Appendix A.

A.1 The optimal equilibrium solutions under strategy $\mathcal{N}$

As $\frac{d^2\Pi_A^{\mathcal{N}}}{dq_A{}^2} = \frac{d^2\Pi_B^{\mathcal{N}}}{dq_B{}^2} = -2$, then solving $\frac{d\Pi_A^{\mathcal{N}}}{dq_A} = 0$ and $\frac{d\Pi_B^{\mathcal{N}}}{dq_B} = 0$, we can get that $q_A^{\mathcal{N}} = \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A)$ and $q_B^{\mathcal{N}} = \frac{1}{2}(a_B - p_{rB} - c_B\varepsilon_B)$, $\Pi_A^{\mathcal{N}} = \frac{1}{4}(a_A - p_{rA} - c_A\varepsilon_A)^2$ and $\Pi_B^{\mathcal{N}} = \frac{1}{4}(a_B - p_{rB} - c_B\varepsilon_B)^2$, $E^{\mathcal{N}} = \frac{1}{2}e(\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B))$. □

A.2 The optimal equilibrium solutions under strategy $\mathcal{C}$

1. q_B

As $\frac{d^2\Pi_B^{\mathcal{C}}}{dq_B{}^2} = -2$, then solving $\frac{d\Pi_B^{\mathcal{C}}}{dq_B} = 0$, we can get that $q_B = \frac{1}{2}(a_B - w - c_d - c_B\varepsilon_B)$.

2. q_A

As $\frac{d^2\Pi_A^{\mathcal{C}}}{dq_A{}^2} = -2$. The unconstraint solution for this problem is $q_A = \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A)$. Substituting this unconstraint solution into the constraint $\varepsilon q_A > q_B$, identifies a cutoff value of $a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$. Then, we know that when $w \geq a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$, the unconstraint solution is optimal. When $w < a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$, the production quantity of manufacturer A is $q_A = \frac{a_B - w - c_d - c_B\varepsilon_B}{2\varepsilon_A}$.

3. w

Depending on $w \geq a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$ and $w < a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$, we propose two sub-optimization problems (Sub-problem 1 and Sub-problem 2). The optimal solution for the original problem of manufacturer A is thus the maximum of these two sub-problems.

Sub-problem 1: When $w \geq a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$

As $\frac{d^2\Pi_A^{\mathcal{C}}}{dw^2} = -1$. The unconstraint solution for this problem is $w^{\mathcal{C}1} = \frac{1}{2}(a_B - c_A - c_d - c_B\varepsilon_B)$. Substituting this unconstraint solution into the constraint identifies two cutoff values of c_{d0} and c_{d1}, where $c_{d0} = a_B - c_B\varepsilon_B + c_A$, $c_{d1} = a_B - c_B\varepsilon_B - 2(a_A - p_{rA})\varepsilon_A + c_A(1 + 2\varepsilon_A^2)$, when $c_{d1} \leq c_d \leq c_{d0}$, the unconstraint solution is optimal, and $\Pi_A^{C1} = \frac{1}{8}((a_B + c_A - c_d - c_B\varepsilon_B)^2 + 2(a_A - p_{rA} - c_A\varepsilon_A)^2)$. When $c_d < c_{d1}$, the wholesale price of the by-product is $w^{C2} = a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$, and $\Pi_A^{C2} = -\frac{1}{4}(a_A - p_{rA} - c_A\varepsilon_A)((a_A - p_{rA})(-1 + 2\varepsilon_A^2) - \varepsilon_A(2(a_B - c_d - c_B\varepsilon_B) + c_A(1 + 2\varepsilon_A^2)))$.

Sub-problem 2: When $w < a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$

As $\frac{d^2\Pi_A^C}{dw^2} = -1 - \frac{1}{2\varepsilon_A^2}$. The unconstraint solution for this problem is $w^{C3} = \frac{a_B(1+\varepsilon_A^2)-c_d(1+\varepsilon_A^2)-c_B(1+\varepsilon_A^2)\varepsilon_B-(a_A-p_{rA})\varepsilon_A}{1+2\varepsilon_A^2}$. Substituting this unconstraint solution into the constraint identifies a cutoff value of c_{d1}, then when $c_d < c_{d1}$ the unconstraint solution is optimal, and $\Pi_A^{C3} = \frac{(a_A-p_{rA}+\varepsilon_A(a_B-c_d-c_B\varepsilon_B))^2}{4+8\varepsilon_A^2}$. When $c_{d1} \le c_d$, the wholesale price of the by-product is $w^{C4} = a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$, and $\Pi_A^{C4} = -\frac{1}{4}(a_A - p_{rA} - c_A\varepsilon_A)((a_A - p_{rA})(-1 + 2\varepsilon_A^2) - \varepsilon_A(2(a_B - c_d - c_B\varepsilon_B) + c_A(1 + 2\varepsilon_A^2)))$.

Then, when $c_{d1} \le c_d \le c_{d0}$, compare Π_A^{C1} and Π_A^{C4}. We can get that $\Pi_A^{C1} - \Pi_A^{C4} = \frac{1}{8}(a_B - c_d - 2(a_A - p_{rA})\varepsilon_A + c_A(1 + 2\varepsilon_A^2) - c_B\varepsilon_B)^2 > 0$, the optimal equilibrium solution is $w^{C1} = \frac{1}{2}(a_B - c_A - c_d - c_B\varepsilon_B)$, $\Pi_B^{C1} = \frac{1}{16}(a_B + c_A - c_d - c_B\varepsilon_B)^2$, $E^{C1} = \frac{1}{4}e(2\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B + c_A - c_d - c_B\varepsilon_B)(1 - \varepsilon_B))$. When $c_d < c_{d1}$, compare Π_A^{C2} and Π_A^{C3}. We can get that $\Pi_A^{C3} - \Pi_A^{C2} = \frac{\varepsilon_A^2(a_B-c_d-2(a_A-p_{rA})\varepsilon_A+c_A(1+2\varepsilon_A^2)-c_B\varepsilon_B)^2}{4+8\varepsilon_A^2} > 0$, the optimal equilibrium solution is $w^{C3} = \frac{(a_B-c_d-c_B\varepsilon_B)(1+\varepsilon_A^2)-(a_A-p_{rA})\varepsilon_A}{1+2\varepsilon_A^2}$, $\Pi_B^{C3} = \frac{\varepsilon_A^2(a_A-p_{rA}+\varepsilon_A(a_B-c_d-c_B\varepsilon_B))^2}{4(1+2\varepsilon_A^2)^2}$, $E^{C3} = \frac{e\varepsilon_A\varepsilon_B(a_A-p_{rA}+\varepsilon_A(a_B-c_d-c_B\varepsilon_B))}{2+4\varepsilon_A^2}$. When $c_d > c_{d0}$, the optimal equilibrium solution is $w^{C4} = a_B - c_d - a_A\varepsilon_A + p_{rA}\varepsilon_A + c_A\varepsilon_A^2 - c_B\varepsilon_B$, $\Pi_B^{C4} = \frac{1}{4}\varepsilon_A^2(a_A - p_{\mathrm{rA}} - c_A\varepsilon_A)^2$, $E^{C4} = \frac{1}{2}e\varepsilon_A(a_A - p_{\mathrm{rA}} - c_A\varepsilon_A)\varepsilon_B$. As $\frac{d\Pi_A^{C4}}{dc_d} = -\frac{1}{2}\varepsilon_A(a_A - p_{\mathrm{rA}} - c_A\varepsilon_A) < 0$ and $\Pi_A^{C4}|_{c_d=c_{d0}} = -\frac{1}{4}(a_A - p_{\mathrm{rA}} - c_A\varepsilon_A)^2(2\varepsilon_A^2 - 1) < 0$, manufacturer A is not willing to produce any products for sale, so we omit this case in our study. □

A.3 The optimal equilibrium solutions under strategy S if s is exogenous

The proof is similar to that of A.2, and the optimal equilibrium solutions are summarized in Table A.1, where $s_1 = -a_B + c_d + c_B\varepsilon_B + 2(a_A - p_{rA})\varepsilon_A - c_A(1 + 2\varepsilon_A^2)$.

Table A.1

The optimal equilibrium solutions under strategy S if s is exogenous

	$s < s_1$	$s > s_1$
q_A^S	$\frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A)$	$\frac{a_A - p_{rA} + \varepsilon_A(s + a_B - c_d - c_B\varepsilon_B)}{2 + 4\varepsilon_A^2}$
q_B^S	$\frac{1}{4}(s + a_B + c_A - c_d - c_B\varepsilon_B)$	$\frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(s + a_B - c_d - c_B\varepsilon_B))}{2 + 4\varepsilon_A^2}$
w^S	$\frac{1}{2}(s + a_B - c_A - c_d - c_B\varepsilon_B)$	$\frac{-(a_A - p_{rA})\varepsilon_A + (s + a_B - c_d - c_B\varepsilon_B)(1 + \varepsilon_A^2)}{1 + 2\varepsilon_A^2}$
Π_A^S	$\frac{1}{8}((s + a_B + c_A - c_d - c_B\varepsilon_B)^2 + 2(a_A - p_{rA} - c_A\varepsilon_A)^2)$	$\frac{(a_A - p_{rA} + \varepsilon_A(s + a_B - c_d - c_B\varepsilon_B))^2}{4 + 8\varepsilon_A^2}$
Π_B^S	$\frac{1}{16}(s + a_B + c_A - c_d - c_B\varepsilon_B)^2$	$\frac{\varepsilon_A^2(a_A - p_{rA} + \varepsilon_A(s + a_B - c_d - c_B\varepsilon_B))^2}{4(1 + 2\varepsilon_A^2)^2}$
E^S	$\frac{1}{4}e(2(a_A - p_{rA})\varepsilon_A + c_A(-1 - 2\varepsilon_A^2 + \varepsilon_B) + (a_B - c_d + s - c_B\varepsilon_B)(-1 + \varepsilon_B))$	$\frac{e\varepsilon_A\varepsilon_B(a_A - p_{rA} + \varepsilon_A(s + a_B - c_d - c_B\varepsilon_B))}{2 + 4\varepsilon_A^2}$

□

A.4 The optimal equilibrium solutions under strategy S if s is endogenous

The proof is similar to that of A.2, and the optimal equilibrium solutions are summarized in Table A.2, where $e_1 = \frac{2\varepsilon_A(-a_A + p_{rA} + c_A\varepsilon_A)}{-1 + \varepsilon_B}$, $c_{d6} = e + a_B + c_A - (e + c_B)\varepsilon_B$, $c_{d7} = e + a_B - 4(a_A - p_{rA})\varepsilon_A + c_A(1 + 4\varepsilon_A^2) - (e + c_B)\varepsilon_B$, $c_{d8} = -e + a_B + c_A + (e - c_B)\varepsilon_B$. As $c_{d6} > c_{d0}$, we just consider the case where $c_d \leq c_{d0}$.

Table A.2

The optimal equilibrium solutions under strategy $\mathcal{S}$ if s is endogenous

	$\langle q_A, w, q_B, s\rangle^{\mathcal{S}}$
$EqS1^{\mathcal{S}}$	$\langle \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), \frac{1}{4}(e + a_B - 3c_A - c_d - (e + c_B)\varepsilon_B), \frac{1}{8}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B), \frac{1}{2}(e - a_B - c_A + c_d + (-e + c_B)\varepsilon_B)\rangle$
$EqS2^{\mathcal{S}}$	$\langle \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), (a_A - p_{rA})\varepsilon_A - c_A(1 + \varepsilon_A^2), \frac{1}{2}\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A), 2\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - c_d - c_B\varepsilon_B + c_A)\rangle$
$EqS3^{\mathcal{S}}$	$\langle \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), \frac{1}{2}(a_B - c_A - c_d - c_B\varepsilon_B), \frac{1}{4}(a_B + c_A - c_d - c_B\varepsilon_B), 0\rangle$
$EqS4^{\mathcal{S}}$	$\langle \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B)}{2 + 4\varepsilon_A^2}, \frac{(a_B - c_d - c_B\varepsilon_B)(1 + \varepsilon_A^2) - (a_A - p_{rA})\varepsilon_A}{1 + 2\varepsilon_A^2}, \frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B))}{2 + 4\varepsilon_A^2}, 0\rangle$

Moreover, the optimal choice of the triplets of $\langle q_A, w, q_B, s\rangle^{\mathcal{S}}$ can be characterized as follows

Condition			$\langle q_A, w, q_B, s\rangle^{\mathcal{S}}$
	$c_d \le c_{d1}$	$\Rightarrow$	$EqS4^{\mathcal{S}}$
$\delta_B > 1$	$c_{d1} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{S}}$
$\delta_B < 1$ and $e < e_1$	$c_{d1} \le c_d \le c_{d8}$	$\Rightarrow$	$EqS3^{\mathcal{S}}$
$\delta_B < 1$ and $e_1 < e$	$c_{d1} \le c_d \le \min\{c_{d0}, c_{d7}\}$	$\Rightarrow$	$EqS2^{\mathcal{S}}$
$\delta_B < 1$ and $e < e_1$	$c_{d8} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS1^{\mathcal{S}}$
$\delta_B < 1$ and $e_1 < e$	$\min\{c_{d0}, c_{d7}\} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS1^{\mathcal{S}}$

Furthermore, the total profits of both manufacturers, the benefit of the government, and the environmental impact under strategy $\mathcal{S}$, $\Pi_A^{\mathcal{S}}$, $\Pi_B^{\mathcal{S}}$, $G^{\mathcal{S}}$ and $E^{\mathcal{S}}$ in each of the possible equilibrium solutions can also be solved. □

A.5 The optimal equilibrium solutions under strategy $\mathcal{T}$ and $\mathcal{NT}$ if t is exogenous

The proof is similar to that of A.2, and the optimal equilibrium solutions are summarized in Tables A.3 and A.4, where $t_1 = \frac{-a_B + c_d + 2(a_A - p_{rA})\varepsilon_A - c_A(1 + 2\varepsilon_A^2) + c_B\varepsilon_B}{1 + 2\varepsilon_A^2 - \varepsilon_B}$.

Table A.3

The optimal equilibrium solutions under strategy $\mathcal{T}$ if t is exogenous

	$t < t_1$	$t > t_1$
$q_A^{\mathcal{T}}$	$\frac{1}{2}(a_A - p_{rA} - (t + c_A)\varepsilon_A)$	$\frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - (t + c_B)\varepsilon_B)}{2 + 4\varepsilon_A^2}$
$q_B^{\mathcal{T}}$	$\frac{1}{4}(t + a_B + c_A - c_d - (t + c_B)\varepsilon_B)$	$\frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (t + c_B)\varepsilon_B))}{2 + 4\varepsilon_A^2}$
$w^{\mathcal{T}}$	$\frac{1}{2}(-t + a_B - c_A - c_d - (t + c_B)\varepsilon_B)$	$\frac{(a_B(1 + \varepsilon_A^2) - (a_A - p_{rA})\varepsilon_A - c_d(1 + \varepsilon_A^2) - (t + c_B)(1 + \varepsilon_A^2)\varepsilon_B)}{1 + 2\varepsilon_A^2}$
$\Pi_A^{\mathcal{T}}$	$\frac{1}{8}((t + a_B + c_A - c_d - (t + c_B)\varepsilon_B)^2 + 2(a_A - p_{rA} - (t + c_A)\varepsilon_A)^2)$	$\frac{(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (t + c_B)\varepsilon_B))^2}{4 + 8\varepsilon_A^2}$
$\Pi_B^{\mathcal{T}}$	$\frac{1}{16}(t + a_B + c_A - c_d - (t + c_B)\varepsilon_B)^2$	$\frac{\varepsilon_A^2(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (t + c_B)\varepsilon_B))^2}{4(1 + 2\varepsilon_A^2)^2}$
$E^{\mathcal{T}}$	$\frac{1}{4}e(c_d + 2(a_A - p_{rA})\varepsilon_A + (a_B - c_B\varepsilon_B - t\varepsilon_B)(-1 + \varepsilon_B) - c_d\varepsilon_B + (t + c_A)(-1 - 2\varepsilon_A^2 + \varepsilon_B))$	$\frac{e\varepsilon_A\varepsilon_B(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (t + c_B)\varepsilon_B))}{2 + 4\varepsilon_A^2}$

Table A.4

The optimal equilibrium solutions under strategy $\mathcal{NT}$ if t is exogenous

$q_A^{\mathcal{NT}}$	$q_B^{\mathcal{NT}}$	$\Pi_A^{\mathcal{NT}}$	$\Pi_B^{\mathcal{NT}}$	$E^{\mathcal{NT}}$
$\frac{1}{2}(a_A - p_{rA} - (t + c_A)\varepsilon_A)$	$\frac{1}{2}(a_B - p_{rB} - (t + c_B)\varepsilon_B)$	$\frac{1}{4}(a_A - p_{rA} - (t + c_A)\varepsilon_A)^2$	$\frac{1}{4}(a_B - p_{rB} - (t + c_B)\varepsilon_B)^2$	$\frac{1}{2}e(\varepsilon_A(a_A - p_{rA} - (t + c_A)\varepsilon_A) + \varepsilon_B(a_B - p_{rB} - (t + c_B)\varepsilon_B))$

□

A.6 The optimal equilibrium solutions under strategy $\mathcal{T}$ and $\mathcal{NT}$ if t is endogenous

The proof is similar to that of A.2, and the optimal equilibrium solutions are summarized in Tables A.5 and A.6, where $e_4 = -c_A + \frac{a_A - p_{rA}}{\varepsilon_A}$, $e_5 = -c_B + \frac{2(a_B - p_{rB})}{\varepsilon_B} + \frac{-\varepsilon_A(a_A - p_{rA} + (-c_A + c_B)\varepsilon_A) + (-a_B + p_{rB})\varepsilon_B}{\varepsilon_A^2 + \varepsilon_B^2}$, $e_6 = -\frac{(a_A - p_{rA})(\varepsilon_A^2 + 2\varepsilon_B^2) + \varepsilon_A(\varepsilon_B(-a_B + p_{rB} + c_B\varepsilon_B) - c_A(\varepsilon_A^2 + 2\varepsilon_B^2))}{\varepsilon_A(\varepsilon_A^2 + \varepsilon_B^2)}$, $c_{d10} = a_B - \frac{(a_A - p_{rA})(-1 + \varepsilon_B)}{\varepsilon_A} + (c_A - c_B)\varepsilon_B$, $c_{d11} = a_B + \frac{a_A - p_{rA}}{\varepsilon_A} - (e + c_B)\varepsilon_B$, $c_{d12} = -e +$

$a_B - c_A + c_A\varepsilon_B - c_B\varepsilon_B - \frac{(a_A-p_{rA}-(e+c_A)\varepsilon_A)(2\varepsilon_A^2+1-\varepsilon_B)}{\sqrt{(1+2\varepsilon_A^2)(2\varepsilon_A^2+(-1+\varepsilon_B)^2)}}(\sqrt{2}+\frac{\varepsilon_B^2}{\sqrt{2}(1+2\varepsilon_A^2-\varepsilon_B)}+\frac{4(1-\varepsilon_B+\varepsilon_B^2)}{\sqrt{2}(-1+2\varepsilon_A^2+\varepsilon_B)}) - \frac{(2(a_A-p_{rA})\varepsilon_A+e(-1+\varepsilon_B)+c_A(-1+\varepsilon_B))(-2+\varepsilon_B)}{-1+2\varepsilon_A^2+\varepsilon_B}$, $c_{d13} = e + a_B + c_A + \frac{2\varepsilon_A(-a_A+p_{rA}+(e+c_A)\varepsilon_A)(-1+\varepsilon_B)}{4\varepsilon_A^2+(-1+\varepsilon_B)^2} - (e+c_B)\varepsilon_B$.

Table A.5

The optimal equilibrium solutions under strategy $\mathcal{T}$ if t is endogenous

	$\langle q_A, w, q_B, t\rangle^{\mathcal{T}}$
$EqS1^{\mathcal{T}}$	$\langle \frac{1}{2}(a_A - p_{rA} - \varepsilon_A(c_A + \frac{e + c_d + 2(a_A - p_{rA})\varepsilon_A + 2e\varepsilon_A^2 + a_B(-1+\varepsilon_B) + (-2e + c_B - c_d)\varepsilon_B + (e - c_B)\varepsilon_B^2 + c_A(-1 - 2\varepsilon_A^2 + \varepsilon_B)}{2(2\varepsilon_A^2 + (-1+\varepsilon_B)^2)})), \frac{(-e - 2\varepsilon_A(a_A - p_{rA} + e\varepsilon_A) - c_d(3 + 4\varepsilon_A^2) + c_A(1 + 2\varepsilon_A^2 - 3\varepsilon_B)(-1+\varepsilon_B) + (e - 3c_B)\varepsilon_B - 2(-2c_d + \varepsilon_A(a_A - p_{rA} + (e + 2c_B)\varepsilon_A))\varepsilon_B + (e + 4c_B - c_d)\varepsilon_B^2 - (e + c_B)\varepsilon_B^3 + a_B(3 + 4\varepsilon_A^2 - 4\varepsilon_B + \varepsilon_B^2))}{4(2\varepsilon_A^2 + (-1+\varepsilon_B)^2)}, \frac{1}{8}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B + \frac{2\varepsilon_A(-(a_A - p_{rA})(-1+\varepsilon_B) + \varepsilon_A(a_B - c_d + (c_A - c_B)\varepsilon_B))}{2\varepsilon_A^2 + (-1+\varepsilon_B)^2}), \frac{e + c_d + 2(a_A - p_{rA})\varepsilon_A + 2e\varepsilon_A^2 + a_B(-1+\varepsilon_B) + (-2e + c_B - c_d)\varepsilon_B + (e - c_B)\varepsilon_B^2 + c_A(-1 - 2\varepsilon_A^2 + \varepsilon_B)}{2(2\varepsilon_A^2 + (-1+\varepsilon_B)^2)} \rangle$
$EqS2^{\mathcal{T}}$	$\langle \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - (e + c_B)\varepsilon_B)}{4 + 8\varepsilon_A^2}, \frac{-(a_A - p_{rA})(1 + 3\varepsilon_A^2) + (\varepsilon_A + \varepsilon_A^3)(a_B - c_d - (e + c_B)\varepsilon_B)}{2(\varepsilon_A + 2\varepsilon_A^3)}, \frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (e + c_B)\varepsilon_B))}{4 + 8\varepsilon_A^2}, \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d + (e - c_B)\varepsilon_B)}{2\varepsilon_A\varepsilon_B} \rangle$
$EqS3^{\mathcal{T}}$	$\langle \frac{1}{2}\left(a_A - p_{rA} + \frac{\varepsilon_A(-a_B + c_d + (-c_A + c_B)\varepsilon_B)}{-1+\varepsilon_B}\right), \frac{-a_B + c_d + (-c_A + c_B)\varepsilon_B}{-1+\varepsilon_B}, 0, \frac{a_B + c_A - c_d - c_B\varepsilon_B}{-1+\varepsilon_B} \rangle$
$EqS4^{\mathcal{T}}$	$\langle 0, -\frac{a_A}{\varepsilon_A}, 0, \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B)}{\varepsilon_A\varepsilon_B} \rangle$

Moreover, the optimal choice of the triplets of $\langle q_A, w, q_B, t\rangle^{\mathcal{T}}$ can be characterized as follows

Condition			$\langle q_A, w, q_B, t\rangle^{\mathcal{T}}$
$e_4 < e$	$c_d \le c_{d11}$	$\Rightarrow$	$EqS2^{\mathcal{T}}$
	$c_{d11} \le c_d \le \min\{c_{d0}, c_{d10}\}$	$\Rightarrow$	$EqS4^{\mathcal{T}}$
	$\min\{c_{d0}, c_{d10}\} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{T}}$
$e < e_4$	$c_d \le c_{d12}$	$\Rightarrow$	$EqS2^{\mathcal{T}}$
	$c_{d12} \le c_d \le \min\{c_{d0}, c_{d13}\}$	$\Rightarrow$	$EqS1^{\mathcal{T}}$
	$\min\{c_{d0}, c_{d13}\} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{T}}$

Furthermore, the total profits of both manufacturers, the environmental impact, and the benefit of the government under $\mathcal{T}$, $\Pi_A^{\mathcal{T}}$, $\Pi_B^{\mathcal{T}}$, $E^{\mathcal{T}}$ and $G^{\mathcal{T}}$ in each of the possible equilibrium solutions can also be solved.

Table A.6

The optimal equilibrium solutions under strategy $\mathcal{NT}$ if t is endogenous

	$e < \min\{e_5, e_6\}$	$e > e_5$	$e > e_6$
$q_A^{\mathcal{NT}}$	$\frac{1}{2}(a_A - p_{rA} - \frac{\varepsilon_A(a_A\varepsilon_A - p_{rA}\varepsilon_A + (e + c_A)\varepsilon_A^2 + \varepsilon_B(a_B - p_{rB} + (e + 2c_A - c_B)\varepsilon_B))}{2(\varepsilon_A^2 + \varepsilon_B^2)})$	$\frac{1}{2}(a_A - p_{rA} - \varepsilon_A(c_A - c_B + \frac{a_B - p_{rB}}{\varepsilon_B}))$	0
$q_B^{\mathcal{NT}}$	$\frac{1}{2}(a_B - p_{rB} - \frac{\varepsilon_B(a_A\varepsilon_A - p_{rA}\varepsilon_A + (e - c_A + 2c_B)\varepsilon_A^2 + \varepsilon_B(a_B - p_{rB} + (e + c_B)\varepsilon_B))}{2(\varepsilon_A^2 + \varepsilon_B^2)})$	0	$\frac{1}{2}(a_B - p_{rB} + (c_A - c_B - \frac{a_A - p_{rA}}{\varepsilon_A})\varepsilon_B)$
$\mathrm{t}^{\mathcal{NT}}$	$\frac{a_A\varepsilon_A - p_{rA}\varepsilon_A + (e - c_A)\varepsilon_A^2 + \varepsilon_B(a_B - p_{rB} + (e - c_B)\varepsilon_B)}{2(\varepsilon_A^2 + \varepsilon_B^2)}$	$-c_B + \frac{a_B - p_{rB}}{\varepsilon_B}$	$-c_A + \frac{a_A - p_{rA}}{\varepsilon_A}$
$\Pi_A^{\mathcal{NT}}$	$\frac{\left((e + c_A)\varepsilon_A^3 + \varepsilon_A\varepsilon_B(a_B - p_{rB} + (e + 2c_A - c_B)\varepsilon_B - (a_A - p_{rA})(\varepsilon_A^2 + 2\varepsilon_B^2)\right)^2}{16(\varepsilon_A^2 + \varepsilon_B^2)^2}$	$\frac{(a_A\varepsilon_B - p_{rA}\varepsilon_B + \varepsilon_A(-a_B + p_{rB} + (-c_A + c_B)\varepsilon_B))^2}{4\varepsilon_B^2}$	0
$\Pi_B^{\mathcal{NT}}$	$\frac{\left((2(-a_B+p_{rB})\varepsilon_A^2+\varepsilon_A(a_A-p_{rA}+(e-c_A+2c_B)\varepsilon_A)\varepsilon_B + (-a_B+p_{rB})\varepsilon_B^2+(e+c_B)\varepsilon_B^3)\right)^2}{16(\varepsilon_A^2+\varepsilon_B^2)^2}$	0	$\frac{(a_A\varepsilon_B - p_{rA}\varepsilon_B + \varepsilon_A(-a_B + p_{rB} + (-c_A + c_B)\varepsilon_B))^2}{4\varepsilon_A^2}$
$E^{\mathcal{NT}}$	$-\frac{1}{4}e(-a_A\varepsilon_A + p_{rA}\varepsilon_A + (e + c_A)\varepsilon_A^2 + \varepsilon_B(-a_B + p_{rB} + (e + c_B)\varepsilon_B))$	$\frac{1}{2}e\varepsilon_A(a_A - p_{rA} - \varepsilon_A(c_A - c_B + \frac{a_B - p_{rB}}{\varepsilon_B}))$	$\frac{1}{2}e\varepsilon_B(a_B - p_{rB} + (c_A - c_B - \frac{a_A - p_{rA}}{\varepsilon_A})\varepsilon_B)$

Furthermore, the benefit of the government under $\mathcal{NT}$, $G^{\mathcal{NT}}$ in each of the possible equilibrium solutions can also be solved. □

A.7 The optimal equilibrium solutions under strategy $\mathcal{S}'$

The proof is similar to that of A.2, and the optimal equilibrium solutions are summarized in Table A.7, where e_{s1}, e_{s2}, e_{s3}, c_{ds1}, c_{ds2}, c_{ds3}, c_{ds4}, c_{ds5} are given in Appendix B.

Table A.7

The optimal equilibrium solutions under strategy $\mathcal{S}'$

	$\langle q_A, w, q_B, s\rangle^{\mathcal{S}'}$
$EqS1^{\mathcal{S}'}$	$\left\langle \begin{array}{c} \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), 2e + 2a_B + c_A - 2c_d - 2(e + c_B)\varepsilon_B, \\ e + a_B + c_A - c_d - (e + c_B)\varepsilon_B, 4e + 3a_B + 3c_A - 3c_d - (4e + 3c_B)\varepsilon_B \end{array} \right\rangle$
$EqS2^{\mathcal{S}'}$	$\left\langle \begin{array}{c} \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), (a_A - p_{rA})\varepsilon_A - c_A(1 + \varepsilon_A^2), \frac{1}{2}\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A), \\ -(a_B - c_d - c_B\varepsilon_B + c_A) + 2\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) \end{array} \right\rangle$
$EqS3^{\mathcal{S}'}$	$\langle \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), \frac{1}{2}(a_B - c_A - c_d - c_B\varepsilon_B), \frac{1}{4}(a_B + c_A - c_d - c_B\varepsilon_B), 0\rangle$
$EqS4^{\mathcal{S}'}$	$\left\langle \begin{array}{c} \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - (e + c_B)\varepsilon_B)}{1 + \varepsilon_A^2}, \\ 2a_B + \frac{a_A - p_{rA}}{\varepsilon_A} - 2(c_d + (e + c_B)\varepsilon_B), \\ \frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (e + c_B)\varepsilon_B))}{1 + \varepsilon_A^2}, \frac{\left(\begin{array}{c}(a_A - p_{rA} + (a_B - c_d)\varepsilon_A)(1 + 3\varepsilon_A^2) \\ -\varepsilon_A(2e + c_B + (4e + 3c_B)\varepsilon_A^2)\varepsilon_B\end{array}\right)}{\varepsilon_A + \varepsilon_A^3} \end{array} \right\rangle$
$EqS5^{\mathcal{S}'}$	$\left\langle \begin{array}{c} \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B)}{2 + 4\varepsilon_A^2}, \\ -\frac{(a_A - p_{rA})\varepsilon_A - a_B(1 + \varepsilon_A^2) + c_d(1 + \varepsilon_A^2) + c_B(1 + \varepsilon_A^2)\varepsilon_B}{1 + 2\varepsilon_A^2}, \\ \frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B))}{2 + 4\varepsilon_A^2}, 0 \end{array} \right\rangle$

Moreover, the optimal choice of the triplets of $\langle q_A, w, q_B, s\rangle^{\mathcal{S}'}$ can be characterized as follows

Condition			$\langle q_A, w, q_B, s\rangle^{\mathcal{S}'}$
$e < e_{s3}$	$c_d \le c_{ds5}$	$\Rightarrow$	$EqS4^{\mathcal{S}'}$
	$c_{ds5} \le c_d \le \min\{c_{ds2}, c_{d0}\}$	$\Rightarrow$	$EqS1^{\mathcal{S}'}$
	$\min\{c_{ds2}, c_{d0}\} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{S}'}$
$e_{s3} < e < e_{s2}$	$c_d \le c_{ds3}$	$\Rightarrow$	$EqS4^{\mathcal{S}'}$
	$c_{ds3} \le c_d \le c_{ds1}$	$\Rightarrow$	$EqS2^{\mathcal{S}'}$
	$c_{ds1} \le c_d \le \min\{c_{ds2}, c_{d0}\}$	$\Rightarrow$	$EqS1^{\mathcal{S}'}$
	$\min\{c_{ds2}, c_{d0}\} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{S}'}$
$e_{s2} < e < e_{s1}$ and $1 < \varepsilon_B$ or $e_{s2} < e$ and $\varepsilon_B < 1$	$c_d \le c_{ds4}$	$\Rightarrow$	$EqS4^{\mathcal{S}'}$
	$c_{ds4} \le c_d \le c_{d1}$	$\Rightarrow$	$EqS5^{\mathcal{S}'}$
	$c_{d1} \le c_d \le c_{ds1}$	$\Rightarrow$	$EqS2^{\mathcal{S}'}$
	$c_{ds1} \le c_d \le \min\{c_{ds2}, c_{d0}\}$	$\Rightarrow$	$EqS1^{\mathcal{S}'}$
	$\min\{c_{ds2}, c_{d0}\} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{S}'}$
$e_{s1} < e$ and $1 < \varepsilon_B$	$c_d \le c_{ds4}$	$\Rightarrow$	$EqS4^{\mathcal{S}'}$
	$c_{ds4} \le c_d \le c_{d1}$	$\Rightarrow$	$EqS5^{\mathcal{S}'}$
	$c_{d1} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{S}'}$

Furthermore, the total profits of both manufacturers, the benefit of the government, and the environmental impact of the strategy $\mathcal{S}'$, $\Pi_A^{\mathcal{S}'}$, $\Pi_B^{\mathcal{S}'}$, $G^{\mathcal{S}'}$ and $E^{\mathcal{S}'}{}'$ in each of the possible equilibriums can be solved. □

A.8 The optimal equilibrium solutions under strategy $\mathcal{NT}'$ and $\mathcal{T}'$

The proof is similar to that of A.2, and the optimal equilibrium solutions are summarized in Tables A.8 and A.9, where e_{t1}, e_{t2}, e_{t3}, e_{t4}, e_{t5}, c_{dt1}, c_{dt2}, c_{dt3}, c_{dt4}, c_{dt5} are given in Appendix B.

Table A.8

The optimal equilibrium solutions under strategy $\mathcal{NT}'$

	$\mathrm{e} < e_{t3}$	$e_{t3} < e < \min\{e_{t1}, e_{t2}\}$	$e > e_{t1}$	$e > e_{t2}$
$q_A^{\mathcal{NT}'}$	$\frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A)$	$\frac{1}{2}\left(a_A - p_{rA} + \frac{\varepsilon_A((a_A - p_{rA})\varepsilon_A - 2(e + c_A)\varepsilon_A^2 + \varepsilon_B(a_B - p_{rB} - (2e + c_A + c_B)\varepsilon_B))}{\varepsilon_A^2 + \varepsilon_B^2}\right)$	$\frac{1}{2}(a_A - p_{rA} - \varepsilon_A(c_A - c_B + \frac{a_B - p_{rB}}{\varepsilon_B}))$	0
$q_B^{\mathcal{NT}'}$	$\frac{1}{2}(a_B - p_{rB} - c_B\varepsilon_B)$	$\frac{1}{2}\left(a_B - p_{rB} + \frac{\varepsilon_B((a_A - p_{rA})\varepsilon_A - (2e + c_A + c_B)\varepsilon_A^2 + \varepsilon_B(a_B - p_{rB} - 2(e + c_B)\varepsilon_B))}{\varepsilon_A^2 + \varepsilon_B^2}\right)$	0	$\frac{1}{2}(a_B - p_{rB} + (c_A - c_B - \frac{a_A - p_{rA}}{\varepsilon_A})\varepsilon_B)$
$t^{\mathcal{NT}'}$	0	$\frac{-(a_A - p_{rA})\varepsilon_A + (2e + c_A)\varepsilon_A^2 + \varepsilon_B(-a_B + p_{rB} + (2e + c_B)\varepsilon_B)}{\varepsilon_A^2 + \varepsilon_B^2}$	$-c_B + \frac{a_B - p_{rB}}{\varepsilon_B}$	$-c_A + \frac{a_A - p_{rA}}{\varepsilon_A}$
$\Pi_A^{\mathcal{NT}'}$	$\frac{1}{4}(a_A - p_{rA} - c_A\varepsilon_A)^2$	$\frac{\left(2(e + c_A)\varepsilon_A^3 + \varepsilon_A\varepsilon_B(-a_B + p_{rB} + (2e + c_A + c_B)\varepsilon_B) - (a_A - p_{rA})(2\varepsilon_A^2 + \varepsilon_B^2)\right)^2}{4(\varepsilon_A^2 + \varepsilon_B^2)^2}$	$\frac{\left((a_A - p_{rA})\varepsilon_B + \varepsilon_A(-a_B + p_{rB} + (-c_A + c_B)\varepsilon_B)\right)^2}{4\varepsilon_B^2}$	0
$\Pi_B^{\mathcal{NT}'}$	$\frac{1}{4}(a_B - p_{rb} - c_B\varepsilon_B)^2$	$\frac{\left((-a_B + p_{rB})\varepsilon_A^2 + \varepsilon_A(-a_A + p_{rA} + (2e + c_A + c_B)\varepsilon_A)\varepsilon_B + 2(-a_B + p_{rB})\varepsilon_B^2 + 2(e + c_B)\varepsilon_B^3\right)^2}{4(\varepsilon_A^2 + \varepsilon_B^2)^2}$	0	$\frac{\left((a_A - p_{rA})\varepsilon_B + \varepsilon_A(-a_B + p_{rB} + (-c_A + c_B)\varepsilon_B)\right)^2}{4\varepsilon_A^2}$
$E^{\mathcal{NT}'}$	$\frac{1}{2}e(\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B))$	$-e(-(a_A - p_{rA})\varepsilon_A + (e + c_A)\varepsilon_A^2 + \varepsilon_B(-a_B + p_{rB} + (e + c_B)\varepsilon_B))$	$\frac{1}{2}e\varepsilon_A(a_A - p_{rA} - \varepsilon_A(c_A - c_B + \frac{a_B - p_{rB}}{\varepsilon_B}))$	$\frac{1}{2}e\varepsilon_B(a_B - p_{rB} + (c_A - c_B - \frac{a_A - p_{rA}}{\varepsilon_A})\varepsilon_B)$

Table A.9

The optimal equilibrium solutions under strategy $\mathcal{T}'$

	$\langle q_A, w, q_B, t\rangle^{\mathcal{T}'}$
$EqS1^{\mathcal{T}'}$	$\langle \frac{\left(a_A - p_{rA} - \varepsilon_A(c_A + (4e + 3a_B - 3c_d - 4(a_A - p_{rA})\varepsilon_A + 8e\varepsilon_A^2 + c_A(3 + 4\varepsilon_A^2) - 8e\varepsilon_B - 3(a_B + c_A + c_B - c_d)\varepsilon_B + (4e + 3c_B)\varepsilon_B^2\right)}{2(4\varepsilon_A^2 + (-1 + \varepsilon_B)^2)}, \frac{\left(-2c_A + c_d + 2(a_A - p_{rA})\varepsilon_A - 2(2c_A + c_d)\varepsilon_A^2 + (c_A + c_B + c_d + 2(a_A - p_{rA})\varepsilon_A - 2(2e + c_A + c_B)\varepsilon_A^2)\varepsilon_B + (2e + c_A + c_B - 2c_d)\varepsilon_B^2\right) - 2(e + c_B)\varepsilon_B^3 + 2e(-1 - 2\varepsilon_A^2 + \varepsilon_B) + a_B\left(2\varepsilon_A^2 + (-1 + \varepsilon_B)(1 + 2\varepsilon_B)\right)}{4\varepsilon_A^2 + (-1 + \varepsilon_B)^2}, e + a_B + c_A - c_d - (e + c_B)\varepsilon_B + \frac{(\varepsilon_A\left((a_A - p_{rA})(-1 + \varepsilon_B) + \varepsilon_A(-2e - 3a_B + 3c_d + (2e + 3c_B)\varepsilon_B - c_A(2 + \varepsilon_B))\right))}{4\varepsilon_A^2 + (-1 + \varepsilon_B)^2}, \frac{\left(4e + 3a_B - 3c_d - 4(a_A - p_{rA})\varepsilon_A + 8e\varepsilon_A^2 + c_A(3 + 4\varepsilon_A^2) - 8e\varepsilon_B - 3(a_B + c_A + c_B - c_d)\varepsilon_B + (4e + 3c_B)\varepsilon_B^2\right)}{4\varepsilon_A^2 + (-1 + \varepsilon_B)^2}$
$EqS2^{\mathcal{T}'}$	$\langle \frac{-(a_A - p_{rA})(-1 + \varepsilon_B) + \varepsilon_A(a_B - c_d + (c_A - c_B)\varepsilon_B)}{2 + 4\varepsilon_A^2 - 2\varepsilon_B}, \frac{(-(a_A - p_{rA})\varepsilon_A + a_B(1 + \varepsilon_A^2) - c_d(1 + \varepsilon_A^2) + (-(a_A - p_{rA})\varepsilon_A + c_A(1 + \varepsilon_A^2) - c_B(1 + \varepsilon_A^2))\varepsilon_B)}{1 + 2\varepsilon_A^2 - \varepsilon_B}, \frac{\varepsilon_A(-(a_A - p_{rA})(-1 + \varepsilon_B) + \varepsilon_A(a_B - c_d + (c_A - c_B)\varepsilon_B))}{2 + 4\varepsilon_A^2 - 2\varepsilon_B}, \frac{-a_B + c_d + 2(a_A - p_{rA})\varepsilon_A - c_A(1 + 2\varepsilon_A^2) + c_B\varepsilon_B}{1 + 2\varepsilon_A^2 - \varepsilon_B} \rangle$
$EqS3^{\mathcal{T}'}$	$\langle \frac{1}{2}(a_A - p_{rA} - c_A\varepsilon_A), \frac{1}{2}(a_B - c_A - c_d - c_B\varepsilon_B), \frac{1}{4}(a_B + c_A - c_d - c_B\varepsilon_B), 0 \rangle$
$EqS4^{\mathcal{T}'}$	$\langle \frac{1}{2}\left(a_A - p_{rA} + \frac{\varepsilon_A(-a_B + c_d + (-c_A + c_B)\varepsilon_B)}{-1 + \varepsilon_B}\right), \frac{-a_B + c_d + (-c_A + c_B)\varepsilon_B}{-1 + \varepsilon_B}, 0, \frac{a_B + c_A - c_d - c_B\varepsilon_B}{-1 + \varepsilon_B} \rangle$
$EqS5^{\mathcal{T}'}$	$\langle \frac{a_A + \varepsilon_A(a_B - c_d - (e + c_B)\varepsilon_B)}{1 + \varepsilon_A^2}, 2a_B + \frac{a_A - p_{rA}}{\varepsilon_A} - 2(c_d + (e + c_B)\varepsilon_B), \frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - (e + c_B)\varepsilon_B))}{1 + \varepsilon_A^2}, \frac{(-(a_A - p_{rA} + (a_B - c_d)\varepsilon_A)(1 + 3\varepsilon_A^2) + \varepsilon_A(2e + c_B + (4e + 3c_B)\varepsilon_A^2)\varepsilon_B)}{\varepsilon_A(1 + \varepsilon_A^2)\varepsilon_B} \rangle$
$EqS6^{\mathcal{T}'}$	$\langle \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B)}{2 + 4\varepsilon_A^2}, -\frac{(a_A - p_{rA})\varepsilon_A - (a_B - c_d - c_B\varepsilon_B)(1 + \varepsilon_A^2)}{1 + 2\varepsilon_A^2}, \frac{\varepsilon_A(a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B))}{2 + 4\varepsilon_A^2}, 0 \rangle$
$EqS7^{\mathcal{T}'}$	$\langle 0, -\frac{a_A - p_{rA}}{\varepsilon_A}, 0, \frac{a_A - p_{rA} + \varepsilon_A(a_B - c_d - c_B\varepsilon_B)}{\varepsilon_A\varepsilon_B} \rangle$

Moreover, the optimal choice of the triplets of $\langle q_A, w, q_B, t\rangle^{\mathcal{T}'}$ can be characterized as follows

Condition			$\langle q_A, w, q_B, t\rangle^{\mathcal{T}'}$
$e < \min\{e_4, e_{t4}, e_{t5}\}$	$c_d \le c_{d1}$	$\Rightarrow$	$EqS6^{\mathcal{T}'}$
	$c_{d1} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{T}'}$
$e_{t5} < e < \min\{e_4, e_{t4}\}$	$c_d \le c_{d1}$	$\Rightarrow$	$EqS6^{\mathcal{T}'}$
	$c_{d1} \le c_d \le c_{dt2}$	$\Rightarrow$	$EqS3^{\mathcal{T}'}$
	$c_{dt2} \le c_d \le c_{dt5}$	$\Rightarrow$	$EqS1^{\mathcal{T}'}$
	$c_{dt5} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS4^{\mathcal{T}'}$
$\min\{e_4, e_{t4}\} < e < e_{t4}$	$c_d \le c_{d1}$	$\Rightarrow$	$EqS6^{\mathcal{T}'}$
	$c_{d1} \le c_d \le c_{dt2}$	$\Rightarrow$	$EqS3^{\mathcal{T}'}$
	$c_{dt2} \le c_d \le c_{dt1}$	$\Rightarrow$	$EqS1^{\mathcal{T}'}$
	$c_{dt2} \le c_d \le c_{dt3}$	$\Rightarrow$	$EqS2^{\mathcal{T}'}$
	$c_{dt3} \le c_d \le c_{d10}$	$\Rightarrow$	$EqS5^{\mathcal{T}'}$
	$c_{d10} \le c_d \le c_{d9}$	$\Rightarrow$	$EqS7^{\mathcal{T}'}$
	$c_{d9} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS4^{\mathcal{T}'}$
$\min\{e_4, e_{t4}\} < e < e_4$	$c_d \le c_{d1}$	$\Rightarrow$	$EqS6^{\mathcal{T}'}$
	$c_{d1} \le c_d \le c_{dt1}$	$\Rightarrow$	$EqS2^{\mathcal{T}'}$
	$\varepsilon_B < 1, c_{dt1} \le c_d \le c_{dt2}$ $1 < \varepsilon_B, c_{dt1} \le c_d \le c_{dt5}$	$\Rightarrow$	$EqS1^{\mathcal{T}'}$
	$\varepsilon_B < 1, c_{dt2} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS3^{\mathcal{T}'}$
	$1 < \varepsilon_B, c_{dt5} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS4^{\mathcal{T}'}$
$\max\{e_4, e_{t4}\} < e < e_2$	$c_d \le c_{d1}$	$\Rightarrow$	$EqS6^{\mathcal{T}'}$
	$c_{d1} \le c_d \le c_{dt3}$	$\Rightarrow$	$EqS2^{\mathcal{T}'}$
	$c_{dt3} \le c_d \le c_{d10}$	$\Rightarrow$	$EqS5^{\mathcal{T}'}$
	$c_{d10} \le c_d \le c_{d9}$	$\Rightarrow$	$EqS7^{\mathcal{T}'}$
	$c_{d9} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS4^{\mathcal{T}'}$
$e_2 < e$	$c_d \le c_{dt4}$	$\Rightarrow$	$EqS6^{\mathcal{T}'}$
	$c_{dt4} \le c_d \le c_{d10}$	$\Rightarrow$	$EqS5^{\mathcal{T}'}$
	$c_{d10} \le c_d \le c_{d9}$	$\Rightarrow$	$EqS7^{\mathcal{T}'}$
	$c_{d9} \le c_d \le c_{d0}$	$\Rightarrow$	$EqS4^{\mathcal{T}'}$

Furthermore, the total profits of both manufacturers, the benefit of the government, and the environmental impact of the strategy $\mathcal{T}'$, $\Pi_A^{\mathcal{T}'}$, $\Pi_B^{\mathcal{T}'}$, $G^{\mathcal{T}'}$, and $E^{\mathcal{T}'}$ in each of the possible equilibriums can also be solved. □

Corollary 1. When $c_{d1} \le c_d \le c_{d0}$, $w^{\mathcal{C}1}|_{c_d=c_{d0}} = -c_A < 0$, $w^{\mathcal{C}1}|_{c_d=c_{d1}} = (a_A - p_{rA})\varepsilon_A - c_A(1+\varepsilon_A^2)$, then if $a_A \ge \frac{c_A(1+\varepsilon_A^2)}{\varepsilon_A} + p_{rA}$, $w^{\mathcal{C}1}|_{c_d=c_{d1}} \ge 0$; otherwise, $w^{\mathcal{C}1}|_{c_d=c_{d1}} < 0$. Therefore, if $a_A \ge \frac{c_A(1+\varepsilon_A^2)}{\varepsilon_A} + p_{rA}$ and $a_B - c_A - c_B\varepsilon_B \le c_d \le c_{d0}$ or $a_A \le \frac{c_A(1+\varepsilon_A^2)}{\varepsilon_A} + p_{rA}$ and $c_{d1} \le c_d \le c_{d0}$, $w^{\mathcal{C}1} \le 0$. When $c_d < c_{d1}$, $w^{\mathcal{C}3}|_{c_d=c_{d1}} = (a_A - p_{rA})\varepsilon_A - c_A(1+\varepsilon_A^2)$, then if $a_A \le \frac{c_A(1+\varepsilon_A^2)}{\varepsilon_A} + p_{rA}$, $w^{\mathcal{C}3}|_{c_d=c_{d1}} \le 0$; otherwise, $w^{\mathcal{C}3}|_{c_d=c_{d1}} > 0$. Therefore, if $a_A \le \frac{c_A(1+\varepsilon_A^2)}{\varepsilon_A} + p_{rA}$ and $a_B - \frac{(a_A - p_{rA})\varepsilon_A}{1+\varepsilon_A^2} - c_B\varepsilon_B \le c_d \le c_{d1}$, $w^{\mathcal{C}3} \le 0$. □

Lemma 1. When $c_{d1} \le c_d \le c_{d0}$, $\Pi_A^{\mathcal{C}1} - \Pi_A^{\mathcal{N}} = \frac{1}{8}(a_B + c_A - c_d - c_B\varepsilon_B)^2 > 0$. When $c_d < c_{d1}$, as $\frac{d^2(\Pi_A^{\mathcal{C}3} - \Pi_A^{\mathcal{N}})}{d(c_d)^2} = \frac{\varepsilon_A^2}{2+4\varepsilon_A^2} > 0$, $\frac{d(\Pi_A^{\mathcal{C}3} - \Pi_A^{\mathcal{N}})}{dc_d}|_{c_d=c_{d1}} = -\frac{1}{2}\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) < 0$, and $\Pi_A^{\mathcal{C}3} - \Pi_A^{\mathcal{N}}|_{c_d=c_{d1}} = \frac{1}{2}\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 > 0$, then $\Pi_A^{\mathcal{C}3} > \Pi_A^{\mathcal{N}}$. □

Lemma 2. When $c_{d1} \le c_d \le c_{d0}$, we can get that $\frac{d^2(\Pi_B^{\mathcal{C}1} - \Pi_B^{\mathcal{N}})}{d(c_d)^2} = \frac{1}{8} > 0$, $\frac{d(\Pi_B^{\mathcal{C}1} - \Pi_B^{\mathcal{N}})}{dc_d}|_{c_d=c_{d1}} = -\frac{1}{4}\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) < 0$, and $\Pi_B^{\mathcal{C}1} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d1}} = \frac{1}{16}(4\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - 4(a_B - p_{rB} - c_B\varepsilon_B)^2)$. When $a_A \ge a_{A1}$, $a_{A1} = \frac{a_B - p_{rB} - c_B\varepsilon_B + c_A\varepsilon_A^2 + p_{rA}\varepsilon_A}{\varepsilon_A}$, $\Pi_B^{\mathcal{C}1} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d1}} \ge 0$, as $\Pi_B^{\mathcal{C}1} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{4}(a_B - p_{rB} - c_B\varepsilon_B)^2 < 0$, then if $c_{d1} \le c_d \le c_{d2}$, $\Pi_B^{\mathcal{C}1} \ge \Pi_B^{\mathcal{N}}$, where $c_{d2} = -a_B + c_A + 2p_{rB} + c_B\varepsilon_B$; if $c_{d2} < c_d \le c_{d0}$, $\Pi_B^{\mathcal{C}1} < \Pi_B^{\mathcal{N}}$. When $a_A < a_{A1}$, $\Pi_B^{\mathcal{C}1} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d1}} < 0$, then if $c_{d1} \le c_d \le c_{d0}$, $\Pi_B^{\mathcal{C}1} < \Pi_B^{\mathcal{N}}$.

When $c_d < c_{d1}$, we can get that $\frac{d^2(\Pi_B^{\mathcal{C}3} - \Pi_B^{\mathcal{N}})}{d(c_d)^2} = \frac{\varepsilon_A^4}{2(1+2\varepsilon_A^2)^2} > 0$, $\frac{d(\Pi_B^{\mathcal{C}3} - \Pi_B^{\mathcal{N}})}{dc_d}|_{c_d=c_{d1}} = -\frac{\varepsilon_A^3(a_A - p_{rA} - c_A\varepsilon_A)}{2+4\varepsilon_A^2} < 0$, and $\Pi_B^{\mathcal{C}3} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d1}} = \frac{1}{4}(\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - (a_B - p_{rB} - c_B\varepsilon_B)^2)$. When $a_A \ge a_{A1}$, $\Pi_B^{\mathcal{C}3} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d1}} \ge 0$, then $\Pi_B^{\mathcal{C}3} - \Pi_B^{\mathcal{N}} \ge 0$. When $a_A < a_{A1}$, $\Pi_B^{\mathcal{C}3} - \Pi_B^{\mathcal{N}}|_{c_d=c_{d1}} < 0$, then if $c_d \le c_{d4}$, $\Pi_B^{\mathcal{C}3} \ge \Pi_B^{\mathcal{N}}$, where $c_{d4} =$

$\frac{(a_A-p_{rA})\varepsilon_A-a_B(1+\varepsilon_A^2)+p_{rB}(1+2\varepsilon_A^2)+c_B(1+\varepsilon_A^2)\varepsilon_B}{\varepsilon_A^2}$; if $c_{d4} < c_d < c_{d1}$, $\Pi_B^{\mathcal{C}3} < \Pi_B^{\mathcal{N}}$. □

Lemma 3. When $c_{d1} \le c_d \le c_{d0}$, we can get that $\frac{d(E^{\mathcal{C}1}-E^{\mathcal{N}})}{dc_d} = \frac{1}{4}e(1-\varepsilon_B)$ and $E^{\mathcal{C}1}-E^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{2}e\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B) < 0$. Then, if $\varepsilon_B \ge 1$, $\frac{d(E^{\mathcal{C}1}-E^{\mathcal{N}})}{dc_d} \le 0$; otherwise, $\frac{d(E^{\mathcal{C}1}-E^{\mathcal{N}})}{dc_d} > 0$. (i) When $\varepsilon_B \ge 1$, $E^{\mathcal{C}1}-E^{\mathcal{N}}|_{c_d=c_{d1}} = \frac{1}{2}e\big(\varepsilon_A(-1+\varepsilon_B)(a_A-p_{rA}-c_A\varepsilon_A)\big)-\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B))$, we can derive that if $a_A \ge a_{A2}$, where $a_{A2} = p_{rA}+c_A\varepsilon_A+\frac{\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B)}{\varepsilon_A(-1+\varepsilon_B)}$, $E^{\mathcal{C}1}-E^{\mathcal{N}}|_{c_d=c_{d1}} \ge 0$, then if $c_{d1} \le c_d \le c_{d3}$, where $c_{d3} = \frac{(a_B-c_B\varepsilon_B)(1+\varepsilon_B)+c_A(1-\varepsilon_B)-2p_{rB}\varepsilon_B}{1-\varepsilon_B}$, $E^{\mathcal{C}1}-E^{\mathcal{N}} \ge 0$, otherwise, if $c_{d3} < c_d \le c_{d0}$, $E^{\mathcal{C}1}-E^{\mathcal{N}} < 0$. If $a_A < a_{A2}$, $E^{\mathcal{C}1}-E^{\mathcal{N}}|_{c_d=c_{d1}} < 0$, $E^{\mathcal{C}1}-E^{\mathcal{N}} < 0$. (ii) When $\varepsilon_B < 1$, $E^{\mathcal{C}1}-E^{\mathcal{N}}|_{c_d=c_{d1}} = \frac{1}{2}e\big(\varepsilon_A(-1+\varepsilon_B)(a_A-p_{rA}-c_A\varepsilon_A)\big)-\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B)) < 0$, we can derive that if $c_{d1} \le c_d \le c_{d0}$, $E^{\mathcal{C}1}-E^{\mathcal{N}} \le 0$.

When $c_d < c_{d1}$, we can get that $\frac{d(E^{\mathcal{C}3}-E^{\mathcal{N}})}{dc_d} = -\frac{e\varepsilon_A^2\varepsilon_B}{2+4\varepsilon_A^2} < 0$, and $E^{\mathcal{C}3}-E^{\mathcal{N}}|_{c_d=c_{d1}} = \frac{1}{2}e\big(\varepsilon_A(-1+\varepsilon_B)(a_A-p_{rA}-c_A\varepsilon_A)\big)-\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B))$. (i) When $\varepsilon_B \ge 1$, we can derive that if $a_A \ge a_{A2}$, $E^{\mathcal{C}3}-E^{\mathcal{N}}|_{c_d=c_{d1}} \ge 0$, then if $c_d \le c_{d1}$, $E^{\mathcal{C}3}-E^{\mathcal{N}} \ge 0$. If $a_A < a_{A2}$, $E^{\mathcal{C}3}-E^{\mathcal{N}}|_{c_d=c_{d1}} < 0$, then if $c_d \le c_{d5}$, $E^{\mathcal{C}3}-E^{\mathcal{N}} \ge 0$, otherwise, if $c_{d5} < c_d < c_{d1}$, $E^{\mathcal{C}3}-E^{\mathcal{N}} < 0$, where $c_{d5} = \frac{-(a_A-p_{rA}-c_A\varepsilon_A)(\varepsilon_A+2\varepsilon_A^3)+((a_A-p_{rA})\varepsilon_A-a_B(1+\varepsilon_A^2)+p_{rB}(1+2\varepsilon_A^2))\varepsilon_B+c_B(1+\varepsilon_A^2)\varepsilon_B^2}{\varepsilon_A^2\varepsilon_B}$. (ii) When $\varepsilon_B < 1$, $E^{\mathcal{C}3}-E^{\mathcal{N}}|_{c_d=c_{d1}} < 0$, we can derive that if $c_{d5} < c_d < c_{d1}$, $E^{\mathcal{C}3}-E^{\mathcal{N}} < 0$, otherwise, if $c_d \le c_{d5}$, $E^{\mathcal{C}3}-E^{\mathcal{N}} \ge 0$. □

Theorem 1. This result can be directly derived from Lemmas 1, 2, and 3. □

Corollary 2. This result can be directly derived based on Theorem 1. □

Theorem 2. When $s < s_1$,

(i) $\Pi_A^{\mathcal{S}}-\Pi_A^{\mathcal{N}} = \frac{1}{8}(s+a_B+c_A-c_d-c_B\varepsilon_B)^2 > 0$;

(ii) $\frac{d^2(\Pi_B^{\mathcal{S}}-\Pi_B^{\mathcal{N}})}{ds^2} = \frac{1}{8} > 0$; $\Pi_B^{\mathcal{S}}-\Pi_B^{\mathcal{N}}|_{s=0} = \frac{1}{16}((a_B+c_A-c_d-c_B\varepsilon_B)^2-4(a_B-p_{rB}-c_B\varepsilon_B)^2)$, $(a_B+c_A-c_d-c_B\varepsilon_B)-2(a_B-p_{rB}-c_B\varepsilon_B) < 0$;

$\frac{d(\Pi_B^{\mathcal{S}}-\Pi_B^{\mathcal{N}})}{ds}|_{s=s_1} = \frac{1}{4}\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) > 0$; $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}}|_{s=s_1} = \frac{1}{16}(4\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - 4(a_B - p_{rB} - c_B\varepsilon_B)^2)$, then if $a_A < a_{A1}$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}}|_{s=s_1} < 0$, otherwise, if $a_A > a_{A1}$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}}|_{s=s_1} > 0$; By solving $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} = 0$, we can get two solutions that satisfy $a_B - c_A + c_d - 2p_{rB} - c_B\varepsilon_B > -3a_B - c_A + c_d + 2p_{rB} + 3c_B\varepsilon_B$, and $-3a_B - c_A + c_d + 2p_{rB} + 3c_B\varepsilon_B < 0$ if $c_d < c_{d0}$; then, we can derive that when $a_A < a_{A1}$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} < 0$, when $a_A > a_{A1}$, if $s_2 < s < s_1$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} > 0$, if $s < s_2$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} < 0$, where $s_2 = a_B - c_A + c_d - 2p_{rB} - c_B\varepsilon_B$;

(iii) $\frac{d(E^{\mathcal{S}}-E^{\mathcal{N}})}{ds} = \frac{1}{4}e(-1+\varepsilon_B)$, if $\varepsilon_B > 1$, $\frac{d(E^{\mathcal{S}}-E^{\mathcal{N}})}{ds} > 0$, otherwise, $\frac{d(E^{\mathcal{S}}-E^{\mathcal{N}})}{ds} < 0$; only consider the case where $\Pi_B^{\mathcal{S}} > \Pi_B^{\mathcal{N}}$, i.e., when $a_A > a_{A1}$, and $s_2 < s < s_1$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_2} = -\frac{1}{2}e(a_B - p_{rB} - c_B\varepsilon_B) < 0$, (a) when $\varepsilon_B > 1$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} = \frac{1}{2}e((a_A - p_{rA} - c_A\varepsilon_A)\varepsilon_A(-1+\varepsilon_B) - \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B))$, then if $a_{A1} < a_A < a_{A2}$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} < 0$, $E^{\mathcal{S}} - E^{\mathcal{N}} < 0$, otherwise, if $a_A > a_{A2}$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} > 0$, if $s_2 < s < s_3$, $E^{\mathcal{S}} - E^{\mathcal{N}} < 0$, if $s_3 < s < s_1$, $E^{\mathcal{S}} - E^{\mathcal{N}} > 0$, where $s_3 = \frac{c_A - c_d + a_B(1+\varepsilon_B) - \varepsilon_B(c_A - c_d + 2p_{rB} + c_B(1+\varepsilon_B))}{-1+\varepsilon_B}$; (b) when $\varepsilon_B < 1$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} < 0$, $E^{\mathcal{S}} - E^{\mathcal{N}} < 0$.

When $s > s_1$,

(i) $\frac{d^2(\Pi_A^{\mathcal{S}}-\Pi_A^{\mathcal{N}})}{ds^2} = \frac{\varepsilon_A^2}{2+4\varepsilon_A^2} > 0$; $\frac{d(\Pi_A^{\mathcal{S}}-\Pi_A^{\mathcal{N}})}{ds}|_{s=s_1} = \frac{1}{2}\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) > 0$; $\Pi_A^{\mathcal{S}} - \Pi_A^{\mathcal{N}}|_{s=s_1} = \frac{1}{2}\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 > 0$, then $\Pi_A^{\mathcal{S}} > \Pi_A^{\mathcal{N}}$;

(ii) $\frac{d^2(\Pi_B^{\mathcal{S}}-\Pi_B^{\mathcal{N}})}{ds^2} = \frac{\varepsilon_A^4}{2(1+2\varepsilon_A^2)^2} > 0$; $\frac{d(\Pi_B^{\mathcal{S}}-\Pi_B^{\mathcal{N}})}{ds}|_{s=s_1} = \frac{\varepsilon_A^3(a_A - p_{rA} - c_A\varepsilon_A)}{2+4\varepsilon_A^2} > 0$; $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}}|_{s=s_1} = \frac{1}{4}(\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - (a_B - p_{rB} - c_B\varepsilon_B)^2)$, then if $a_A < a_{A1}$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}}|_{s=s_1} < 0$, otherwise, if $a_A > a_{A1}$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}}|_{s=s_1} > 0$; then, we can derive that when $a_A > a_{A1}$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} > 0$, when $a_A < a_{A1}$, if $s_1 < s < s_4$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} < 0$, if $s > s_4$, $\Pi_B^{\mathcal{S}} - \Pi_B^{\mathcal{N}} > 0$, where $s_4 = c_d - 2p_{rB} - c_B\varepsilon_B - \frac{p_{rB} + (a_A - p_{rA})\varepsilon_A - a_B(1+\varepsilon_A^2) + c_B\varepsilon_B}{\varepsilon_A^2}$;

(iii) $\frac{d(E^{\mathcal{S}}-E^{\mathcal{N}})}{ds} = \frac{e\varepsilon_A^2\varepsilon_B}{2+4\varepsilon_A^2} > 0$; only consider the case where $\Pi_B^{\mathcal{S}} > \Pi_B^{\mathcal{N}}$, (a) when $a_A <$

a_{A1} and $s > s_4$, as $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_4} = -\frac{1}{2}e\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) < 0$, then if $s_4 < s < s_5$, $E^{\mathcal{S}} - E^{\mathcal{N}} < 0$, otherwise, if $s > s_5$, $E^{\mathcal{S}} - E^{\mathcal{N}} > 0$, where $s_5 = \frac{(a_A - p_{rA} - c_A\varepsilon_A)(\varepsilon_A + 2\varepsilon_A^3) + (a_B - p_{rB} - (a_A - p_{rA})\varepsilon_A + (a_B + c_d - 2p_{rB})\varepsilon_A^2)\varepsilon_B - c_B(1+\varepsilon_A^2)\varepsilon_B^2}{\varepsilon_A^2\varepsilon_B}$; (b) when $a_A > a_{A1}$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} = \frac{1}{2}e(a_A - p_{rA} - c_A\varepsilon_A)\varepsilon_A(-1+\varepsilon_B) - \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B))$; Then if $\varepsilon_B < 1$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} < 0$, and if $s_1 < s < s_5$, $E^{\mathcal{S}} - E^{\mathcal{N}} < 0$, if $s > s_5$, $E^{\mathcal{S}} - E^{\mathcal{N}} > 0$; Otherwise, if $\varepsilon_B > 1$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} > E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_{1|a_A=a_{A1}}} = -\frac{1}{2}e(a_B - p_{rB} - c_B\varepsilon_B)$, if $a_{A1} < a_A < a_{A2}$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} < 0$, then if $s_1 < s < s_5$, $E^{\mathcal{S}} - E^{\mathcal{N}} < 0$, if $s > s_5$, $E^{\mathcal{S}} - E^{\mathcal{N}} > 0$, otherwise, if $a_A > a_{A2}$, $E^{\mathcal{S}} - E^{\mathcal{N}}|_{s=s_1} > 0$, $E^{\mathcal{S}} - E^{\mathcal{N}} > 0$. □

Corollary 3 and Corollary 4. The results can be directly derived based on the equilibrium solution in Appendix A.4. □

Lemma 4. We hereafter use $EqSk$ to represent $EqSk^{\mathcal{S}}$, where $k = 1,2,3,4$.

(1) When $\varepsilon_B > 1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

When $c_{d4} < c_d < c_{d1}$, $\Pi_A^{\mathcal{S}}(EqS4) = \Pi_A^{\mathcal{C}3} > \Pi_A^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS3) = \Pi_A^{\mathcal{C}1} > \Pi_A^{\mathcal{N}}$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$. Then, $\Pi_A^{\mathcal{S}}(EqS3) = \Pi_A^{\mathcal{C}1} > \Pi_A^{\mathcal{N}}$.

(2) When $\varepsilon_B < 1$ and $e < e_1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

When $c_{d4} < c_d < c_{d1}$, $\Pi_A^{\mathcal{S}}(EqS4) = \Pi_A^{\mathcal{C}3} > \Pi_A^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d8}$, $\Pi_A^{\mathcal{S}}(EqS3) = \Pi_A^{\mathcal{C}1} > \Pi_A^{\mathcal{N}}$; when $c_{d8} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS1) - \Pi_A^{\mathcal{N}} = \frac{1}{32}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 > 0$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$.

As $c_{d2} - c_{d8} = e - 2a_B + 2p_{rB} - (e - 2c_B)\varepsilon_B < c_{d2} - c_{d8}|_{e=e_1} = 2(-a_B + p_{rB} + \varepsilon_A(a_A - c_A\varepsilon_A) + c_B\varepsilon_B)$, $c_{d2} - c_{d8}|_{e=e_1} > c_{d2} - c_{d8}|_{e=e_1|_{a_A=a_{A1}}} = 0$, so there exists a threshold value of e_2, $e_2 = \frac{2(-a_B + p_{rB} + c_B\varepsilon_B)}{-1+\varepsilon_B}$, if $e < e_2$, $c_{d2} - c_{d8} < 0$, else if $e > e_2$, $c_{d2} - c_{d8} > 0$.

If $e < e_2$, when $c_{d2} < c_d < c_{d8}$, $\Pi_A^{\mathcal{S}}(EqS3) = \Pi_A^{\mathcal{C}1} > \Pi_A^{\mathcal{N}}$; when $c_{d8} < c_d < c_{d0}$,

$\Pi_A^{\mathcal{S}}(EqS1) - \Pi_A^{\mathcal{N}} = \frac{1}{32}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 > 0$. Otherwise, if $e > e_2$, when $c_{d2} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS1) - \Pi_A^{\mathcal{N}} > 0$.

(3) When $\varepsilon_B < 1$ and $e > e_1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$. $c_{d7} - c_{d0} = e - 4(a_A - p_{rA})\varepsilon_A + 4c_A\varepsilon_A^2 - e\varepsilon_B$, then if $e > 2e_1$, $c_{d7} > c_{d0}$; else if $e < 2e_1$, $c_{d7} < c_{d0}$.

If $e_1 < e < 2e_1$, when $c_{d4} < c_d < c_{d1}$, $\Pi_A^{\mathcal{S}}(EqS4) = \Pi_A^{\mathcal{C}3} > \Pi_A^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d7}$, $\Pi_A^{\mathcal{S}}(EqS2) - \Pi_A^{\mathcal{N}} = \frac{1}{2}\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 > 0$; when $c_{d7} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS1) - \Pi_A^{\mathcal{N}} = \frac{1}{32}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 > 0$.

If $e > 2e_1$, when $c_{d4} < c_d < c_{d1}$, $\Pi_A^{\mathcal{S}}(EqS4) = \Pi_A^{\mathcal{C}3} > \Pi_A^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS2) - \Pi_A^{\mathcal{N}} = \frac{1}{2}\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 > 0$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$. $\frac{d(c_{d2}-c_{d7})}{de} = -1 + \varepsilon_B < 0$, $c_{d2} - c_{d7} < c_{d2} - c_{d7}|_{e=e_1} = 2(-a_B + p_{rB} + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B)$, as $c_{d2} - c_{d7}|_{e=e_1} > c_{d2} - c_{d7}|_{e=e_{1|a_A=a_{A1}}} = 0$, then there exists a threshold value of e_3, where $e_3 = \frac{2(-a_B+p_{rB}+2\varepsilon_A(a_A-p_{rA}-c_A\varepsilon_A)+c_B\varepsilon_B)}{1-\varepsilon_B}$, then if $e_1 < e < e_3$, $c_{d7} < c_{d2} < c_{d0}$, else if $e_3 < e < 2e_1$, $c_{d2} < c_{d7} < c_{d0}$, else if $e > 2e_1$, $c_{d2} < c_{d0} < c_{d7}$.

If $e_1 < e < e_3$, when $c_{d2} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS1) - \Pi_A^{\mathcal{N}} = \frac{1}{32}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 > 0$.

If $e_1 < e < 2e_1$, when $c_{d2} < c_d < c_{d7}$, $\Pi_A^{\mathcal{S}}(EqS2) - \Pi_A^{\mathcal{N}} = \frac{1}{2}\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 > 0$; when $c_{d7} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS1) - \Pi_A^{\mathcal{N}} = \frac{1}{32}(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 > 0$.

If $e > 2e_1$, when $c_{d2} < c_d < c_{d0}$, $\Pi_A^{\mathcal{S}}(EqS2) - \Pi_A^{\mathcal{N}} = \frac{1}{2}\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 > 0$. □

Lemma 5.

(1) When $\varepsilon_B > 1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

When $c_{d4} < c_d < c_{d1}$, $\Pi_B^{\mathcal{S}}(EqS4) = \Pi_B^{\mathcal{C}3} < \Pi_B^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS3) = \Pi_B^{\mathcal{C}1} < \Pi_B^{\mathcal{N}}$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$. Then, $\Pi_B^{\mathcal{S}}(EqS3) = \Pi_B^{\mathcal{C}1} < \Pi_B^{\mathcal{N}}$.

(2) When $\varepsilon_B < 1$ and $e < e_1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

When $c_{d4} < c_d < c_{d1}$, $\Pi_B^{\mathcal{S}}(EqS4) = \Pi_B^{\mathcal{C}3} < \Pi_B^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d8}$, $\Pi_B^{\mathcal{S}}(EqS3) = \Pi_B^{\mathcal{C}1} < \Pi_B^{\mathcal{N}}$; when $c_{d8} < c_d < c_{d0}$, $\frac{d^2(\Pi_B^{\mathcal{S}}(EqS1)-\Pi_B^{\mathcal{N}})}{dc_d{}^2} = \frac{1}{32} > 0$, $\frac{d(\Pi_B^{\mathcal{S}}(EqS1)-\Pi_B^{\mathcal{N}})}{dc_d}|_{c_d=c_{d0}} = \frac{1}{32}e(-1+\varepsilon_B) < 0$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}}|_{c_d=c_{d8}} = \frac{1}{64}(4e^2(-1+\varepsilon_B)^2 - 16(-a_B + p_{rB} + c_B\varepsilon_B)^2)$, as $2e(1-\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) < 2e(1-\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{e=e_1} = 4(-a_B + p_{rB} + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B) < 4(-a_B + p_r + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B)|_{a_A=a_{A1}} = 0$, so $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}}|_{c_d=c_{d8}} < 0$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$.

If $e < e_2$, when $c_{d2} < c_d < c_{d8} < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS3) = \Pi_B^{\mathcal{C}1} < \Pi_B^{\mathcal{N}}$; when $c_{d8} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} = \frac{1}{64}(-16(-a_B + p_{rB} + c_B\varepsilon_B)^2 + (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2)$, as $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) < (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d8}} = 2e - 4a_B + 4p_{rB} - 2(e - 2c_B)\varepsilon_B < 2e - 4a_B + 4p_{rB} - 2(e - 2c_B)\varepsilon_B|_{e=e_2} = 0$, then $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$.

If $e > e_2$, when $c_{d2} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} = \frac{1}{64}(-16(-a_B + p_{rB} + c_B\varepsilon_B)^2 + (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2)$, as $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d2}} = e - 2a_B + 2p_{rB} - (e - 2c_B)\varepsilon_B > e - 2a_B + 2p_{rB} - (e - 2c_B)\varepsilon_B|_{e=e_2} = 0$, then $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}}|_{c_d=c_{d2}} > 0$. $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} = e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B > e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=e_2} = 2(-a_B + p_{rB} + c_B\varepsilon_B)$, then there exists a threshold value of $2e_2$, if $e > 2e_2$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} > 0$, then $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$, else if $e_2 < e < 2e_2$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} < 0$, and there exists a threshold value of c_{d9}, where $c_{d9} = e - 3a_B + c_A + 4p_{rB} - (e - 3c_B)\varepsilon_B$, if $c_d < c_{d9}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$, else if $c_{d9} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$. $2e_2 -$

$e_1 = \frac{-4a_B+4p_{rB}+2\varepsilon_A(a_A-p_{rA}-c_A\varepsilon_A)+4c_B\varepsilon_B}{-1+\varepsilon_B} < 2e_2 - e_1|_{a_A=a_{A1}} = \frac{2(-a_B+p_{rB}+c_B\varepsilon_B)}{-1+\varepsilon_B} > 0$,

then there exists a threshold value of a_{A3}, where $a_{A3} = \frac{2a_B-2p_{rB}+c_A\varepsilon_A^2-2c_B\varepsilon_B}{\varepsilon_A}$, if $a_{A1} < a_A < a_{A3}$, $2e_2 > e_1$; else if $a_A > a_{A3}$, $2e_2 < e_1$. We can find that $c_{d9} > c_{d0}$ if $e > 2e_2$.

(3) When $\varepsilon_B < 1$ and $e > e_1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

If $e_1 < e < 2e_1$, when $c_{d4} < c_d < c_{d1}$, $\Pi_B^{\mathcal{S}}(EqS4) = \Pi_B^{\mathcal{C}3} < \Pi_B^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d7}$, $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} = \frac{1}{4}(\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - (-a_B + p_{rB} + c_B\varepsilon_B)^2)$, as $\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - p_{rB} - c_B\varepsilon_B) < \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - p_{rB} - c_B\varepsilon_B)|_{a_A=a_{A1}} = 0$, then $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} < 0$; when $c_{d7} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} = \frac{1}{64}((e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 - 16(-a_B + p_{rB} + c_B\varepsilon_B)^2)$, as $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) < (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d7}} = 4(-a_B + p_{rB} + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B) < 4(-a_B + p_{rB} + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B)|_{a_A=a_{A1}} = 0$, then $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$.

If $e > 2e_1$, when $c_{d4} < c_d < c_{d1}$, $\Pi_B^{\mathcal{S}}(EqS4) = \Pi_B^{\mathcal{C}3} < \Pi_B^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} = \frac{1}{4}(\varepsilon_A^2(a_A - c_A\varepsilon_A)^2 - (-a_B + p_r + c_B\varepsilon_B)^2) < 0$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$.

If $e_1 < e < e_3$, when $c_{d2} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} = \frac{1}{64}((e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 - 16(-a_B + p_{rB} + c_B\varepsilon_B)^2)$, as $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) > (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} = e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B$, $e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=e_1} = -4a_B + 4p_{rB} + 2\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + 4c_B\varepsilon_B > 0$ if $a_A > a_{A3}$, otherwise, $e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=e_1} < 0$; then if $a_A > a_{A3}$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) > (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} > 0$, $\Pi_B^{\mathcal{S}}(EqS1) > \Pi_B^{\mathcal{N}}$; if $a_{A1} < a_A < a_{A3}$, there exists a threshold value of a_{A4}, where $a_{A4} = \frac{3a_B-3p_{rB}+2c_A\varepsilon_A^2-3c_B\varepsilon_B}{2\varepsilon_A}$, $e - 4a_B + 4p_{rB} - (e -$

$4c_B)\varepsilon_B|_{e=e_3} = -6a_B + 6p_{rB} + 4\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + 6c_B\varepsilon_B > 0$ if $a_{A4} < a_A < a_{A3}$, otherwise, $e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=e_3} = -6a_B + 6p_{rB} + 4\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + 6c_B\varepsilon_B < 0$; then when $a_{A1} < a_A < a_{A4}$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} < 0$, if $c_{d2} < c_d < c_{d9}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$, if $c_{d9} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$; when $a_{A4} < a_A < a_{A3}$, if $e < 2e_2$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} < 0$, if $c_{d2} < c_d < c_{d9}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$, if $c_{d9} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$, if $2e_2 < e < e_3$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$.

If $e_3 < e < 2e_1$, when $c_{d2} < c_d < c_{d7}$, $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} = \frac{1}{4}(\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - (a_B - p_{rB} - c_B\varepsilon_B)^2)$, as $\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - p_{rB} - c_B\varepsilon_B) > \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - p_{rB} - c_B\varepsilon_B)|_{a_A=a_{A1}} = 0$, then $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} > 0$; when $c_{d7} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} = \frac{1}{64}((e + a_B + c_A - c_d - (e + c_B)\varepsilon_B)^2 - 16(-a_B + p_{rB} + c_B\varepsilon_B)^2)$, as $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) > (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} = e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B$, $e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=e_3} = -6a_B + 6p_{rB} + 4\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + 6c_B\varepsilon_B > 0$ if $a_A > a_{A4}$, otherwise, $e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=e_3} < 0$; then if $a_A > a_{A4}$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B) > (e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} > 0$, $\Pi_B^{\mathcal{S}}(EqS1) > \Pi_B^{\mathcal{N}}$; if $a_{A1} < a_A < a_{A4}$, $e - 4a_B + 4p_{rB} - (e - 4c_B)\varepsilon_B|_{e=2e_1} = 4(-a_B + p_{rB} + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B) > 4(-a_B + p_{rB} + \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B)|_{a_A=a_{A1}} > 0$, then if $e_3 < e < 2e_2$, $(e + a_B + c_A - c_d - (e + c_B)\varepsilon_B) - 4(a_B - p_{rB} - c_B\varepsilon_B)|_{c_d=c_{d0}} < 0$, if $c_{d7} < c_d < c_{d9}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$, if $c_{d9} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} < 0$, if $2e_2 < e < 2e_1$, $\Pi_B^{\mathcal{S}}(EqS1) - \Pi_B^{\mathcal{N}} > 0$.

If $e > 2e_1$, when $c_{d2} < c_d < c_{d0}$, $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} = \frac{1}{4}(\varepsilon_A^2(a_A - p_{rA} - c_A\varepsilon_A)^2 - (a_B - p_{rB} - c_B\varepsilon_B)^2)$, as $\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - p_{rB} - c_B\varepsilon_B) > \varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) - (a_B - p_{rB} - c_B\varepsilon_B)|_{a_A=a_{A1}} = 0$, then $\Pi_B^{\mathcal{S}}(EqS2) - \Pi_B^{\mathcal{N}} > 0$.□

Lemma 6.

(1) When $\varepsilon_B > 1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

When $c_{d4} < c_d < c_{d1}$, $E^{\mathcal{S}}(EqS4) = E^{\mathcal{C}3} < E^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d0}$, $E^{\mathcal{S}}(EqS3) = E^{\mathcal{C}1} < E^{\mathcal{N}}$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$. Then, $E^{\mathcal{S}}(EqS3) = E^{\mathcal{C}1} < E^{\mathcal{N}}$.

(2) When $\varepsilon_B < 1$ and $e < e_1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

When $c_{d4} < c_d < c_{d1}$, $E^{\mathcal{S}}(EqS4) = E^{\mathcal{C}3} < E^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d8}$, $E^{\mathcal{S}}(EqS3) = E^{\mathcal{C}1} < E^{\mathcal{N}}$; when $c_{d8} < c_d < c_{d0}$, $\frac{d(E^{\mathcal{S}}(EqS1)-E^{\mathcal{N}})}{dc_d} = \frac{1}{8}e(1-\varepsilon_B) > 0$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{8}e\big(e + \varepsilon_B(-2e + 4a_B - 4p_{rB} + (e - 4c_B)\varepsilon_B)\big) < 0$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}} < 0$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$.

If $e < e_2$, when $c_{d2} < c_d < c_{d8}$, $E^{\mathcal{S}}(EqS3) = E^{\mathcal{C}1} < E^{\mathcal{N}}$; when $c_{d8} < c_d < c_{d0}$, $\frac{d(E^{\mathcal{S}}(EqS1)-E^{\mathcal{N}})}{dc_d} = \frac{1}{8}e(1-\varepsilon_B) > 0$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{8}e\big(e + \varepsilon_B(-2e + 4a_B - 4p_{rB} + (e - 4c_B)\varepsilon_B)\big) < 0$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}} < 0$. Similarly, if $e > e_2$, when $c_{d2} < c_d < c_{d0}$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}} < 0$.

(3) When $\varepsilon_B < 1$ and $e > e_1$, then

(i) If $a_A < a_{A1}$, we need to compare $c_{d4} < c_d < c_{d0}$.

If $e_1 < e < 2e_1$, when $c_{d4} < c_d < c_{d1}$, $E^{\mathcal{S}}(EqS4) = E^{\mathcal{C}3} < E^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d7}$, $E^{\mathcal{S}}(EqS2) - E^{\mathcal{N}} = \frac{1}{2}e\big((a_A - p_{rA} - c_A\varepsilon_A)\varepsilon_A(-1+\varepsilon_B) - \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0$; when $c_{d7} < c_d < c_{d0}$, $\frac{d(E^{\mathcal{S}}(EqS1)-E^{\mathcal{N}})}{dc_d} = \frac{1}{8}e(1-\varepsilon_B) > 0$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}} < E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{8}e\big(e(1-\varepsilon_B)^2 + 4\varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0$.

If $e > 2e_1$, when $c_{d4} < c_d < c_{d1}$, $E^{\mathcal{S}}(EqS4) = E^{\mathcal{C}3} < E^{\mathcal{N}}$, when $c_{d1} < c_d < c_{d0}$, $E^{\mathcal{S}}(EqS2) - E^{\mathcal{N}} = \frac{1}{2}e\big((a_A - p_{rA} - c_A\varepsilon_A)\varepsilon_A(-1+\varepsilon_B) - \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0$.

(ii) If $a_A > a_{A1}$, we need to compare $c_{d2} < c_d < c_{d0}$.

If $e_1 < e < e_3$, when $c_{d2} < c_d < c_{d0}$, $\frac{d(E^{\mathcal{S}}(EqS1)-E^{\mathcal{N}})}{dc_d} = \frac{1}{8}e(1-\varepsilon_B) > 0$,

$E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}} < E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{8}e\big(e(1-\varepsilon_B)^2 + 4\varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0.$

If $e_1 < e < 2e_1$, when $c_{d2} < c_d < c_{d7}$, $E^{\mathcal{S}}(EqS2) - E^{\mathcal{N}} = \frac{1}{2}e\big((a_A - p_{rA} - c_A\varepsilon_A)\varepsilon_A(-1+\varepsilon_B) - \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0$; when $c_{d7} < c_d < c_{d0}$, $\frac{d(E^{\mathcal{S}}(EqS1)-E^{\mathcal{N}})}{dc_d} = \frac{1}{8}e(1-\varepsilon_B) > 0$, $E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}} < E^{\mathcal{S}}(EqS1) - E^{\mathcal{N}}|_{c_d=c_{d0}} = -\frac{1}{8}e\big(e(1-\varepsilon_B)^2 + 4\varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0.$

If $e > 2e_1$, when $c_{d2} < c_d < c_{d0}$, $E^{\mathcal{S}}(EqS2) - E^{\mathcal{N}} = \frac{1}{2}e\big((a_A - p_{rA} - c_A\varepsilon_A)\varepsilon_A(-1+\varepsilon_B) - \varepsilon_B(a_B - p_{rB} - c_B\varepsilon_B)\big) < 0.$ □

Theorem 3. The result can be directly derived from Lemmas 4, 5, 6. □

Theorem 4. The proof is similar to that of Theorem 1. □

Corollary 5. The result can be derived directly based on the optimal equilibrium solutions in Appendix A.6. □

Theorem 5. The proof is similar to that of Theorem 1. □

Corollary 6 and Corollary 7. The results can be directly derived based on the optimal solutions in Appendix A.7. □

Lemma 7. The proof is similar to that of Lemma 4. □

Lemma 8. The proof is similar to that of Lemma 5. □

Lemma 9. The proof is similar to that of Lemma 6. □

Theorem 6. The result can be directly derived from Lemmas 7, 8, and 9. □

Corollary 8 and Corollary 9. The result can be derived directly based on the optimal equilibrium solutions in Appendix A.8. □

Lemma 10. The proof is similar to that of Lemma 6. □

Corollary 10. The result can be derived directly. □

Appendix B.

c_{d0}	$a_B - c_B\varepsilon_B + c_A$
c_{d1}	$a_B - c_B\varepsilon_B - 2(a_A - p_{rA})\varepsilon_A + c_A(1 + 2\varepsilon_A^2)$
c_{d2}	$-a_B + c_A + 2p_{rB} + c_B\varepsilon_B$
c_{d3}	$\frac{(a_B - c_B\varepsilon_B)(1 + \varepsilon_B) + c_A(1 - \varepsilon_B) - 2p_{rB}\varepsilon_B}{1 - \varepsilon_B}$
c_{d4}	$\frac{(a_A - p_{rA})\varepsilon_A - a_B(1 + \varepsilon_A^2) + p_{rB}(1 + 2\varepsilon_A^2) + c_B(1 + \varepsilon_A^2)\varepsilon_B}{\varepsilon_A^2}$
c_{d5}	$\frac{-(a_A - p_{rA} - c_A\varepsilon_A)(\varepsilon_A + 2\varepsilon_A^3) + ((a_A - p_{rA})\varepsilon_A - (a_B - c_B\varepsilon_B)(1 + \varepsilon_A^2) + p_{rB}(1 + 2\varepsilon_A^2))\varepsilon_B}{\varepsilon_A^2\varepsilon_B}$
c_{d6}	$e + a_B + c_A - (e + c_B)\varepsilon_B$
c_{d7}	$e + a_B - 4(a_A - p_{rA})\varepsilon_A + c_A(1 + 4\varepsilon_A^2) - (e + c_B)\varepsilon_B$
c_{d8}	$-e + a_B + c_A + (e - c_B)\varepsilon_B$
c_{d9}	$e - 3a_B + c_A + 4p_{rB} - (e - 3c_B)\varepsilon_B$
c_{d10}	$a_B - \frac{(a_A - p_{rA})(-1 + \varepsilon_B)}{\varepsilon_A} + (c_A - c_B)\varepsilon_B$
c_{d11}	$a_B + \frac{a_A - p_{rA}}{\varepsilon_A} - (e + c_B)\varepsilon_B$
c_{d12}	$-e + a_B - c_A + c_A\varepsilon_B - c_B\varepsilon_B - \frac{(a_A - p_{rA} - (e + c_A)\varepsilon_A)(2\varepsilon_A^2 + 1 - \varepsilon_B)}{\sqrt{(1 + 2\varepsilon_A^2)(2\varepsilon_A^2 + (-1 + \varepsilon_B)^2)}}(\sqrt{2} + \frac{\varepsilon_B^2}{\sqrt{2}(1 + 2\varepsilon_A^2 - \varepsilon_B)} + \frac{4(1 - \varepsilon_B + \varepsilon_B^2)}{\sqrt{2}(-1 + 2\varepsilon_A^2 + \varepsilon_B)}) - \frac{(2(a_A - p_{rA})\varepsilon_A + e(-1 + \varepsilon_B) + c_A(-1 + \varepsilon_B))(-2 + \varepsilon_B)}{-1 + 2\varepsilon_A^2 + \varepsilon_B}$
c_{d13}	$e + a_B + c_A + \frac{2\varepsilon_A(-a_A + p_{rA} + (e + c_A)\varepsilon_A)(-1 + \varepsilon_B)}{4\varepsilon_A^2 + (-1 + \varepsilon_B)^2} - (e + c_B)\varepsilon_B$
c_{d14}	$\frac{1}{\varepsilon_A^2\varepsilon_B}(-2(a_A - p_{rA} - c_A\varepsilon_A)(\varepsilon_A + 2\varepsilon_A^3) + (a_A\varepsilon_A - p_{rA}\varepsilon_A - a_B(2 + 3\varepsilon_A^2) + p_{rB}(2 + 4\varepsilon_A^2))\varepsilon_B + (2c_B - (e - 3c_B)\varepsilon_A^2)\varepsilon_B^2)$
c_{ds1}	$e + a_B - \frac{(a_A - p_{rA})\varepsilon_A}{2} + \frac{1}{2}c_A(2 + \varepsilon_A^2) - (e + c_B)\varepsilon_B$
c_{ds2}	$\frac{4e}{3} + a_B + c_A - \frac{1}{3}(4e + 3c_B)\varepsilon_B$
c_{ds3}	$a_B + \frac{1}{2}((a_A - p_{rA})(\frac{1}{\varepsilon_A} - \varepsilon_A) + c_A(1 + \varepsilon_A^2) - 2(e + c_B)\varepsilon_B)$
c_{ds4}	$a_B + \frac{a_A - p_{rA}}{\varepsilon_A} - \frac{(2e + c_B + (4e + 3c_B)\varepsilon_A^2)\varepsilon_B}{1 + 3\varepsilon_A^2}$
c_{ds5}	$\frac{1}{2}(-2(a_A - p_{rA})\varepsilon_A + (a_A - p_{rA} - (2e + c_A)\varepsilon_A)\sqrt{1 + \varepsilon_A^2} +$

	$2(a_B+(e+c_A)(1+\varepsilon_A^2)-(e+c_B)\varepsilon_B))$
c_{ds6}	$\frac{p_r+2(a_A-p_{rA})\varepsilon_A+a_B(-1+\varepsilon_A^2)+c_B\varepsilon_B+\varepsilon_A^2(p_{rB}-(2e+c_B)\varepsilon_B)}{2\varepsilon_A^2}$
c_{ds7}	$\frac{1}{2}(2e+a_B+2c_A+p_{rB}-(2e+c_B)\varepsilon_B)$
c_{ds8}	$\frac{(-(a_A-p_{rA}-c_A\varepsilon_A)(\varepsilon_A+\varepsilon_A^3)+(-a_B+p_{rB}+2(a_A-p_{rA})\varepsilon_A +(a_B+p_{rB})\varepsilon_A^2)\varepsilon_B+(c_B-(2e+c_B)\varepsilon_A^2)\varepsilon_B^2)}{2\varepsilon_A^2\varepsilon_B}$
c_{ds9}	$\frac{(-2(e+a_B+c_A)+(a_B+2(2e+c_A+c_B)+p_{rB})\varepsilon_B-(2e+c_B)\varepsilon_B^2)}{(2(-1+\varepsilon_B))}$
c_{dt1}	$\frac{(2e-3(a_A-p_{rA})\varepsilon_A+8e\varepsilon_A^2+8\varepsilon_A^3(-a_A+p_{rA}+e\varepsilon_A)+2c_A(1+2\varepsilon_A^2)^2 +a_B(\varepsilon_A^2(5-3\varepsilon_B)+2(-1+\varepsilon_B)^2)-(2(3e+2c_A+c_B)-4(a_A-p_{rA})\varepsilon_A +(12e+7c_A+5c_B)\varepsilon_A^2)\varepsilon_B+(2(3e+c_A+2c_B)-(a_A-p_{rA})\varepsilon_A +(4e+c_A+3c_B)\varepsilon_A^2)\varepsilon_B^2-2(e+c_B)\varepsilon_B^3)}{\varepsilon_A^2(5-3\varepsilon_B)+2(-1+\varepsilon_B)^2}$
c_{dt2}	$\frac{4e}{3}+a_B+c_A+\frac{4\varepsilon_A(a_A-p_{rA}-(2e+c_A)\varepsilon_A)}{3(-1+\varepsilon_B)}-\frac{1}{3}(4e+3c_B)\varepsilon_B$
c_{dt3}	$\frac{((a_A-p_{rA}+a_B\varepsilon_A)(1+3\varepsilon_A^2)+(-(2e+2a_B+c_A+c_B)\varepsilon_A -(4e+c_A+3c_B)\varepsilon_A^3+(a_A-p_{rA})(-1+\varepsilon_A^2))\varepsilon_B+2(e+c_B)\varepsilon_A\varepsilon_B^2)}{\varepsilon_A(1+3\varepsilon_A^2-2\varepsilon_B)}$
c_{dt4}	$a_B+\frac{a_A-p_{rA}}{\varepsilon_A}-\frac{(2e+c_B+(4e+3c_B)\varepsilon_A^2)\varepsilon_B}{1+3\varepsilon_A^2}$
c_{dt5}	$e+a_B+c_A+\frac{\varepsilon_A(a_A-p_{rA}-(e+c_A)\varepsilon_A)(-1+\varepsilon_B)}{\varepsilon_A^2+(-1+\varepsilon_B)^2}-(e+c_B)\varepsilon_B$
c_{dt6}	$\frac{(-2(1+2\varepsilon_A^2)(e-(a_A-p_{rA})\varepsilon_A+2e\varepsilon_A^2)+a_B(\varepsilon_A^2(-5+\varepsilon_B) +(-2+\varepsilon_B)(-1+\varepsilon_B)^2)+(8e+2c_B+p_{rB}-4(a_A-p_{rA})\varepsilon_A+(5c_B+4(4e+p_{rB}))\varepsilon_A^2)\varepsilon_B -(12e+5c_B+2p_{rB}-2(a_A-p_{rA})\varepsilon_A+(8e+c_B)\varepsilon_A^2)\varepsilon_B^2+(8e+4c_B+p_{rB})\varepsilon_B^3 -(2e+c_B)\varepsilon_B^4-c_A(4\varepsilon_A^4-2(-1+\varepsilon_B)^3+\varepsilon_A^2(-1+\varepsilon_B)(-7+2\varepsilon_B)))}{(5\varepsilon_A^2+2(-1+\varepsilon_B)^2)(-1+\varepsilon_B)}$
c_{dt7}	$\frac{(-(a_A-p_{rA})\varepsilon_A(2\varepsilon_A^2+(-1+\varepsilon_B)^2)+c_A\varepsilon_A^2(1+2\varepsilon_A^2+(-1+\varepsilon_B)\varepsilon_B) +\varepsilon_B(p_{rB}(1+2\varepsilon_A^2-\varepsilon_B)+c_B(1+\varepsilon_A^2-\varepsilon_B)\varepsilon_B+a_B(-1-\varepsilon_A^2+\varepsilon_B)))}{\varepsilon_A^2\varepsilon_B}$
c_{dt8}	$\frac{(-(a_A-p_{rA}-c_A\varepsilon_A)(\varepsilon_A+\varepsilon_A^3)+(-a_B+p_{rB}+2(a_A-p_{rA})\varepsilon_A+(a_B+p_{rB})\varepsilon_A^2)\varepsilon_B +(c_B-(2e+c_B)\varepsilon_A^2)\varepsilon_B^2)}{2\varepsilon_A^2\varepsilon_B}$
a_{A1}	$\frac{a_B-p_{rB}-c_B\varepsilon_B+c_A\varepsilon_A^2+p_{rA}\varepsilon_A}{\varepsilon_A}$
a_{A2}	$p_{rA}+c_A\varepsilon_A+\frac{\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B)}{\varepsilon_A(-1+\varepsilon_B)}$
a_{A3}	$p_{rA}+\frac{2a_B-2p_{rB}+c_A\varepsilon_A^2-2c_B\varepsilon_B}{\varepsilon_A}$
a_{A4}	$p_{rA}+\frac{3a_B-3p_{rB}+2c_A\varepsilon_A^2-3c_B\varepsilon_B}{2\varepsilon_A}$

s_1	$2(a_A - p_{rA})\varepsilon_A - c_A(1+2\varepsilon_A^2) - (a_B - c_d - c_B\varepsilon_B)$
s_2	$a_B - c_A + c_d - 2p_{rB} - c_B\varepsilon_B$
s_3	$\frac{c_A - c_d + a_B(1+\varepsilon_B) - \varepsilon_B(c_A - c_d + 2p_{rB} + c_B(1+\varepsilon_B))}{-1+\varepsilon_B}$
s_4	$c_d - 2p_{rB} - c_B\varepsilon_B - \frac{p_{rB} + (a_A - p_{rA})\varepsilon_A - a_B(1+\varepsilon_A^2) + c_B\varepsilon_B}{\varepsilon_A^2}$
s_5	$\frac{((a_A - p_{rA} - c_A\varepsilon_A)(\varepsilon_A + 2\varepsilon_A^3) + (a_B - p_{rB} - (a_A - p_{rA})\varepsilon_A + (a_B + c_d - 2p_{rB})\varepsilon_A^2)\varepsilon_B - c_B(1+\varepsilon_A^2)\varepsilon_B^2)}{\varepsilon_A^2\varepsilon_B}$
t_1	$\frac{-a_B + c_d + 2(a_A - p_{rA})\varepsilon_A - c_A(1+2\varepsilon_A^2) + c_B\varepsilon_B}{1+2\varepsilon_A^2 - \varepsilon_B}$
t_2	$\frac{(-(a_A - p_{rA} - c_A\varepsilon_A)(\varepsilon_A + 2\varepsilon_A^3) + (-a_B + p_{rB} + (a_A - p_{rA})\varepsilon_A - (a_B + c_d - 2p_{rB})\varepsilon_A^2)\varepsilon_B + c_B(1+\varepsilon_A^2)\varepsilon_B^2)}{\varepsilon_A^2\varepsilon_B^2}$
t_3	$\frac{-c_A + c_d - (a_B - c_B\varepsilon_B)(1+\varepsilon_B) + \varepsilon_B(c_A - c_d + 2p_{rB})}{2\varepsilon_A^2 + (-1+\varepsilon_B)^2}$
t_4	$\frac{a_B - p_{rB} - (a_A - p_{rA})\varepsilon_A + (a_B + c_d - 2p_{rB})\varepsilon_A^2}{(1+\varepsilon_A^2)\varepsilon_B} - c_B$
t_5	$\frac{a_B - c_A + c_d - 2p_{rB} - c_B\varepsilon_B}{1+\varepsilon_B}$
e_1	$\frac{2\varepsilon_A(-a_A + p_{rA} + c_A\varepsilon_A)}{-1+\varepsilon_B}$
e_2	$\frac{2(-a_B + p_{rB} + c_B\varepsilon_B)}{-1+\varepsilon_B}$
e_3	$\frac{2(-a_B + p_{rB} + 2\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A) + c_B\varepsilon_B)}{1-\varepsilon_B}$
e_4	$-c_A + \frac{a_A - p_{rA}}{\varepsilon_A}$
e_5	$-c_B + \frac{2(a_B - p_{rB})}{\varepsilon_B} + \frac{-\varepsilon_A(a_A - p_{rA} + (-c_A + c_B)\varepsilon_A) + (-a_B + p_{rB})\varepsilon_B}{\varepsilon_A^2 + \varepsilon_B^2}$
e_6	$\frac{(a_A - p_{rA})(\varepsilon_A^2 + 2\varepsilon_B^2) + \varepsilon_A(\varepsilon_B(-a_B + p_{rB} + c_B\varepsilon_B) - c_A(\varepsilon_A^2 + 2\varepsilon_B^2))}{\varepsilon_A(\varepsilon_A^2 + \varepsilon_B^2)}$
e_{s1}	$\frac{3\varepsilon_A(a_A - p_{rA} - c_A\varepsilon_A)}{2(-1+\varepsilon_B)}$
e_{s2}	$\frac{(a_A - p_{rA} - c_A\varepsilon_A)(1+3\varepsilon_A^2)}{2\varepsilon_A\varepsilon_B}$
e_{s3}	$\frac{1}{2}(-c_A + \frac{a_A - p_{rA}}{\varepsilon_A})$
e_{s4}	$-\frac{(1+3\varepsilon_A^2)(-a_B + p_{rB} + c_B\varepsilon_B)}{2\varepsilon_A^2\varepsilon_B}$
e_{s5}	$\frac{-a_B + p_{rB} + c_B\varepsilon_B}{2(-1+\varepsilon_B)}$

e_{t1}	$\frac{1}{2}(-2c_B+\frac{a_B-p_{rB}}{\varepsilon_B}+\frac{\varepsilon_A(a_A-p_{rA}+(-c_A+c_B)\varepsilon_A)+(a_B-p_{rB})\varepsilon_B}{\varepsilon_A^2+\varepsilon_B^2})$
e_{t2}	$\frac{2\varepsilon_A^2(a_A-p_{rA}-c_A\varepsilon_A)+(a_B-p_{rB})\varepsilon_A\varepsilon_B+(a_A-p_{rA}-(c_A+c_B)\varepsilon_A)\varepsilon_B^2}{2\varepsilon_A(\varepsilon_A^2+\varepsilon_B^2)}$
e_{t3}	$\frac{(a_A-p_{rA})\varepsilon_A-c_A\varepsilon_A^2+\varepsilon_B(a_B-p_{rB}-c_B\varepsilon_B)}{2(\varepsilon_A^2+\varepsilon_B^2)}$
e_{t4}	$\frac{\varepsilon_A(a_A-p_{rA}-c_A\varepsilon_A)(-1+3\varepsilon_B)}{2(2\varepsilon_A^2+(-1+\varepsilon_B)^2)}$
e_{t5}	$\frac{\varepsilon_A(a_A-p_{rA}-c_A\varepsilon_A)}{2\varepsilon_A^2+(-1+\varepsilon_B)^2}$
e_{t6}	$\frac{2\varepsilon_A(a_A-p_{rA}-c_A\varepsilon_A)-3\varepsilon_B(-a_B+p_{rB}+c_B\varepsilon_B)}{2(2\varepsilon_A^2+(-1+\varepsilon_B)^2)}$
e_{t7}	$\frac{(c_A\varepsilon_A^2(\varepsilon_A^2(5-7\varepsilon_B)-2(-1+\varepsilon_B)^3)+(\varepsilon_A^2(5-3\varepsilon_B)+2(-1+\varepsilon_B)^2)\varepsilon_B(-a_B+p_{rB}+c_B\varepsilon_B)+(a_A-p_{rA})\varepsilon_A(2(-1+\varepsilon_B)^3+\varepsilon_A^2(-5+7\varepsilon_B)))}{2\varepsilon_A^2(2\varepsilon_A^2+(-1+\varepsilon_B)^2)\varepsilon_B}$
e_{t8}	$-\frac{((1+3\varepsilon_A^2-2\varepsilon_B)\varepsilon_B(-a_B+p_{rB}+c_B\varepsilon_B)-(a_A-p_{rA})\varepsilon_A(1+3\varepsilon_A^2+2(-1+\varepsilon_B)\varepsilon_B)+c_A\varepsilon_A^2(1+3\varepsilon_A^2+2(-1+\varepsilon_B)\varepsilon_B))}{2\varepsilon_A^2\varepsilon_B^2}$