Online Appendix for Sourcing from Suppliers with Financial Constraints and Performance Risk

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Appendix A: Proofs

Proof of Lemma 1. In a centralized chain, the system's payoff $\Pi_c = v - [(1-e)v + c + ke^2]$, which is maximized at $e = \frac{v}{2k}$. By substituting e into Π_c, it is easy to check that the corresponding optimal payoff is equal to $\frac{v^2}{4k} - c$. For the centralized system to be viable, the optimal payoff has to be non-negative, i.e. $\frac{v^2}{4k} \geq c$, as desired. □

Proof of Proposition 1. We prove the results by using e as the decision variable (instead of p). In preparation, let us transform the constraints in terms of e (instead of p). First, by considering (7) and (8), the joint acceptance constraint (8) (or the indicator function as stated in (9)) holds if and only if $4ke \geq 4\sqrt{ka}$ or, equivalently, $e \geq \sqrt{\frac{a}{k}}$.

Second, we can apply (7) to express p in terms of e so that $p = 2ke + \frac{c-a}{e}$. By using this expression of p, it is easy to check that the boundary constraint $p \leq v$ holds if and only if $e \in [\underline{e}, \bar{e}]$, where $\underline{e} = \frac{v}{4k} - \frac{\sqrt{v^2 - 8k(c-a)}}{4k}$, $\bar{e} = \frac{v}{4k} + \frac{\sqrt{v^2 - 8k(c-a)}}{4k}$.

By substituting $p = 2ke + \frac{c-a}{e}$ into the manufacturer's payoff (9) along with the transformed constraints in terms of e, the manufacturer's problem can be rewritten as:

$$\max_e \Pi_M = e(v-p) = ev - 2ke^2 - (c-a) \tag{1}$$

$$\text{s.t.} \quad e \geq \sqrt{\frac{a}{k}} \tag{2}$$

$$e \in [\underline{e}, \bar{e}]. \tag{3}$$

We now solve this problem by mapping out the optimal solution within different regions of (c, a). In preparation, recall from Assumption 1 that (c, a) lies within the region $0 \leq a \leq c \leq \frac{v^2}{4k}$. Also, combine the boundary constraint and the bank's lending constraint so that $v \geq p \geq \sqrt{8k(c-a)}$. Hence, (c, a) must lie within the region that has $v \geq \sqrt{8k(c-a)}$, or, equivalently, $a \geq c - \frac{v^2}{8k}$. By considering the intersection of these two regions, we now present the optimal solution e^* to the manufacturer's problem as follows.

First, observe that the unconstrained solution to the manufacturer's problem is given as $e = \frac{v}{4k}$. Now observe that $\frac{v}{4k} \in (\underline{e}, \bar{e})$. Therefore, if $\frac{v}{4k} \geq \sqrt{\frac{a}{k}}$ (or, equivalently, when $a \leq \frac{v^2}{16k}$), then $e = \frac{v}{4k}$ satisfies all of the constraints. Thus, it is the optimal solution. By combining the region that has $a \leq \frac{v^2}{16k}$ with the feasible region stated above, we can conclude that $e = \frac{v}{4k}$ is optimal when (c, a) lies in Region II as stated in Figure 2. Correspondingly, $\Pi_M = \frac{v^2}{8k} - (c-a) > 0$ and $\Pi_S = \frac{v^2}{16k} - a \geq 0$.

It remains to examine the case where $\frac{v}{4k} < \sqrt{\frac{a}{k}}$. There are two scenarios to consider:

1. If $\sqrt{\frac{a}{k}} \leq \bar{e}$ or, equivalently, when $a \geq \frac{v^2 - v\sqrt{v^2-4kc}}{2k} - c$, then the boundary solution $e = \sqrt{\frac{a}{k}}$ is the optimal solution that satisfies all constraints. By combining the region that has $a \leq \frac{v^2 - v\sqrt{v^2-4kc}}{2k} - c$ with the feasible region stated above, we can conclude that $e = \sqrt{\frac{a}{k}}$ is the optimal solution when (c,a) lies in Region I as shown in Figure 2. Correspondingly, $\Pi_M = v\sqrt{\frac{a}{k}} - c - a \geq 0$ and $\Pi_s = ke^2 - a = 0$.

2. If $\sqrt{\frac{a}{k}} > \bar{e}$ or, equivalently, when $a < \frac{v^2 - v\sqrt{v^2-4kc}}{2k} - c$, then there is no e that can satisfy both constraints (i.e. $e \geq \sqrt{\frac{a}{k}}$ and $e \leq \bar{e}$). Thus, the manufacturer does not source from the supplier. By combining the region that has $a < \frac{v^2 - v\sqrt{v^2-4kc}}{2k} - c$ for $a \geq \frac{v^2}{16k}$ with the constraint $c - a \leq \frac{v^2}{8k}$ stated above, we can conclude that there is no feasible solution e for the manufacturer's problem when $a < \max\left(c - \frac{v^2}{8k}, \frac{v^2 - v\sqrt{v^2-4kc}}{2k} - c\right)$ (Region III as shown in Figure 2).

Finally, for Regions I and II, p follows directly from $p = 2ke + \frac{c-a}{e}$, and (6) i_B, Π_S and Π_M can also be directly derived from e. □

Proof of Corollary 1. This corollary follows directly from Proposition 1. First, it is easy to verify that the desired monotonicity holds for each of the three regions in Proposition 1. For example, when $a > \frac{v^2}{16k}$ and $c < v\sqrt{\frac{a}{k}} - a$ as in Region I, $e^S = \sqrt{\frac{a}{k}}$ and $p^S = 2\sqrt{ka} + (c-a)\sqrt{\frac{k}{a}}$. $i_B = \left(\sqrt{\frac{k}{a}} - 1\right)\left(\frac{c-a}{c}\right)$, $\Pi_M^S = v\sqrt{\frac{a}{k}} - c - a$, and $\Pi_S^S = 0$. Thus, we have $\frac{\partial p^S}{\partial k} > 0$, $\frac{\partial i_B^S}{\partial k} > 0$, $\frac{\partial e^S}{\partial k} < 0$, $\frac{\partial \Pi_S^S}{\partial k} = 0$, and $\frac{\partial \Pi_M^S}{\partial k} < 0$, ad desired. □

Proof of Proposition 2. In BDF, the bank is not involved and the manufacturer's problem can be formulated as: $\max_{p,i_M} \Pi_M = \max_{p,i_M} \{e(v-p) + [e(1+i_M)c + (1-e)a - c]\}$, subject to the supplier's participation constraint given in (5); i.e. $p \geq (1+i_M)c + 2\sqrt{ka} - a$.

We now prove the results by using e as the decision variable (instead of p). In preparation, let us transform the constraints in terms of e (instead of p). First, by considering the supplier's best response given in (3) (with i_B being replaced by i_M), we can express p as a function of e, i.e. $p = 2k \cdot e + (1+i_M)c - a$. Second, by using this expression of p, it is easy to check that the supplier's participation constraint given in (5) can be rewritten as $e \geq \sqrt{\frac{a}{k}}$. By using this simplified supplier's participation constraint and by substituting this expression of p into the manufacturer's payoff, we can transform the above manufacturer's problem as follows:

$$\max_{e,i_M} \Pi_M = \max_{e,i_M} \{-2ke^2 + ve - (c-a)\}, \text{ subject to } e \geq \sqrt{\frac{a}{k}}. \tag{4}$$

Observe that i_M does not appear in the objective function Π_M and the manufacturer can select any interest rate i_M satisfying $p = 2ke + (1+i_M)c - a$.

By considering the first-order condition along with the constraint $e \geq \sqrt{\frac{a}{k}}$, it is easy to check that the supplier's optimal effort is $e^B = \max\{\frac{v}{4k}, \sqrt{\frac{a}{k}}\}$. Similarly to the proof for Proposition 1, depending on region that (c,a) lies within, we have the following three scenarios.

1. When (c,a) lies in Region I as depicted in Figure 2 so that $0 \leq a \leq c \leq \frac{v^2}{4k}$ (Assumption 1) and $a > \frac{v^2}{16k}$ and $c < v\sqrt{\frac{a}{k}} - a$, it is easy to check that $\sqrt{\frac{a}{k}} \geq \frac{v}{4k}$ in Region I. Therefore, the optimal $e^* = \sqrt{\frac{a}{k}}$. Correspondingly, $\Pi_M^B = -2k(e^B)^2 + ve^B - (c-a) = v\sqrt{\frac{a}{k}} - c - a$ and $\Pi_S^B = k(e^B)^2 - a = 0$. The manufacturer offers (p^B, i_M) such that $p^B = 2ke^B + (1+i_M)c - a = 2\sqrt{ak} + (1+i_M)c - a$.

2. When (c,a) lies in Region II as depicted in Figure 2 so that $0 \leq a \leq c \leq \frac{v^2}{4k}$ (Assumption 1) and $a \in \left[c - \frac{v^2}{8k}, \frac{v^2}{16k}\right)$, it is easy to check that $\sqrt{\frac{a}{k}} < \frac{v}{4k}$ in Region II. Therefore, we have $e^B = \frac{v}{4k}$. Correspondingly, $\Pi_M^B = -2k(e^B)^2 + ve^B - (c-a) = \frac{v^2}{8k} - (c-a)$, $\Pi_S^B = \frac{v^2}{16k} - a$. The manufacturer offers (p^B, i_M^B) such that $p^B = 2ke^B + (1+i_M)c - a = \frac{v}{2} + (1+i_M)c - a$.

3. When (c,a) lies in Region III as depicted in Figure 2, let us first examine the condition under which the manufacturer will source from the supplier, i.e. the condition under which $\Pi_M^B \geq 0$. By using the fact that $\Pi_M = -2ke^2 + ve - (c-a)$, we can conclude that $\Pi_M^B \geq 0$ if and only if $e \in [\underline{e}, \bar{e}]$, where $\underline{e} = \frac{v}{4k} - \frac{\sqrt{v^2 - 8k(c-a)}}{4k}$, $\bar{e} = \frac{v}{4k} + \frac{\sqrt{v^2-8k(c-a)}}{4k}$. By using the same argument as presented in the proof of Proposition 1, we know that there is no e that can satisfy both constraints (i.e. $e \geq \sqrt{\frac{a}{k}}$ and $e \leq \bar{e}$) within Region III. In other words, when (a,c) lies in Region III, the manufacturer's payoff is always negative. Consequently, the manufacturer will not source from the supplier. □

Proof of Lemma 2. We first show that any (p_H, p_L) satisfying the conditions is part of a separating PBE. Based on the definition of a PBE, there is no restriction on the off-equilibrium belief (**??**). Therefore, we specify the bank's off-equilibrium belief as follows: For $p \neq p_H$, the bank believes that the supplier is inefficient, i.e. $\mu = 0$.

Under such an off-equilibrium belief, p_L^S is the rational choice for the manufacturer if the supplier is inefficient as $p_L^S = \arg\max_p \Pi_M(L,p,L)$ (so that if the bank believes the supplier is inefficient, p_L^S is the manufacturer's optimal choice) and $\Pi_M(L, p_L^S, L) \geq \Pi_M(L, p_H, H)$ (so that the manufacturer has no incentive to misrepresent an inefficient supplier as an efficient one).

Symmetrically, p_H is also the rational choice for the manufacturer facing an efficient supplier as $\Pi_M(L, p_L^S, L) \geq \Pi_M(L, p_H, H)$ (so that p_H serves as a credible signal that the supplier is efficient) and $\Pi_M(H, p_H, H) \geq \max_{p \neq p_H} \Pi_M(H, p, L)$ (so that it is indeed profitable for the manufacturer to signal that the supplier is efficient instead of being perceived as an inefficient one).

In addition, it is clear that the bank's belief is consistent with Bayes' rule. Therefore, (p_H, p_L) is indeed part of a separating PBE.

Next, we prove that (p_H, p_L) that does not satisfy the conditions does not correspond to a separating PBE. To prove this, we basically show that (p_H, p_L) does not correspond to a separating PBE if any one of the three conditions, i.e. $p_L = p_L^S$, (14), and (15), is violated.

First, assume $p_L \neq p_L^S$. As $p_L^S = \arg\max_p \Pi_M(L,p,L)$, and $\Pi_M(L, p_L^S, H) > \Pi_M(L, p_L^S, L)$, the manufacturer is always better off offering p_L^S to an inefficient supplier than some other price p_L, regardless whether the bank believes that the supplier is efficient or not. Therefore, offering p_L other than p_L^S is not rational for the manufacturer, violating the sequential rationality requirement for a PBE.

Second, assume that (14) does not hold, i.e. $\Pi_M(L, p_H, H) > \Pi_M(L, p_L^S, L)$. In this case, it is clear that the manufacturer has the incentive to misrepresent an inefficient supplier as an efficient one and, hence, p_H is not a credible signal that the supplier is efficient.

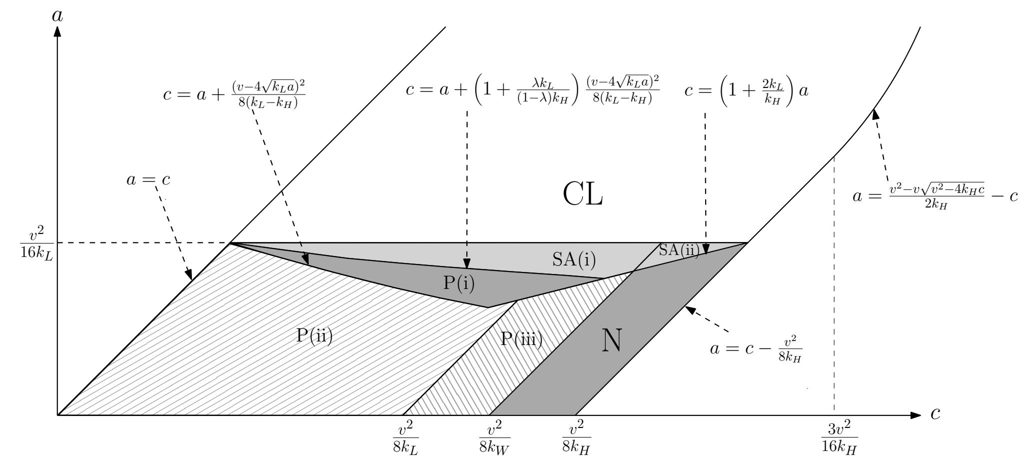
Third, assume that (15) does not hold, i.e. $\Pi_M(H, p_H, H) < \max_{p \neq p_H} \Pi_M(H, p, L)$. In this case, it is clear that the manufacturer will be better off offering some other price to the efficient supplier, even if this leads to the bank's belief that the supplier is inefficient. And as $\Pi_M(H, p, L) \leq \Pi_M(H, p, H)$ for all p, it is also clear that the manufacturer will be better off offering some other price to the efficient supplier, even if this leads to the bank's belief that the supplier is efficient.

Combining the above three cases, we can see that all three conditions are necessarily for (p_H, p_L) to correspond to a separating PBE. □

Proof of Lemma 3. The proof is similar to that of Lemma 2. We first show that p_W that satisfies (18) is part of a pooling PBE. To see this, we specify that the bank's off-equilibrium path belief is that $\mu = 0$ for $p \neq p_W$. Under this belief, it is clear that for both the efficient and inefficient supplier, the manufacturer is better off offering p_W (under which the bank believes that the supplier is a weighted-average one) than any other price (under which the bank believes that the supplier is inefficient). Therefore, offering p_W under the above-specified belief is rational for the manufacturer.

Next, we note that p_W that does not satisfy (18) cannot be part of a pooling PBE, as the manufacturer is better off offering some other price, even if the bank believes that the supplier is inefficient. □

Figure 1 Illustration of different cases in proof of Proposition 3.



Notes. Regions CL, SA(i), SA(ii), P(i), P(ii), P(iii), and N correspond to different cases in the proof of Proposition 3 below. The illustration is generated using $\frac{k_L}{k_H} = 1.5$ and $\lambda = 0.5$.

Proof of Proposition 3. In our setting, it is clear that (1) the least costly separating PBE (Proposition B.2) Pareto dominates all other separating PBE and (2) the Pareto-dominant pooling equilibrium (Proposition B.3) Pareto dominates all other pooling PBE. Therefore, in this proof, we only need to apply Pareto dominance and the Intuitive Criterion to the least costly separating PBE and the Pareto-dominant pooling PBE. Specifically, we apply the following processes to identify the stable dominant equilibrium for each (c, a) that satisfies Assumption 2.

Step 1: If neither equilibrium (the least costly separating or the Pareto-dominant pooling) exists, no equilibrium exists, i.e. the manufacturer does not source from either type of supplier.

Step 2: If only one equilibrium exists, then this equilibrium is the stable dominant equilibrium.

Step 3: If both equilibria exist, we examine if the pooling equilibrium survives the Intuitive Criterion. Note that it is straightforward that the least costly separating equilibrium always survives the Intuitive Criterion. If the pooling equilibrium can be eliminated by the Intuitive Criterion, then the separating PBE is the stable dominant equilibrium.

Step 4: if the pooling equilibrium survives the Intuitive Criterion, we compare it with the least costly separating equilibrium and see whether one Pareto dominates the other. If the answer is yes, then the Pareto-dominant equilibrium is the stable dominant equilibrium.

Next, we show that applying these steps in our setting allows us to identify (at most) one stable dominant equilibrium. In particular, we consider the four cases: Case CL, Case SA (with two sub-cases), Case P (with three sub-cases), and Case N. The (c,a) region that corresponds to each sub-cases is illustrated in Figure 1.

Case CL: $a \geq \frac{v^2}{16k_L}$ **(Region CL in Figure 3).** According to Proposition B.2 (Statement 1), in this region, $p_H^A = p_H^S$ and $p_L^A = p_L^S$, and hence, separating is costless. Therefore, it is clear that the least costly separating equilibrium survives the Intuitive Criterion and, hence, is the stable dominant equilibrium.

Case SA: $a < \frac{v^2}{16k_L}$ **and** $c-a \in \left[\left(1+\frac{\lambda k_L}{(1-\lambda)k_H}\right)\frac{(v-4\sqrt{k_L a})^2}{8(k_L-k_H)},\ \frac{2k_L a}{k_H}\right]$ **(Region SA in Figure 3).** For (c,a) within this region, consider two further scenarios.

Case SA(i): $c-a \leq \frac{v^2}{8k_W}$. According to Proposition B.2 (Statement 2), in the separating equilibrium the manufacturer's payoff when facing an efficient supplier is $\Pi_M(H, p_{L,H}^{SA}-\epsilon, H) = \frac{v\sqrt{k_L a}}{k_H} - \left(\frac{2k_L}{k_H}-1\right)a - c - \delta(\epsilon)$, where $\delta(\epsilon)$ is arbitrarily small for arbitrarily small ϵ. Her payoff facing an inefficient supplier is $\Pi_M(L, p_L^S, L) = \frac{v^2}{8k_L} - (c-a)$. On the other hand, according to Proposition B.3 (Statement 1), in the pooling equilibrium the manufacturer's payoff when facing a type-τ supplier is $\Pi_M(\tau, p_W^*, W) = \frac{v^2}{8k_\tau} - \frac{k_W(c-a)}{k_\tau}$ for $\tau = L, H$. Next, we show that the above pooling equilibrium can be eliminated by the Intuitive Criterion.

Intuitively speaking, the Intuitive Criterion eliminates those PBEs that are built only on "unreasonable" off-equilibrium beliefs. In our setting, to eliminate the above pooling equilibrium, consider the off-equilibrium signal $p_{L,H}^{SA}-\epsilon$. It is easy to verify that $\Pi_M(H, p_W^*, W) < \Pi_M(H, p_{L,H}^{SA}-\epsilon, H)$; therefore, for a manufacturer facing an efficient supplier, the signal $p_{L,H}^{SA}-\epsilon$ is *not* equilibrium dominated by p_W^*. On the other hand, note that $\Pi_M(L, p_W^*, W) > \Pi_M(L, p_{L,H}^{SA}-\epsilon, H) = 0$, and hence, for a manufacturer facing an inefficient supplier, the signal $p_{L,H}^{SA}-\epsilon$ is equilibrium dominated by p_W^*. Let us now apply the Intuitive Criterion, under which one should assume zero probability for the inefficient type when observing the off-equilibrium signal $p_{L,H}^{SA}-\epsilon$. In other words, upon observing $p_{L,H}^{SA}-\epsilon$, the bank's posterior belief should be $\mu = 1$. Under this belief, the manufacturer facing an efficient supplier has the incentive to deviate from p_W^* to $p_{L,H}^{SA}-\epsilon$. Thus, the Intuitive Criterion eliminates the pooling equilibrium.

Case SA(ii): $c-a > \frac{v^2}{8k_W}$. According to Proposition B.3 (Statement 2), no pooling equilibrium exists. Therefore, the least costly separating equilibrium is the stable dominant equilibrium.

Combining Case SA(i) and SA(ii), in Region SA of Figure 3 the least costly separating equilibrium is the stable dominant one.

Case P: $c-a \in \left(0,\ \left(1+\frac{\lambda k_L}{(1-\lambda)k_H}\right)\frac{(v-4\sqrt{k_L a})^2}{8(k_L-k_H)}\right) \cup \left(\frac{2k_L a}{k_H},\ \frac{v^2}{8k_W}\right)$ **(Region P in Figure 3).** For (c,a) within the above region, we consider three further scenarios.

Case P(i): $c-a \in \left(\frac{(v-4\sqrt{k_L a})^2}{8(k_L-k_H)}, \frac{2k_L}{k_H}a\right)$**.** For the pooling equilibrium, the manufacturer's payoff facing a type-τ supplier is $\Pi_M(\tau, p_W^*, W) = \frac{v^2}{8k_\tau} - \frac{k_W(c-a)}{k_\tau}$ for $\tau = L, H$, the same as in Case SA(i) above. For the separating equilibrium, this region corresponds to Statement 2 in Proposition B.2. Therefore, the manufacturer's payoff when facing the efficient supplier is $\Pi_M(H, p_{L,H}^{SA} - \epsilon, H) = \frac{v\sqrt{k_L a}}{k_H} - \left(\frac{2k_L}{k_H} - 1\right)a - c - \delta(\epsilon)$, which is also the same as in Case SA(i) above.

Next, we apply the Intuitive Criterion to the pooling equilibrium as in Case SA(i). Differently from in Case SA(i), we cannot find any off-equilibrium signal p that allows us to put restrictions on the off-equilibrium belief, which are necessary to eliminate the pooling equilibrium. To see this, consider the following two scenarios.

1. If the off-equilibrium signal p is not acceptable to the inefficient supplier, even if the bank believes that the supplier is efficient, i.e. p satisfies $p + \sqrt{p^2 - 8k_H(c-a)} < 4\sqrt{k_L a}$ (from the indicator function within equation 13 under $\tau = L$ and $\tau' = H$), it is easy to verify that we have $\Pi_M(H, p, H) \leq \Pi_M(H, p_{L,H}^{SA} - \epsilon, H) < \Pi_M(\tau, p_W^*, W)$. Therefore, the above signal p is equilibrium dominated by p_W^* under the pooling belief for both $\tau = H$ and $\tau = L$. Hence, the Intuitive Criterion cannot put any restriction on the off-equilibrium belief at p.
2. If the off-equilibrium signal p is acceptable to the inefficient supplier when the bank believes that the supplier is efficient, i.e. for p that satisfy $p + \sqrt{p^2 - 8k_H(c-a)} \geq 4\sqrt{k_L a}$, we can show that $\Pi_M(H, p, H) \geq \Pi_M(H, p_W^*, W)$ and $\Pi_M(L, p, H) \geq \Pi_M(L, p_W^*, W)$ are equivalent. Therefore, the signal p is either equilibrium dominated under both $\tau = H$ and $\tau = L$ or under neither $\tau = H$ nor $\tau = L$ and, hence, the Intuitive Criterion cannot put any restriction on the off-equilibrium belief at such p either.

Combining the above two cases, we can conclude that the pooling equilibrium survives the Intuitive Criterion.

Finally, we apply our **Step 4** to identify whether one equilibrium Pareto dominates the other. Note that in this region, $\Pi_M(H, p_{L,H}^{SA} - \epsilon, H) < \Pi_M(H, p_W^*, W)$. Similarly, we can show that when facing an inefficient supplier, the manufacturer's payoff in the separating equilibrium, $\Pi_M(L, p_L^S, L)$, is strictly lower than her payoff in the pooling equilibrium, $\Pi_M(H, p_W^*, W)$. Therefore, the pooling equilibrium Pareto dominates the separating one and, hence, is the stable dominant equilibrium.

Case P(ii): $c - a \in \left[0, \min\left\{\frac{v^2}{8k_L}, \frac{(v-4\sqrt{k_L a})^2}{8(k_L-k_H)}\right\}\right] \cup \left[\frac{2k_L a}{k_H}, \frac{v^2}{8k_L}\right]$**.** For the pooling equilibrium, the manufacturer's payoff is the same as in Case P(i) above. For the separating equilibrium, this region corresponds to Statement 3 in Proposition B.2, and hence, the manufacturer's payoff facing an efficient supplier is $\Pi_M(H, p^{MI}, H) = \frac{v^2}{8k_H} - \frac{k_L}{k_H}(c-a)$. It is easy to see that $\Pi_M(H, p^{MI}, H) < \Pi_M(H, p_W^*, W)$. Similarly, we can show that the manufacture's payoff facing an inefficient supplier, $\Pi_M(L, p_L^S, L)$, is also less than $\Pi_M(L, p_W^*, W)$. Therefore, the pooling equilibrium Pareto dominates the separating one. Following the same argument as in Case P(i) above, we can show that the pooling PBE survives the Intuitive Criterion and, hence, is the stable dominant equilibrium.

Case P(iii): $c - a \in \left(\frac{v^2}{8k_L}, \frac{v^2}{8k_W}\right)$. This region corresponds to Statement 4 in Proposition B.2, where no separating equilibrium exists. Therefore, the pooling equilibrium is the stable dominant equilibrium.

Combining Cases P(i), P(ii), and P(iii), we have shown that in Region P, the pooling PBE in Proposition B.3 is the stable dominant equilibrium.

Case N: $c-a>\max\left\{\frac{2k_L}{k_H}a, \frac{v^2}{8k_W}\right\}$ **(Region N in Figure 3).** According to Proposition B.2 (Statement 4) and Proposition B.3 (Statement 2), neither separating nor pooling equilibria exist in this region. Therefore, the manufacturer does not source from either type of supplier. □

Proof of Proposition 4. Note that for $a<\frac{v^2}{16k_L}$, under BDF, the manufacturer's payoff facing an efficient supplier is $\Pi_M^B=\frac{v^2}{8k_H}-(c-a)$.

In Region SA of Proposition 3, $\Pi_M(H,p_{L,H}^{SA},H)=\frac{v\sqrt{k_L a}}{k_H}-\frac{2k_L}{k_H}a-(c-a)$. Therefore, $\Delta_M=\frac{(v-4\sqrt{k_L a})^2}{8k_H}$. Taking partial derivatives of Δ_M with respect to a, v, λ, and k_H, we have $\frac{\partial\Delta_M}{\partial a}=-\frac{(v-4\sqrt{ak_L})}{2k_H}\sqrt{\frac{k_L}{a}}<0$, $\frac{\partial\Delta_M}{\partial v}=\frac{v-4\sqrt{ak_L}}{4k_H}>0$, $\frac{\partial\Delta_M}{\partial\lambda}=0$, and $\frac{\partial\Delta_M}{\partial k_H}=-\frac{(v-4\sqrt{ak_L})^2}{8k_H^2}<0$.

In Region P, $\Pi_M(H,p_W^*,W)=\frac{v^2}{8k_H}-\frac{k_W}{k_H}(c-a)$, $\Delta_M=\left(\frac{k_W}{k_H}-1\right)(c-a)=\frac{\frac{k_L}{k_H}-1}{1+\frac{\lambda}{1-\lambda}\frac{k_L}{k_H}}(c-a)$. Therefore, $\frac{\partial\Delta_M}{\partial a}=-\frac{(1-\lambda)(k_L-k_H)}{\lambda k_L+(1-\lambda)k_H}<0$, $\frac{\partial\Delta_M}{\partial v}=0$, $\frac{\partial\Delta_M}{\partial\lambda}=-\frac{k_L(k_L-k_H)}{(\lambda k_L+(1-\lambda)k_H)^2}(c-a)<0$, and $\frac{\partial\Delta_M}{\partial k_H}=-\frac{(1-\lambda)k_L}{(\lambda k_L+(1-\lambda)k_H)^2}(c-a)<0$. □

Proof of Corollary 2. In Region N, Π_S is strictly positive under Propositions 1 and 2. However, with information asymmetry, the manufacturer does not source from the efficient supplier, leading to $\Pi_S=0$. In Region SA, it is also easy to check that Π_S under Propositions 1 and 2 is strictly greater than Π_S under the contract in Proposition 3, as desired. □

Appendix B: Technical results

This section includes the technical results that are needed for the proofs of the results and statements in the main body of the paper as well as short explanations of some of them. The proofs of these technical results are available upon request from the authors.

Lemma B.1 *Under a given contract price p, it is optimal for the supplier to pledge his entire asset a as collateral for the POF loan.*

This lemma shows that when the supplier takes a purchase order with contract price p to the bank for a POF loan, even if he has the option to pledge only part of his assets as collateral, it is in his best interest to pledge all of his assets. Intuitively, this is because that a smaller collateral lowers the supplier's incentive to exert effort. Anticipating that, the bank charges a higher interest rate on the loan, which eventually hurts the supplier.

Proposition B.1 *Assume that under POF the manufacturer has the freedom to offer the following contract to the supplier: Upon successful delivery, she pays the supplier payment $p>0$; if the supplier fails to deliver, she imposes a penalty $p_n\geq 0$ on the supplier. Under the optimal contract in such a form, the manufacturer's and supplier's payoffs and the equilibrium delivery probability are the same as under the optimal contract in Proposition 1.*

This result supports the statement that it is sufficient to consider the contract form we focus on in the paper – the supplier receives p upon successful delivery and 0 otherwise. As shown in the Proposition B.1, charging the supplier a penalty for a failed delivery does not improve contract performance (either profitability or delivery probability).

Proposition B.2 *For (c,a) that satisfies Assumption 2 in the least costly separating equilibrium, the manufacturer offers p_L^S to the inefficient supplier. The manufacturer's payoff is the same as in Proposition 1 with $k=k_L$.*

The contract price p_H^* she offers the efficient supplier ($\tau=H$) is as follows:

1. *For $a \geq \frac{v^2}{16k_L}$, $p_H^A = p_H^S$.*
2. *For $a < \frac{v^2}{16k_L}$ and $c-a \in \left(\frac{(v-4\sqrt{k_L a})^2}{8(k_L-k_H)}, \frac{2k_L a}{k_H}\right)$, $p_H^A = p_{L,H}^{SA} - \epsilon = 2\sqrt{k_L a} + \frac{k_H(c-a)}{\sqrt{k_L a}} - \epsilon$, where $\epsilon > 0$ is sufficiently small.*
3. *For $c-a \in \left[0, \min\left\{\frac{v^2}{8k_L}, \frac{(v-4\sqrt{k_L a})^2}{8(k_L-k_H)}\right\}\right] \cup \left[\frac{2k_L a}{k_H}, \frac{v^2}{8k_L}\right]$, $p_H^A = p^{MI} \equiv \frac{v}{2} + \sqrt{2(k_L-k_H)(c-a)} + \frac{4k_H(c-a)}{v+2\sqrt{2(k_L-k_H)(c-a)}}$.*
4. *For $c-a > \max\left\{\frac{v^2}{8k_L}, \frac{2k_L a}{k_H}\right\}$, no separating equilibrium exists.*

Proposition B.3 *For (c,a) that satisfies Assumption 2 and $a < \frac{v^2}{16k_L}$, in the Pareto-dominant pooling equilibrium,*

1. *when $c-a \leq \frac{v^2}{8k_W}$, the manufacturer sets $p_W^* = \frac{v}{2} + \frac{4k_W(c-a)}{v}$ for both types of supplier;*
2. *when $c-a > \frac{v^2}{8k_W}$, the manufacturer does not source from any supplier.*

Corollary B.1 *When the supplier is inefficient, the manufacturer's payoff under POF with symmetric information (Proposition 1 with $k=k_L$) are identical to that under asymmetric information in Region CL, SA, and N in Proposition 3, and her payoff under symmetric information is lower than that under information asymmetric in Region P in Proposition 3.*

In addition, the inefficient supplier's payoff under POF with symmetric information (Proposition 1 with $k=k_L$) is identical to that under POF with asymmetric information in all regions under Assumption 2, except for in Region P where $c-a > \frac{v^2}{8k_L}$. In Region P where $c-a > \frac{v^2}{8k_L}$, the supplier's payoff under asymmetric information is higher than that under symmetric information.