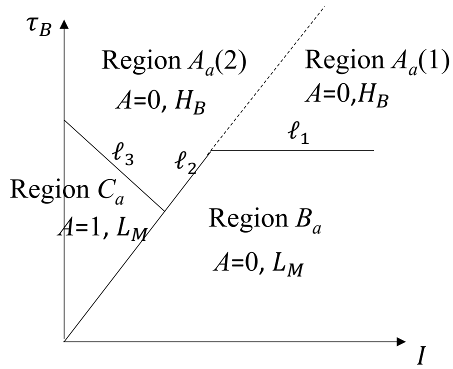

Figure A.1: Proof of Corollary 2

and $A_a(2)$, we get Region A_a in Figure 5. ■

Proof of Proposition 4: Proof of part (i): Under full delegation, the buyer's problem is similar to Cases 1 and 2 in the proof of Corollary 2 (but without the auditing cost constraint). The optimal contract is $w^* = w_2$ when τ_B is above the line ℓ_1 and $w^* = \alpha c - \frac{\varphi}{1-\tau_M}$ when τ_B is below ℓ_1. The manufacturer chooses a risk-free supplier in the former case and a risky supplier in the latter case. Compare the full- and guided-delegation solutions, we see that in the dark shaded region (b) in Figure A.2 (i), the manufacturer chooses H_B under guided delegation and a risky supplier under full delegation. In the dark shaded region (a), the manufacturer chooses a risky supplier under either delegation strategy, but conducts auditing only under guided delegation. Finally, in the light shaded region, the manufacturer chooses a risk-free supplier under full delegation, but a risky supplier (although auditing is conducted) under guided delegation. The optimal contract and induced supplier selection are the same in the white regions.

Proof of part (ii): Under guided delegation, the buyer's optimal profit π_B^* is equal to $r - w_2$ in region A_a, and $r - \alpha c - \frac{\mu(1-\alpha)c+\mu s-(1-\mu)\varphi}{1-(1-\mu)\tau_M} - (1-\mu)\tau_B - I$ in region C_a. Under full delegation, the buyer's optimal profit $\tilde{\pi}_B^*$ is equal to $r - w_2$ when τ_B is above ℓ_1, and $r - \alpha c + \frac{\varphi}{1-\tau_M} - \tau_B$ when τ_B is below ℓ_1. First, in region (c) in Figure A.2(ii), $\pi_B^* - \tilde{\pi}_B = \tau_B - \frac{(1-\alpha)c(1-\tau_M)+\varphi}{\tau_M(1-\tau_M)} < 0$ since the region is below the line ℓ_1. Second, in region (a), $\pi_B^* - \tilde{\pi}_B^* = \frac{(1-\alpha)c(1-\tau_M)+\varphi-\mu s\tau_M}{\tau_M[1-(1-\mu)\tau_M]} - (1-\mu)\tau_B - I > 0$ since the region is below the line ℓ_3. Finally, define line ℓ_4 as:

$$\ell_4: \ \tau_B = \frac{(1-\alpha)c+s}{1-(1-\mu)\tau_M} + \frac{\varphi}{[1-(1-\mu)\tau_M](1-\tau_M)} + \frac{I}{\mu}$$

In the shaded region (b), $\pi_B^* - \tilde{\pi}_B = \mu\left\{\tau_B - \frac{(1-\alpha)c+s}{1-(1-\mu)\tau_M} - \frac{\varphi}{[1-(1-\mu)\tau_M](1-\tau_M)}\right\} - I$. So, the buyer earns a higher profit under guided delegation when τ_B is above the line ℓ_4, and a higher profit under full delegation when τ_B is below ℓ_4. The optimal contract and induced supplier selection are the same in the white regions, and therefore the buyer's profit is the same under the two delegation strategies.

Proof of Proposition 5: When sourcing from his preferred (low-type) supplier L_M, the manufacturer's profit function $\hat{\pi}_M(L_M)$ is given in (8). The manufacturer's optimal auditing decision is given in (9). When sourcing from a high-type supplier H, the manufacturer's profit is $\hat{\pi}_M(H) = w - c$. The manufacturer's optimal supplier choice can be derived by comparing $\hat{\pi}_M(H)$

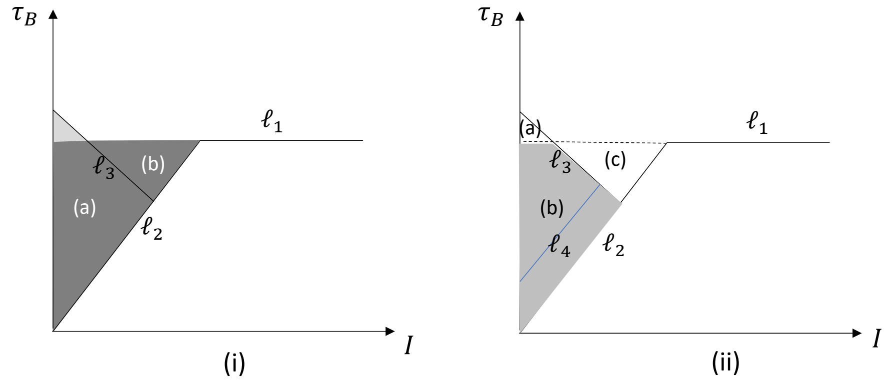

Figure A.2: Proof of Proposition 4

and $\hat{\pi}_M(L_M)$ at the optimal auditing level.

When $I > I_1 := \theta\mu\{\beta\gamma(w-\alpha c) - [(1-\alpha)c + s]\}$, we have $\hat{\pi}_M(H) - \hat{\pi}_M(L_M)|_{e=0} = \tau_M(w-\alpha c) - (1-\alpha)c - \varphi$. When $I \le I_1$, we have $\hat{\pi}_M(H) - \hat{\pi}_M(L_M)|_{e=1} = I - I_2$, where $I_2 := (1-\alpha)c + \varphi - \theta\mu[(1-\alpha)c + s] - \tau_M(1-\mu)(w-\alpha c)$.

When $\tau_M(w-\alpha c) \le (1-\alpha)c + \varphi$, we have $I_1 \le I_2$. When $I \le I_1$, we must have $I \le I_2$. Therefore, it follows that $\hat{\pi}_M(L_M)|_{e=1} > \hat{\pi}_M(H)$, and the manufacturer's optimal decision is $(L_M, e=1)$. When $I > I_1$, we have $\hat{\pi}_M(L_M)|_{e=0} > \hat{\pi}_M(H)$, and the manufacturer's optimal decision is $(L_M, e=0)$. Part (a) follows.

When $\tau_M(w-\alpha c) > (1-\alpha)c + \varphi$, we have $I_1 > I_2$. When $I \le I_2$, we have $\hat{\pi}_M(L_M)|_{e=1} > \hat{\pi}_M(H)$, and the manufacturer's optimal decision is $(L_M, e=1)$. When $I_2 < I \le I_1$, we have $\hat{\pi}_M(H) > \hat{\pi}_M(L_M)|_{e=1}$, and the manufacturer prefers H. When $I > I_1$, we have $\hat{\pi}_M(H) > \hat{\pi}_M(L_M)|_{e=0}$, and the manufacturer again prefers H. Part (b) follows. ■

Proof of Proposition 6: We first solve each sub-problem below.

$$P1: \max_w r - w$$
$$s.t.\ \tau_M(w-\alpha c) > (1-\alpha)c + \varphi;\ I \ge I_2;\ \hat{\pi}_M(H) = w - c \ge 0$$

The first constraint can be expressed as $w \ge \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$. Since $\alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M} > c$, the last constraint is always satisfied. The second constraint can be expressed as $w \ge \alpha c + \frac{(1-\alpha)c(1-\theta\mu)-\theta\mu s+\varphi-I}{\tau_M(1-\mu)}$. Define:

$$I_3 := (1-\alpha)c(1-\theta)\mu + \mu\varphi - \theta\mu s \quad \text{(A-1)}$$

When $I \ge I_3$, $\hat{w}_1^* = \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$; otherwise, $\hat{w}_1^* = \alpha c + \frac{(1-\alpha)c(1-\theta\mu)-\theta\mu s+\varphi-I}{\tau_M(1-\mu)}$.

$$P2: \max_w (r-w) - (1-\mu)\tau_B$$
$$s.t.\ \tau_M(w-\alpha c) > (1-\alpha)c + \varphi;\ I \le I_2,$$
$$\hat{\pi}_M(L_M)|_{e=1} = w - \alpha c - \theta\{\mu[(1-\alpha)c + s] + (1-\mu)\beta\gamma(w-\alpha c)\} + \varphi - I \ge 0$$

The first constraint can be expressed as $w \ge \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$. The second constraint can be expressed as $w \le \alpha c + \frac{(1-\alpha)c(1-\theta\mu)-\theta\mu s+\varphi-I}{\tau_M(1-\mu)}$. The third constraint can be expressed as $w \ge \alpha c + \frac{\theta\mu(1-\alpha)c+\theta\mu s+I-\varphi}{1-\tau_M(1-\mu)}$. For the former two constraints to hold, feasibility requires that $I \le I_3$. For the latter two constraints to hold, feasibility requires that $\theta\mu s+I \le (1-\alpha)c[1-\theta\mu-\tau_M(1-\mu)]+\varphi$. When the first feasibility constraint holds, the second is also satisfied, and $\alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M} > \alpha c + \frac{\theta\mu(1-\alpha)c+\theta\mu s+I-\varphi}{1-\tau_M(1-\mu)}$. Since the objective function is decreasing in w, $\hat{w}_2^* = \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$.

$$
\begin{aligned}
P3:\ & \max_w\ (r-w)-(1-\mu)\tau_B \\
& s.t.\ \tau_M(w-\alpha c) \le (1-\alpha)c+\varphi;\ I \le I_1; \\
& \quad \hat{\pi}_M(L_M)|_{e=1} = w-\alpha c-\theta\left\{\mu\left[(1-\alpha)c+s\right]+(1-\mu)\beta\gamma(w-\alpha c)\right\}+\varphi-I \ge 0
\end{aligned}
$$

The first constraint can be expressed as $w \le \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$. The second constraint can be expressed as $w \ge \alpha c + \frac{I+(1-\alpha)c\theta\mu+s\theta\mu}{\mu\tau_M}$. The third constraint can be expressed as $w \ge \alpha c + \frac{\theta\mu(1-\alpha)c+\theta\mu s+I-\varphi}{1-\tau_M(1-\mu)}$. For the former two constraints to hold, feasibility requires that $I \le I_3$. For the first and third constraints to hold, feasibility requires that $(\theta\mu s+I)\tau_M \le (1-\alpha)c(1-\tau_M(1-\mu)-\theta\mu\tau_M)+\varphi(1+\tau_M\mu)$. When the first feasibility constraint holds, the second is also satisfied, and $\alpha c + \frac{I+(1-\alpha)c\theta\mu+s\theta\mu}{\mu\tau_M} > \alpha c + \frac{\theta\mu(1-\alpha)c+\theta\mu s+I-\varphi}{1-\tau_M(1-\mu)}$. Since the objective function is decreasing in w, $\hat{w}_3^* = \alpha c + \frac{I+(1-\alpha)c\theta\mu+s\theta\mu}{\mu\tau_M}$.

$$
\begin{aligned}
P4:\ & \max_w\ (r-w)-\tau_B \\
& s.t.\ \tau_M(w-\alpha c) \le (1-\alpha)c+\varphi;\ I \ge I_1 \\
& \quad \hat{\pi}_M(L_M)|_{e=0} = (1-\tau_M)(w-\alpha c)+\varphi \ge 0
\end{aligned}
$$

The first constraint can be expressed as $w \le \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$. The second constraint can be expressed as $w \le \alpha c + \frac{I+(1-\alpha)c\theta\mu+s\theta\mu}{\mu\tau_M}$. The third constraint can be expressed as $w \ge \alpha c - \frac{\varphi}{1-\tau_M}$. Since the objective function is decreasing in w, $\hat{w}_4^* = \alpha c - \frac{\varphi}{1-\tau_M}$.

Next, we compare the optimal solutions across the four sub-problems to obtain optimal solution to the original problem. It is easy to check that $\hat{\pi}_B^{P3} > \hat{\pi}_B^{P2}$ since P2 and P3 have the same objective function which is decreasing in w and $\hat{w}_3^* < \hat{w}_2^*$. When $I \ge I_3$, only $P1$ and $P4$ are feasible, and we have $\hat{\pi}_B^{P1} - \hat{\pi}_B^{P4} = \tau_B - \frac{(1-\alpha)c}{\tau_M} - \frac{\varphi}{\tau_M(1-\tau_M)}$. So the optimal solution is given by $P1$ (i.e., H) in Region $\hat{A}_1$ shown in Figure A.3, and is given by $P4$ ($L_M, e=0$) in Region $\hat{B}_1$.

When $I \le I_3$, we need to compare the optimal solutions from $P1$, $P3$, and $P4$. Define:

$$
\begin{aligned}
\ell_2' &: \tau_B = \frac{(1-\alpha)c+s}{\mu\beta\gamma} + \frac{\varphi}{(1-\tau_M)\mu} + \frac{I}{\mu^2\tau_M} \\
\ell_3' &: \tau_B = \frac{(1-\alpha)c(1-\theta\mu)-\theta\mu s}{\tau_M(1-\mu)} + \frac{\varphi(1-\tau_M\mu)}{\tau_M(1-\mu)(1-\tau_M)} - \frac{I}{\tau_M(1-\mu)} \\
\ell_4' &: \tau_B = \frac{(1-\alpha)c(1-\theta)\mu+\varphi\mu-\theta\mu s-I}{\tau_M(1-\mu)^2\mu}
\end{aligned}
$$

Since $\hat{\pi}_B^{P1} - \hat{\pi}_B^{P4} = \tau_B - \{\frac{(1-\alpha)c(1-\theta\mu)-\theta\mu s}{\tau_M(1-\mu)} + \frac{\varphi(1-\tau_M\mu)}{\tau_M(1-\mu)(1-\tau_M)} - \frac{I}{\tau_M(1-\mu)}\}$, when τ_B is above line

ℓ_3', we have $\hat{\pi}_B^{P1} > \hat{\pi}_B^{P4}$ and the comparison is between $P1$ and $P3$. Since $\hat{\pi}_B^{P1} - \hat{\pi}_B^{P3} = \tau_B - \frac{(1-\alpha)c(1-\theta)\mu+\varphi\mu-\theta\mu s-I}{\tau_M(1-\mu)^2\mu}$, the optimal solution is given by $P1$ (i.e., H) in region $\hat{A}_2$, and is given by $P3$ $(L_M, e=1)$ in region $\hat{C}_1$. When τ_B is below line ℓ_3', we have $\hat{\pi}_B^{P4} > \hat{\pi}_B^{P1}$ and the comparison is between $P4$ and $P3$. Since $\hat{\pi}_B^{P3} - \hat{\pi}_B^{P4} = \tau_B - \{\frac{(1-\alpha)c+s}{\tau_M} + \frac{\varphi}{(1-\tau_M)\mu} + \frac{I}{\tau_M\mu}\}$, the optimal solution is given by $P3$ in region $\hat{C}_2$ $(L_M, e=1)$, and is given by $P4$ $(L_M, e=0)$ in region $\hat{B}_2$.

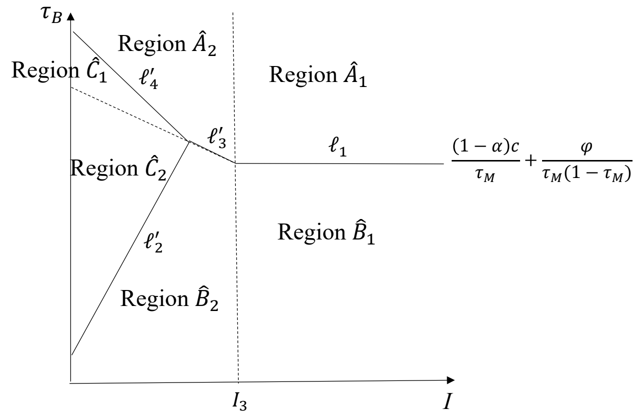

Figure A.3: Proof of Proposition 6

In summary, combining regions $\hat{A}_1$ and $\hat{A}_2$, we get region $\hat{A}$ in Figure 8. Combining regions $\hat{B}_1$ and $\hat{B}_2$, we get region $\hat{B}$. Combining regions $\hat{C}_1$ and $\hat{C}_2$, we get region $\hat{C}$. ■

Proof of Proposition 7: Proof of part (i): In Figure 9 panel (i), the buyer-auditing solution is characterized by the boundary lines ℓ_1, ℓ_2, ℓ_3. The manufacturer-auditing solution is characterized by the boundary lines $\ell_1, \ell_2', \ell_3', \ell_4'$. In the dark shaded region (b), the manufacturer chooses H_B in the buyer-auditing model and L_M in the manufacturer-auditing model. In the dark shaded region (a), the manufacturer chooses L_M in both models. But auditing is conducted only in the buyer-auditing model. The optimal contract and induced supplier selection and auditing decision are the same in the white regions.

Proof of part (ii): We refer to Figure A.4 for this proof. In Region (1), the manufacturer chooses a risk-free supplier in both models, so the buyer earns a profit of $r-w$. The optimal wholesale price is $w^* = w_2 = \alpha c + \frac{(1-\alpha)c+\varphi}{\tau_M}$ in the buyer-auditing model, and is $\hat{w}^* = \hat{w}_1 = \alpha c + \frac{(1-\alpha)c(1-\theta\mu)-\theta\mu s+\varphi-I}{\tau_M(1-\mu)}$. Since $\hat{w}^* - w^* = \frac{I_3-I}{\tau_M(1-\mu)} > 0$, we have $\pi_B^* > \hat{\pi}_B^*$.

In Region (2), $\pi_B^* = r - \alpha c - \frac{(1-\alpha)c+\varphi}{\tau_M}$ and $\hat{\pi}_B^* = r - \alpha c + \frac{\varphi}{1-\tau_M} - \tau_B$. We have $\pi_B^* - \hat{\pi}_B^* = \tau_B - [\frac{(1-\alpha)c}{\tau_M} + \frac{\varphi}{\tau_M(1-\tau_M)}]$. So $\pi_B^* > \hat{\pi}_B^*$ if and only if τ_B is above the boundary line ℓ_1.

In Region (3), $\pi_B^* = r - \alpha c - \frac{(1-\alpha)c+\varphi}{\tau_M}$ and $\hat{\pi}_B^* = r - \alpha c - \frac{\theta\mu[(1-\alpha)c+s]+I}{\mu\tau_M} - (1-\mu)\tau_B$. We have $\pi_B^* - \hat{\pi}_B^* = \frac{(1-\mu)\mu\tau_M\tau_B - [(1-\alpha)c(1-\theta)\mu+\mu\varphi-\theta\mu s-I]}{\mu\tau_M}$. It can be shown that the line $\tau_B = \frac{(1-\alpha)c(1-\theta)\mu+\mu\varphi-\theta\mu s-I}{(1-\mu)\mu\tau_M}$ is below the boundary line ℓ_3 since the intercept of the former is smaller than the latter ($\frac{(1-\alpha)c(1-\theta)\mu+\mu\varphi-\theta\mu s}{(1-\mu)\mu\tau_M} - \frac{(1-\alpha)c(1-\tau_M)+\varphi-\mu s\tau_M}{\tau_M(1-\mu)[1-(1-\mu)\tau_M]} = \frac{-I_3(1-\mu)\tau_M-\theta s(1-\mu\beta\gamma)}{\tau_M[1-(1-\mu)\tau_M](1-\mu)} < 0$) and the absolute value of the slope of the former is larger than the latter. Therefore, $\pi_B^* > \hat{\pi}_B^*$.

In Region (4), $\pi_B^* = r - \alpha c - \frac{(1-\alpha)c\mu+\mu s-(1-\mu)\varphi}{1-(1-\mu)\tau_M} - (1-\mu)\tau_B - I$, and $\hat{\pi}_B^* = r - \alpha c - \frac{(1-\alpha)c\theta\mu+\theta\mu s+I}{\mu\tau_M} -$

$(1-\mu)\tau_B$. We have $\pi_B^* - \hat{\pi}_B^* = \frac{\theta[1-\tau_M-\mu\beta\gamma(1-\theta)][(1-\alpha)c\mu+\mu]+I(1-\mu\tau_M)[1-(1-\mu)\tau_M]+(1-\mu)\mu\tau_M\varphi}{\mu\tau_M[1-(1-\mu)\beta\gamma]} > 0$.

In Region (5), $\pi_B^* = r-\alpha c-\frac{(1-\alpha)c\mu+\mu s-(1-\mu)\varphi}{1-(1-\mu)\tau_M}-(1-\mu)\tau_B-I$, and $\hat{\pi}_B^* = r-\alpha c+\frac{\varphi}{1-\tau_M}-\tau_B$. We have $\pi_B^*-\hat{\pi}_B^* = \mu\tau_B-I-\frac{\mu\{(1-\tau_M)[(1-\alpha)c+s]+\varphi\}}{(1-\tau_M)[1-(1-\mu)\tau_M]}$. Define ℓ_5' as $\tau_B = \frac{(1-\tau_M)[(1-\alpha)c+s]+\varphi}{(1-\tau_M)[1-(1-\mu)\tau_M]}+\frac{I}{\mu}$. Clearly, ℓ_5' is above ℓ_2. It can also be shown that ℓ_5' is below ℓ_2' since the intercept of the former is smaller than the latter ($\frac{(1-\tau_M)[(1-\alpha)c+s]+\varphi}{(1-\tau_M)[1-(1-\mu)\tau_M]}-[\frac{(1-\alpha)c+s}{\mu\beta\gamma}+\frac{\varphi}{(1-\tau_M)\mu}] = \frac{[(1-\alpha)c+s][\mu\beta\gamma(1-\theta)-(1-\theta\beta\gamma)]}{\mu\beta\gamma[1-(1-\mu)\tau_M]}-\frac{\varphi(1-\mu)}{\mu[1-(1-\mu)t_M]} < 0$) and the slope of the former is smaller than the latter. Therefore, in this region, we have $\pi_B^* > \hat{\pi}_B^*$ when τ_B is above ℓ_5' and $\pi_B^* < \hat{\pi}_B^*$ when τ_B is below ℓ_5'. ■

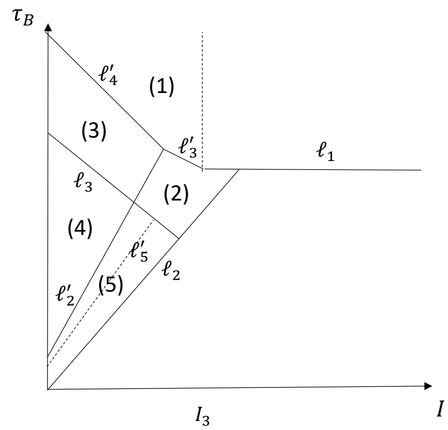

Figure A.4: Proof of Proposition 7 part (ii)