Supplements to "Open or Closed? Technology Sharing, Supplier Investment, and Competition"

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A. Sequential Competition

In Stage 4, we model the decision process of two manufacturers as a sequential game when they adopt the same technology. In particular, the supplier first sets component wholesale price for this technology. The technology owner then decide on his order quantity. Finally, the other manufacturer decides on his order quantity.

A.1. Decisions from Stages 2 to 4

A.1.1. Scenario CC In this scenario, the analysis is identical to that in the base model.

Lemma S1 (Scenario CC). *When both manufacturers close their technologies:*

(i) if $K \geq 1/24$*, the supplier invests in neither technology, and* $\pi_{s,2}^{\mathrm{CC}} = \pi_{m1,2}^{\mathrm{CC}} = \pi_{m2,2}^{\mathrm{CC}} = 0$;

(ii) if $K < 1/24$*, the supplier invests in both technologies,* $\pi_{s,2}^{\mathrm{CC}} = 1/12 - 2K$*, and* $\pi_{m1,2}^{\mathrm{CC}} = \pi_{m2,2}^{\mathrm{CC}} = 1/48$.

A.1.2. Scenarios OC and CO Due to symmetry, it suffices to consider Scenario OC, where only M_1 opens the technology. We derive the firms' profits on the basis of the supplier's investment decisions.

Case 1: supplier invests in neither technology. In this trivial case, every player receives zero profit: $\pi_{s,2}^{\mathrm{OC}} = \pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} = 0$.

Case 2: supplier invests in only one technology. Clearly, the supplier prefers to invest in T_1 whose market size becomes $\widehat{A} \equiv A + \gamma(1-A) = \gamma + (1-\gamma)A$ due to spillover. In Stage 4, given wholesale price w_1, M_1 and M_2 engage in sequentially Cournot competition. As the technology owner, M_1 first decides on his order quantity, q_1. Given q_1, M_2 then decides on his order quantity with the profit function $\pi_{m2,4}^{\mathrm{OC}} = (\widehat{A} - q_1 - q_2 - w_1)q_2$. Thus, M_2's optimal order quantity in terms of q_1 and w_1 is $q_2^* = \frac{\widehat{A}-q_1-w_1}{2}$. Back to M_1's order decision, he should maximize $\pi_{m1,4}^{\mathrm{OC}} = (\widehat{A} - q_1 - \frac{\widehat{A}-q_1-w_1}{2} - w_1)q_1$ and hence the optimal decision is $q_1^* = \frac{\widehat{A}-w_1}{2}$. The resulting supplier's profit is $\pi_{s,4}^{\mathrm{OC}} = \frac{3w_1(\widehat{A}-w_1)}{4}$ and her optimal decision is $w_1^* = \frac{\widehat{A}}{2}$. In summary, the equilibrium order quantity are $q_{m1,1}^{\mathrm{OC}} = \frac{\widehat{A}}{4}$, and $q_{m2,1}^{\mathrm{OC}} = \frac{\widehat{A}}{8}$. Equilibrium profits are $\pi_{s,4}^{\mathrm{OC}} = 3\widehat{A}^2/16$, $\pi_{m1,4}^{\mathrm{OC}} = \widehat{A}^2/32$, and $\pi_{m2,4}^{\mathrm{OC}} = \widehat{A}^2/64$. By taking expectations with respect to A, the firms' Stage 2 expected profits are $\pi_{s,2}^{\mathrm{OC}} = (1+\gamma+\gamma^2)/16 - K$, $\pi_{m1,2}^{\mathrm{OC}} = (1+\gamma+\gamma^2)/96$, and $\pi_{m2,2}^{\mathrm{OC}} = (1+\gamma+\gamma^2)/192$.

Case 3: supplier invests in both technologies. In this case, since T_1 is open and the supplier has both supply capabilities, M_2 can adopt either T_1 or T_2 in Stage 3. Therefore, we analyze two subcases: (I) M_2 adopts T_1; (II) M_2 adopts T_2. This case captures the available technology flexibility for a manufacturer when his competitor opens technology.

In Subcase (I), M_1 and M_2 engage in Cournot competition in T_1's market, which has a total size of $\widehat{A}$ due to spillover. The analysis is similar to Case 2, and the firms' Stage 4 profits are $\pi_{s,4}^{\mathrm{OCI}} = 3\widehat{A}^2/16$, $\pi_{m1,4}^{\mathrm{OCI}} = \widehat{A}^2/32$, and $\pi_{m2,4}^{\mathrm{OCI}} = \widehat{A}^2/64$.

In Subcase (II), M_1 and M_2 each monopolize the market, of sizes A and $1-A$ respectively, for their own technology. The analysis is similar to that of scenario CC, and the firms' Stage 4 profits are $\pi_{s,4}^{\mathrm{OCII}} = A^2/8 + (1-A)^2/8$, $\pi_{m1,4}^{\mathrm{OCII}} = A^2/16$, $\pi_{m2,4}^{\mathrm{OCII}} = (1-A)^2/16$.

By comparing the two subcases, it is straightforward to show that M_2 will adopt T_1 if and only if $\widehat{A}^2/64 \geq (1-A)^2/16 \Leftrightarrow A \geq (2-\gamma)/(3-\gamma)$, namely, when T_1 is highly popular. We can then calculate the firms' Stage 2 expected profits:

$$
\begin{aligned}
\pi_{s,2}^{\mathrm{OC}} &= \int_0^{\frac{2-\gamma}{3-\gamma}} \frac{A^2 + (1-A)^2}{8}\,\mathrm{d}A + \int_{\frac{2-\gamma}{3-\gamma}}^1 \frac{3(A+\gamma(1-A))^2}{16}\,\mathrm{d}A - 2K = \frac{1}{12} + \frac{17+6\gamma-3\gamma^2}{48(3-\gamma)^3} - 2K,\\
\pi_{m1,2}^{\mathrm{OC}} &= \int_0^{\frac{2-\gamma}{3-\gamma}} \frac{A^2}{16}\,\mathrm{d}A + \int_{\frac{2-\gamma}{3-\gamma}}^1 \frac{(A+\gamma(1-A))^2}{32}\,\mathrm{d}A = \frac{1}{48} - \frac{19-22\gamma+5\gamma^2}{96(3-\gamma)^3},\\
\pi_{m2,2}^{\mathrm{OC}} &= \int_0^{\frac{2-\gamma}{3-\gamma}} \frac{(1-A)^2}{16}\,\mathrm{d}A + \int_{\frac{2-\gamma}{3-\gamma}}^1 \frac{(A+\gamma(1-A))^2}{64}\,\mathrm{d}A = \frac{1}{48} + \frac{5-\gamma}{192(3-\gamma)^2}.
\end{aligned}
$$

With all three cases analyzed, we can determine the supplier's optimal technology investment decision in Stage 2. Define two thresholds for the supplier's investment cost:

$$
\begin{aligned}
\beta_1^{\mathrm{OC}}(\gamma) &\equiv \frac{1+\gamma+\gamma^2}{16},\\
\beta_2^{\mathrm{OC}}(\gamma) &\equiv \frac{(2-\gamma)(22-40\gamma-17\gamma^2+18\gamma^3-3\gamma^4)}{48(3-\gamma)^3}.
\end{aligned}
$$

Note that $\beta_1^{\mathrm{OC}}(\gamma) \geq \beta_2^{\mathrm{OC}}(\gamma)$ for all $\gamma \in [0,1]$. The following proposition characterizes the equilibrium in Scenario OC (and by symmetry, CO, with the manufacturer indices swapped).

Lemma S2 (Scenario OC). *When only M_1 opens technology:*

(i) if $K \geq \beta_1^{\mathrm{OC}}(\gamma)$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{OC}} = \pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} = 0$;

(ii) if $\beta_2^{\mathrm{OC}}(\gamma) \leq K < \beta_1^{\mathrm{OC}}(\gamma)$, the supplier invests in T_1, and $\pi_{s,2}^{\mathrm{OC}} = (1+\gamma+\gamma^2)/16 - K$, $\pi_{m1,2}^{\mathrm{OC}} = (1+\gamma+\gamma^2)/96$, and $\pi_{m2,2}^{\mathrm{OC}} = (1+\gamma+\gamma^2)/192$;

(iii) if $K < \beta_2^{\mathrm{OC}}(\gamma)$, the supplier invests in both technologies, and $\pi_{s,2}^{\mathrm{OC}} = \frac{1}{12} + \frac{17+6\gamma-3\gamma^2}{48(3-\gamma)^3} - 2K$, $\pi_{m1,2}^{\mathrm{OC}} = \frac{1}{48} - \frac{19-22\gamma+5\gamma^2}{96(3-\gamma)^3}$, $\pi_{m2,2}^{\mathrm{OC}} = \frac{1}{48} + \frac{5-\gamma}{192(3-\gamma)^2}$.

A.1.3. Scenario OO: both manufacturers open their technologies. We derive the firms' profits on the basis of the supplier's investment decisions.

Case 1: supplier invests in neither technology. In this trivial case, every firm receives zero profits: $\pi_{s,2}^{\mathrm{OO}} = \pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = 0$.

Case 2: supplier invests in only one technology. By symmetry, we can assume that the supplier invests in T_1.

The analysis is similar to Scenario OC's Case 2, and the firms' Stage 2 expected profits are $\pi_{s,2}^{\mathrm{OO}} = (1+\gamma+\gamma^2)/16 - K$, $\pi_{m1,2}^{\mathrm{OO}} = (1+\gamma+\gamma^2)/96$, and $\pi_{m2,2}^{\mathrm{OO}} = (1+\gamma+\gamma^2)/192$.

Case 3: supplier invests in both technologies. In this case, both manufacturers can freely adopt any technology. The manufacturers' technology choice equilibria in Stage 3 are shown in Table S1, which presents the manufacturers' profits given their technology choices.

		M_2's choice	
	$\pi_{m1,3}^{\mathrm{OO}}$, $\pi_{m2,3}^{\mathrm{OO}}$	T_1	T_2
M_1's choice	T_1	$\frac{(A+\gamma(1-A))^2}{32}$, $\frac{(A+\gamma(1-A))^2}{64}$	$\frac{A^2}{16}$, $\frac{(1-A)^2}{16}$
	T_2	$\frac{(1-A)^2}{16}$, $\frac{A^2}{16}$	$\frac{(1-A+\gamma A)^2}{64}$, $\frac{(1-A+\gamma A)^2}{32}$

Table S1 Payoff Matrix of the Manufacturer Technology Choice Game in Scenario OO

The next proposition characterizes the equilibrium of Stage 3's manufacturer technology-choice game.

PROPOSITION S1. *When both manufacturers open their technologies and the supplier invests in both technologies, the Nash equilibrium of manufacturer technology choice game in Stage 3 is*

$$\begin{cases} (T_1, T_1) & \text{if} \quad A \geq (2-\gamma)/(3-\gamma), \\ (T_1, T_2) & \text{if} \quad 1/(3-\gamma) < A < (2-\gamma)/(3-\gamma), \\ (T_2, T_2) & \text{if} \quad A \leq 1/(3-\gamma). \end{cases}$$

Using the equilibria in Stage 3, we can then calculate the firms' expected profits in Stage 2:

$$\begin{aligned} \pi_{s,2}^{\mathrm{OO}} &= \int_0^{\frac{1}{3-\gamma}} \frac{3(1-A+\gamma A)^2}{16}\,\mathrm{d}A + \int_{\frac{1}{3-\gamma}}^{\frac{2-\gamma}{3-\gamma}} \frac{A^2+(1-A)^2}{8}\,\mathrm{d}A + \int_{\frac{2-\gamma}{3-\gamma}}^{1} \frac{3(A+\gamma(1-A))^2}{16}\,\mathrm{d}A - 2K \\ &= \frac{1}{12} + \frac{17+6\gamma-3\gamma^2}{24(3-\gamma)^3} - 2K, \\ \pi_{m1,2}^{\mathrm{OO}} &= \int_0^{\frac{1}{3-\gamma}} \frac{(1-A+\gamma A)^2}{64}\,\mathrm{d}A + \int_{\frac{1}{3-\gamma}}^{\frac{2-\gamma}{3-\gamma}} \frac{A^2}{16}\,\mathrm{d}A + \int_{\frac{2-\gamma}{3-\gamma}}^{1} \frac{(A+\gamma(1-A))^2}{32}\,\mathrm{d}A \\ &= \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}; \end{aligned}$$

$$\pi^{\mathrm{OO}}_{m2,2} = \int_0^{\frac{1}{3-\gamma}} \frac{(1-A+\gamma A)^2}{32}\,\mathrm{d}A + \int_{\frac{1}{3-\gamma}}^{\frac{2-\gamma}{3-\gamma}} \frac{(1-A)^2}{16}\,\mathrm{d}A + \int_{\frac{2-\gamma}{3-\gamma}}^{1} \frac{(A+\gamma(1-A))^2}{64}\,\mathrm{d}A$$
$$= \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}.$$

With all three cases analyzed, we can determine the supplier's optimal decision on technology investment in Stage 2. Define three thresholds for this purpose on the supplier's investment cost:

$$\beta^{\mathrm{OO}}_1(\gamma) \equiv \frac{1+\gamma+\gamma^2}{16},$$
$$\beta^{\mathrm{OO}}_2(\gamma) \equiv \frac{(1-\gamma)(61-35\gamma-32\gamma^2+21\gamma^3-3\gamma^4)}{48(3-\gamma)^3}.$$

The following proposition characterizes the optimal and equilibrium outcomes in Scenario OO.

Proposition S2 (Scenario OO). *When both manufacturers open their technologies:*

(i) if $K \geq \beta^{\mathrm{OO}}_1(\gamma)$, the supplier invests in neither technology, and $\pi^{\mathrm{OO}}_{s,2} = \pi^{\mathrm{OO}}_{m1,2} = \pi^{\mathrm{OO}}_{m2,2} = 0$;

(ii) if $\beta^{\mathrm{OO}}_2(\gamma) \leq K < \beta^{\mathrm{OO}}_1(\gamma)$, the supplier invests in only one technology, and $\pi^{\mathrm{OO}}_{s,2} = (1+\gamma+\gamma^2)/16 - K$, $\pi^{\mathrm{OO}}_{m1,2} = \pi^{\mathrm{OO}}_{m2,2} = (1+\gamma+\gamma^2)/128$;

(iii) if $K < \beta^{\mathrm{OO}}_2(\gamma)$, the supplier invests in both technologies, and $\pi^{\mathrm{OO}}_{s,2} = \frac{1}{12} + \frac{17+6\gamma-3\gamma^2}{24(3-\gamma)^3} - 2K$, $\pi^{\mathrm{OO}}_{m1,2} = \pi^{\mathrm{OO}}_{m2,2} = \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}$.

A.2. Decisions in Stages 1

With subgame equilibria in Stages 2-4, we next derive the equilibria in Stage 1. Define $\beta^{CC}_1(\gamma) = 1/24$. First, note that $\beta^{OC}_1(\gamma) = \beta^{OO}_1(\gamma) > \beta^{CC}_1(\gamma), \beta^{OO}_2(\gamma) > \beta^{OC}_2(\gamma)$ for any $\gamma \in [0,1]$. However, $\beta^{CC}_1(\gamma) \leq \beta^{OO}_2(\gamma)$ if $0 \leq \gamma \leq 0.1625$ and $\beta^{CC}_1(\gamma) > \beta^{OO}_2(\gamma)$ if $0.1625 < \gamma \leq 1$. Hence, we consider two cases: $0 \leq \gamma \leq 0.1625$ and $0.1625 < \gamma \leq 1$.

Case 1: $0 \leq \gamma \leq 0.1625$. In this case, $\beta^{OC}_1(\gamma) = \beta^{OO}_1(\gamma) > \beta^{OO}_2(\gamma) \geq \beta^{CC}_1(\gamma) > \beta^{OC}_2(\gamma)$. Table S2 presents the payoff matrix of the Nash Game under different parameter regions. After a simple comparison, we can obtain that the equilibrium is {XX, Neither} in region (i); {OO, One} in region (ii); {OO, Both} in region (iii); {CC, Both} in regions (vi) and (vii).

Case 2: $0.1625 < \gamma \leq 1$. In this case, $\beta^{OC}_1(\gamma) = \beta^{OO}_1(\gamma) > \beta^{CC}_1(\gamma) \geq \beta^{OO}_2(\gamma) > \beta^{OC}_2(\gamma)$. Table S3 presents the payoff matrix of the Nash Game under different parameter regions. After a simple comparison, we can obtain that the equilibrium is {XX, Neither} in region (i); {OO, One} in region (ii); and {CC, Both} in region (v).

Now consider the region (iii). Note that $\frac{1}{48} \geq \frac{1+\gamma+\gamma^2}{96}$ if and only if $\gamma \leq 0.6180$ and that $\frac{1}{48} \geq \frac{1+\gamma+\gamma^2}{128}$ if and only if $\gamma \leq 0.8844$. First, {OO} is a Nash equilibrium. However, {CC} is a Nash equilibrium only when $\gamma \leq 0.6810$. That is, when $\gamma > 0.6810$, {OO, One} is a unique Nash equilibrium, however,

	(i): $K > \beta_1^{OO}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	(0,0)	(0,0)
	(ii): $\beta_2^{OO}(\gamma) \leq K < \beta_1^{OO}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	$(\frac{1+\gamma+\gamma^2}{192}, \frac{1+\gamma+\gamma^2}{96})$
O	$(\frac{1+\gamma+\gamma^2}{96}, \frac{1+\gamma+\gamma^2}{192})$	$(\frac{(1+\gamma+\gamma^2)}{128}, \frac{(1+\gamma+\gamma^2)}{128})$
	(iii): $\beta_1^{CC}(\gamma) \leq K < \beta_2^{OO}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	$(\frac{1+\gamma+\gamma^2}{192}, \frac{1+\gamma+\gamma^2}{96})$
O	$(\frac{1+\gamma+\gamma^2}{96}, \frac{1+\gamma+\gamma^2}{192})$	$(\frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}, \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3})$
	(iv): $\beta_2^{OC}(\gamma) \leq K < \beta_1^{CC}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{1+\gamma+\gamma^2}{192}, \frac{1+\gamma+\gamma^2}{96})$
O	$(\frac{1+\gamma+\gamma^2}{96}, \frac{1+\gamma+\gamma^2}{192})$	$(\frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}, \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3})$
	(v): $K < \beta_2^{OC}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{1}{48} + \frac{5-\gamma}{192(3-\gamma)^2}, \frac{1}{48} - \frac{19-22\gamma+5\gamma^2}{96(3-\gamma)^3})$
O	$(\frac{1}{48} - \frac{19-22\gamma+5\gamma^2}{96(3-\gamma)^3}, \frac{1}{48} + \frac{5-\gamma}{192(3-\gamma)^2})$	$(\frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}, \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3})$

Table S2 Nash Game with $0 \leq \gamma \leq 0.1625$ under Sequential Game

when $\gamma \leq 0.6810$, both {OO, One} and {CC, Both} are Nash equilibria. In the later case, {CC, Both} Pareto dominates {OO, One}.

Consider the regin (iv). Similar to the discussion on region (iii), {OO, Both} is a unique Nash equilibrium when $\gamma > 0.6810$ and both {OO, Both} and {CC, Both} are Nash equilibria when $\gamma \leq 0.6810$. Again, in the later case, {CC, Both} Pareto dominates {OO, Both}.

B. Asymmetric Fixed Costs

In this section, we assume that the fixed costs of the two technologies are different. Denote by K_1 and K_2 the fixed costs of T_1 and T_2, respectively. Without loss of generality, it is assumed that $K_1 \leq K_2$.

B.1. Decisions in Stages 2-4

Given players' decisions in Stages 1 and 2, the fixed costs do not affect the subsequent decisions and thus, the analysis of Stages 3 and 4 is the same as in the symmetric system (see Section 4). Following the backward induction, we directly study supplier's decisions in Stage 2 under four scenarios CC, OC, CO, and OO. In Stage 2, the supplier has four feasible options, i.e., investing in neither, T_1, T_2 and both technologies, denoted by Options Neither, T_1, T_2 and Both, respectively. Based on the analysis in the symmetric system, we can easily derive players' expected profits under four scenarios.

	(i): $K > \beta_1^{\rm OO}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	(0,0)	(0,0)
	(ii): $\beta_1^{\rm CC} \le K < \beta_1^{\rm OO}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	$(\frac{1+\gamma+\gamma^2}{192}, \frac{1+\gamma+\gamma^2}{96})$
O	$(\frac{1+\gamma+\gamma^2}{96}, \frac{1+\gamma+\gamma^2}{192})$	$(\frac{(1+\gamma+\gamma^2)}{128}, \frac{(1+\gamma+\gamma^2)}{128})$
	(iii): $\beta_2^{\rm OO}(\gamma) \le K < \beta_1^{\rm CC}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{1+\gamma+\gamma^2}{192}, \frac{1+\gamma+\gamma^2}{96})$
O	$(\frac{1+\gamma+\gamma^2}{96}, \frac{1+\gamma+\gamma^2}{192})$	$(\frac{(1+\gamma+\gamma^2)}{128}, \frac{(1+\gamma+\gamma^2)}{128})$
	(iv): $\beta_2^{OC}(\gamma) \le K < \beta_2^{\rm OO}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{1+\gamma+\gamma^2}{192}, \frac{1+\gamma+\gamma^2}{96})$
O	$(\frac{1+\gamma+\gamma^2}{96}, \frac{1+\gamma+\gamma^2}{192})$	$(\frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}, \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3})$
	(v): $K < \beta_2^{OC}(\gamma)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{1}{48} + \frac{5-\gamma}{192(3-\gamma)^2}, \frac{1}{48} - \frac{19-22\gamma+5\gamma^2}{96(3-\gamma)^3})$
O	$(\frac{1}{48} - \frac{19-22\gamma+5\gamma^2}{96(3-\gamma)^3}, \frac{1}{48} + \frac{5-\gamma}{192(3-\gamma)^2})$	$(\frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3}, \frac{1}{48} - \frac{23-36\gamma+9\gamma^2}{192(3-\gamma)^3})$

Table S3 Nash Game with $0.1625 < \gamma \le 1$ under Sequential Game

Scenario CC.

- Option of Investing in Neither: $\pi_{s,2}^{CC} = \pi_{m1,2}^{\rm CC} = \pi_{m2,2}^{\rm CC} = 0$.
- Option T_1: $\pi_{s,2}^{\rm CC} = \frac{1}{24} - K_1$, $\pi_{m1,2}^{CC} = \frac{1}{48}$, and $\pi_{m2,2}^{\rm CC} = 0$.
- Option T_2: $\pi_{s,2}^{\rm CC} = \frac{1}{24} - K_2$, $\pi_{m1,2}^{CC} = 0$, and $\pi_{m2,2}^{\rm CC} = \frac{1}{48}$.
- Option Both: $\pi_{s,2}^{\rm CC} = \frac{1}{12} - K_1 - K_2$, $\pi_{m1,2}^{CC} = \frac{1}{48}$, and $\pi_{m2,2}^{\rm CC} = \frac{1}{48}$.

Comparing supplier's expected profits under four options, we can determine supplier's optimal decision and accordingly, players' expected profits in Stage 2 under scenario CC.

Lemma S3 (Scenario CC). *Suppose neither firm opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(i) if $K_1 \ge \frac{1}{24}$, *the supplier invests in neither technology, and* $\pi_{s,2}^{\rm CC} = 0$, $\pi_{m1,2}^{\rm CC} = \pi_{m2,2}^{\rm CC} = 0$;

(ii) if $K_1 < \frac{1}{24} \le K_2$, *then the supplier invests in* T_1, *and* $\pi_{s,2}^{\rm CC} = \frac{1}{24} - K_1$, $\pi_{m1,2}^{\rm CC} = \frac{1}{48}$, $\pi_{m2,2}^{\rm CC} = 0$.

(iii) if $K_2 < \frac{1}{24}$, *then the supplier invests in both technologies, and* $\pi_{s,2}^{\rm CC} = \frac{1}{12} - K_1 - K_2$, $\pi_{m1,2}^{\rm CC} = \pi_{m2,2}^{\rm CC} = \frac{1}{48}$.

Scenario OC.

- Option of Investing in Neither: $\pi_{s,2}^{\rm OC} = \pi_{m1,2}^{\rm OC} = \pi_{m2,2}^{\rm OC} = 0$.
- Option T_1: $\pi_{s,2}^{\rm OC} = \frac{1+\gamma+\gamma^2}{18} - K_1$, and $\pi_{m1,2}^{\rm OC} = \pi_{m2,2}^{\rm OC} = \frac{1+\gamma+\gamma^2}{108}$.
- Option T_2: $\pi_{s,2}^{\rm OC} = \frac{1}{24} - K_2$, $\pi_{m1,2}^{\rm OC} = 0$, and $\pi_{m2,2}^{\rm OC} = \frac{1}{48}$.

• Option Both: $\pi^{\mathrm{OC}}_{s,2} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - K_1 - K_2$, $\pi^{\mathrm{OC}}_{m1,2} = \frac{1}{48} - \frac{49-46\gamma}{216(5-2\gamma)^2}$, and $\pi^{\mathrm{OC}}_{m2,2} = \frac{1}{48} + \frac{4-\gamma}{27(5-2\gamma)^2}$.

Note that $\frac{1+\gamma+\gamma^2}{18} - K_1 > \frac{1}{24} - K_2$. Thus, the supplier will never choose T_2. Define $\beta^{\mathrm{OC}}_1(\gamma) = \frac{1+\gamma+\gamma^2}{18}$ and $\beta^{\mathrm{OC}}_2(\gamma) = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - \frac{1+\gamma+\gamma^2}{18}$.

Lemma S4 (Scenario OC). *Suppose only M_1 opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(i) if $K_1 \geq \beta^{\mathrm{OC}}_1(\gamma)$, the supplier invests in neither technology, and $\pi^{\mathrm{OC}}_{s,2} = 0$, $\pi^{\mathrm{OC}}_{m1,2} = 0$, $\pi^{\mathrm{OC}}_{m2,2} = 0$;

(ii) if $K_1 < \beta^{\mathrm{OC}}_1(\gamma)$ and $K_2 \geq \beta^{\mathrm{OC}}_2(\gamma)$, the supplier invests in only T_1, and $\pi^{\mathrm{OC}}_{s,2} = \frac{1+\gamma+\gamma^2}{18} - K_1$, $\pi^{\mathrm{OC}}_{m1,2} = \pi^{\mathrm{OC}}_{m2,2} = \frac{1+\gamma+\gamma^2}{108}$;

(iii) if $K_2 < \beta^{\mathrm{OC}}_2(\gamma)$, the supplier invests in both technologies, and $\pi^{\mathrm{OC}}_{s,2} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - K_1 - K_2$, $\pi^{\mathrm{OC}}_{m1,2} = \frac{1}{48} - \frac{49-46\gamma}{216(5-2\gamma)^2}$, $\pi^{\mathrm{OC}}_{m2,2} = \frac{1}{48} + \frac{4-\gamma}{27(5-2\gamma)^2}$.

Scenario CO.

• Option of Investing in Neither: $\pi^{\mathrm{CO}}_{s,2} = \pi^{\mathrm{CO}}_{m1,2} = \pi^{\mathrm{CO}}_{m2,2} = 0$.

• Option T_1: $\pi^{\mathrm{CO}}_{s,2} = \frac{1}{24} - K_1$, and $\pi^{\mathrm{CO}}_{m1,2} = \frac{1}{48}$, and $\pi^{\mathrm{CO}}_{m2,2} = 0$.

• Option T_2: $\pi^{\mathrm{CO}}_{s,2} = \frac{1+\gamma+\gamma^2}{18} - K_2$, $\pi^{\mathrm{CO}}_{m1,2} = \pi^{\mathrm{CO}}_{m2,2} = \frac{1+\gamma+\gamma^2}{108}$.

• Option Both: $\pi^{\mathrm{CO}}_{s,2} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - K_1 - K_2$, $\pi^{\mathrm{CO}}_{m1,2} = \frac{1}{48} + \frac{4-\gamma}{27(5-2\gamma)^2}$, and $\pi^{\mathrm{CO}}_{m2,2} = \frac{1}{48} - \frac{49-46\gamma}{216(5-2\gamma)^2}$.

Define $\beta^{\mathrm{CO}}_1(\gamma) = \frac{1}{24} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3}$.

Lemma S5 (Scenario CO). *Suppose only M_2 opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(a) when $K_2 - K_1 \leq \frac{1+\gamma+\gamma^2}{18} - \frac{1}{24}$,

(i) if $K_2 \geq \beta^{\mathrm{OC}}_1(\gamma)$, the supplier invests in neither technology, and $\pi^{\mathrm{CO}}_{s,2} = 0$, $\pi^{\mathrm{CO}}_{m1,2} = 0$, $\pi^{\mathrm{CO}}_{m2,2} = 0$;

(ii) if $K_2 < \beta^{\mathrm{OC}}_1(\gamma)$ and $K_1 \geq \beta^{\mathrm{OC}}_2(\gamma)$, the supplier invests in only T_2, and $\pi^{\mathrm{CO}}_{s,2} = \frac{1+\gamma+\gamma^2}{18} - K_2$, $\pi^{\mathrm{CO}}_{m1,2} = \pi^{\mathrm{CO}}_{m2,2} = \frac{1+\gamma+\gamma^2}{108}$;

(iii) if $K_1 < \beta^{\mathrm{OC}}_2(\gamma)$, the supplier invests in both technologies, and $\pi^{\mathrm{CO}}_{s,2} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - K_1 - K_2$, $\pi^{\mathrm{CO}}_{m1,2} = \frac{1}{48} + \frac{4-\gamma}{27(5-2\gamma)^2}$, $\pi^{\mathrm{CO}}_{m2,2} = \frac{1}{48} - \frac{49-46\gamma}{216(5-2\gamma)^2}$.

(b) when $K_2 - K_1 > \frac{1+\gamma+\gamma^2}{18} - \frac{1}{24}$,

(i) if $K_1 \geq \frac{1}{24}$, the supplier invests in neither technology, and $\pi^{\mathrm{CO}}_{s,2} = 0$, $\pi^{\mathrm{CO}}_{m1,2} = 0$, $\pi^{\mathrm{CO}}_{m2,2} = 0$;

(ii) if $K_1 < \frac{1}{24}$ and $K_2 \geq \beta^{\mathrm{CO}}_1(\gamma)$, the supplier invests in only T_1, and $\pi^{\mathrm{CO}}_{s,2} = \frac{1}{24} - K_1$, $\pi^{\mathrm{CO}}_{m1,2} = \frac{1}{48}$, $\pi^{\mathrm{CO}}_{m2,2} = 0$;

(iii) if $K_1 < \frac{1}{24}$ and $K_2 < \beta_1^{\mathrm{CO}}(\gamma)$, the supplier invests in both technologies, and $\pi_{s,2}^{\mathrm{CO}} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - K_1 - K_2$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{1}{48} + \frac{4-\gamma}{27(5-2\gamma)^2}$, $\pi_{m2,2}^{\mathrm{CO}} = \frac{1}{48} - \frac{49-46\gamma}{216(5-2\gamma)^2}$.

Proof of Lemma S5. We first consider the case with $K_2 - K_1 \le \frac{1+\gamma+\gamma^2}{18} - \frac{1}{24}$. It implies that $\pi_{s,2}^{\mathrm{CO}} \ge \pi_{s,2}^{\mathrm{CO}}$, i.e., the supplier will prefer investing in T_2 than T_1 provided that only one technology is invested. In other words, the supplier will never choose option T_1. Then, the results are straightforward by comparing supplier's expected profits in three other scenarios.

Now turn to the case with $K_2 - K_1 > \frac{1+\gamma+\gamma^2}{18} - \frac{1}{24}$. In this case, the supplier never chooses option T_2. Comparing other options will lead to the following result.

(i) if $K_1 \ge \frac{1}{24}$ and $K_1 + K_2 \ge \frac{1}{24} + \beta_3^{\mathrm{OC}}(\gamma)$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{CO}} = 0$, $\pi_{m1,2}^{\mathrm{CO}} = 0$, $\pi_{m2,2}^{\mathrm{CO}} = 0$;

(ii) if $K_1 < \frac{1}{24}$ and $K_2 \ge \beta_3^{\mathrm{OC}}(\gamma)$, the supplier invests in only T_1, and $\pi_{s,2}^{\mathrm{CO}} = \frac{1}{24} - K_1$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{1}{48}$, $\pi_{m2,2}^{\mathrm{CO}} = 0$;

(iii) if $K_2 < \beta_3^{\mathrm{OC}}(\gamma)$ and $K_1 + K_2 < \frac{1}{24} + \beta_3^{\mathrm{OC}}(\gamma)$, the supplier invests in both technologies, and $\pi_{s,2}^{\mathrm{CO}} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - K_1 - K_2$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{1}{48} + \frac{4-\gamma}{27(5-2\gamma)^2}$, $\pi_{m2,2}^{\mathrm{CO}} = \frac{1}{48} - \frac{49-46\gamma}{216(5-2\gamma)^2}$.
Note that if $K_1 \ge 1/24$, then $K_1 + K_2 \ge \frac{1+\gamma+\gamma^2}{18} - \frac{1}{24} + 2K_1 \ge \frac{1+\gamma+\gamma^2}{18} + \frac{1}{24} \ge \frac{1}{24} + \beta_3^{\mathrm{OC}}(\gamma)$. Thus, the conditions in (i) can be reduced to $K_1 \ge \frac{1}{24}$. Furthermore, we can replace the conditions in (iii) with $K_2 < \beta_3^{\mathrm{OC}}(\gamma)$ and $K_1 < \frac{1}{24}$. $\square$

Scenario OO.

- Option of Investing in Neither: $\pi_{s,2}^{\mathrm{OO}} = \pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = 0$.
- Option T_1: $\pi_{s,2}^{\mathrm{OO}} = \frac{1+\gamma+\gamma^2}{18} - K_1$, and $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{1+\gamma+\gamma^2}{108}$.
- Option T_2: $\pi_{s,2}^{\mathrm{OO}} = \frac{1+\gamma+\gamma^2}{18} - K_2$, and $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{1+\gamma+\gamma^2}{108}$.
- Option Both: (i) When $\gamma \le \frac{1}{2}$, $\pi_{s,2}^{\mathrm{OO}} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{18(5-2\gamma)^3} - K_1 - K_2$, and $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{1}{48} + \frac{38\gamma-17}{216(5-2\gamma)^3}$.

  (ii) When $\gamma > \frac{1}{2}$, $\pi_{s,2}^{\mathrm{OO}} = \frac{7+4\gamma+\gamma^2}{72} - K_1 - K_2$, and $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{7+4\gamma+\gamma^2}{432}$.

Note that the supplier never chooses to open T_2 as $\pi_{s,2}^{\mathrm{OO1}} \ge \pi_{s,2}^{\mathrm{OO2}}$. Define $\beta_1^{\mathrm{OO}}(\gamma) = \beta_1^{\mathrm{OC}}(\gamma) = \frac{1+\gamma+\gamma^2}{18}$, $\beta_2^{\mathrm{OO}}(\gamma) = \beta_2^{\mathrm{OC}}(\gamma) = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{36(5-2\gamma)^3} - \frac{1+\gamma+\gamma^2}{18}$, and $\beta_3^{\mathrm{OO}}(\gamma) = \frac{3-3\gamma^2}{72}$.

Lemma S6 (Scenario OO). *Suppose only M_1 opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(a) when $\gamma \le \frac{1}{2}$,

(i) if $K_1 \ge \beta_1^{\mathrm{OO}}(\gamma)$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{OO}} = 0$, $\pi_{m1,2}^{\mathrm{OO}} = 0$, $\pi_{m2,2}^{\mathrm{OO}} = 0$;

(ii) if $K_1 < \beta_1^{\mathrm{OO}}(\gamma)$ and $K_2 \ge \beta_2^{\mathrm{OO}}(\gamma)$, the supplier invests in only T_1, and $\pi_{s,2}^{\mathrm{OO}} = \frac{1+\gamma+\gamma^2}{18} - K_1$, $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{1+\gamma+\gamma^2}{108}$;

(iii) if $K_2 < \beta_2^{OO}(\gamma)$*, the supplier invests in both technologies, and* $\pi_{s,2}^{OO} = \frac{1}{12} + \frac{37+40\gamma-20\gamma^2}{18(5-2\gamma)^3} - K_1 - K_2$, $\pi_{m1,2}^{OO} = \pi_{m2,2}^{OO} = \frac{1}{48} + \frac{38\gamma-17}{216(5-2\gamma)^2}$.

(b) when $\gamma > \frac{1}{2}$,

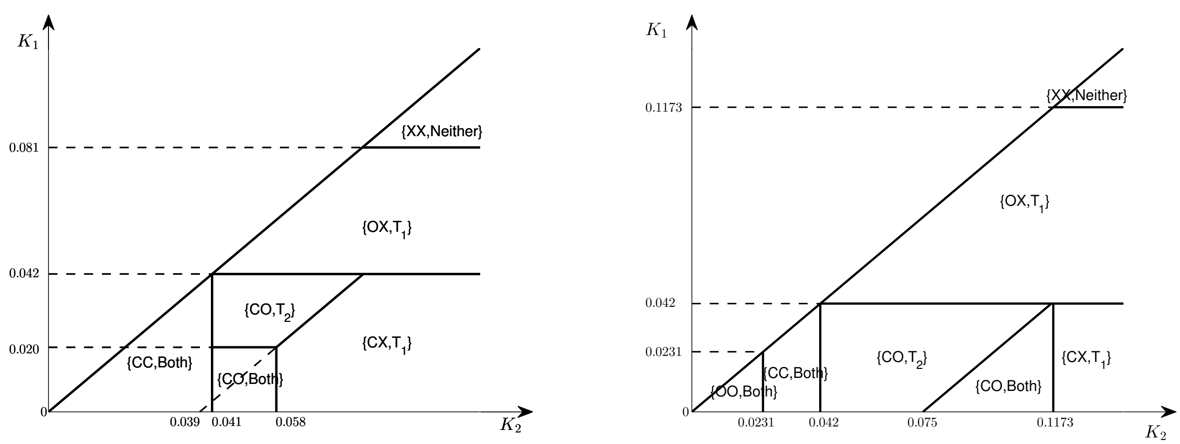
(i) if $K_1 \geq \beta_1^{OO}(\gamma)$*, the supplier invests in neither technology, and* $\pi_{s,2}^{OO} = 0$, $\pi_{m1,2}^{OO} = 0$, $\pi_{m2,2}^{OO} = 0$;

(ii) if $K_1 < \beta_1^{OO}(\gamma)$ *and* $K_2 \geq \beta_3^{OO}(\gamma)$*, the supplier invests in only* T_1*, and* $\pi_{s,2}^{OO} = \frac{1+\gamma+\gamma^2}{18} - K_1$, $\pi_{m1,2}^{OO} = \pi_{m2,2}^{OO} = \frac{1+\gamma+\gamma^2}{108}$;

(iii) if $K_2 < \beta_3^{OO}(\gamma)$*, then the supplier invests in both technologies, and then* $\pi_{s,2}^{OO} = \frac{7+4\gamma+\gamma^2}{72} - K_1 - K_2$, $\pi_{m1,2}^{OO} = \pi_{m2,2}^{OO} = \frac{7+4\gamma+\gamma^2}{432}$.

B.2. Decisions in Stage 1

With subgame equilibria in stages 2-4, one can readily derive the equilibrium in Stage 1. The analysis is analogous to the symmetric system and thus omitted. The equilibria are illustrated by Figure 6 for the setting with $\gamma = \frac{1}{2}$. Figure S1 (a) and (b) illustrate the optimal decisions for the setting with $\gamma = \frac{1}{3}$ and $\gamma = \frac{2}{3}$, respectively.



(a) $\gamma = \frac{1}{3}$ (b) $\gamma = \frac{2}{3}$

Figure S1 Optimal decisions under asymmetric fixed costs with varying γ

C. Asymmetric Market Size

In this section, we assume that the future market sizes of two technologies are asymmetric. In particular, we assume that the demand of T_1 follows the Bernoulli 0-1 distribution, taking one with the probability α and zero with $1-\alpha$. That is, only one technology emerges in the future market, while the other disappears. Without loss of generality, we assume $\alpha \geq \frac{1}{2}$.

C.1. Decisions in Stages 2-4

Note that given the realized demand, the analysis of stage 4 is the same as that in the basic model. Still following the backward induction, we first study the game in stages 2 and 3 under four scenarios.

Scenario CC.

- Option of Investing in Neither: $\pi_{s,2}^{CC} = \pi_{m1,2}^{\mathrm{CC}} = \pi_{m2,2}^{\mathrm{CC}} = 0$.
- Option T_1: $\pi_{s,2}^{\mathrm{CC}} = \frac{\alpha}{8} - K$, $\pi_{m1,2}^{CC} = \frac{\alpha}{16}$, and $\pi_{m2,2}^{\mathrm{CC}} = 0$.
- Option T_2: $\pi_{s,2}^{\mathrm{CC}} = \frac{1-\alpha}{8} - K$, $\pi_{m1,2}^{CC} = 0$, and $\pi_{m2,2}^{\mathrm{CC}} = \frac{1-\alpha}{16}$.
- Option Both: $\pi_{s,2}^{\mathrm{CC}} = \frac{1}{8} - 2K$, $\pi_{m1,2}^{CC} = \frac{\alpha}{16}$, and $\pi_{m2,2}^{\mathrm{CC}} = \frac{1-\alpha}{16}$.

Note that as $\alpha \geq \frac{1}{2}$, the firm prefers T_1 if determining to invest only one technology. Comparing supplier's expected profits under four options, we can determine her optimal decision and accordingly, players' expected profits in stage 2 under scenario CC.

Lemma S7 (Scenario CC). *Suppose neither firm opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(i) if $K \geq \frac{\alpha}{8}$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{CC}} = 0$, $\pi_{m1,2}^{\mathrm{CC}} = \pi_{m2,2}^{\mathrm{CC}} = 0$;

(ii) if $\frac{1-\alpha}{8} \leq K_< \frac{\alpha}{8}$, the supplier invests in T_1, and $\pi_{s,2}^{\mathrm{CC}} = \frac{\alpha}{8} - K$, $\pi_{m1,2}^{\mathrm{CC}} = \frac{\alpha}{16}$, $\pi_{m2,2}^{\mathrm{CC}} = 0$.

(iii) if $K < \frac{1-\alpha}{8}$, the supplier invests in both technologies, and $\pi_{s,2}^{\mathrm{CC}} = \frac{1}{8} - 2K$, $\pi_{m1,2}^{\mathrm{CC}} = \frac{\alpha}{16}$, $\pi_{m2,2}^{\mathrm{CC}} = \frac{1-\alpha}{16}$.

Under scenario OC, the supplier always prefers T_1 to T_2, if only one technology is invested in. Therefore, we ignore the option of investing in T_2.

Scenario OC.

- Option of Investing in Neither: $\pi_{s,2}^{\mathrm{OC}} = \pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} = 0$.
- Option T_1: $\pi_{s,2}^{\mathrm{OC}} = \frac{\alpha+(1-\alpha)\gamma^2}{6} - K$, and $\pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} = \frac{\alpha+(1-\alpha)\gamma^2}{36}$.
- Option Both: $\pi_{s,2}^{\mathrm{OC}} = \frac{\alpha}{6} + \frac{1-\alpha}{8} - 2K$, $\pi_{m1,2}^{\mathrm{OC}} = \frac{\alpha}{36}$, and $\pi_{m2,2}^{\mathrm{OC}} = \frac{\alpha}{36} + \frac{1-\alpha}{16}$.

Define $\beta_1^{\mathrm{OC}}(\alpha,\gamma) = \frac{\alpha+(1-\alpha)\gamma^2}{6}$ and $\beta_2^{\mathrm{OC}}(\alpha,\gamma) = \frac{(1-\alpha)(3-4\gamma^2)}{24}$.

Lemma S8 (Scenario OC). *Suppose only M_1 opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(i) if $K \geq \beta_1^{\mathrm{OC}}(\alpha,\gamma)$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{OC}} = 0$, $\pi_{m1,2}^{\mathrm{OC}} = 0$ and $\pi_{m2,2}^{\mathrm{OC}} = 0$;

(ii) if $\beta_2^{\mathrm{OC}}(\alpha,\gamma) \leq K < \beta_1^{\mathrm{OC}}(\alpha,\gamma)$, the supplier invests in only T_1, and $\pi_{s,2}^{\mathrm{OC}} = \frac{\alpha+(1-\alpha)\gamma^2}{6} - K$, $\pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} = \frac{\alpha+(1-\alpha)\gamma^2}{36}$;

(iii) if $K_2 < \beta_2^{\mathrm{OC}}(\alpha,\gamma)$*, the supplier invests in both technologies, and* $\pi_{s,2}^{\mathrm{OC}} = \frac{\alpha}{6} + \frac{1-\alpha}{8} - 2K$, $\pi_{m1,2}^{\mathrm{OC}} = \frac{\alpha}{36}$, $\pi_{m2,2}^{\mathrm{OC}} = \frac{\alpha}{36} + \frac{1-\alpha}{16}$.

Scenario CO.

- Option of Investing in Neither: $\pi_{s,2}^{\mathrm{CO}} = \pi_{m1,2}^{\mathrm{CO}} = \pi_{m2,2}^{\mathrm{CO}} = 0$.
- Option T_1: $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha}{8} - K$, $\pi_{m1,2}^{CO} = \frac{\alpha}{16}$, and $\pi_{m2,2}^{\mathrm{CO}} = 0$.
- Option T_2: $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha\gamma^2+(1-\alpha)}{6} - K$, $\pi_{m1,2}^{\mathrm{CO}} = \pi_{m2,2}^{\mathrm{CO}} = \frac{\alpha\gamma^2+(1-\alpha)}{36}$.
- Option Both: $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha}{8} + \frac{1-\alpha}{6} - 2K$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{\alpha}{16} + \frac{1-\alpha}{36}$, and $\pi_{m2,2}^{\mathrm{CO}} = \frac{1-\alpha}{36}$.

Define $\beta_1^{\mathrm{CO}}(\alpha,\gamma) = \frac{\alpha\gamma^2+(1-\alpha)}{6}$, $\beta_2^{\mathrm{CO}}(\alpha,\gamma) = \frac{\alpha}{8}$, $\beta_3^{\mathrm{CO}}(\alpha,\gamma) = \frac{\alpha(3-4\gamma^2)}{24}$, and $\beta_4^{\mathrm{CO}}(\alpha,\gamma) = \frac{1-\alpha}{6}$.

LEMMA S9 (SCENARIO CO). *Suppose only* M_2 *opens his own technology, then the supplier's optimal decision and players' optimal profits are given by*

(a) when $4(1+\alpha\gamma^2) \geq 7\alpha$,

(i) if $K \geq \beta_1^{\mathrm{CO}}(\alpha,\gamma)$*, the supplier invests in neither technology, and* $\pi_{s,2}^{\mathrm{CO}} = 0$, $\pi_{m1,2}^{\mathrm{CO}} = 0$ *and* $\pi_{m2,2}^{\mathrm{CO}} = 0$;

(ii) if $\beta_3^{\mathrm{CO}}(\alpha,\gamma) \leq K < \beta_1^{\mathrm{CO}}(\alpha,\gamma)$*, the supplier invests in only* T_2*, and* $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha\gamma^2+(1-\alpha)}{6} - K$, $\pi_{m1,2}^{\mathrm{CO}} = \pi_{m2,2}^{\mathrm{CO}} = \frac{\alpha\gamma^2+(1-\alpha)}{36}$;

(iii) if $K < \beta_3^{\mathrm{CO}}(\alpha,\gamma)$*, the supplier invests in both technologies, and* $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha}{8} + \frac{1-\alpha}{6} - 2K$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{\alpha}{16} + \frac{1-\alpha}{36}$, $\pi_{m2,2}^{\mathrm{CO}} = \frac{1-\alpha}{36}$.

(b) when $4(1+\alpha\gamma^2) < 7\alpha$,

(i) if $K \geq \beta_2^{\mathrm{CO}}(\alpha,\gamma)$*, the supplier invests in neither technology, and* $\pi_{s,2}^{\mathrm{CO}} = 0$, $\pi_{m1,2}^{\mathrm{CO}} = 0$ *and* $\pi_{m2,2}^{\mathrm{CO}} = 0$;

(ii) if $\beta_4^{\mathrm{CO}}(a) \leq K < \beta_2^{\mathrm{CO}}(\alpha,\gamma)$*, the supplier invests in only* T_1*, and* $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha}{8} - K$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{\alpha}{16}$, $\pi_{m2,2}^{\mathrm{CO}} = 0$;

(iii) if $K < \beta_4^{\mathrm{CO}}(\alpha,\gamma)$*, the supplier invests in both technologies, and* $\pi_{s,2}^{\mathrm{CO}} = \frac{\alpha}{8} + \frac{1-\alpha}{6} - 2K$, $\pi_{m1,2}^{\mathrm{CO}} = \frac{\alpha}{16} + \frac{1-\alpha}{36}$, $\pi_{m2,2}^{\mathrm{CO}} = \frac{1-\alpha}{36}$.

Scenario OO.

- Option of Investing in Neither: $\pi_{s,2}^{\mathrm{OO}} = \pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = 0$.
- Option T_1: $\pi_{s,2}^{\mathrm{OO}} = \frac{\alpha+(1-\alpha)\gamma^2}{6} - K$, and $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{\alpha+(1-\alpha)\gamma^2}{36}$.
- Option Both: $\pi_{s,2}^{\mathrm{OO}} = \frac{1}{6} - 2K$, and $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{1}{36}$.

Note that the supplier never choose to invest in T_2 if only one technology is invested in. Define $\beta_1^{\mathrm{OO}}(\alpha,\gamma) = \frac{\alpha+(1-\alpha)\gamma^2}{6}$ and $\beta_2^{\mathrm{OO}}(\alpha,\gamma) = \frac{(1-\alpha)(1-\gamma^2)}{6}$.

LEMMA S10 (SCENARIO OO). *Suppose both manufacturers open their own technologies, then the supplier's optimal decision and players' optimal profits are given by* *(i) if* $K \geq \beta_1^{\mathrm{OO}}(\alpha,\gamma)$*, the supplier invests in neither technology, and* $\pi_{s,2}^{\mathrm{OO}}=0$*,* $\pi_{m1,2}^{\mathrm{OO}}=0$ *and* $\pi_{m2,2}^{\mathrm{OO}}=0$*;*

(ii) if $\beta_2^{\mathrm{OO}}(\alpha,\gamma) \leq K < \beta_1^{\mathrm{OO}}(\alpha,\gamma)$*, the supplier invests in only* T_1*, and* $\pi_{s,2}^{\mathrm{OO}} = \frac{\alpha+(1-\alpha)\gamma^2}{6} - K$*,* $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{\alpha+(1-\alpha)\gamma^2}{36}$*;*

(iii) if $K < \beta_2^{\mathrm{OO}}(\alpha,\gamma)$*, then the supplier invests in both technologies, and then* $\pi_{s,2}^{\mathrm{OO}} = \frac{1}{6} - 2K$*,* $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{1}{36}$*.*

C.2. Decisions in Stage 1

With subgame equilibria in Stages 2-4, we next derive the equilibria in Stage 1 by considering two cases: $4(1+\alpha\gamma^2) \geq 7\alpha$, and $4(1+\alpha\gamma^2) < 7\alpha$. Again, we first fix $\gamma = 1/2$. Thus, the two cases become $\alpha \leq 2/3$ and $\alpha > 2/3$. As $\alpha \geq 1/2$, one can easily prove that $\beta_1^{OC} = \beta_1^{OO} \geq \beta_1^{CO} \geq \frac{\alpha}{8}$.

Case 1: $1/2 \leq \alpha < 2/3$. In this case, when $3/5 \leq \alpha < 2/3$, $\beta_3^{CO} \geq \beta_2^{OO} = \frac{1-\alpha}{8} \geq \beta_2^{OC}$, and when $1/2 \leq \alpha < 3/5$, $\beta_2^{OO} = \frac{1-\alpha}{8} \geq \beta_3^{CO} \geq \beta_2^{OC}$. Thus, we consider these two subcases.

Table S4 presents the payoff matrix of the Nash Game under different parameter regions for the subcase of $1/2 \leq \alpha < 3/5$. After a simple comparison, we can obtain that the equilibrium is {XX, Neither} in region (i); {OX, T_1} in both regions (ii) and (iii); {OO, T_1} in regions (iv) and (v); {CC, Both} in regions (vi) and (vii).

Table S5 presents the payoff matrix of the Nash Game under different parameter regions for the subcase of $3/5 \leq \alpha < 2/3$. After a simple comparison, we can obtain that the equilibrium is {XX, Neither} in region (i); {OX, T_1} in both regions (ii) and (iii); {OO, T_1} in region (iv); {CO, Both} in region (v); {CC, Both} in regions (vi) and (vii).

Case 2: $\alpha > 2/3$. In this case, $\beta_1^{OC} = \beta_1^{OO} \geq \beta_2^{CO} = \frac{\alpha}{8} \geq \beta_4^{CO} \geq \beta_2^{OO} = \frac{1-\alpha}{8} \geq \beta_2^{OC}$. Table S6 presents the payoff matrix of the Nash Game under different parameter regions. Similar to Case 1, after a simple comparison, we can obtain that the equilibrium is {XX, Neither} in region (i); {OX, T_1} in region (ii); {CX, T_1} in region (iii); {CO, Both} in region (iv); {CC, Both} in regions (v) and (vi).

In summary, the equilibria are illustrated by Figure 7. Figure S2(a) and (b) illustrate the optimal decisions for the setting with $\gamma = \frac{1}{3}$ and $\gamma = \frac{2}{3}$, respectively.

D. Game Equilibria with Outside Supplier

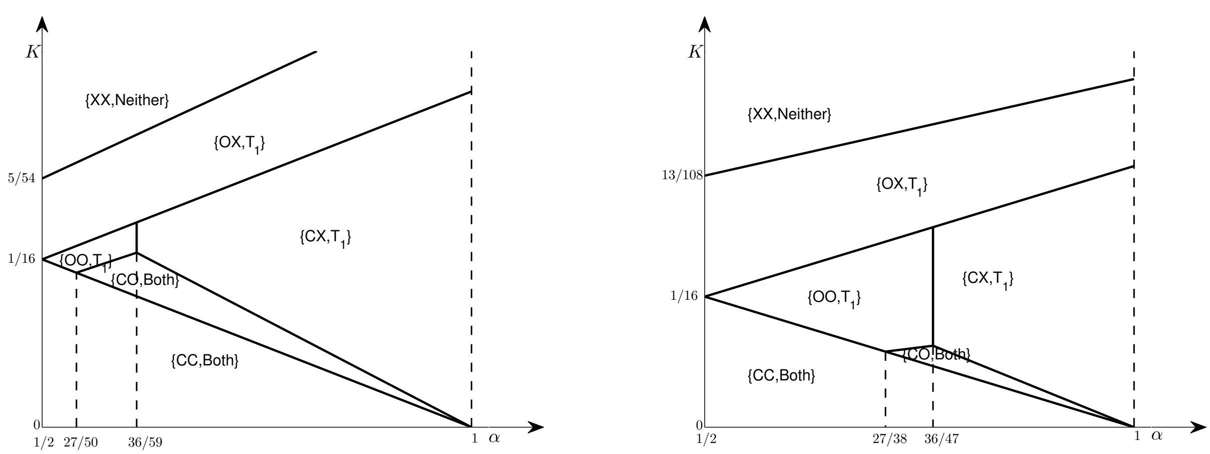
In this section, we assume there exists an outside supplier whose wholesale price is fixed and denoted by s. For convenience, we set $\gamma = \frac{1}{2}$ and assume $\frac{1}{2} \leq s \leq \frac{2}{3}$.

D.1. Decisions in Stage 2-4

Following backward induction, we first derive the subgame equilibria given firms's decisions in Stage 1, i.e., under four scenarios: CC, OC, CO, and OO.

	(i): $K > \beta_1^{\mathrm{OO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	(0,0)	(0,0)
	(ii): $\beta_1^{\mathrm{CO}}(\alpha) \le K < \beta_1^{\mathrm{OO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(iii): $\alpha/8 \le K < \beta_1^{\mathrm{CO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	$(\frac{4-3\alpha}{144}, \frac{4-3\alpha}{144})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(iv): $\beta_2^{OO} \le K < \alpha/8$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, 0)$	$(\frac{4-3\alpha}{144}, \frac{4-3\alpha}{144})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(v): $\beta_3^{CO} \le K < \beta_2^{OO}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4-3\alpha}{144}, \frac{4-3\alpha}{144})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$
	(vi): $\beta_2^{OC} \le K < \beta_3^{CO}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$
	(vii): $K < \beta_2^{OC}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{\alpha}{36}, \frac{9-5\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$

Table S4 Nash Game with $1/2 \le \alpha < 3/5$ under Asymmetric Market Size



(a) $\gamma = \frac{1}{3}$

(b) $\gamma = \frac{2}{3}$

Figure S2 Optimal decisions under asymmetric market sizes with varying γ

D.1.1. Scenario CC. As the two technologies are symmetric, we take T_1 for example to investigate players' decisions in stages 3 and 4.

	(i): $K > \beta_1^{\mathrm{OO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	(0,0)	(0,0)
	(ii): $\beta_1^{\mathrm{CO}}(\alpha) \leq K < \beta_1^{\mathrm{OO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(iii): $\alpha/8 \leq K < \beta_1^{\mathrm{CO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	$(\frac{4-3\alpha}{144}, \frac{4-3\alpha}{144})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(iv): $\beta_4^{CO} \leq K < \alpha/8$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, 0)$	$(\frac{4-3\alpha}{144}, \frac{4-3\alpha}{144})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(v): $\beta_2^{OO} \leq K < \beta_4^{CO}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, 0)$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(vi): $\beta_2^{OC} \leq K < \beta_2^{OO}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$
	(vii): $K < \beta_2^{OC}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{\alpha}{36}, \frac{9-5\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$

Table S5 Nash Game with $3/5 \leq \alpha < 2/3$ under Asymmetric Market Size

• Option of Investing in Neither: If the supplier does not invest in T_1, then she clearly gains zero profit from this technology market, i.e., $\pi_{s,4}^{\mathrm{CC}} = 0$. Moreover, M_1 has to order if profitable from the outside supplier with the wholesale price s. In particular, M_1 chooses the outside supplier if the realized market size is larger than s and accordingly, his profit can be expressed as $\pi_{m1,4}^{\mathrm{CC}}(q_1) = (A - q_1 - s)q_1$; otherwise, M_1 has to quit from market. Then, the optimal order quantity is $q_1^* = \frac{A-s}{2}$ and the optimal profit is $\pi_{m1,4}^{\mathrm{CC}} = \frac{(A-s)^2}{4}$.

• Option of Investing in T_1: As the supplier invested in the capacity of T_1, M_1 has the option to order from the supplier or the outside supplier. By a similar analysis to the symmetric case, the supplier offers the wholesale price $w_1^{\mathrm{CC}} = \frac{A}{2}$. By assumption, $s \geq \frac{1}{2} \geq \frac{A}{2}$, i.e., the wholesale price offered by the supplier is always less than that offered by the outside supplier. Therefore, M_1 always orders from the supplier. Given the realized market size, the optimal profits of the supplier and M_1 are $\pi_{s,4}^{\mathrm{CC}} = \frac{A^2}{8}$ and $\pi_{m1,4}^{\mathrm{CC}} = \frac{A^2}{16}$, respectively.

Now back to Stage 2. Supplier's expected profit from investing in one technology is $\mathbb{E}_A[\pi_{s,2}^{\mathrm{CC}}] = \frac{1}{24}$. Clearly, if K is larger than $\frac{1}{24}$, the supplier invests in neither technology; otherwise, to invest in both technologies.

	(i): $K > \beta_1^{\mathrm{OO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	(0,0)	(0,0)
	(ii): $\alpha/8 \le K < \beta_1^{\mathrm{OO}}(\alpha)$	
Firm 1 \ Firm 2	C	O
C	(0,0)	(0,0)
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(iii): $\beta_4^{CO} \le K < \alpha/8$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, 0)$	$(\frac{\alpha}{16}, 0)$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(iv): $\beta_2^{OO} \le K < \beta_4^{CO}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, 0)$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$
	(v): $\beta_2^{OC} \le K < \beta_2^{OO}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{1+3\alpha}{144}, \frac{1+3\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$
	(vi): $K < \beta_2^{OC}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{\alpha}{16}, \frac{1-\alpha}{16})$	$(\frac{4+5\alpha}{144}, \frac{1-\alpha}{36})$
O	$(\frac{\alpha}{36}, \frac{9-5\alpha}{144})$	$(\frac{1}{36}, \frac{1}{36})$

Table S6 Nash Game with $\alpha > 2/3$ under Asymmetric Market Size

LEMMA S11. *Suppose neither firm opens his own technology, then the supplier's optimal decision and firms' optimal profits are given by*

(i) if $K \ge \frac{1}{24}$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{CC}} = 0$, $\pi_{m1,2}^{\mathrm{CC}} = \pi_{m2,2}^{\mathrm{CC}} = \frac{(1-s)^3}{12}$;

(ii) if $K < \frac{1}{24}$, the supplier invests in both technologies, and $\pi_{s,2}^{\mathrm{CC}} = \frac{1}{12} - 2K$, $\pi_{m1,2}^{\mathrm{CC}} = \pi_{m2,2}^{\mathrm{CC}} = \frac{1}{48}$.

D.1.2. Scenarios OC and CO. In this scenario, it is supposed that only one firm opens his technology, either F1 or F2. As the two technologies are homogenous, the two scenarios OC and CO are completely equivalent. Therefore, we only consider Scenario OC.

• Option of Investing in Neither: The supplier invests in neither technology and gains zero profit, i.e., $\pi_{s,4}^{\mathrm{OC}} = 0$. Moreover, both manufactures have to order from the outside supplier if profitable. As M_1 has already opened his technology, M_2 has the option to adopt T_1 or T_2.

If M_2 adopts T_2, then his profit is $\frac{(1-A-s)^2}{4}$ if $A < 1-s$; otherwise, zero. Accordingly, M_1's profit is $\frac{(A-s)^2}{4}$ if $A > s$; otherwise, zero.

If M_2 adopts T_1, then the two manufacturers compete in T_1 market with the size of $\widehat{A} = A + \gamma(1-A) = \frac{1+A}{2}$. Then, the two manufacturers will gain the same profit equal to $\frac{(\widehat{A}-s)^2}{9}$ if $\widehat{A} \ge s$; otherwise, zero.

By comparing M_2's profits of adopting T_1 and T_2, we know that if $A \ge \frac{2-s}{4}$, then M_2 adopts T_1

and $\pi^{\mathrm{OC}}_{m1,4} = \pi^{\mathrm{OC}}_{m2,4} = \frac{(\widehat{A}-s)^2}{9}$; if $A < \frac{2-s}{4}$, M_2 adopts T_2, $\pi^{\mathrm{OC}}_{m2,4} = \frac{(1-A-s)^2}{4}$ and $\pi^{\mathrm{OC}}_{m1,4} = \frac{(A-s)^2}{4}$, when $2s-1 \le A < \frac{2-s}{4}$; $\pi^{\mathrm{OC}}_{m1,4} = 0$, when $A < 2s-1$.

Then, players' expected profits in Stage 2 can be expressed as:

$$\begin{aligned}
\pi^{\mathrm{OC}}_{s,2} &= 0;\\
\pi^{\mathrm{OC}}_{m1,2} &= \int_{2s-1}^{\frac{2-s}{4}} \frac{(A-s)^2}{4}\,\mathrm{d}A + \int_{\frac{2-s}{4}}^{1} \frac{(\widehat{A}-s)^2}{9}\,\mathrm{d}A;\\
&= \frac{-371s^3+789s^2-708s+236}{1728};\\
\pi^{\mathrm{OC}}_{m2,2} &= \int_{0}^{\frac{2-s}{4}} \frac{(1-A-s)^2}{4}\,\mathrm{d}A + \int_{\frac{2-s}{4}}^{1} \frac{(\widehat{A}-s)^2}{9}\,\mathrm{d}A;\\
&= \frac{-29s^3+330s^2-492s+200}{1728}.
\end{aligned} \tag{S1}$$

• Option of Investing in One Technology: In this case, the supplier is supposed to invest in only one technology, T_1 or T_2. Intuitively, the opened technology is more attractive for the supplier. That is, the supplier will invest in T_1 instead of T_2. Then, M_2 has the option to choose T_1 or T_2, while M_1 sticks to T_1. Note that both manufacturers never quit the market as they can always gain a positive profit if adopting T_1. We first need to characterize M_2's optimal decision in Stage 3, i.e., which technology to adopt.

If M_2 adopts T_1, the two manufacturers compete in the T_1 market with the size of $\widehat{A}$. By the same analysis as the symmetric model, the supplier will offer the wholesale price $w = \frac{\widehat{A}}{2}$ which is less than s. It implies that manufacturers never choose the outside supplier. Accordingly, $\pi^{\mathrm{OC}}_{m1,4} = \pi^{\mathrm{OC}}_{m2,4} = \frac{\widehat{A}^2}{36}$, and $\pi^{\mathrm{OC}}_{s,4} = \frac{\widehat{A}^2}{6}$.

If M_2 adopts T_2, the manufacturers stand in their own markets. As the supplier only invests in T_1, M_2 has to order from the outside supplier, while M_1 orders from the supplier. Then, $\pi^{\mathrm{OC}}_{m1,4} = \frac{A^2}{16}$, $\pi^{\mathrm{OC}}_{s,4} = \frac{A^2}{8}$, and $\pi^{\mathrm{OC}}_{m2,4} = \frac{(1-A-s)^2}{4}$ if $A < 1-s$; otherwise, zero.

By comparing M_2's profits, we can obtain that if $A \ge \frac{2-3s}{4}$, then M_2 chooses T_1;otherwise, T_2. Back to Stage 2, players' expected profits are given by

$$\begin{aligned}
\pi^{\mathrm{OC}}_{s,2} &= \int_{0}^{\frac{2-3s}{4}} \frac{A^2}{8}\,\mathrm{d}A + \int_{\frac{2-3s}{4}}^{1} \frac{\widehat{A}^2}{6}\,\mathrm{d}A - K\\
&= \frac{-27s^3+108s+160}{2304} - K;\\
\pi^{\mathrm{OC}}_{m1,2} &= \int_{0}^{\frac{2-3s}{4}} \frac{A^2}{16}\,\mathrm{d}A + \int_{\frac{2-3s}{4}}^{1} \frac{\widehat{A}^2}{36}\,\mathrm{d}A\\
&= \frac{-54s^3+81s^2+92}{6912};
\end{aligned}$$

$$\pi_{m2,2}^{\mathrm{OC}} = \int_0^{\frac{2-3s}{4}} \frac{(1-A-s)^2}{4}\,\mathrm{d}A + \int_{\frac{2-3s}{4}}^{1} \frac{\widehat{A}^2}{36}\,\mathrm{d}A$$
$$= \frac{-560.25s^3+1633.5s^2-1539s+578}{6912}. \tag{S2}$$

• Option of Investing in Both Technologies: In this case, as the supplier always offers a lower price than the outside supplier. Therefore, the existence of the outside supplier does not affect players' decisions as well as their expected profits. By the same analysis with the symmetric model, we can obtain

$$\pi_{s,2}^{\mathrm{OC}} = \frac{61}{576} - 2K; \quad \pi_{m1,2}^{\mathrm{OC}} = \frac{23}{1728}; \quad \pi_{m2,2}^{\mathrm{OC}} = \frac{25}{864}. \tag{S3}$$

Define

$$\beta_1^{\mathrm{OC}}(s) = \frac{-27s^3+108s+160}{2304}$$
$$\beta_2^{\mathrm{OC}}(s) = \frac{27s^3-108s+84}{2304}.$$

Note that $\beta_1^{\mathrm{OC}}(s) > \beta_2^{\mathrm{OC}}(s)$. By comparing supplier's profits in (S1), (S2) and (S3), we can obtain supplier's decision in stage 2 as well as players' expected profits which are presented in the following lemma.

LEMMA S12. *Suppose only M_1 opens his own technology, then the supplier's optimal decision and firms' optimal profits are given by*

- *if $K \ge \beta_1^{\mathrm{OC}}(s)$, the supplier invests in neither technology, and $\pi_{s,2}^{\mathrm{OC}} = 0$, and $\pi_{m1,2}^{\mathrm{OC}} = \frac{-371s^3+789s^2-708s+236}{1728}$, $\pi_{m2,2}^{\mathrm{OC}} = \frac{-29s^3+330s^2-492s+200}{1728}$;*
- *if $\beta_2^{\mathrm{OC}}(s) \le K < \beta_1^{\mathrm{OC}}(s)$, the supplier invests in only T_1, and $\pi_{s,2}^{\mathrm{OC}} = \frac{-27s^3+108s+160}{2304} - K$, $\pi_{m1,2}^{\mathrm{OC}} = \frac{-54s^3+81s^2+92}{6912}$, $\pi_{m2,2}^{\mathrm{OC}} = \frac{-560.25s^3+1633.5s^2-1539s+578}{6912}$;*
- *if $K < \beta_2^{\mathrm{OC}}(s)$, the supplier invests in both technologies, and $\pi_{s,2}^{\mathrm{OC}} = \frac{61}{576} - 2K$, $\pi_{m1,2}^{\mathrm{OC}} = \frac{23}{1728}$, $\pi_{m2,2}^{\mathrm{OC}} = \frac{25}{864}$.*

D.1.3. Scenario OO. In this scenario, it is supposed that both manufacturers open technologies.

• Option of Investing in Neither: The supplier invests in neither technology and gains zero profit, i.e., $\pi_{s,4}^{\mathrm{OO}} = 0$. Moreover, both manufactures have to order from the outside supplier if profitable. As both technologies are opened, manufacturers can adopt either technology. By an analogous proof with Lemma 3, one can prove that if $A \ge \frac{1}{2}$, both manufacturers adopt T_1 and $\pi_{m1,1}^{\mathrm{OO}} = \pi_{m2,4}^{\mathrm{OO}} = \frac{(\widehat{A}-s)^2}{9}$; if $A < \frac{1}{2}$, both manufacturers adopt T_2 and $\pi_{m1,4}^{\mathrm{OO}} = \pi_{m2,4}^{\mathrm{OO}N} = \frac{(\widetilde{A}-s)^2}{9}$, where $\widetilde{A} = 1 - \frac{A}{2}$.

Consequently, players' expected profits in Stage 2 can be expressed as:

$$\begin{aligned}
\pi_{s,2}^{\mathrm{OO}} &= 0; \\
\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} &= \int_0^{\frac{1}{2}} \frac{(\widetilde{A}-s)^2}{9}\,\mathrm{d}A + \int_{\frac{1}{2}}^{1} \frac{(\widehat{A}-s)^2}{9}\,\mathrm{d}A; \\
&= \frac{48s^2-84s+37}{432}; \qquad \text{(S4)}
\end{aligned}$$

• Option of Investing in One Technology: In this case, the two technologies are equivalent in the eye of the supplier. Thus, without loss of generality, we assume that the supplier invests in T_1. As both technologies are opened, manufacturers can adopt either technology. By an analogous proof with Lemma 3, one can prove that if $A \geq \frac{3-4s}{3}$, both manufacturers adopt T_1, $\pi_{s,4}^{\mathrm{OO}} = \frac{\widehat{A}^2}{6}$ and $\pi_{m1,4}^{\mathrm{OO}} = \pi_{m2,4}^{\mathrm{OO}} = \frac{\widehat{A}^2}{36}$; if $A < \frac{3-4s}{3}$, both manufacturers adopt T_2, $\pi_{s,4}^{\mathrm{OO}} = 0$ and $\pi_{m1,4}^{\mathrm{OO}} = \pi_{m2,4}^{\mathrm{OO}} = \frac{(\widetilde{A}-s)^2}{9}$.

Back to Stage 2, players' expected profits are given by

$$\begin{aligned}
\pi_{s,2}^{\mathrm{OC}} &= \int_{\frac{3-4s}{3}}^{1} \frac{\widehat{A}^2}{6}\,\mathrm{d}A - K \\
&= \frac{8s^3-36s^2+54s}{243} - K; \\
\pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} &= \int_0^{\frac{3-4s}{3}} \frac{(\widetilde{A}-s)^2}{9}\,\mathrm{d}A + \int_{\frac{3-4s}{3}}^{1} \frac{\widehat{A}^2}{36}\,\mathrm{d}A \\
&= \frac{-64s^3+180s^2-162s+63}{972}. \qquad \text{(S5)}
\end{aligned}$$

• Option of Investing in Both Technologies: In this case, as the supplier always offers a lower price than the outside supplier. Therefore, the existence of the outside supplier does not affect players' decisions as well as their expected profits. By the same analysis with the symmetric model, we can obtain

$$\pi_{s,2}^{\mathrm{OC}} = \frac{37}{288} - 2K; \quad \pi_{m1,2}^{\mathrm{OC}} = \pi_{m2,2}^{\mathrm{OC}} = \frac{37}{1728}. \qquad \text{(S6)}$$

Define

$$\begin{aligned}
\beta_1^{\mathrm{OO}}(s) &= \frac{8s^3-36s^2+54s}{243} \\
\beta_2^{\mathrm{OO}}(s) &= \frac{37}{288} - \frac{8s^3-36s^2+54s}{243}.
\end{aligned}$$

Note that $\beta_1^{\mathrm{OO}}(s) > \beta_2^{\mathrm{OO}}(s)$ for any $s \in [\frac{1}{2}, \frac{2}{3}]$. By comparing supplier's profits in (S4), (S5) and (S6), we can obtain supplier's decision in stage 2 as well as players' expected profits which are presented in the following lemma.

LEMMA S13. *Suppose both manufacturers open technologies, then the supplier's optimal decision and firms' optimal profits are given by*

- *if* $K \geq \beta_1^{\mathrm{OO}}(s)$, *the supplier invests in neither technology, and then,* $\pi_{s,2}^{\mathrm{OO}} = 0$, *and* $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{48s^2-84s+37}{432}$;
- *if* $\beta_2^{\mathrm{OO}}(s) \leq K < \beta_1^{\mathrm{OO}}(s)$, *then the supplier invests in only* T_1, *and then,* $\pi_{s,2}^{\mathrm{OO}} = \frac{8s^3-36s^2+54s}{243} - K$, $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{-64s^3+180s^2-162s+63}{972}$;
- *if* $K < \beta_2^{\mathrm{OO}}(s)$, *then the supplier invests in both technologies, and then* $\pi_{s,2}^{\mathrm{OO}} = \frac{37}{288} - 2K$, $\pi_{m1,2}^{\mathrm{OO}} = \pi_{m2,2}^{\mathrm{OO}} = \frac{37}{1728}$.

D.2. Decisions in Stage 1

Combing the results in Lemmas S11, S12 and S13, we can derive the equilibria in stage 1. Note that $\beta_1^{\mathrm{OC}}(s) > \beta_1^{\mathrm{OO}}(s) > \{\beta_2^{\mathrm{OO}}(s), \frac{1}{24}\} > \beta_2^{\mathrm{OC}}(s)$. However, $\beta_2^{\mathrm{OO}}(s)$ could be larger or less than $\frac{1}{24}$. Table S7 presents the payoff matrix of the Nash Game according to parameter values. We derive the equilibria in each subcase.

(i) As $\frac{48s^2-84s+37}{432} < \frac{-29s^3+330s^2-492s+200}{1728}$, (O,O) is not an equilibrium. One can prove that there exists $a_1 \in [\frac{1}{2}, \frac{2}{3}]$ such that $\frac{(1-s)^3}{12} < \frac{-371s^3+789s^2-708s+236}{1728}$ if $a < a_1$; otherwise, $\frac{(1-s)^3}{12} \geq \frac{-371s^3+789s^2-708s+236}{1728}$. Therefore, if $a < a_1$, both {CO,neither} and {OC,neither} are equilibria; if $a \geq a_1$, then {CC,neither} is a unique equilibrium.

(ii) As $\frac{48s^2-84s+37}{432} < \frac{-560.25s^3+1633.5s^2-1539s+578}{6912}$ and $\frac{(1-s)^3}{12} < \frac{-54s^3+81s^2+92}{6912}$, both {CO,$T_2$} and {OC,$T_1$} are equilibria.

(iii) As $\frac{(1-s)^3}{12} < \frac{-54s^3+81s^2+92}{6912}$, then {CC,neither} is not a equilibrium. One can prove that there exists $a_2 \in [\frac{1}{2}, \frac{2}{3}]$ such that $\frac{-64s^3+180s^2-162s+63}{972} < \frac{-560.25s^3+1633.5s^2-1539s+578}{6912}$ if $a < a_2$; otherwise, $\frac{-64s^3+180s^2-162s+63}{972} \geq \frac{-560.25s^3+1633.5s^2-1539s+578}{6912}$. Therefore, if $a < a_2$, both {CO,T_2} and {OC,T_1} are equilibria; if $a \geq a_2$, then {OO, One} is a unique equilibrium.

(iv) Note that $\frac{(1-s)^3}{12} < \frac{-54s^3+81s^2+92}{6912}$ and $\frac{37}{1728} > \frac{-560.25s^3+1633.5s^2-1539s+578}{6912}$. Thus, {OO, Both} is a unique equilibrium.

(v) As $\frac{1}{48} > \frac{-54s^3+81s^2+92}{6912}$, {CC, Both} is an equilibrium, but not for {OC,T_1} and {CO,T_2}. Also note that $\frac{1}{48} > \frac{-64s^3+180s^2-162s+63}{972}$. It implies {CC, Both} is a pareto-dominate equilibrium even if {OO, One} is an equilibrium.

(vi) In this case, one can prove that both {CC, Both} and {OO, Both} are equilibria. However, {OO, Both} is a pareto-dominate equilibrium.

(vii) As $\frac{1}{48} > \frac{23}{1728}$ and $\frac{25}{864} > \frac{37}{1728}$, {CC, Both} is a unique equilibrium. It is worthy noting that $\frac{37}{1728} > \frac{1}{48}$. That is, manufacturers face a prisoner's dilemma.

Summarizing all the results from (i) to (vii), Figure 8 illustrates the equilibria in different regions, where $\widehat{a}$ is defined as the solution of $\beta_2^{\mathrm{OO}}(s) = \frac{1}{24}$.

	(i): $K \geq \beta_1^{\mathrm{OC}}(s)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{(1-s)^3}{12}, \frac{(1-s)^3}{12})$	$(\frac{-29s^3+330s^2-492s+200}{1728}, \frac{-371s^3+789s^2-708s+236}{1728})$
O	$(\frac{-371s^3+789s^2-708s+236}{1728}, \frac{-29s^3+330s^2-492s+200}{1728})$	$(\frac{48s^2-84s+37}{432}, \frac{48s^2-84s+37}{432})$
	(ii): $\beta_1^{\mathrm{OO}}(s) \leq K < \beta_1^{\mathrm{OC}}(s)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{(1-s)^3}{12}, \frac{(1-s)^3}{12})$	$(\frac{-560.25s^3+1633.5s^2-1539s+578}{6912}, \frac{-54s^3+81s^2+92}{6912})$
O	$(\frac{-54s^3+81s^2+92}{6912}, \frac{-560.25s^3+1633.5s^2-1539s+578}{6912})$	$(\frac{48s^2-84s+37}{432}, \frac{48s^2-84s+37}{432})$
	(iii): $\max\{\beta_2^{\mathrm{OO}}(s), \frac{1}{24}\} \leq K < \beta_1^{\mathrm{OO}}(s)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{(1-s)^3}{12}, \frac{(1-s)^3}{12})$	$(\frac{-560.25s^3+1633.5s^2-1539s+578}{6912}, \frac{-54s^3+81s^2+92}{6912})$
O	$(\frac{-54s^3+81s^2+92}{6912}, \frac{-560.25s^3+1633.5s^2-1539s+578}{6912})$	$(\frac{-64s^3+180s^2-162s+63}{972}, \frac{-64s^3+180s^2-162s+63}{972})$
	(iv): $\beta_2^{\mathrm{OO}}(s) > K \geq \frac{1}{24}$, if $\beta_2^{\mathrm{OO}}(s) \geq \frac{1}{24}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{(1-s)^3}{12}, \frac{(1-s)^3}{12})$	$(\frac{-560.25s^3+1633.5s^2-1539s+578}{6912}, \frac{-54s^3+81s^2+92}{6912})$
O	$(\frac{-54s^3+81s^2+92}{6912}, \frac{-560.25s^3+1633.5s^2-1539s+578}{6912})$	$(\frac{37}{1728}, \frac{37}{1728})$
	(v): $\frac{1}{24} > K \geq \beta_2^{\mathrm{OO}}(s)$, if $\beta_2^{\mathrm{OO}}(s) < \frac{1}{24}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{-560.25s^3+1633.5s^2-1539s+578}{6912}, \frac{-54s^3+81s^2+92}{6912})$
O	$(\frac{-54s^3+81s^2+92}{6912}, \frac{-560.25s^3+1633.5s^2-1539s+578}{6912})$	$(\frac{-64s^3+180s^2-162s+63}{972}, \frac{-64s^3+180s^2-162s+63}{972})$
	(vi): $\beta_2^{\mathrm{OC}}(s) \leq K < \min\{\beta_2^{\mathrm{OO}}(s), \frac{1}{24}\}$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{-560.25s^3+1633.5s^2-1539s+578}{6912}, \frac{-54s^3+81s^2+92}{6912})$
O	$(\frac{-54s^3+81s^2+92}{6912}, \frac{-560.25s^3+1633.5s^2-1539s+578}{6912})$	$(\frac{37}{1728}, \frac{37}{1728})$
	(vii): $K < \beta_2^{\mathrm{OC}}(s)$	
Firm 1 \ Firm 2	C	O
C	$(\frac{1}{48}, \frac{1}{48})$	$(\frac{25}{864}, \frac{23}{1728})$
O	$(\frac{23}{1728}, \frac{25}{864})$	$(\frac{37}{1728}, \frac{37}{1728})$

Table S7 Nash Game in the presence of Outside Supplier