Appendix for Manuscript

Proof of Lemma 1:

Sequential game with "outcome unknown" Case 1:

The two firms' expected profits can be characterized as follows:

$$E(\pi_L^U)=\frac{\alpha^2(c_F^U-c_L^U+3t)^2+\alpha(1-\alpha)(c_O-c_L^U+3t)^2+(1-\alpha)\alpha(c_F^U-c_O+3t)^2+(1-\alpha)^2(3t)^2}{18t}-k(c_O-c_L^U)^2$$

$$E(\pi_F^U)=\frac{\alpha^2(c_L^U-c_F^U+3t)^2+\alpha(1-\alpha)(c_L^U-c_O+3t)^2+(1-\alpha)\alpha(c_O-c_F^U+3t)^2+(1-\alpha)^2(3t)^2}{18t}-k(c_O-c_F^U)^2$$

By taking the first derivative of the follower's expected profit w.r.t. the follower's new marginal cost if his implementation is successful, c_F^U, and solving its first order condition, we get $c_F^U(c_L^U)=\frac{\alpha\left(c_L^U+3t\right)+c_O\left(\alpha-\alpha^2-18kt\right)}{\alpha-18kt}$, which is the response function of the follower conditioning on the leader's investment level. Then, we substitute the follower's response function into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c_L^U, and solving its first order condition, we get $c_L^U=c_O-\frac{3\alpha t\left(\alpha^2-\alpha^3-36k\alpha t+324k^2t^2\right)}{\alpha^5-36k\alpha^4t-\alpha^3+54k\alpha^2t-972k^2\alpha t^2+5832k^3t^3}$. Then check the second order condition, and with the assumption $kt>1/6$, we can show that $\frac{\delta^2E(\pi_L^U)}{\delta c_L^{U2}}=\frac{2\alpha-36kt+\frac{2\alpha^5}{\left(\alpha-18kt\right)^2}-\frac{4\alpha^4}{\alpha-18kt}}{18t}<0$. Then we substitute the leader's new marginal cost in the event of a successful implementation into the follower's response function and get $c_F^U=c_O-\frac{3\alpha t\left(\alpha+2\alpha^2-18kt\right)\left(18kt-\left(1-\alpha\right)\alpha\right)}{\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3}$. We also check the second order condition, and with the assumption $kt>1/6$, we show that $\frac{\delta^2E(\pi_F^U)}{\delta c_F^{U2}}=\frac{\alpha-18kt}{9t}<0$.

We substitute the firms' new marginal costs in the event of a successful implementation into the investment function $f_i^U=k(c_O-c_i^U)^2$ and get the optimal investment levels of the leader and the follower $f_L^U=k\left(\frac{3\alpha t\left(\alpha^2-\alpha^3-36k\alpha t+324k^2t^2\right)}{\alpha^5-36k\alpha^4t-\alpha^3+54k\alpha^2t-972k^2\alpha t^2+5832k^3t^3}\right)^2$ and $f_F^U=k\left(\frac{3\alpha t\left(\alpha+2\alpha^2-18kt\right)\left(18kt-\left(1-\alpha\right)\alpha\right)}{\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3}\right)^2$.

The two firms' expected profits are:

$$E(\pi_L^U)=\frac{t}{2}\left(1+\frac{2\alpha^2\left(\alpha+2\alpha^2-18kt\right)\left(9kt-\left(1-\alpha\right)\alpha\right)}{\alpha^5-\alpha^3+54k\alpha^2t-36k\alpha^4t-972k^2\alpha t^2+5832k^3t^3}\right)$$

$$E(\pi_F^U)=\frac{t\begin{pmatrix}(1-\alpha)^3\alpha^6(1+\alpha)(1+4\alpha)+18k(1-\alpha)^2\alpha^5\left(\alpha(2\alpha-7)(3+2\alpha)-6\right)t+324k^2(1-\alpha)\alpha^4\left(15-\alpha\left(\alpha(7+8\alpha)-31\right)\right)t^2\\ 5832k^3\alpha^3\left(-20+\alpha\left(-14+\alpha(24+\alpha)\right)\right)t^3+314928k^4\alpha^2\left(5+2(1-\alpha)\alpha\right)t^4-1889568k^5\alpha(6+\alpha)t^5+34012224k^6t^6\end{pmatrix}}{2\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2}$$

We substitute the new marginal costs in the event of a successful implementation to solve for the optimal prices, $p_{i,j}^U=t+(2c_{i,j}^U+c_{-i,j}^U)/3$, market shares $m_{i,j}^U=1/2+(c_{-i,j}^U-c_{i,j}^U)/(6t)$, and consumer surplus $CS_j^U=\int_0^{x_{i,j}}(U-tx^2-p_{F,j})dx+\int_{x_{i,j}}^1(U-t(1-x)^2-p_{L,j})dx$ given an outcome case j, where $x_{i,j}=m_{F,j}$. Then we can get the expected consumer surplus $E(CS^U)=\alpha^2CS_{ss}^U+\alpha(1-\alpha)CS_{sf}^U+(1-\alpha)\alpha CS_{fs}^U+(1-\alpha)(1-\alpha)CS_{ff}^U$

$$=U-c_O-\frac{t\begin{pmatrix}(1-\alpha)^2\alpha^6(1+\alpha)\left(13+\alpha(43+36\alpha)\right)-36k(1-\alpha)\alpha^5(1+\alpha)\left(39+2\alpha\left(39-2\alpha(2+9\alpha)\right)\right)t+\\ 324k^2\alpha^4\left(195+\alpha\left(324-\alpha\left(156+\alpha(267-4\alpha)\right)\right)\right)t^2+11664k^3\alpha^3\left(\alpha\left(\alpha(55+51\alpha)-168\right)-130\right)t^3+\\ 104976k^4\alpha^2\left(195+2\alpha(87-14\alpha)\right)t^4-11337408k^5\alpha(13+6\alpha)t^5+442158912k^6t^6\end{pmatrix}}{12\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2}$$

The social welfare is the sum of the two firms' profits and the consumer surplus:

$$E(SW^U)=E(\pi_L^U)+E(\pi_F^U)+E(CS^U)$$

$$=U-c_O+\frac{t\begin{pmatrix}36k(1-\alpha)\alpha^5\left(3+\alpha\left(27+4\alpha\left(19+4\alpha-6\alpha^2\right)\right)\right)t-(1-\alpha)^2\alpha^6(1+\alpha)\left(1+\alpha(7+36\alpha)\right)+\\ 324k^2\alpha^4\left(\alpha\left(\alpha\left(\alpha(147+68\alpha)-144\right)-132\right)-15\right)t^2+11664k^3\alpha^3\left(10+\alpha\left(84+\alpha(53-30\alpha)\right)\right)t^3-\\ 104976k^4\alpha^2\left(15+2\alpha(51+16\alpha)\right)t^4+11337408k^5\alpha(1+4\alpha)t^5-34012224k^6t^6\end{pmatrix}}{12\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2}$$

Q.E.D.

Proof of Lemma 2:

Sequential game with "outcome known" Case 2:

The leader's expected profit can be characterized as follows:

$$E(\pi_L^K)=\frac{\alpha^2(c_{F,ss}^K-c_L^K+3t)^2+\alpha(1-\alpha)(c_O-c_L^K+3t)^2+(1-\alpha)\alpha(c_{F,fs}^k-c_O+3t)^2+(1-\alpha)^2(3t)^2}{18t}-k(c_O-c_L^K)^2;$$

And the follower's expected profit depending on the outcome of the leader's implementation can be characterized as follows:

$$E(\pi_{F,s}^K)=\frac{\alpha(c_L^K-c_{F,ss}^K+3t)^2+(1-\alpha)(c_L^K-c_O+3t)^2}{18t}-k(c_O-c_{F,ss}^K)^2$$ if the leader's implementation is successful;

$$E(\pi_{F,f}^K)=\frac{\alpha(c_O-c_{F,fs}^K+3t)^2+(1-\alpha)(3t)^2}{18t}-k(c_O-c_{F,fs}^K)^2$$ if the leader's implementation is unsuccessful.

By taking the first derivative of the follower's expected profits, $E(\pi^K_{F,s})$ and $E(\pi^K_{F,f})$ w.r.t. the follower's new marginal costs if his implementation is successful, $c^K_{F,s}$ and $c^K_{F,f}$, and solving its first order conditions, we get $c^K_{F,ss} = \frac{c^K_L + 3(\alpha - 6c_O k)t}{\alpha - 18kt}$ and $c^K_{F,fs} = \frac{c_O\alpha + 3(\alpha - 6c_O k)t}{\alpha - 18kt}$, which is the response function of the Follower conditioning on the leader's investment level and implementation outcome. We also check the second order condition, with assumption $kt > 1/6$, we show that $\frac{\delta^2 E(\pi^K_{F,s})}{\delta c^{K\ 2}_{F,s}} = \frac{\delta^2 E(\pi^K_{F,f})}{\delta c^{K\ 2}_{F,f}} = \frac{2\alpha - 36kt}{18t} < 0$.

Then, we substitute the follower's response functions into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c^K_L, and solving its first order condition, we get $c^K_L = c_O - \frac{3pt\left(36k\alpha t - (1-\alpha)\alpha^2 - 324k^2t^2\right)}{18k(3-2\alpha)\alpha^2 t - (1-\alpha)\alpha^3 - 972k^2\alpha t^2 + 5832k^3t^3}$. Then check the second order condition, and with the assumption $kt > 1/6$, we show that $\frac{\delta^2 E(\pi^K_L)}{\delta c^{K2}_L} = \frac{(1-\alpha)\alpha}{9t} - k\left(2 - \frac{36\alpha^2 kt}{(\alpha - 18kt)^2}\right) < 0$. Then we substitute the leader's new marginal cost into the follower's response functions and get $c^K_{F,ss} = c_O - \frac{6\alpha^2t^2\left(27k\alpha t - (1-\alpha)\alpha^2 - 162k^2t^2\right)}{18k(3-2\alpha)\alpha^2 t - (1-\alpha)\alpha^3 - 972k^2\alpha t^2 + 5832k^3t^3}$ and $c^K_{F,fs} = c_O - \frac{3\alpha t}{\alpha - 18kt}$.

After applying the investment function $f^U_i = k(c_O - c^U_i)^2$, we get the optimal investment levels of the leader as $f^K_L = k\left(\frac{3pt\left(36k\alpha t - (1-\alpha)\alpha^2 - 324k^2t^2\right)}{18k(3-2\alpha)\alpha^2 t - (1-\alpha)\alpha^3 - 972k^2\alpha t^2 + 5832k^3t^3}\right)^2$, and that of the follower as

$f^K_{F,s} = k\left(\frac{6\alpha^2t^2\left(27k\alpha t - (1-\alpha)\alpha^2 - 162k^2t^2\right)}{18k(3-2\alpha)\alpha^2 t - (1-\alpha)\alpha^3 - 972k^2\alpha t^2 + 5832k^3t^3}\right)^2$ if the leader's implementation fails, and

$f^K_{F,f} = k\left(\frac{3\alpha t}{\alpha - 18kt}\right)^2$ if the leader's implementation succeeds.

The two firms' expected profits are:

$$E(\pi^K_L) = \frac{t\begin{pmatrix} 18k\alpha^4\left(5 + (3-4\alpha)\alpha\right)t - 648k^2\alpha^3\left(5 + (2-\alpha)\alpha\right)t^2 - (1-\alpha)\alpha^5(1+\alpha)^2 \\ 5832k^3\alpha^2(10+3\alpha)t^3 - 104976k^4\alpha(5+\alpha)t^4 + 1889568k^5t^5 \end{pmatrix}}{2(\alpha - 18kt)^2\left((-1+p)\alpha\alpha^3 + 18k(3-2\alpha)\alpha^2 t - 972k^2\alpha t^2 + 5832k^3t^3\right)}$$

$$E(\pi^K_F) = E(\pi^K_{F,s}) + E(\pi^K_{F,f})$$

$$= \frac{t\begin{pmatrix} (1-\alpha)^3\alpha^7(1+3\alpha) - 18k(1-\alpha)^2\alpha^6\left(7 + \alpha(13-4\alpha)\right)t + 34012224k^6p(7+\alpha)t^6 + \\ 972k^2(1-\alpha)\alpha^5\left(7 + 6(1-\alpha)\alpha\right)t^2 - 5832k^3\alpha^4\left(35 - 2\alpha\left(1 + 3(5-\alpha)\alpha\right)\right)t^3 + \\ 104976k^4\alpha^3\left(35 + \alpha(2-13\alpha)\right)t^4 - 1889568k^5\alpha^2\left(21 + \alpha(3-2\alpha)\right)t^5 - 612220032k^7t^7 \end{pmatrix}}{2(\alpha - 18kt)\left(18k(3-2\alpha)\alpha^2 t - (1-\alpha)\alpha^3 - 972k^2\alpha t^2 + 5832k^3t^3\right)^2}$$

Then we substitute the firms' optimal investment levels and get the expected consumer surplus $E(CS^K)$

$$=U-c_O-\frac{t\left(\begin{array}{l}(-1+\alpha)^2\alpha^8(13+3\alpha(10+7\alpha))-36k(-1+\alpha)\alpha^7(-52+3\alpha(-23+\alpha(2+11\alpha)))t+\\324k^2\alpha^6(364+\alpha(146-\alpha(335+3\alpha(41-16\alpha))))t^2+11664k^3\alpha^5(3\alpha(\alpha(59+25\alpha)-60)-364)t^3-\\104976k^4\alpha^4(\alpha(\alpha(149+72\alpha)-520)-910)t^4-3779136k^5\alpha^3(364+\alpha(217+9\alpha))t^5+\\68024448k^6\alpha^2(182+\alpha(97+12\alpha))t^6-2448880128k^7\alpha(26+9\alpha)t^7+143259487488k^8t^8\end{array}\right)}{12(18kt-\alpha)^2(\alpha^4-\alpha^3+54k\alpha^2t-36k\alpha^3t-972k^2\alpha t^2+5832k^3t^3)^2}$$

Social welfare is:

$$E(SW^K)=E(\pi_L^K)+E(\pi_F^K)+E(CS^K)$$

$$=U-c_O+\frac{1}{72}\left(\begin{array}{l}\frac{8\alpha^2}{k}-6t-\frac{3(1-\alpha)\alpha^4}{k(18kt-\alpha)^2}+\frac{7(1-\alpha)\alpha^3}{k(18kt-\alpha)}+\frac{\alpha^7(\alpha^2+\alpha^3-2\alpha^4-18kp(5-2\alpha)t+324k^2(4+3\alpha)t^2)}{k(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972k^2\alpha t^2+5832k^3t^3)^2}+\\\frac{\alpha^3(\alpha^2(4+\alpha-2\alpha^2)-18k\alpha(11-5\alpha)t+324k^2(7-5\alpha)t^2)}{k(+18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972k^2\alpha t^2+5832k^3t^3)}\end{array}\right)$$

"Simultaneous" case:

Firms' optimal investment is $f_i^S=k\left(\frac{3\alpha t}{18kt-(1-\alpha)\alpha}\right)^2$ and his new marginal cost is

$c_i^S=c_O-\frac{3\alpha t}{18kt-(1-\alpha)\alpha}$ if the IT is implemented successfully, the expected profit is

$E(\pi_i^S)=\frac{t(324k^2t^2+\alpha^2(1+18kt)-\alpha^4-36k\alpha t)}{2(18kt-(1-\alpha)\alpha)^2}$, where $i\in\{L,F\}$. Expected consumer surplus is

$E(CS^S)=U-c_O-\frac{t(4\alpha^3-17\alpha^4-468k\alpha t+4212k^2t^2+\alpha^2(13-180kt))}{12(18kt-(1-\alpha)\alpha)^2}$, and social welfare is

$E(SW^S)=U-c_O+\frac{t(36k\alpha(1+11\alpha)t-(1-\alpha)\alpha^2(1+5\alpha)-324k^2t^2)}{12(18kt-(1-\alpha)\alpha)^2}$.

Q.E.D.

Proof of Proposition 1:

a) and b) of Proposition 1:

Note, the following proof is valid for $\forall\alpha\in[0,1]$.

$$f_L^U - f_L^S = k\left(\frac{3\alpha t\left(\alpha^2-\alpha^3-36k\alpha t+324k^2t^2\right)}{\alpha^5-36k\alpha^4 t-\alpha^3+54k\alpha^2 t-972k^2\alpha t^2+5832k^3t^3}\right)^2 - k\left(\frac{3\alpha t}{18kt-(1-\alpha)\alpha}\right)^2$$

$$=9k\alpha^2t^2\,\frac{4\alpha^2(18kt-\alpha)\,(9kt-\alpha(1+\alpha))\,((1-\alpha)\alpha^3+9\,k\alpha^2\,\,(\alpha(3+2\alpha)\text{-}6)t+162k^2(6-\alpha)\alpha t^2\text{ - }5832\,k^3t^3)}{(\alpha^5-36k\alpha^4t-\alpha^3+54k\alpha^2t-972k^2\alpha t^2+5832k^3t^3)^2(18kt-(1-\alpha)\alpha)^2}$$

Since $kt>\frac{1}{6}$, the numerator and the denominator of $f_L^U - f_L^S$ are positive. Thus, $f_L^U - f_L^S > 0$, and we show that the leader's investment is higher in Case 1 than in the simultaneous game.

$$f_F^U - f_F^S = k\left(\frac{3\alpha t\left(\alpha+2\alpha^2-18kt\right)\left(18kt-\left(1-\alpha\right)\alpha\right)}{\alpha^3-\alpha^5-54k\alpha^2 t+36k\alpha^4 t+972k^2\alpha t^2-5832k^3t^3}\right)^2 - k\left(\frac{3\alpha t}{18kt-(1-\alpha)\alpha}\right)^2$$

$$=\frac{9kp^2t^2\left(\dfrac{\left(\alpha+2\alpha^2-18kt\right)^2\left(18kt-\left(1-\alpha\right)\alpha\right)^4}{\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\left(-1+\alpha\right)\alpha t^2-5832k^3t^3\right)^2}-1\right)}{\left(18kt-\left(1-\alpha\right)\alpha\right)^2}$$

Since $kt>\frac{1}{6}$, we have $\frac{\left(\alpha+2\alpha^2-18kt\right)^2\left(18kt-\left(1-\alpha\right)\alpha\right)^4}{\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\left(-1+\alpha\right)\alpha t^2-5832k^3t^3\right)^2}<1$. This means that the numerator of $f_F^U - f_F^S$ is negative, whereas the denominator is positive. Thus, $f_F^U - f_F^S < 0$, and the follower's investment is lower in Case 1 than in the simultaneous game.

Since the leader and the follower have identical investment levels in the simultaneous game ($f_L^S = f_F^S$), the above result shows that the leader's investment is higher than the follower's investment in Case 1, $f_L^U > f_F^U$.

$E(\pi_L^U)-E(\pi_L^S)=\frac{2\alpha^6 t\left(9kt-\left(1-\alpha\right)\alpha\right)^2}{\left(18kt-\left(1-\alpha\right)\alpha\right)^2\left(\alpha^5-\alpha^3+54k\alpha^2t-36k\alpha^4t-972k^2\alpha t^2+5832k^3t^3\right)}$. It is clear that its numerator is positive. We can show that if $kt>\frac{1}{6}$, then $\alpha^5-\alpha^3+54k\alpha^2t-36k\alpha^4t-972k^2\alpha t^2+5832k^3t^3>0$. This implies that the denominator is also positive. Thus, $\pi_L^U - \pi_L^S > 0$, and the leader's profit is higher in Case 1 than in the simultaneous game.

$E(\pi_F^U)-E(\pi_F^S)=\frac{2\alpha^4 t\left(18kt-\alpha\right)\left(9kt-\left(1-\alpha\right)\alpha\right)^2\left(\left(2-\alpha\right)\left(1-\alpha\right)\alpha^3\left(1+\alpha\right)-18k\alpha^2\left(6-\alpha-4\alpha^2\right)t+1944k^2\alpha t^2-11664k^3t^3\right)}{\left(18kt-\left(1-\alpha\right)\alpha\right)^2\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2}$. It is clear that its denominator is positive. Since $kt>\frac{1}{6}$, we have $\left(2-\alpha\right)\left(1-\alpha\right)\alpha^3\left(1+\alpha\right)<18k\alpha^2\left(6-\alpha-4\alpha^2\right)t-1944k^2\alpha t^2+11664k^3t^3$. This means that the numerator is negative. Thus, $E(\pi_F^U) - E(\pi_F^S) < 0$, and the follower's profit is lower in Case 1 than in the simultaneous game.

Since the leader and the follower have identical profits in the simultaneous move game ($E(\pi_L^S) = E(\pi_F^S)$), our results show that the leader's profit is higher than the follower's profit in Case 1, $E(\pi_L^U) > E(\pi_F^U)$.

Note, when $\alpha = 1$, Case 1 and Case 2 become identical. Thus, when $\alpha = 1$, $\pi_L^U > \pi_F^U$, $f_L^U > f_F^U$, and $\pi_L^K > \pi_F^K$, $f_L^K > f_F^K$.

c) of Proposition 1:

When neither of the two firms has the opportunity to invest in IT, they split the market in half and their profits are the same, $\pi_L^U |_{f_L=0, f_F=0} = \pi_F^U |_{f_L=0, f_F=0} = t/2$.

$\pi_L^U |_{\alpha=1} - \pi_L^U |_{f_L=0, f_F=0} = \dfrac{3t(1-6kt)}{2+108kt(6kt-1)}$. Since $kt > \dfrac{1}{6}$, the numerator is negative, whereas the denominator is positive. Thus, $\pi_L^U |_{\alpha=1} - \pi_L^U |_{f_L=0, f_F=0} < 0$, and when IT implementation always succeeds, the leader has a lower profit when he invests in IT than when neither of the firms has the opportunity to invest in IT.

$\pi_F^U |_{\alpha=1} - \pi_F^U |_{f_L=0, f_F=0} = \dfrac{-t(1+54kt(1-6kt)(1-18kt))}{2(1+54kt(6kt-1))^2}$. Since $kt > \dfrac{1}{6}$, the numerator is negative, whereas the denominator is positive. Thus, $\pi_F^U |_{\alpha=1} - \pi_F^U |_{f_L=0, f_F=0} < 0$, and when implementation always succeeds, the follower has a lower profit when he invests in IT than when neither of the firms has the opportunity to invest in IT.

Q.E.D.

Proof of Proposition 2:

a) part of Proposition 2

$$\frac{\delta f_L^U}{\delta \alpha} = \frac{18k\alpha t^2\left((1-\alpha)\alpha^2 + 324k^2t^2 - 36k\alpha t\right)\begin{pmatrix}(1-\alpha)^2\alpha^6 + 18k\alpha^4(1-6\alpha+8\alpha^2)t - 324k^2\alpha^3(4-3\alpha(3-4\alpha))t^2 + \\ 11664k^3\alpha^2(3-\alpha(2-3\alpha))t^3 - 419904k^4\alpha t^4 + 1889568k^5t^5\end{pmatrix}}{\left(\alpha^5 - \alpha^3 + 54k\alpha^2 t - 36k\alpha^4 t - 972k^2\alpha t^2 + 5832k^3t^3\right)^3}$$

We can check that since $kt > \dfrac{1}{6}$, the numerator and denominator of $\dfrac{\delta f_L^U}{\delta \alpha}$ are positive. Thus, $\dfrac{\delta f_L^U}{\delta \alpha} > 0$, and the leader's IT investment always decreases as α decreases.

$$\frac{\delta E(\pi_L^U)}{\delta\alpha}=\frac{\alpha t\begin{pmatrix}629856k^4\alpha t^4-18k(1-\alpha)\alpha^4\left(6+\alpha\left(15-6\alpha-8\alpha^2\right)\right)t+\\162k^2\alpha^3\left(26+3(8-17\alpha)\alpha\right)t^2-5832k^3\alpha^2\left(13-5\alpha(2\alpha-1)\right)t^3-\\1889568k^5t^5+(1-\alpha)^2\alpha^5\left(1+2\alpha(2+\alpha)\right)\end{pmatrix}}{\left(\alpha^3-\alpha^5-54kt\alpha^2+36kt\alpha^4+972k^2t^2\alpha-5832k^3t^3\right)^2}$$

We can check when $\left(1+144kt(-2+9kt)(-1+9kt)\right)>0$ (approximately $kt>0.22$), the numerator is negative for $0<\alpha<1$. Moreover, the denominator of $\frac{\delta E(\pi_L^U)}{\delta\alpha}$ is positive. This implies that when kt is large, or $kt>0.22$, $\frac{\delta E(\pi_L^U)}{\delta\alpha}<0$. When $\left(1+144kt(-2+9kt)(-1+9kt)\right)<0$, or when kt is small, the numerator of $\frac{\delta E(\pi_L^U)}{\delta\alpha}$ can be positive or negative, depending on kt and α, and we will show it numerically in the following specific case.

See Figure 3. $\frac{\delta E(\pi_L^U)}{\delta\alpha}\leq 0$, when $\alpha\leq 0.881011$, and $\frac{\delta E(\pi_L^U)}{\delta\alpha}>0$, when $\alpha>0.881011$, given that $c_O=1$, $k=0.47$ and $t=0.34$. We show that leader's profit can change non-monotonically: it first decreases and then increases as α decreases.

b) part of Proposition 2

$$\frac{\delta f_F^U}{\delta\alpha}=\frac{18kt^2\alpha\begin{pmatrix}612220032k^7t^7-(1-\alpha)^3\alpha^8(1+2\alpha)+18kt\alpha^6\left(1-\alpha\left(-9+\alpha\left(9+\alpha\left(20-27\alpha+8\alpha^3\right)\right)\right)\right)-\\972k^2t^2\alpha^5\left(2+\alpha\left(10-\alpha\left(8+\alpha(13-12\alpha)\right)\right)\right)+5832k^3t^3\alpha^4\left(15+2\alpha\left(25-\alpha\left(14+\alpha(15-7\alpha)\right)\right)\right)-\\104976k^4t^4\alpha^3\left(20+\alpha\left(45-\alpha(15+8\alpha)\right)\right)+5668704k^5t^5\alpha^2\left(5+(7-\alpha)\alpha\right)-68024448k^6t^6(3+2\alpha)\alpha\end{pmatrix}}{\left(\alpha^5-\alpha^3+54kt\alpha^2-36kt\alpha^4-972k^2t^2\alpha+5832k^3t^3\right)^3}$$

We can check when $\left(1+36kt(18kt-1)\left(1-18kt(1-3kt)\right)\right)<0$ (approximately $kt>0.26$), the numerator of $\frac{\delta f_F^U}{\delta\alpha}$ is negative for $0<\alpha<1$. Moreover, the denominator of $\frac{\delta f_F^U}{\delta\alpha}$ is positive. This implies that when kt is large, or $kt>0.26$, $\frac{\delta f_F^U}{\delta\alpha}<0$. When $\left(1+36kt(18kt-1)\left(1-18kt(1-3kt)\right)\right)>0$, or kt is small, the numerator of $\frac{\delta f_F^U}{\delta\alpha}$ can be positive or negative, depending on kt and α, and we will show it numerically in the following specific case.

See Figure 4. $\frac{\delta f_F^U}{\delta\alpha}\geq 0$, when $\alpha\leq 0.78$, and $\frac{\delta f_F^U}{\delta\alpha}<0$, when $\alpha>0.78$, given that $c_O=1$, $k=0.47$ and $t=0.34$. We show that the follower's IT investment can change non-monotonically: it first increases and then decreases as α decreases.

$$\frac{\delta E(\pi_F^U)}{\delta\alpha}=\frac{\alpha t\begin{pmatrix}(1-\alpha)^3\alpha^8(1+\alpha)(2\alpha(2+\alpha)-1)+54k(1-\alpha)^2\alpha^7\left(3-\alpha\left(9+\alpha\left(9-6\alpha-4\alpha^2\right)\right)\right)t- \\ 162k^2(1-\alpha)^2\alpha^6\left(68-\alpha\left(134+\alpha\left(167-16\alpha(1+\alpha)\right)\right)\right)t^2+612220032k^7\alpha(9-4\alpha)t^7-11019960576k^8t^8+ \\ 52488k^4\alpha^4\left(\alpha\left(392-\alpha\left(141-4\alpha(27-11\alpha)\right)\right)-180\right)t^4+944784k^5\alpha^3\left(142-\alpha\left(210-\alpha(49+16\alpha)\right)\right)t^5- \\ 34012224k^6\alpha^2\left(34-\alpha(31-3\alpha)\right)t^6+2916k^3\alpha^5\left(142-\alpha\left(428-\alpha\left(207+2\alpha(115-73\alpha)\right)\right)\right)t^3\end{pmatrix}}{\left(\alpha^5-\alpha^3+54k\alpha^2t-36k\alpha^4t-972k^2\alpha t^2+5832k^3t^3\right)^3}$$

We can check that since $kt>\frac{1}{6}$, the numerator of $\frac{\delta E(\pi_F^U)}{\delta\alpha}$ is negative and the denominator of $\frac{\delta E(\pi_F^U)}{\delta\alpha}$ is positive. Thus, $\frac{\delta E(\pi_F^U)}{\delta\alpha}<0$, and the follower's profit always increases as α decreases.

c) part of Proposition 2 that $f_L^U>f_F^U$ and $E(\pi_L^U)>E(\pi_F^U)$ are proved in the proof for a) and b) of Proposition 1.

Q.E.D.

Proof of Proposition 3:

a) part of Proposition 3:

$$f_L^K-f_L^U=\frac{9k\alpha^2t^2\left(36k\alpha t-(1-\alpha)\alpha^2-324k^2t^2\right)^2 4\alpha^2(\alpha-18kt)\left(9kt-(1-\alpha)\alpha\right)\begin{pmatrix}(1-\alpha)\alpha^3+162k^2(6-\alpha)\alpha t^2- \\ 5832k^3t^3-9k\alpha^2\left(6-\alpha(3+2\alpha)\right)t\end{pmatrix}}{\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2\left(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972k^2\alpha t^2+5832k^3t^3\right)^2}$$

We can check that since $kt>\frac{1}{6}$, the numerator of $f_L^K-f_L^U$ is positive and the denominator of $f_L^K-f_L^U$ is positive. Thus, $f_L^K-f_L^U>0$ and the leader's IT investment is higher in Case 2 than in Case 1.

$$E(\pi_L^K)-E(\pi_L^U)=\frac{(1-\alpha)\alpha^5t(36kt-\alpha)\left(36k\alpha t-324k^2t^2-(1-\alpha)\alpha^2\right)^2}{2(\alpha-18kt)^2\begin{pmatrix}\left(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972k^2\alpha t^2+5832k^3t^3\right) \\ \left(\alpha^5-\alpha^3+54k\alpha^2t-36k\alpha^4t-972k^2\alpha t^2+5832k^3t^3\right)\end{pmatrix}}.$$

We can check that since $kt>\frac{1}{6}$, the numerator and the denominator of $E(\pi_L^K)-E(\pi_L^U)$ are positive. Thus, $E(\pi_L^K)-E(\pi_L^U)>0$ and the leader's profit is higher in Case 2 than in Case 1.

b) part of Proposition 3:

$$E(\pi_F^K)-E(\pi_F^U)=\frac{1}{2}\alpha^2 t\left(\begin{array}{l}\dfrac{\alpha^4\left(\left(1-\alpha\right)\alpha^2\left(1+\alpha\right)\left(3\alpha-2\right)-18kt\alpha\left(\alpha\left(5+2\left(1-\alpha\right)\alpha\right)-4\right)+324k^2\left(3\alpha-2\right)t^2\right)}{\left(\alpha^3-\alpha^5-54k\alpha^2 t+36k\alpha^4 t+972k^2\alpha t^2-5832k^3t^3\right)^2}+\\ \dfrac{\alpha^5\left(\alpha-3\alpha^2+2p^3+36k\alpha t-18kt\left(1+18kt\right)\right)}{\left(18kt\left(3-2\alpha\right)\alpha^2-\left(1-\alpha\right)\alpha^3-972k^2\alpha t^2+5832k^3t^3\right)^2}+\dfrac{1-\alpha}{\alpha-18kt}+\\ \dfrac{\alpha^2\left(\left(4-\alpha\right)\alpha-2\right)+18k\left(3-2\alpha\right)\alpha t-324k^2t^2}{\alpha^5-\alpha^3+54kt\alpha^2-36kt\alpha^4-972k^2t^2\alpha+5832k^3t^3}+\\ \dfrac{\alpha^2\left(3-2\left(3-\alpha\right)\alpha\right)-18k\alpha\left(5-4\alpha\right)t+324k^2\left(2-\alpha\right)t^2}{18k\left(3-2\alpha\right)\alpha^2 t-\left(1-\alpha\right)\alpha^3-972k^2\alpha t^2+5832k^3t^3}\end{array}\right)$$

To find the critical values of α and kt for $E(\pi_F^K)-E(\pi_F^U)>0$, we can reduce the task of finding $E(\pi_F^K)-E(\pi_F^U)=0$ as to find the critical values of α and kt of the following equality:

$$\left(\begin{array}{l}408146688b^7\alpha\left(13-2\alpha\right)-\left(1-\alpha\right)^3\alpha^8\left(1+\alpha\right)-11019960576b^8+1259712b^5\alpha^3\left(3+\alpha\right)\left(33-30\alpha+4\alpha^2\right)-\\ 11337408b^6\alpha^2\left(96-\alpha\left(33+8\alpha\right)\right)+6\alpha\left(1-\alpha\right)^2\alpha^7\left(26+\alpha\left(7-16\alpha\right)\right)+34992b^4\alpha^4\left(\alpha\left(211+66\alpha-52\alpha^2\right)-250\right)-\\ 108b^2\left(1-\alpha\right)\alpha^6\left(96-\alpha\left(42+\alpha\left(67-28\alpha\right)\right)\right)+1944b^3\alpha^5\left(198-\alpha\left(225+\alpha\left(59-2\alpha\left(53-8\alpha\right)\right)\right)\right)\end{array}\right)=0$$

where $b=kt$. It is evident that the solution to this equality is mathematically challenging. Thus, we show that $E(\pi_F^K)-E(\pi_F^U)$ can be positive or negative with respect to α and kt in the following two specific cases.

See Figure 5. $E(\pi_F^K)-E(\pi_F^U)<0$ when $\alpha<0.956$, $E(\pi_F^K)-E(\pi_F^U)\geq 0$ when $\alpha\geq 0.956$, given that $c_O=1$, $k=0.47$ and $t=0.34$.

See Figure 7. $E(\pi_F^K)-E(\pi_F^U)\geq 0$ when $t\leq 0.3371$, $E(\pi_F^K)-E(\pi_F^U)<0$ when $t>0.3371$, given that $c_O=1$, $k=0.47$ and $\alpha=0.95$.

As these examples show the follower's profit can be higher in Case 2 than in Case 1 when the probability of implementation success is high and the extent of market competition is high.

Q.E.D.

Proof of Proposition 4:

a) part of Proposition 4:

$$\frac{\delta f_L^U}{\delta t}=\frac{18k\alpha^3 t\begin{pmatrix}108k(1-\alpha)^2\alpha^5(1+\alpha)t-(1-\alpha)^3\alpha^6(1+\alpha)-324k^2(1-\alpha)\alpha^4(15+\alpha(11+8\alpha))t^2-34012224k^6t^6+\\23328k^3\alpha^3(5+\alpha-6\alpha^2+\alpha^3)t^3+314928k^4\alpha^2(\alpha(5\alpha-2)-5)t^4+3779136k^5\alpha(1+\alpha)(3-2\alpha)t^5\end{pmatrix}}{\left(\alpha^5-\alpha^3+54kt\alpha^2-36kt\alpha^4-972k^2t^2\alpha+5832k^3t^3\right)^3}$$

We can show that since $kt>\frac{1}{6}$, the numerator of $\frac{\delta f_L^U}{\delta t}$ is negative and the denominator of $\frac{\delta f_L^U}{\delta t}$ is positive. Thus, $\frac{\delta f_L^U}{\delta t}<0$ and the Leader's investment level always increases as t decreases in Case 1.

$$\frac{\delta f_L^K}{\delta t}=\frac{18k\alpha^3 t\begin{pmatrix}108k(1-\alpha)^2\alpha^5(1+\alpha)t-(1-\alpha)^3\alpha^6(1+\alpha)-324k^2(1-\alpha)\alpha^4(15+\alpha(11-8\alpha))t^2-34012224k^6t^6+\\23328k^3\alpha^3(5+\alpha-6\alpha^2+\alpha^3)t^3+314928k^4\alpha^2(\alpha(5\alpha-2)-5)t^4+3779136k^5\alpha(1+p)(3-2\alpha)t^5\end{pmatrix}}{\left(\alpha^5-\alpha^3+54kt\alpha^2-36kt\alpha^4-972k^2t^2\alpha+5832k^3t^3\right)^3}$$

We can show that since $kt>\frac{1}{6}$, the numerator of $\frac{\delta f_L^K}{\delta t}$ is negative and the denominator of $\frac{\delta f_L^K}{\delta t}$ is positive. Thus, $\frac{\delta f_L^K}{\delta t}<0$ and the Leader's investment level always increases as t decreases in Case 2.

b) part of Proposition 4:

$$\frac{\delta f_F^U}{\delta t}=\frac{18k\alpha^3 t\left(\alpha+2\alpha^2-18kt\right)\left(18kt-(1-\alpha)\alpha\right)\begin{pmatrix}(1-\alpha)^2\alpha^4(1+\alpha)(1+2\alpha)-36k(1-\alpha)\alpha^3(1+\alpha)(2+\alpha)t+\\324k^2\alpha^2(6-\alpha^2-2\alpha^3)t^2-11664k^3(\alpha-2)\alpha t^3+104976k^4(1-\alpha)t^4\end{pmatrix}}{\left(\alpha^5-\alpha^3+54kt\alpha^2-36kt\alpha^4-972k^2t^2\alpha+5832k^3t^3\right)^3}$$

We can show that $\frac{\delta f_F^U}{\delta t}|_{k=0.46,\alpha=0.96,t=0.33}=-1.4707<0$ and $\frac{\delta f_F^U}{\delta t}|_{k=0.46,\alpha=0.96,t=0.34}=0.1116>0$. Thus, the Follower's investment level may increase or decrease as t decreases in Case 1.

c) part of Proposition 4:

$$\frac{\delta f_{F,s}^U}{\delta t}=\frac{72kt\alpha^4\left(27kt\alpha-162k^2t^2-(1-\alpha)\alpha^2\right)\left((1-\alpha)^2\alpha^3-54kt(1-\alpha)\alpha^2+486k^2t^2(2-\alpha)\alpha-5832k^3t^3\right)}{\left(18kt(3-2\alpha)\alpha^2-(1-\alpha)\alpha^3-972k^2t^2\alpha+5832k^3t^3\right)^3}$$

We can show that since $kt>\frac{1}{6}$, the numerator of $\frac{\delta f_{F,s}^U}{\delta t}$ is positive and its denominator is positive. Thus, $\frac{\delta f_{F,s}^K}{\delta t}>0$ and the Follower's investment level if the Leader's implementation has succeeded decreases as t decreases in Case 2.

$\frac{\delta f_{F,f}^U}{\delta t}=\frac{18kt\alpha^3}{(\alpha-18kt)^3}$, and since $kt>\frac{1}{6}$, the numerator is positive, and the denominator is negative. Thus, $\frac{\delta f_{F,f}^K}{\delta t}<0$ and the Follower's investment level if the Leader's implementation has failed increases as t decreases in Case 2.

Q.E.D.

Proof of Proposition 5:

The social welfare in the case where firms do not have the opportunity to invest in IT is:

$SW^{\text{no IT investment}} = U - c_O - \frac{t}{12}$.

The difference between the social welfares in Case 1 and in the case where firms do not have the opportunity to invest in IT is:

$$E(SW^U) - SW^{\text{no IT investment}} = \frac{kt\alpha^2 \begin{pmatrix} 7558272k^5t^5 + 162k^2t^2\alpha^3(-44+\alpha(-54+\alpha(49+24\alpha))) \\ -11664k^3t^3\alpha^2(-14+5(-2+\alpha)\alpha) - 104976k^4t^4\alpha(17+6\alpha) \\ 36kt\alpha^4(4+\alpha(9-\alpha(10+\alpha(7-4\alpha)))) - (1-\alpha)^2\alpha^5(1+\alpha)(1+6\alpha) \end{pmatrix}}{2k(5832k^3t^3 - 972k^2t^2\alpha - \alpha^3 + \alpha^5 + 18kt\alpha^2(3-2\alpha^2))^2}$$

We can show that since $0<\alpha<1$ and $\frac{1}{6}<kt$, the numerator of $E(SW^U) - SW^{\text{no IT investment}}$ is positive, and it is easy to see that the denominator of $E(SW^U) - SW^{\text{no IT investment}}$ is positive. Thus, $E(SW^U) - SW^{\text{no IT investment}} > 0$ and social welfare is higher in Case 1 than in the case where firms do not have the opportunity to invest in IT.

$$E(SW^K) - SW^{\text{no IT investment}} = \frac{kt\alpha^2 \begin{pmatrix} 4897760256k^7t^7 - 324k^2t^2\alpha^5(78+\alpha(56+\alpha(-133+24\alpha))) - \\ 68024448k^6t^6\alpha(25+6\alpha) + 104976k^4t^4\alpha^3(-190-69\alpha+36\alpha^2) - \\ (1-\alpha)^2\alpha^7(2+11\alpha) + 36kt(1-\alpha)\alpha^6(10+\alpha(25-16\alpha)) + \\ 83140992k^5t^5\alpha^2(3+\alpha) - 11664k^3t^3\alpha^4(-80+\alpha(-35+52\alpha)) \end{pmatrix}}{4k(18kt-\alpha)^2(5832k^3t^3 - 972k^2t^2\alpha + 18kt(3-2\alpha)\alpha^2 + (-1+\alpha)\alpha^3)^2}$$

We can show that since $0<\alpha<1$ and $\frac{1}{6}<kt$, the numerator of $E(SW^K) - SW^{\text{no IT investment}}$ is positive, and it is easy to see that the denominator of $E(SW^K) - SW^{\text{no IT investment}}$ is positive. Thus, $E(SW^K) - SW^{\text{no IT investment}} > 0$ and social welfare is higher in Case 2 than in the case where firms do not have the opportunity to invest in IT.

Q.E.D.

Proof of Proposition 6:

a) part of Proposition 6:

$E(SW^K)-E(SW^U)$

$$=\frac{(1-\alpha)\alpha^5 t\left(\begin{array}{l}-(1-\alpha)^3\alpha^{11}(1+\alpha)(1+11\alpha)+23328k^3\alpha^8(111+\alpha(266-\alpha(503+\alpha(85-7\alpha(39-8\alpha)))))t^3-\\ 324k^2(1-\alpha)\alpha^9(111+\alpha(512-\alpha(334+\alpha(401-196\alpha))))t^2+36k(1-\alpha)^2\alpha^{10}(8+\alpha(61+\alpha(11-38\alpha)))t-\\ 104976k^4\alpha^7(1146+\alpha(1893-\alpha(3062+\alpha(769-24\alpha(47-4\alpha)))))t^4+3779136k^5\alpha^6\\ -(1008+\alpha(1199-\alpha(1543+8\alpha(61-39\alpha))))t^5-34012224k^6\alpha^5(2478+\alpha(2215-2\alpha(1021+72(5-\alpha)\alpha)))t^6+\\ 7346640384k^7\alpha^4(178+\alpha(123-70\alpha-24\alpha^2))t^7-11019960576k^8\alpha^3(1269+2\alpha(337-94\alpha-24\alpha^2))t^8+\\ 793437161472k^9\alpha^2(124+\alpha(47-4\alpha))t^9-3570467226624k^{10}\alpha(115+24\alpha)t^{10}+771220920950784k^{11}t^{11}\end{array}\right)}{4(\alpha-18kt)^2(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3)^2(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972k^2\alpha t^2+5832k^3t^3)^2}$$

It is clear that the denominator of $E(SW^K)-E(SW^U)$ is positive. One can show that the numerator of $E(SW^K)-E(SW^U)$ is also positive since $kt>\frac{1}{6}$. Thus, $E(SW^K)-E(SW^U)>0$ and social welfare is higher in Case 2 than in the Case 1.

$E(SW^K)-E(SW^S)$

$$=\frac{\alpha^4 t\left(\begin{array}{l}(1-\alpha)^3\alpha^8(9-11\alpha)+72k(1-\alpha)^2\alpha^7(5-2\alpha)(3-4\alpha)t+324k^2(1-\alpha)\alpha^6(175-\alpha(390-\alpha(221-24\alpha)))t^2+\\ 46656k^3\alpha^5(36-\alpha(99-\alpha(81-19\alpha)))t^3-314928k^4\alpha^4(95-\alpha(223-\alpha(127-12\alpha)))t^4+\\ 3779136k^5\alpha^3(82-\alpha(173-58\alpha))t^5-34012224k^6\alpha^2(45-2\alpha(53-6\alpha))t^6-9795520512k^7\alpha^2t^7+22039921152k^8t^8\end{array}\right)}{4(\alpha-18kt)^2(18kt-(1-\alpha)\alpha)^2(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972k^2\alpha t^2+5832k^3t^3)^2}$$

It is clear that the denominator of $E(SW^K)-E(SW^S)$ is positive. One can show that the numerator of $E(SW^K)-E(SW^S)$ is also positive since $kt>\frac{1}{6}$. Thus, $E(SW^K)-E(SW^S)>0$ and social welfare is higher in Case 2 than in the simultaneous game.

b) part of Proposition 6:

$\left(E(\pi_L^S)+E(\pi_F^S)\right)-\left(E(\pi_L^K)+E(\pi_F^K)\right)$

$$=\frac{\alpha^4 t\left(\begin{array}{l}\alpha^{12}-5816090304k^7\alpha t^7+11019960576k^8t^8-3\alpha^{11}(2+15kt)+324k^2\alpha^6t^2(62+3699kt+19764k^2t^2)-\\ 8503056k^5\alpha^3t^5(19+96kt)+6p^{10}(2+69kt+108k^2t^2)+314928k^4\alpha^4t^4(40+513kt+108k^2t^2)-\\ 2\alpha^9(5+531kt+5184k^2t^2)-2916k^3\alpha^5t^3(217+6156kt+10044k^2t^2)+68024448k^6\alpha^2t^6(19+27kt)+\\ 3\alpha^8(1+354kt+12528k^2t^2+34020k^3t^3)-9k\alpha^7t(41+5328kt+74844k^2t^2+34992k^3t^3)\end{array}\right)}{(\alpha-18kt)^2(\alpha^2-\alpha+18kt)^2(\alpha^4+54k\alpha^2t-972k^2\alpha t^2+5832k^3t^3-\alpha^3(1+36kt))^2}$$

It is clear that the denominator of $\left(E(\pi_L^S)+E(\pi_F^S)\right)-\left(E(\pi_L^K)+E(\pi_F^K)\right)$ is positive. One can show that the numerator of $\left(E(\pi_L^S)+E(\pi_F^S)\right)-\left(E(\pi_L^K)+E(\pi_F^K)\right)$ is also positive since $kt>\frac{1}{6}$. Thus, $E(\pi_L^S)+E(\pi_F^S)>E(\pi_L^K)+E(\pi_F^K)$ and the industry-wide profit is higher in the simultaneous game than in the Case 2.

$$\left(E(\pi_L^S)+E(\pi_F^S)\right)-\left(E(\pi_L^U)+E(\pi_F^U)\right)=\frac{4\alpha^4 t(\alpha^2-\alpha+9kt)^2\begin{pmatrix}54\alpha^5 kt-23328\alpha k^3t^3+104976k^4t^4-972\alpha^2k^2t^2(3kt-2)+\\36\alpha^3kt(9kt-2)+\alpha^6(9kt-1)+\alpha^4(1-9kt-648k^2t^2)\end{pmatrix}}{(\alpha^2-\alpha+18kt)^2(\alpha^3-\alpha^5-54\alpha^2kt+36\alpha^4kt+972\alpha k^2t^2-5832k^3t^3)^2}$$

It is clear that the denominator of $\left(E(\pi_L^S)+E(\pi_F^S)\right)-\left(E(\pi_L^U)+E(\pi_F^U)\right)$ is positive. One can show that the numerator of $\left(E(\pi_L^S)+E(\pi_F^S)\right)-\left(E(\pi_L^U)+E(\pi_F^U)\right)$ is also positive since $kt>\frac{1}{6}$. Thus, $E(\pi_L^S)+E(\pi_F^S)>E(\pi_L^U)+E(\pi_F^U)$ and the industry-wide profit is higher in the simultaneous game than in the Case 1.

$$\textit{Total Investment}^K=f_L^K+(\alpha f_{F,s}^K+(1-\alpha)f_{F,f}^K)$$

$$=9k\alpha^2t^2\left(\frac{1-\alpha}{(\alpha-18kt)^2}+\frac{\left(36\alpha kt-(1-\alpha)\alpha^2-324k^2t^2\right)^2+4\alpha\left(27\alpha kt-(1-\alpha)\alpha^2-162k^2t^2\right)^2}{\left(18\alpha^2k(3-2\alpha)t-(1-\alpha)\alpha^3-972\alpha k^2t^2+5832k^3t^3\right)^2}\right)$$

$$\textit{Total Investment}^S=f_L^S+f_F^S=\frac{18\alpha^2kt^2}{\left(18kt-(1-\alpha)\alpha\right)^2}$$

$$\textit{Total Investment}^K-\textit{Total Investment}^S$$

$$=9k\alpha^2t^2\left(\frac{1-\alpha}{(\alpha-18kt)^2}+\frac{\left(36\alpha kt-(1-\alpha)\alpha^2-324k^2t^2\right)^2+4\alpha\left(27\alpha kt-(1-\alpha)\alpha^2-162k^2t^2\right)^2}{\left(18\alpha^2k(3-2\alpha)t-(1-\alpha)\alpha^3-972\alpha k^2t^2+5832k^3t^3\right)^2}-\frac{2}{\left(18kt-(1-\alpha)\alpha\right)^2}\right)$$

We can check that since $kt>\frac{1}{6}$,

$$\frac{1-\alpha}{(\alpha-18kt)^2}+\frac{\left(36\alpha kt-(1-\alpha)\alpha^2-324k^2t^2\right)^2+4\alpha\left(27\alpha kt-(1-\alpha)\alpha^2-162k^2t^2\right)^2}{\left(18\alpha^2k(3-2\alpha)t-(1-\alpha)\alpha^3-972\alpha k^2t^2+5832k^3t^3\right)^2}>\frac{2}{\left(18kt-(1-\alpha)\alpha\right)^2}.$$

Thus, $\textit{Total Investment}^K>\textit{Total Investment}^S$ and the industry-wide investment is higher in Case 2 than in the simultaneous game.

$$\textit{Total Investment}^U=f_L^U+f_F^U$$

$$=\frac{9\alpha^2kt^2\left(\left(\alpha+2\alpha^2-18kt\right)^2\left(18kt-(1-\alpha)\alpha\right)^2+\left(36kt(\alpha-9kt)-(1-\alpha)\alpha^2\right)^2\right)}{\left(\alpha^3-\alpha^5-54\alpha^2kt+36\alpha^4kt+972k^2t^2(\alpha-6kt)\right)^2}$$

$$\textit{Total Investment}^K-\textit{Total Investment}^U$$

$$=9k\alpha^2t^2\left(\begin{array}{l}\frac{1-\alpha}{(\alpha-18kt)^2}+\frac{\left(36\alpha kt-324k^2t^2-(1-\alpha)\alpha^2\right)^2+4\alpha\left(27\alpha kt-(1-\alpha)\alpha^2-162k^2t^2\right)^2}{\left(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972\alpha k^2t^2+5832k^3t^3\right)^2}-\\\frac{\left(\alpha+2\alpha^2-18kt\right)^2\left(18kt-(1-\alpha)\alpha\right)^2+\left(36\alpha kt-(1-\alpha)\alpha^2-324k^2t^2\right)^2}{\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2}\end{array}\right)$$

One can show that since $kt>\frac{1}{6}$,

$$\frac{1-\alpha}{(\alpha-18kt)^2}+\frac{\left(36\alpha kt-324k^2t^2-(1-\alpha)\alpha^2\right)^2+4\alpha\left(27\alpha kt-(1-\alpha)\alpha^2-162k^2t^2\right)^2}{\left(18k(3-2\alpha)\alpha^2t-(1-\alpha)\alpha^3-972\alpha k^2t^2+5832k^3t^3\right)^2}>$$
$$\frac{\left(\alpha+2\alpha^2-18kt\right)^2\left(18kt-(1-\alpha)\alpha\right)^2+\left(36\alpha kt-(1-\alpha)\alpha^2-324k^2t^2\right)^2}{\left(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3\right)^2}$$

Thus, $\textit{Total Investment}^K>\textit{Total Investment}^U$ and the industry-wide investment is higher in Case 2 than in Case 1.

c) part of Proposition 6:

$$E(CS^K)-E(CS^U)$$
$$=\frac{(1-\alpha)\alpha^5t\left(\begin{array}{l}33059881728k^8t^8\alpha^3(648kt-611)+34992k^3\alpha^8t^3(193+1341kt-163188k^2t^2+237168k^3t^3)+\\2\alpha^{14}(720kt+21384k^2t^2-5)-9\alpha^{15}(1+100kt)+204073344\alpha^5k^6t^6(1206kt+12744k^2t^2-721)+\\11337408k^5\alpha^6t^5(658-549kt-51624k^2t^2+31104k^3t^3)-396718580736k^9\alpha^2t^9(144kt-331)-\\629856k^4\alpha^7t^4(427+696kt-116316k^2t^2+147744k^3t^3)+\\\alpha^{11}(206712k^2t^2-5-576kt+2531088k^3t^3-69284160k^4t^4)+899757741109248k^{11}t^{11}+\\3\alpha^{12}(1-852kt-29052k^2t^2+1146960k^3t^3+2239488k^4t^4)-510576813407232k^{10}\alpha t^{10}-\\324\alpha^9k^2t^2(347+6156kt-896184k^2t^2+338256k^3t^3+10077696k^4t^4)+7\alpha^{16}+\\36\alpha^{10}kt(31+1287kt-269568k^2t^2-883548k^3t^3+20575296k^4t^4)-\\2\alpha^{13}(48114k^2t^2-7-738kt+443232k^3t^3)-7346640384k^7\alpha^4t^7(447kt+648k^2t^2-281)\end{array}\right)}{4(p-18kt)^2(\alpha^3-\alpha^5-54k\alpha^2t+36k\alpha^4t+972k^2\alpha t^2-5832k^3t^3)^2(\alpha^4+54k\alpha^2t-972k^2\alpha t^2+5832k^3t^3-\alpha^3(1+36kt))^2}$$

It is clear that the denominator of $E(CS^K)-E(CS^U)$ is positive. One can show that the numerator of $E(CS^K)-E(CS^U)$ is also positive since $kt>\frac{1}{6}$. Thus, $E(CS^K)-E(CS^U)>0$ and consumer surplus is higher in Case 2 than in Case 1.

$$E(CS^K)-E(CS^S)$$
$$=\frac{\alpha^4t\left(\begin{array}{l}-7\alpha^{12}-23264361216\alpha k^7t^7+66119763456k^8t^8+18\alpha^{11}(1+22kt)+34012224\alpha^2k^6t^6(107-72kt)-\\3779136\alpha^3k^5t^5(89-90kt)-12\alpha^{10}(1+114kt+432k^2t^2)+314928\alpha^4k^4t^4(65-24kt-864k^2t^2)+\\11664\alpha^5k^3t^3(8748k^2t^2-73-135kt)+2\alpha^9(576kt+18954k^2t^2-1)-324\alpha^6k^2t^2(44388k^2t^2-73-540kt)+\\36\alpha^7kt(30132k^2t^2+69984k^3t^3-11-243kt)-3\alpha^8(15876k^2t^2+159408k^3t^3-1-72kt)\end{array}\right)}{4(\alpha-18kt)^2(\alpha^2-\alpha+18kt)^2(\alpha^4+54\alpha^2kt-972\alpha k^2t^2+5832k^3t^3-\alpha^3(1+36kt))^2}$$

It is clear that the denominator of $E(CS^K)-E(CS^S)$ is positive. One can show that the numerator of $E(CS^K)-E(CS^S)$ is also positive since $kt>\frac{1}{6}$. Thus, $E(CS^K)-E(CS^S)>0$, and consumer surplus is higher in Case 2 than in the simultaneous move game.

Q.E.D.

Note, in all the proofs in Extension 2, we replace α^F with α_F and α^L with α_L.

Proof of Lemma E2.1:

Firm *i*'s decision problem in the Outcome Unknown can be formulated as:

$$\max_{c_i^U} E(\pi_i^U) = \max_{c_i^U}\left(\alpha_i\alpha_{-i}\pi_{i,ss}^U + \alpha_i(1-\alpha_{-i})\pi_{i,sf}^U + (1-\alpha_i)\alpha_{-i}\pi_{i,fs}^U + (1-\alpha_i)(1-\alpha_{-i})\pi_{i,ff}^U\right)$$
$$s.t., c_i^U \in [0, c_O],$$

where $\pi_{i,j}^U$ denotes firm *i*'s payoff given implementation outcome j in this "outcome unknown" Case 1, $i \in \{L, F\}$, and $j = ss, sf, fs, ff$.

The two firms' expected profits can be characterized as follows:

$$E(\pi_L^U) = \frac{9t^2 + \left(c_L^U - c_O\right)\left(c_L^U - 6t - c_O\right)\alpha_L + \left(c_F^U - c_O\right)\alpha_F\left(c_F^U + 6t - 2c_L^U\alpha_L + c_O\left(-1+2\alpha_L\right)\right)}{18t} - k(c_O - c_L^U)^2$$

$$E(\pi_F^U) = \frac{9t^2 + \left(c_L^U - c_O\right)\left(c_L^U + 6t - c_O\right)\alpha_L + \left(c_F^U - c_O\right)\alpha_F\left(c_F^U - 6t - 2c_L^U\alpha_L + c_O\left(-1+2\alpha_L\right)\right)}{18t} - k(c_O - c_F^U)^2$$

By taking the first derivative of the follower's expected profit w.r.t. the follower's new marginal cost if his implementation is successful, c_F^U, and solving its first order condition, we get $c_F^U(c_L^U) = \dfrac{\alpha_F\left(c_O - c_O c_L^U + c_L^U\alpha_L\right) + 3\left(-6c_O k + \alpha_F\right)t}{\alpha_F - 18kt}$, which is the response function of the follower conditioning on the leader's investment level. Then, we substitute the follower's response function into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c_L^U, and solving its first order condition, we get the leader's new marginal cost if his implementation is successful $c_L^U = c_O + \dfrac{3t\left(-324k^2t^2 + \alpha_F\left(36kt + \left(-1+\alpha_F\right)\alpha_F\right)\right)\alpha_L}{18kt\left(-18kt+\alpha_F\right)^2 - \left(-18kt+\alpha_F\right)^2\alpha_L + \alpha_F^2\left(-36kt+\alpha_F\right)\alpha_L^2}$. Then check the second order condition, and with the assumption $kt > 1/6$, one can show that

$$\frac{\delta^2 E(\pi_L^U)}{\delta c_L^{U2}} = \frac{\alpha_L - 18kt - \dfrac{\alpha_F{}^2\alpha_L{}^2\left(\alpha_F - 36kt\right)}{\left(\alpha_F - 18kt\right)^2}}{9t} < 0.$$

Then we substitute the leader's new marginal cost into the follower's response function and get the follower's new marginal cost if his implementation is successful

$$c_F^U = \frac{-18ktc_O + 3t\alpha_F + c_O\alpha_F + \dfrac{3t\alpha_F\left(-324k^2t^2 + \alpha_F\left(36kt + \left(-1+\alpha_F\right)\alpha_F\right)\right)\alpha_L^2}{18kt\left(-18kt+\alpha_F\right)^2 - \left(-18kt+\alpha_F\right)^2\alpha_L + \alpha_F^2\left(-36kt+\alpha_F\right)\alpha_L^2}}{-18kt+\alpha_F}.$$ We also

check the second order condition, and with the assumption $kt > 1/6$, one can show that $\frac{\delta^2 E(\pi_F^U)}{\delta c_F^{U2}} = \frac{\alpha - 18kt}{9t} < 0$.

We substitute the firms' new marginal costs in the event of a successful implementation into the investment functions and get the optimal investment levels of the leader and the follower:

$$f_L^U = k(c_O - c_L^U)^2 = \frac{9kt^2\left(324k^2t^2 - 36kt\alpha_F + \alpha_F{}^2 - \alpha_F{}^3\right)^2 \alpha_L{}^2}{\left(18kt\left(-18kt+\alpha_F\right)^2 - \left(-18kt+\alpha_F\right)^2\alpha_L + \alpha_F^2\left(-36kt+\alpha_F\right)\alpha_L^2\right)^2},$$

$$f_F^U = k(c_o - c_F^U)^2 = \frac{9kt^2\alpha_F{}^2\left(-2(\alpha_F\alpha_L)^2 + \alpha_F(-18kt+\alpha_L+\alpha_L{}^2) + 18kt(18kt - \alpha_L(1+\alpha_L))\right)^2}{\left(18kt\left(-18kt+\alpha_F\right)^2 - \left(-18kt+\alpha_F\right)^2\alpha_L + \alpha_F^2\left(-36kt+\alpha_F\right)\alpha_L^2\right)^2}.$$

Q.E.D.

Proof of Lemma E2.2:

In the Outcome Known case, the leader's expected profit can be characterized as follows:

$$E(\pi_L^K) = \frac{\alpha_L\alpha_F(c_{F,ss}^K - c_L^K + 3t)^2 + \alpha_L(1-\alpha_F)(c_O - c_L^K + 3t)^2 + (1-\alpha_L)\alpha_F(c_{F,fs}^k - c_O + 3t)^2 + (1-\alpha_L)(1-\alpha_F)(3t)^2}{18t} - k(c_O - c_L^K)^2$$

And the follower's expected profits depending on the outcome of the leader's implementation can be characterized as follows:

$E(\pi_{F,s}^K) = \frac{\alpha_F(c_L^K - c_{F,ss}^K + 3t)^2 + (1-\alpha_F)(c_L^K - c_O + 3t)^2}{18t} - k(c_O - c_{F,ss}^K)^2$ if the leader's implementation is successful; $E(\pi_{F,f}^K) = \frac{\alpha_F(c_O - c_{F,fs}^K + 3t)^2 + (1-\alpha_F)(3t)^2}{18t} - k(c_O - c_{F,fs}^K)^2$ if the leader's implementation is unsuccessful.

By taking the first derivative of the follower's expected profits, $E(\pi_{F,s}^K)$ and $E(\pi_{F,f}^K)$ w.r.t. the follower's new marginal costs if his implementation is successful, $c_{F,s}^K$ and $c_{F,f}^K$, and solving its first order conditions, we get $c_{F,ss}^K = \frac{c_L^K + 3\left(\alpha_F - 6c_Ok\right)t}{\alpha_F - 18kt}$ and $c_{F,fs}^K = \frac{c_O\alpha_F + 3\left(\alpha_F - 6c_Ok\right)t}{\alpha_F - 18kt}$, which are the response functions of the follower conditioning on the leader's investment level and implementation outcome. We also check the second order condition, with assumption $kt > 1/6$, one can show that $\frac{\delta^2 E(\pi_{F,s}^K)}{\delta c_{F,s}^{K\ 2}} = \frac{\delta^2 E(\pi_{F,f}^K)}{\delta c_{F,f}^{K\ 2}} = \frac{2\alpha_F - 36kt}{18t} < 0$. Then, we substitute the follower's response functions into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t., the leader's new marginal cost if his implementation is successful, c_L^K, and solving its first order condition, we get

$$c_L^K = \frac{3t\left(\alpha_F - 6kc_O\right) + \alpha_F\left(c_O + \frac{3t\left(-324k^2t^2 + \alpha_F\left(36kt + \left(-1+\alpha_F\right)\alpha_F\right)\right)\alpha_L}{18kt\left(-18kt+\alpha_F\right)^2 + \left(-324k^2t^2 - \left(36kt - \alpha_F\right)\left(-1+\alpha_F\right)\alpha_F\right)\alpha_L}\right)}{-18kt + \alpha_F}$$

. Then check the second order condition, and with the assumption $kt > 1/6$, one can show that

$$\frac{\delta^2 E(\pi_L^K)}{\delta c_L^{K2}} = -2k + \frac{\alpha_L\left(1 + \frac{\alpha_F{}^3}{\left(\alpha_F - 18kt\right)^2} - \frac{2\alpha_F{}^2}{\alpha_F - 18kt}\right)}{9t} < 0$$

. Then we substitute the leader's new marginal cost if his implementation is successful into the follower's response functions and get the follower's new marginal costs if his implementation is successful

$$c_{F,s}^K = c_O + \frac{3t\left(-324k^2t^2 + \alpha_F\left(36kt + \left(-1+\alpha_F\right)\alpha_F\right)\right)\alpha_L}{18kt\left(-18kt+\alpha_F\right)^2 + \left(-324k^2t^2 - \left(36kt - \alpha_F\right)\left(-1+\alpha_F\right)\alpha_F\right)\alpha_L} \text{ and } c_{F,f}^K = c_O - \frac{3t\alpha_F}{18kt - \alpha_F}.$$

We substitute the firms' new marginal costs in the event of a successful implementation into the investment functions and get the optimal investment levels of the leader and the follower:

$$f_L^K = k(c_O - c_L^K)^2 = \frac{9k\alpha_L{}^2t^2((-1+\alpha_F)\alpha_F{}^2 + 36k\alpha_F t - 324k^2t^2)^2}{((-1+\alpha_F)\alpha_F{}^2\alpha_L + 18k\alpha_F(\alpha_F + 2\alpha_L - 2\alpha_F\alpha_L)t - 324k^2(2\alpha_F + \alpha_L)t^2 + 5832k^3t^3)^2},$$

$$f_{F,s}^K = k(c_o - c_{F,s}^U)^2 = \frac{36k\alpha_F{}^2t^2((-1+\alpha_F)\alpha_F\alpha_L + 9k(\alpha_F + 2\alpha_L)t - 162k^2t^2)^2}{((-1+\alpha_F)\alpha_F{}^2\alpha_L + 18k\alpha_F(\alpha_F + 2\alpha_L - 2\alpha_F\alpha_L)t - 324k^2(2\alpha_F + \alpha_L)t^2 + 5832k^3t^3)^2},$$

$$f_{F,f}^K = k(c_o - c_{F,f}^U)^2 = \frac{9k\alpha_F{}^2t^2}{(\alpha_F - 18kt)^2}.$$

Q.E.D.

Proof of Proposition E2.1:

1) With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.7$, the first derivative of the leader's investment level with respect to α_Δ in Case 1 $\frac{df_L^U}{d\alpha_\Delta} = 0$ at $\alpha_\Delta = 0.0991$. We further check that $f_L^U|_{\alpha_\Delta = 0.01} = 0.0523$, $f_L^U|_{\alpha_\Delta = 0.1} = 0.0526$, and $f_L^U|_{\alpha_\Delta = 0.2} = 0.0521$. Thus, f_L^U can increase first and then decrease as α_Δ increases.

With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.5$, the first derivative of the leader's investment level with respect to α_Δ in Case 2 $\frac{df_L^K}{d\alpha_\Delta} = 0$ at $\alpha_\Delta = 0.2489$. We further check that $f_L^K|_{\alpha_\Delta = 0} = 0.0218$, $f_L^K|_{\alpha_\Delta = 0.25} = 0.0223$, and $f_L^K|_{\alpha_\Delta = 0.5} = 0.0208$. Thus, f_L^K can increase first and then decrease as α_Δ increases.

The first derivative of expected profit of leader with respect to α_Δ is in Case 1:

$$\frac{dE(\pi_L^U)}{d\alpha_{\mathrm{V}}}=\frac{\begin{pmatrix}2(\alpha_\Delta+\alpha_L)t(\alpha_L(\alpha_\Delta+\alpha_L)(-1+\alpha_L(-1+2\alpha_\Delta+2\alpha_L))+18(\alpha_\Delta+\alpha_L(2+\alpha_L))kt-324k^2t^2)\\ (\alpha_L(\alpha_\Delta+\alpha_L)^2(-3+\alpha_L+2\alpha_\Delta\alpha_L+2\alpha_L{}^2)-18\alpha_\Delta+\alpha_L)(3(-4+\alpha_L)\alpha_L+8\alpha_L{}^3+\alpha_\Delta(-3+8\alpha_L{}^2))kt-\\ 324(9\alpha_\Delta+(13-4\alpha_L)\alpha_L)k^2t^2+23328k^3t^3)\end{pmatrix}}{(2\alpha_L{}^2(\alpha_\Delta+\alpha_L)^3+72(\alpha_\Delta+\alpha_L)(\alpha_L-18kt)kt-648(\alpha_L-18kt)k^2t^2-2(\alpha_\Delta+\alpha_L)^2(\alpha_L-18kt+36\alpha_L{}^2kt))^2}$$

We can prove that since $0<\alpha_\Delta<1$, $0<\alpha_\Delta+\alpha_L<1$ and $\frac{1}{6}<kt$, the numerator of $\frac{dE(\pi_L^U)}{d\alpha_{\mathrm{V}}}$ is negative, and it is easy to see that the denominator of $\frac{dE(\pi_L^U)}{d\alpha_{\mathrm{V}}}$ is positive. Thus, $\frac{dE(\pi_L^U)}{d\alpha_{\mathrm{V}}}$ is negative and the leader's expected profit in Case 1 decreases as α_Δ increases.

The first derivative of the leaders' expected profit with respect to α_Δ in Case 2 is:

$$\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}=\frac{\begin{pmatrix}(-18kt+\alpha_L+\alpha_\Delta)(324kt^2(18kt-\alpha_L)+36kt(-18kt+\alpha_L)(\alpha_L+\alpha_\Delta)-(-18kt+(1+36kt)\alpha_L)(\alpha_L+\alpha_\Delta)^2+\alpha_L(\alpha_L+\alpha_\Delta)^3)\\ (-18kt+\alpha_L+\alpha_\Delta)(324kt^2(18kt-\alpha_L)+36kt(-18kt+\alpha_L)(\alpha_L+\alpha_\Delta)-(-18kt+(1+36kt)\alpha_L)(\alpha_L+\alpha_\Delta)^2+\alpha_L(\alpha_L+\alpha_\Delta)^3)\\ 216kt(9kt(-2+63kt)-\alpha_L(-1+9kt+(1+9kt)\alpha_L))(\alpha_L+\alpha_\Delta)^2+4(18(1-144kt)kt+\alpha_L(-1+72kt(1+18kt)+(1+72kt)\alpha_L))\\ (\alpha_L+\alpha_\Delta)^3-10(-27kt+\alpha_L(1+72kt+\alpha_L))(\alpha_L+\alpha_\Delta)^4+6\alpha_L(3+\alpha_L)(\alpha_L+\alpha_\Delta)^5)-\\ (-18kt+\alpha_L+\alpha_\Delta)(36kt(-18kt+\alpha_L)-2(-18kt+(1+36kt)\alpha_L)(\alpha_L+\alpha_\Delta)+3\alpha_L(\alpha_L+\alpha_\Delta)^2)\\ (104976kt^4(18kt+(-1+\alpha_L)\alpha_L)-23328kt^3(18kt+(-1+\alpha_L)\alpha_L)(\alpha_L+\alpha_\Delta)-1944kt^2(18kt(-1+6kt)+\alpha_L-\alpha_L^2)(\alpha_L+\alpha_\Delta)^2+\\ 72kt(9kt(-2+63kt)-\alpha_L(-1+9kt+(1+9kt)\alpha_L))(\alpha_L+\alpha_\Delta)^3+(18(1-144kt)kt+\alpha_L(-1+72kt(1+18kt)+(1+72kt)\alpha_L))\\ (\alpha_L+\alpha_\Delta)^4-2(-27kt+\alpha_L(1+72kt+\alpha_L))(\alpha_L+\alpha_\Delta)^5+\alpha_L(3+\alpha_L)(\alpha_L+\alpha_\Delta)^6)-\\ 2(324kt^2(18kt-\alpha_L)+36kt(-18kt+\alpha_L)(\alpha_L+\alpha_\Delta)-(-18kt+(1+36kt)\alpha_L)(\alpha_L+\alpha_\Delta)^2+\alpha_L(\alpha_L+\alpha_\Delta)^3)\\ (104976kt^4(18kt+(-1+\alpha_L)\alpha_L)-23328kt^3(18kt+(-1+\alpha_L)\alpha_L)(\alpha_L+\alpha_\Delta)-1944kt^2(18kt(-1+6kt)+\alpha_L-\alpha_L^2)(\alpha_L+\alpha_\Delta)^2+\\ 72kt(9kt(-2+63kt)-\alpha_L(-1+9kt+(1+9kt)\alpha_L))(\alpha_L+\alpha_\Delta)^3+(18(1-144kt)kt+\alpha_L(-1+72kt(1+18kt)+(1+72kt)\alpha_L))\\ (\alpha_L+\alpha_\Delta)^4-2(-27kt+\alpha_L(1+72kt+\alpha_L))(\alpha_L+\alpha_\Delta)^5+\alpha_L(3+\alpha_L)(\alpha_L+\alpha_\Delta)^6)\end{pmatrix}}{2(-18kt+\alpha_L+\alpha_\Delta)^3(324kt^2(18kt-\alpha_L)+36kt(-18kt+\alpha_L)(\alpha_L+\alpha_\Delta)-(-18kt+(1+36kt)\alpha_L)(\alpha_L+\alpha_\Delta)^2+\alpha_L(\alpha_L+\alpha_\Delta)^3)^2}$$

It is easy to see that the denominator of $\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}$ is negative since $\frac{1}{6}<kt$. Then we can take the third derivative of the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}$, and we can show it is positive since $\frac{1}{6}<kt$. Then we evaluate the second derivative of the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}$ at $kt=\frac{1}{6}$, and we can show it is positive. Thus, the second derivative of the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}$ is positive for $\frac{1}{6}<kt$ since its third derivative is positive. Then we evaluate the first derivative of the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}$ at $kt=\frac{1}{6}$, and we can show it is positive. Thus, the first derivative of the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\mathrm{V}}}$ is positive for $\frac{1}{6}<kt$ since its second is

positive. Then we evaluate the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\text{V}}}$ at $kt = \frac{1}{6}$, and we can show it is positive. Thus, the numerator of $\frac{dE(\pi_L^K)}{d\alpha_{\text{V}}}$ is positive. Therefore, $\frac{dE(\pi_L^K)}{d\alpha_{\text{V}}} < 0$ and the leader's expected profit in Case 2 decreases as α_Δ increases.

2) With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.91$, the first derivative of the follower's investment level with respect to α_Δ in the Case 1 $\frac{df_F^U}{d\alpha_\Delta} = 0$ at $\alpha_\Delta = 0.07$. We further check that $f_F^U |_{\alpha_{\text{V}}=0} = 0.0227$, $f_F^U |_{\alpha_{\text{V}}=0.07} = 0.0237$, and $f_F^U |_{\alpha_{\text{V}}=0.09} = 0.0236$. Thus, f_F^U can increase first and then decrease as α_Δ increases.

The first derivative of expected profit of follower with respect to α_Δ is in Case 1:

$$\frac{dE(\pi_F^U)}{d\alpha_{\text{V}}} = \frac{\left(\begin{aligned}&(324kt^2(18kt-\alpha_L)+36kt(-18kt+\alpha_L)(\alpha_L+\alpha_\Delta)-(-18kt+\alpha_L+36kt\alpha_L^2)(\alpha_L+\alpha_\Delta)^2+\alpha_L^2(\alpha_L+\alpha_\Delta)^3)\\&(-23328kt^3(324kt^2-36kt\alpha_L+(1-36kt)\alpha_L^2+3\alpha_L^3)+\\&3888kt^2(324kt^2(1+3kt)-36kt(1+3kt)\alpha_L+(1-33kt-324kt^2)\alpha_L^2+3(1+6kt)\alpha_L^3+15kt\alpha_L^4)(\alpha_L+\alpha_\Delta)-\\&108kt(324kt^2(2+27kt)-36kt(2+27kt)\alpha_L+(2-45kt-2916kt^2)\alpha_L^2+6(1+30kt)\alpha_L^3+117kt\alpha_L^4)(\alpha_L+\alpha_\Delta)^2+\\&4(324kt^2(1+54kt)-36kt(1+54kt)\alpha_L+(1+18kt-5832kt^2-23328kt^3)\alpha_L^2+3(1+132kt+432kt^2)\alpha_L^3+18kt(11+144kt)\alpha_L^4)\\&(\alpha_L+\alpha_\Delta)^3-5(324kt^2-36kt\alpha_L+(1-108kt-2592kt^2)\alpha_L^2+8(1+18kt)\alpha_L^3+3(1+96kt)\alpha_L^4)(\alpha_L+\alpha_\Delta)^4+\\&6\alpha_L^2(-72kt+5\alpha_L+(7+72kt)\alpha_L^2)(\alpha_L+\alpha_\Delta)^5-28\alpha_L^4(\alpha_L+\alpha_\Delta)^6)-\\&2(36kt(-18kt+\alpha_L)-2(-18kt+\alpha_L+36kt\alpha_L^2)(\alpha_L+\alpha_\Delta)+3\alpha_L^2(\alpha_L+\alpha_\Delta)^2)\\&(104976kt^4(324kt^2-36kt\alpha_L+(1-36kt)\alpha_L^2+3\alpha_L^3)-23328kt^3(324kt^2-36kt\alpha_L+(1-36kt)\alpha_L^2+3\alpha_L^3)(\alpha_L+\alpha_\Delta)+\\&1944kt^2(324kt^2(1+3kt)-36kt(1+3kt)\alpha_L+(1-33kt-324kt^2)\alpha_L^2+3(1+6kt)\alpha_L^3+15kt\alpha_L^4)(\alpha_L+\alpha_\Delta)^2-\\&36kt(324kt^2(2+27kt)-36kt(2+27kt)\alpha_L+(2-45kt-2916kt^2)\alpha_L^2+6(1+30kt)\alpha_L^3+117kt\alpha_L^4)(\alpha_L+\alpha_\Delta)^3+\\&(324kt^2(1+54kt)-36kt(1+54kt)\alpha_L+(1+18kt-5832kt^2-23328kt^3)\alpha_L^2+3(1+132kt+432kt^2)\alpha_L^3+18kt(11+144kt)\alpha_L^4)\\&(\alpha_L+\alpha_\Delta)^4-(324kt^2-36kt\alpha_L+(1-108kt-2592kt^2)\alpha_L^2+8(1+18kt)\alpha_L^3+3(1+96kt)\alpha_L^4)(\alpha_L+\alpha_\Delta)^5+\\&\alpha_L^2(-72kt+5\alpha_L+(7+72kt)\alpha_L^2)(\alpha_L+\alpha_\Delta)^6-4\alpha_L^4(\alpha_L+\alpha_\Delta)^7)\end{aligned}\right)}{2(324kt^2(18kt-\alpha_L)+36kt(-18kt+\alpha_L)(\alpha_L+\alpha_\Delta)-(-18kt+\alpha_L+36kt\alpha_L^2)(\alpha_L+\alpha_\Delta)^2+\alpha_L^2(\alpha_L+\alpha_\Delta)^3)^3}$$

With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.86$, the first derivative of the follower's investment level with respect to α_Δ in the Case 1 $\frac{dE(\pi_F^U)}{d\alpha_{\text{V}}} = 0$ at $\alpha_\Delta = 0.0518$. We further check that $E(\pi_F^U |_{\alpha_{\text{V}}=0}) = 0.08647$, $E(\pi_F^U |_{\alpha_{\text{V}}=0.05}) = 0.08665$, and $E(\pi_F^U |_{\alpha_{\text{V}}=0.13}) = 0.08603$. Thus, $E(\pi_F^U)$ can increase first and then decrease as α_Δ increases.

In Case 2, the first derivative of the follower's expected profit if leader's implementation failed with respect to α_Δ is:

$\frac{dE(\pi^K_{F,f})}{d\alpha_\nabla} = \frac{(\alpha_\Delta + \alpha)(36kt - \alpha_\Delta - \alpha)}{2(18kt - \alpha_\Delta - \alpha)^2}$. Since $\frac{1}{6} < kt$, $\frac{dE(\pi^K_{F,f})}{d\alpha_\nabla} > 0$.

In Case 2, the first derivative of follower's IT investment level if leader's implementation failed with respect to α_Δ is:

$\frac{df^K_{F,f}}{d\alpha_\nabla} = \frac{324(\alpha_\Delta + \alpha)k^2t^2}{(18kt - \alpha_\Delta - \alpha)^3}$. Since $\frac{1}{6} < kt$, $\frac{df^K_{F,f}}{d\alpha_\nabla} > 0$.

With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.86$, the first derivative of the follower's investment level with respect to α_Δ when leader's implementation succeeded in the Case 2, $\frac{df^K_{F,s}}{d\alpha_\nabla} = 0$ at $\alpha_\Delta = 0.1058$. We further check that $f^K_{F,s}|_{\alpha_\nabla=0} = 0.02012$, $f^K_{F,s}|_{\alpha_\nabla=0.1} = 0.02219$, and $f^K_{F,s}|_{\alpha_\nabla=0.13} = 0.02203$. Thus, $f^K_{F,s}$ can increase first and then decrease as α_Δ increases.

With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.77$, the first derivative of the follower's investment level with respect to α_Δ when leader's implementation succeeded in the Case 2, $\frac{dE(\pi^K_{F,s})}{d\alpha_\nabla} = 0$ at $\alpha_\Delta = 0.1053$. We further check that $E(\pi^K_{F,s}|_{\alpha_\nabla=0}) = 0.0812$, $E(\pi^K_{F,s}|_{\alpha_\nabla=0.1}) = 0.0817$, and $E(\pi^K_{F,s}|_{\alpha_\nabla=0.2}) = 0.0809$. Thus, $E(\pi^K_{F,s})$ can increase first and then decrease as α_Δ increases.

3) With the following set of parameters, $k = 0.48, c_O = 1, t = 0.35, \alpha_L = 0.7$, $E(\pi^U_F | \alpha_F = 0.73) = 0.13475$, $E(\pi^K_L | \alpha_F = 0.73) = 0.14233$, $E(\pi^U_F | \alpha_F = 0.75) = 0.13631$, $E(\pi^U_L | \alpha_F = 0.75) = 0.13813$. Thus, when $\alpha_F = 0.73$ and $\alpha_F = 0.75$, $E(\pi^U_L) > E(\pi^U_F)$.

With the same set of parameters, $E(\pi^K_F | \alpha_F = 0.73) = 0.13186$, $E(\pi^K_L | \alpha_F = 0.73) = 0.1444$, $E(\pi^K_F | \alpha_F = 0.75) = 0.13311$, $E(\pi^K_L | \alpha_F = 0.75) = 0.14036$. Thus, when $\alpha_F = 0.73$ and $\alpha_F = 0.75$, $E(\pi^K_L) > E(\pi^K_F)$.

Q.E.D.

Proof of Proposition E2.2:

a) We first substitute $\alpha_L = \alpha$ and $\alpha_F = \alpha + \alpha_\Delta$. Then we get the first derivative of leader's new marginal cost in the event of a successful implementation in Case 1 with respect to α is:

$$\frac{dc_L^U}{d\alpha}=\frac{\left(\begin{array}{l}3t(\alpha\left(36kt+2\left(-1+\alpha_\Delta+\alpha\right)\left(\alpha_\Delta+\alpha\right)+\left(\alpha_\Delta+\alpha\right)^2\right)\\ \left(5832k^3t^3-324k^2t^2\left(2\alpha_\Delta+3\alpha\right)+\alpha\left(\alpha_\Delta+\alpha\right)^2\left(-1+\alpha\left(\alpha_\Delta+\alpha\right)\right)+18kt\left(\alpha_\Delta+\alpha\right)\left(\alpha_\Delta+3\alpha-2\alpha^2\left(\alpha_\Delta+\alpha\right)\right)\right)+\\ \left(-324k^2t^2+36kt\left(\alpha_\Delta+\alpha\right)+\left(-1+\alpha_\Delta+\alpha\right)\left(\alpha_\Delta+\alpha\right)^2\right)\\ \left(5832k^3t^3-324k^2t^2\left(2\alpha_\Delta+3\alpha\right)+\alpha\left(\alpha_\Delta+\alpha\right)^2\left(-1+\alpha\left(\alpha_\Delta+\alpha\right)\right)+18kt\left(\alpha_\Delta+\alpha\right)\left(\alpha_\Delta+3\alpha-2\alpha^2\left(\alpha_\Delta+\alpha\right)\right)\right)-\\ \alpha\left(-324k^2t^2+36kt\left(\alpha_\Delta+\alpha\right)+\left(-1+\alpha_\Delta+\alpha\right)\left(\alpha_\Delta+\alpha\right)^2\right)(-972k^2t^2+2\alpha_\Delta{}^3\alpha+108kt\alpha-3\alpha^2-\\ 144kt\alpha^3+5\alpha^4+4\alpha_\Delta\left(-18kt+\alpha\right)\left(-1+3\alpha^2\right)+d^2\left(-1+9\alpha\left(-8kt+\alpha\right)\right)))\end{array}\right)}{\left(5832k^3t^3-324k^2t^2\left(2\alpha_\Delta+3\alpha\right)+\alpha\left(\alpha_\Delta+\alpha\right)^2\left(-1+\alpha\left(\alpha_\Delta+\alpha\right)\right)+18kt\left(\alpha_\Delta+\alpha\right)\left(\alpha_\Delta+3\alpha-2\alpha^2\left(\alpha_\Delta+\alpha\right)\right)\right)^2}$$

It is easy to see the denominator of $\frac{dc_L^U}{d\alpha}$ is positive. Further, we can prove that since $kt > 1/6$, the numerator of $\frac{dc_L^U}{d\alpha}$ is negative. Thus, $\frac{dc_L^U}{d\alpha} < 0$, and it follows that $\frac{df_L^U}{d\alpha} > 0$.

With the following set of parameters, $k = 0.48, c_O = 1, t = 0.34, \alpha_\Delta = 0.1$, $\frac{dE(\pi_L^U)}{d\alpha} = 0$ at $\alpha = 0.8510$. We further check that $E(\pi_L^U)|_{\alpha=0.7} = 0.1220$, $E(\pi_L^U)|_{\alpha=0.85} = 0.1116$ and $E(\pi_L^U)|_{\alpha=0.9} = 0.1150$. This means $E(\pi_L^U)$ can first decrease and then increase as α decreases.

b) With the following set of parameters, $k = 0.48, c_O = 1, t = 0.34, \alpha_\Delta = 0.1$, $\frac{dc_F^U}{d\alpha} = 0$ at $\alpha = 0.7545$. We further check that $c_F^U|_{\alpha=0.6} = 0.7306$, $c_F^U|_{\alpha=0.75} = 0.7014$ and $c_F^U|_{\alpha=0.8} = 0.7062$. Thus, c_F^U can increase or decrease when α decreases. Thus, the follower's investment f_F^U can first increase and then decrease when α decreases.

With the following set of parameters, $k = 0.48, c_O = 1, t = 0.34, \alpha_\Delta = 0.1$, $\frac{dE(\pi_F^U)}{d\alpha} = 0$ at $\alpha = 0.1135$. We further check that $E(\pi_F^U)|_{\alpha=0.05} = 0.1711$, $E(\pi_F^U)|_{\alpha=0.12} = 0.1713$ and $E(\pi_F^U)|_{\alpha=0.2} = 0.1709$. Thus, the follower's expected profit $E(\pi_F^U)$ can first increase and then decrease when α increases.

Q.E.D.

Proof of Proposition E2.3:

a) The leader's new marginal cost in the event of a successful implementation in simultaneous investment game is

$$c_L^S = c_O + \frac{3\alpha_L t\left(\alpha_F + {\alpha_F}^2 - 18kt\right)}{-{\alpha_F}^2{\alpha_L}^2 + \alpha_F\left(\alpha_L - 18kt\right) + 18kt\left(-\alpha_L + 18kt\right)} .$$

$$c_L^S - c_L^U = 3t\alpha_L\left(\frac{18kt - \alpha_F\left(1+\alpha_F\right)}{-324k^2t^2 + 18kt\left(\alpha_F + \alpha_L\right) + \alpha_F\alpha_L\left(-1+\alpha_F\alpha_L\right)} + \\ + \frac{324k^2t^2 - 36kt\alpha_F + \alpha_F^2 - \alpha_F^3}{5832k^3t^3 - 324k^2t^2\left(2\alpha_F + \alpha_L\right) + \alpha_F^2\alpha_L\left(-1+\alpha_F\alpha_L\right) + 18kt\alpha_F\left(\alpha_F + 2\alpha_L - 2\alpha_F\alpha_L^2\right)}\right)$$

We can prove that since $kt > 1/6$, $c_L^S - c_L^U > 0$, which implies that $f_L^U > f_L^S$.

The leader's expected profit in the simultaneous investment game is

$$E(\pi_L^S) = \frac{t\left(\begin{array}{l}\alpha_F^3\left(972k^2t^2 - 108kt\alpha_L + 3\alpha_L^2 + \alpha_L^4\right) - 36kt\alpha_F\left(324k^2t^2 - 36kt\alpha_L + \left(1+18kt\right)\alpha_L^2 - \alpha_L^3\right) + \\ \left(-1+36kt\right)\alpha_F^2\left(-324k^2t^2 + 36kt\alpha_L - \left(1+18kt\right)\alpha_L^2 + \alpha_L^3\right) + \\ 324k^2t^2\left(324k^2t^2 - 36kt\alpha_L + \left(1+18kt\right)\alpha_L^2 - \alpha_L^3\right) - \alpha_F^4\alpha_L^2\left(-54kt + 3\alpha_L + \alpha_L^2\right)\end{array}\right)}{2\left(\alpha_F^2\alpha_L^2 + 18kt\left(-18kt + \alpha_L\right) - \alpha_F\left(-18kt + \alpha_L\right)\right)^2}$$

$$E(\pi_L^S) - E(\pi_L^U) = \frac{\left(2t\alpha_F^4\alpha_L^2\left(-162k^2t^2 + \alpha_F\alpha_L\left(-1+\alpha_F\alpha_L\right) + 9kt\left(2\alpha_F + \alpha_L - \alpha_L^2\right)\right)^2\right)}{\left(\begin{array}{l}\left(-324k^2t^2 + 18kt\left(\alpha_F + \alpha_L\right) + \alpha_F\alpha_L\left(-1+\alpha_F\alpha_L\right)\right)^2 \\ \left(5832k^3t^3 - 324k^2t^2\left(2\alpha_F + \alpha_L\right) + \alpha_F^2\alpha_L\left(-1+\alpha_F\alpha_L\right) + 18kt\alpha_F\left(\alpha_F + 2\alpha_L - 2\alpha_F\alpha_L^2\right)\right)\end{array}\right)}$$

We can prove that since $kt > 1/6$, the numerator of $E(\pi_L^S) - E(\pi_L^U)$ is negative while the denominator of $E(\pi_L^S) - E(\pi_L^U)$ is positive. Thus, $E(\pi_L^S) < E(\pi_L^U)$.

The follower's new marginal cost in the event of a successful implementation in the simultaneous investment game is

$$c_F^S = c_O + \frac{3t\alpha_F\left(-18kt + \alpha_L + \alpha_L^2\right)}{18kt\left(18kt - \alpha_L\right) - \alpha_F^2\alpha_L^2 + \alpha_F\left(-18kt + \alpha_L\right)} .$$

$$c_F^S - c_F^U = \frac{6t\alpha_F^3\alpha_L^2\left(-\alpha_F^2\alpha_L^2 + \alpha_F\left(-18kt + \alpha_L\right) + 9kt\left(18kt + \left(-1+\alpha_L\right)\alpha_L\right)\right)}{\left(\begin{array}{l}\left(-324k^2t^2 + 18kt\left(\alpha_F + \alpha_L\right) + \alpha_F\alpha_L\left(-1+\alpha_F\alpha_L\right)\right) \\ \left(5832k^3t^3 - 324k^2t^2\left(2\alpha_F + \alpha_L\right) + \alpha_F^2\alpha_L\left(-1+\alpha_F\alpha_L\right) + 18kt\alpha_F\left(\alpha_F + 2\alpha_L - 2\alpha_F\alpha_L^2\right)\right)\end{array}\right)}$$

We can prove that since $kt > 1/6$, the numerator of $c_F^S - c_F^U$ is positive while the denominator of $c_F^S - c_F^U$ is negative. Thus, $c_F^S - c_F^U < 0$, and it follows $f_F^U < f_F^S$.

The follower's expected profit in the simultaneous investment game is

$$E(\pi_F^S)=\frac{\begin{pmatrix}324k^2t^2\left(324k^2t^2-36kt\alpha_L+(1-36kt)\alpha_L^2+3\alpha_L^3\right)-36kt\alpha_F\left(324k^2t^2-36kt\alpha_L+(1-36kt)\alpha_L^2+3\alpha_L^3\right)\\ -\alpha_F^3\left(324k^2t^2-36kt\alpha_L+(1-36kt)\alpha_L^2+3\alpha_L^4\right)-\alpha_F^4(-1+\alpha_L)\alpha_L^3+\\ \alpha_F^2\left(324k^2t^2(1+18kt)-36kt(1+18kt)\alpha_L+\left(1-18kt-648k^2t^2\right)\alpha_L^2+3\alpha_L^3+54kt\alpha_L^4\right)\end{pmatrix}}{2\left(\alpha_F^2\alpha_L^2+18kt(-18kt+\alpha_L)-\alpha_F(-18kt+\alpha_L)\right)^2}$$, and

$$E(\pi_F^S)-E(\pi_F^U)=\frac{\begin{pmatrix}2t\alpha_F^2(-18kt+\alpha_F)\alpha_L^2\left(-162k^2t^2+\alpha_F\alpha_L(-1+\alpha_F\alpha_L)+9kt\left(2\alpha_F+\alpha_L-\alpha_L^2\right)\right)\\ (1889568k^5t^5+104976k^4t^4\left((-3+\alpha_F)\alpha_F-3\alpha_L\right)+(-2+\alpha_F)\alpha_F^3\alpha_L^2(-1+\alpha_F\alpha_L)^2\\ -162k^2t^2\alpha_F\left(12\alpha_L^2+\alpha_F^3\left(-2+5\alpha_L^2\right)-\alpha_F\alpha_L\left(-18+\alpha_L+11\alpha_L^2\right)+\alpha_F^2\left(2-7\alpha_L(1+2\alpha_L)\right)\right)+\\ 9kt\alpha_F^2\alpha_L(-1+\alpha_F\alpha_L)\left(-12\alpha_L+\alpha_F\left(-6+4\alpha_F+\alpha_L(3+7\alpha_L)\right)\right)-\\ 2916k^3t^3\left(4\alpha_F^3-18\alpha_F\alpha_L-4\alpha_L^2+\alpha_F^2\left(-6+\alpha_L(3+8\alpha_L)\right)\right))\end{pmatrix}}{\begin{pmatrix}\left(-324k^2t^2+18kt(\alpha_F+\alpha_L)+\alpha_F\alpha_L(-1+\alpha_F\alpha_L)\right)^2\\ \left(5832k^3t^3-324k^2t^2(2\alpha_F+\alpha_L)+\alpha_F^2\alpha_L(-1+\alpha_F\alpha_L)+18kt\alpha_F\left(\alpha_F+2\alpha_L-2\alpha_F\alpha_L^2\right)\right)^2\end{pmatrix}}$$

We can prove that since $kt>1/6$, the numerator and the denominator of $E(\pi_F^S)-E(\pi_F^U)$ are positive. Thus, $E(\pi_F^S)-E(\pi_F^U)>0$.

b) The difference between the leader's new marginal cost if implementation is successful in Case 1 and Case 2:

$$c_L^U-c_L^K=\frac{3t\alpha_F^2(36kt-\alpha_F)\left(-324k^2t^2+36kt\alpha_F+(-1+\alpha_F)\alpha_F^2\right)(-1+\alpha_L)\alpha_L^2}{\begin{pmatrix}\left(5832k^3t^3+(-1+\alpha_F)\alpha_F^2\alpha_L-324k^2t^2(2\alpha_F+\alpha_L)+18kt\alpha_F(\alpha_F+2\alpha_L-2\alpha_F\alpha_L)\right)\\ \left(5832k^3t^3-324k^2t^2(2\alpha_F+\alpha_L)+\alpha_F^2\alpha_L(-1+\alpha_F\alpha_L)+18kt\alpha_F\left(\alpha_F+2\alpha_L-2\alpha_F\alpha_L^2\right)\right)\end{pmatrix}}$$

We can prove that since $kt>1/6$, the numerator and the denominator of $c_L^U-c_L^K$ are positive. Thus, $c_L^U-c_L^K>0$, and it follows $f_L^K>f_L^U$.

The difference between the leader's expected profits in Case 1 and Case 2:

$$E(\pi_L^U)-E(\pi_L^K)=\frac{t\alpha_F^2(36kt-\alpha_F)\left(-324k^2t^2+36kt\alpha_F+(-1+\alpha_F)\alpha_F^2\right)^2(-1+\alpha_L)\alpha_L^3}{\begin{pmatrix}2(-18kt+\alpha_F)^2\left(5832k^3t^3+(-1+\alpha_F)\alpha_F^2\alpha_L-324k^2t^2(2\alpha_F+\alpha_L)+18kt\alpha_F(\alpha_F+2\alpha_L-2\alpha_F\alpha_L)\right)\\ \left(5832k^3t^3-324k^2t^2(2\alpha_F+\alpha_L)+\alpha_F^2\alpha_L(-1+\alpha_F\alpha_L)+18kt\alpha_F\left(\alpha_F+2\alpha_L-2\alpha_F\alpha_L^2\right)\right)\end{pmatrix}}$$

We can prove that since $kt>1/6$, the numerator of $E(\pi_L^U)-E(\pi_L^K)$ is negative while the denominator of $E(\pi_L^U)-E(\pi_L^K)$ is positive. Thus, $E(\pi_L^U)<E(\pi_L^K)$.

c) With the following set of parameter values: $k = 0.48, c_O = 1, t = 0.34$, we compare the followers' expected profits in Case 1 and Case 2 when the follower

$E(\pi_F^U \mid \alpha_L = 0.91, \alpha_F = 0.9) = 0.052$ and $E(\pi_F^K \mid \alpha_L = 0.91, \alpha_F = 0.9) = 0.047$. Thus, the follower's profit in Case 1 can be higher than that in Case 2.

$E(\pi_F^U \mid \alpha_L = 0.985, \alpha_F = 0.975) = 0.0031$ and $E(\pi_F^K \mid \alpha_L = 0.985, \alpha_F = 0.975) = 0.0039$. Thus, the follower's profit in Case 2 can be higher than that in Case 1.

Q.E.D.

Extension 5

One can show that when *n* is large enough, or $n > \frac{2-3kt}{6kt}$, the market is not fully covered without IT investment.

LEMMA E5.1:

Firm i's decision problem in the Outcome Unknown case can be formulated as:

$$\max_{c_i^U} E(\pi_i^U) = \max_{c_i^U} \left(\alpha^2 \pi_{i,ss}^U + \alpha(1-\alpha)\pi_{i,sf}^U + (1-\alpha)\alpha\pi_{i,fs}^U + (1-\alpha)^2 \pi_{i,ff}^U \right)$$

$$s.t., c_i^U \in [0, c_O],$$

where $\pi_{i,j}^U$ denotes firm i's payoff given implementation outcome j in this "outcome unknown" Case 1, $i \in \{L, F\}$, and $j = ss, sf, fs, ff$.

The two firms' expected profits can be characterized as follows:

$$E(\pi_L^U) = \frac{\left(\begin{aligned} & 9t^2 + c_L^{U2}\alpha - 6c_L^U\alpha + c_F^{U2}(1+2w)^3\alpha + 128w^5\left(U^2 + c_L^{U2}\alpha - 2c_L^U U\alpha\right) + \\ & 2w\left(3t(7t+6U) + 9c_L^{U2}\alpha - 2c_L^U(17t+3U)\alpha\right) + \\ & 64w^4\left(2U(t+2U) + 5c_L^{U2}\alpha - c_L^U(2t+9U)\alpha\right) + \\ & 8w^3\left(4t^2 + 32tU + 21U^2 + 36c_L^{U2}\alpha - 4c_L^U(9t+14U)\alpha\right) + \\ & 4w^2\left(16t^2 + 42tU + 9U^2 + 28c_L^{U2}\alpha - 2c_L^U(28t+17U)\alpha\right) + 2(1+2w)(-1+\alpha) \\ & \left(2w(3+4w)^2(t+2Uw) + c_L^U(1+2w)\left(1+8w(1+w)\right)\alpha\right)c_O - \\ & 2(1+2w)(-1+\alpha)\left(2w^2(3+4w)^2 + (1+2w)\left(1+8w(1+w)\right)\alpha\right)c_O^2 + \\ & 2c_F^U(1+2w)^2\alpha\left((3+4w)(t+2Uw) - c_L^U\left(1+8w(1+w)\right)\alpha + \left(1+8w(1+w)\right)(-1+\alpha)c_O\right) \end{aligned} \right)}{2(1+4w)^2(3+4w)^2(t+2ntw)} - k(c_O - c_L^U)^2$$

$$E(\pi_F^U) = (1+2w)\frac{\begin{pmatrix} 9t^2 + 24t^2 w + 36tUw + 16t^2 w^2 + 96tUw^2 + 36U^2 w^2 + 64tUw^3 + 12c_L^U Uw\alpha + \\ 96U^2 w^3 + 64U^2 w^4 + c_L^{U2}\alpha + 6c_L^U t\alpha + 4c_L^{U2} w\alpha + 20c_L^U tw\alpha + 4c_L^{U2} w^2\alpha + \\ 16c_L^U tw^2\alpha + 40c_L^U Uw^2\alpha + 32c_L^U Uw^3\alpha + c_F^{U2}\left(1+8w+8w^2\right)^2 \alpha + \\ 2(-1+\alpha)\left(2w(3+4w)^2 (t+2Uw) + c_L^U \left(1+10w+24w^2+16w^3\right)\alpha\right)c_O - \\ 2\left(-2w^2(3+4w)^2 + \left(-1-10w-6w^2+32w^3+32w^4\right)\alpha + \left(1+10w+24w^2+16w^3\right)\alpha^2\right)c_O^2 - \\ 2c_F^U\left(1+8w+8w^2\right)\alpha\left((3+4w)(t+2Uw) + c_L^U(\alpha+2w\alpha) - (1+2w)(-1+\alpha)c_O\right) \end{pmatrix}}{2(1+4w)^2(3+4w)^2(t+2ntw)} - k(c_O - c_F^U)^2$$

By taking the first derivative of the follower's expected profit w.r.t. the follower's new marginal cost in the event of a successful implementation, c_F^U , and solving its first order condition, we get

$$c_F^U(c_L^U) = \frac{\begin{pmatrix} -(1+2w)(1+8w(1+w))\alpha\left((3+4w)(t+2vw) + c_L^U(\alpha+2w\alpha)\right) + \\ \left(2kt(1+4w)^2(3+4w)^2(1+2nw) + (1+2w)^2(1+8w(1+w))(-1+\alpha)\alpha\right)c_O \end{pmatrix}}{2kt(1+4w)^2(3+4w)^2(1+2nw) - (1+2w)(1+8w(1+w))^2\alpha}$$

, which is the response function of the follower conditioning on the leader's investment level. Then, we substitute the follower's response function into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c_L^U , and solving its first order condition, we get the leader's new marginal cost if his implementation is successful

$$c_L^U = \frac{\begin{pmatrix} (1+2w)(3+4w)(t+2Uw)(1+8w(1+w))\alpha \\ (4k^2t^2(1+4w)^4(3+4w)^4(1+2nw)^2 - 4kt(1+2w)(1+4w)^2(3+4w)^2(1+2nw)(1+8w(1+w))^2\alpha + \\ \left(1-4ktw(1+4w)^2(3+4w)^3(1+2nw)+32w(1+w)(1+2w)^2\left(1+8w(1+w)(1+2w)^2\right)\right)(\alpha+2w\alpha)^2 + \\ (1+8w(1+w))\left(-1+2w\left(1+2w(13+4w(7+4w))\right)\right)(\alpha+2w\alpha)^3) + \\ (-8k^3t^3(1+4w)^6(3+4w)^6(1+2nw)^3 + 4k^2t^2(1+2w)(1+4w)^4(3+4w)^4(1+2nw)^2(1+8w(1+w)) \\ (3+2w(9+8w))\alpha - 2kt(1+2w)^2(1+4w)^2(3+4w)^2(1+2nw)(1+8w(1+w))^3(3+4w(3+2w))\alpha^2 + \\ (1+8w(1+w))(1+2w(17+4w(60+kt(1+4w)^2(3+4w)^4(1+2nw)+8w \\ \left(57+2w\left(127+2w\left(171+8w(5+2w)(7+2w(2+w))\right)\right)\right))))(\alpha+2w\alpha)^3 + \\ 2(3+4w)(1+8w(1+w))^2\left(w+2kt(1+4w)^2(3+4w)(1+2nw)-2w^2\left(1+2w(13+4w(7+4w))\right)\right) \\ (\alpha+2w\alpha)^4 - (1+8w(1+w))^2\left(1+4w(1+w)(7+32w(1+w))\right)(\alpha+2w\alpha)^5)c_O \end{pmatrix}}{\begin{pmatrix} \left(-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha\right)^2 \\ (-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha + \\ \frac{(1+2w)^7(1+8w(1+w))^2\alpha^5}{\left(-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha\right)^2} - \\ \frac{2(1+8w(1+w))^2(\alpha+2w\alpha)^4}{-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha}) \end{pmatrix}}$$

. Then check the second order condition, and with the assumption $kt > 1/6$, one can show that

$$\frac{\delta^2 E(\pi_L^U)}{\delta c_L^{U2}} = \frac{\begin{pmatrix} -2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha + \\ \frac{(1+2w)^7(1+8w(1+w))^2\alpha^5}{\left(-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha\right)^2} - \\ \frac{2(1+8w(1+w))^2(\alpha+2w\alpha)^4}{-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha} \end{pmatrix}}{(1+4w)^2(3+4w)^2(t+2ntw)} < 0$$

. Then we substitute the leader's new marginal cost into the follower's response function and get the follower's new marginal cost if his implementation is successful

$$
c_F^U = \frac{\left(\begin{array}{l}
((2kt(1+2nw)(3+16w+16w^2)^2-(1+2w)^2(1+8w+8w^2)\alpha+(1+8w+8w^2)(\alpha+2w\alpha)^2)c_O- \\
(1+10w+24w^2+16w^3)\alpha \\
((3+4w)(t+2Uw)+((\alpha+2w\alpha)((1+2w)(3+4w)(t+2Uw)(1+8w(1+w))\alpha(4k^2t^2(1+4w)^4 \\
(3+4w)^4(1+2nw)^2-4kt(1+2w)(1+4w)^2(3+4w)^2(1+2nw)(1+8w(1+w))^2\alpha+ \\
(1-4ktw(1+4w)^2(3+4w)^3(1+2nw)+32w(1+w)(1+2w)^2(1+8w(1+w)(1+2w)^2)) \\
(\alpha+2w\alpha)^2+(1+8w(1+w))(-1+2w(1+2w(13+4w(7+4w))))(\alpha+2w\alpha)^3)+ \\
(-8k^3t^3(1+4w)^6(3+4w)^6(1+2nw)^3+4k^2t^2(1+2w)(1+4w)^4(3+4w)^4 \\
(1+2nw)^2(1+8w(1+w))(3+2w(9+8w))\alpha-2kt(1+2w)^2 \\
(1+4w)^2(3+4w)^2(1+2nw)(1+8w(1+w))^3(3+4w(3+2w))\alpha^2+ \\
(1+8w(1+w))(1+2w(17+4w(60+kt(1+4w)^2(3+4w)^4(1+2nw)+8w(57+ \\
2w(127+2w(171+8w(5+2w)(7+2w(2+w))))))))(\alpha+2w\alpha)^3+2(3+4w) \\
(1+8w(1+w))^2(w+2kt(1+4w)^2(3+4w)(1+2nw)-2w^2(1+2w(13+4w(7+4w)))) \\
(\alpha+2w\alpha)^4-(1+8w(1+w))^2(1+4w(1+w)(7+32w(1+w)))(\alpha+2w\alpha)^5)c_O))/ \\
((-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha)^2 \\
(-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha+ \\
\frac{(1+2w)^7(1+8w(1+w))^2\alpha^5}{(-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha)^2}- \\
\frac{2(1+8w(1+w))^2(\alpha+2w\alpha)^4}{-2kt(1+4w)^2(3+4w)^2(1+2nw)+(1+2w)(1+8w(1+w))^2\alpha})))
\end{array}\right)}{\alpha(1+2w)(1+8w+8w^2)^2-2kt(1+2nw)(3+16w+16w^2)^2}.
$$

We also check the second order condition, and with the assumption $kt > 1/6$, one can show that $\frac{\delta^2 E(\pi_F^U)}{\delta c_F^{U2}} = -2k + \frac{(1+2w)(1+8w(1+w))^2\alpha}{(1+4w)^2(3+4w)^2(t+2ntw)} < 0$.

LEMMA E5.2:

In the Outcome Known case, the leader's expected profit can be characterized as follows:

$$E(\pi_L^K)=\begin{pmatrix} \alpha^2\dfrac{(1+2w)\left(c_{F,ss}^K+2c_{F,ss}^K w+(3+4w)(t+2Uw)-c_L^K(1+8w(1+w))\right)^2}{2(1+4w)^2(3+4w)^2(t+2ntw)}+ \\ \alpha(1-\alpha)\dfrac{(1+2w)\left((3+4w)(t+2Uw)-c_L^K(1+8w(1+w))+(1+2w)c_O\right)^2}{2(1+4w)^2(3+4w)^2(t+2ntw)}+ \\ (1-\alpha)\alpha\dfrac{(1+2w)\left(c_{F,fs}^K+2c_{F,fs}^K w+(3+4w)(t+2Uw)-(1+8w(1+w))c_O\right)^2}{2(1+4w)^2(3+4w)^2(t+2ntw)}+ \\ (1-\alpha)^2\dfrac{(1+2w)(t+2Uw-2wc_O)^2}{2(1+4w)^2(t+2ntw)} \end{pmatrix}-k(c_O-c_L^K)^2$$

And the follower's expected profit depending on the outcome of the leader's implementation can be characterized as follows:

$$E(\pi_{F,s}^K)=\begin{pmatrix} \alpha\dfrac{(1+2w)\left(c_L^K+2c_L^K w+(3+4w)(t+2Uw)-c_{F,ss}^K(1+8w(1+w))\right)^2}{2(1+4w)^2(3+4w)^2(t+2ntw)}+ \\ (1-\alpha)\dfrac{(1+2w)\left(c_L^K+2c_L^K w+(3+4w)(t+2Uw)-(1+8w(1+w))c_O\right)^2}{2(1+4w)^2(3+4w)^2(t+2ntw)} \end{pmatrix}-k(c_O-c_{F,ss}^K)^2 \text{ if the}$$

leader's implementation is successful;

$$E(\pi_{F,f}^K)=\begin{pmatrix} \alpha\dfrac{(1+2w)\left((3+4w)(t+2Uw)-c_{F,fs}^K l(1+8w(1+w))+(1+2w)c_O\right)^2}{2(1+4w)^2(3+4w)^2(t+2ntw)}+ \\ (1-\alpha)\dfrac{(1+2w)(t+2Uw-2wc_O)^2}{2(1+4w)^2(t+2ntw)} \end{pmatrix}-k(c_O-c_{F,fs}^K)^2 \text{ if the}$$

leader's implementation is unsuccessful.

By taking the first derivative of the follower's expected profits, $E(\pi_{F,s}^K)$ and $E(\pi_{F,f}^K)$ w.r.t. the follower's new marginal costs in the event of a successful implementation, $c_{F,s}^K$ and $c_{F,f}^K$, and solving its first order conditions, we get $c_{F,s}^K=\dfrac{\begin{pmatrix} -c_L^K(1+2w)^2(1+8w(1+w))\alpha+(3+4w) \\ \left(-(1+2w)(t+2Uw)(1+8w(1+w))\alpha+2kt(1+4w)^2(3+4w)(1+2nw)c_O\right) \end{pmatrix}}{2kt(1+4w)^2(3+4w)^2(1+2nw)-(1+2w)(1+8w(1+w))^2\alpha}$

and $c_{F,f}^K=\dfrac{\begin{pmatrix} (1+2w)(3+4w)(t+2Uw)(1+8w(1+w))\alpha- \\ 2kt(1+4w)^2(3+4w)^2(1+2nw)c_O+(1+2w)^2(1+8w(1+w))\alpha c_O \end{pmatrix}}{(1+2w)(1+8w(1+w))^2\alpha-2kt(1+4w)^2(3+4w)^2(1+2nw)}$, which are the response functions of the follower conditioning on the leader's investment level and implementation outcome. We also check the second order condition, with assumption $kt>1/6$, one can show that

$\frac{\delta^2 E(\pi^K_{F,s})}{\delta {c^K_{F,s}}^2} = \frac{\delta^2 E(\pi^K_{F,f})}{\delta {c^K_{F,f}}^2} = \frac{-4kt(1+2nw)(3+16w+16w^2)^2 + 2(1+2w)(-1-8w-8w^2)^2\alpha}{2(t+2ntw)(3+16w+16w^2)^2} < 0$. Then, we substitute the follower's response functions into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c^K_L, and solving its first order condition, we get

$$c_L^K = \frac{\left(\begin{array}{l}
\frac{(1+2w)(t+2Uw)(1+8w+8w^2)\alpha}{t(1+4w)^2(3+4w)(1+2nw)} - \frac{(1+2w)(t+2Uw)(1+8w+8w^2)\alpha^2}{t(1+4w)^2(3+4w)(1+2nw)} + \\
\frac{2(1+2w)(t+2Uw)(1+8w+8w^2)\alpha^2\left(kt(1+2nw)(3+16w+16w^2) - 2w(1+3w+2w^2)\alpha\right)}{t(1+4w)(1+2nw)\left(2kt(1+2nw)(3+16w+16w^2)^2 - (1+2w)(1+8w+8w^2)^2\alpha\right)} - \\
2k(-1+\alpha)^2 c_O - 2k\alpha c_O + \frac{(1+2w)(1+8w+8w^2)\alpha c_O}{(t+2ntw)(3+16w+16w^2)^2} + \frac{2w(1+2w)(1+8w+8w^2)\alpha c_O}{(t+2ntw)(3+16w+16w^2)^2} + \\
2k(-1+\alpha)\alpha c_O + \frac{(1+2w)(-1-8w-8w^2)\alpha^2 c_O}{(t+2ntw)(3+16w+16w^2)^2} + \frac{2w(1+2w)(-1-8w-8w^2)\alpha^2 c_O}{(t+2ntw)(3+16w+16w^2)^2} - \\
(2(1+2w)(1+8w+8w^2)\alpha^2\left(kt(1+2nw)(3+16w+16w^2) - 2w(1+3w+2w^2)\alpha\right) \\
\left((t+2Uw)(1+10w+24w^2+16w^3)\alpha - 2kt(1+4w)^2(3+4w)(1+2nw)c_O\right)) / \\
\left(t(1+4w)(1+2nw)\left(-2kt(1+2nw)(3+16w+16w^2)^2 + (1+2w)(1+8w+8w^2)^2\alpha\right)^2\right) - \\
(4w(1+2w)(1+8w+8w^2)\alpha^2\left(kt(1+2nw)(3+16w+16w^2) - 2w(1+3w+2w^2)\alpha\right) \\
\left((t+2Uw)(1+10w+24w^2+16w^3)\alpha - 2kt(1+4w)^2(3+4w)(1+2nw)c_O\right)) / \\
\left(t(1+4w)(1+2nw)\left(-2kt(1+2nw)(3+16w+16w^2)^2 + (1+2w)(1+8w+8w^2)^2\alpha\right)^2\right)
\end{array}\right)}{\left(\begin{array}{l}
-2k(-1+\alpha)^2 - 2k\alpha + \frac{(1+2w)(1+8w+8w^2)^2\alpha}{(t+2ntw)(3+16w+16w^2)^2} + 2k(-1+\alpha)\alpha - \frac{(1+2w)(1+8w+8w^2)^2\alpha^2}{(t+2ntw)(3+16w+16w^2)^2} + \\
\frac{2(1+2w)(1+8w+8w^2)^2\alpha^2\left(kt(1+2nw)(3+16w+16w^2) - 2w(1+3w+2w^2)\alpha\right)}{t(1+2nw)(3+16w+16w^2)\left(2kt(1+2nw)(3+16w+16w^2)^2 - (1+2w)(1+8w+8w^2)^2\alpha\right)} + \\
\frac{2(1+8w+8w^2)^2(\alpha+2w\alpha)^3\left(kt(1+2nw)(3+16w+16w^2) - 2w(1+3w+2w^2)\alpha\right)}{t(1+2nw)(3+16w+16w^2)\left(-2kt(1+2nw)(3+16w+16w^2)^2 + (1+2w)(1+8w+8w^2)^2\alpha\right)^2} + \\
\frac{4w(1+8w+8w^2)^2(\alpha+2w\alpha)^3\left(kt(1+2nw)(3+16w+16w^2) - 2w(1+3w+2w^2)\alpha\right)}{t(1+2nw)(3+16w+16w^2)\left(-2kt(1+2nw)(3+16w+16w^2)^2 + (1+2w)(1+8w+8w^2)^2\alpha\right)^2}
\end{array}\right)}.$$

Then check the second order condition, and with the assumption $kt > 1/6$, one can show that

$$\frac{\delta^2 E(\pi_L^K)}{\delta c_L^{K2}} = 2k(-1+\alpha) + \frac{\alpha\left(\begin{array}{l} -4k(t+2ntw)(3+16w+16w^2)^2 - 2(1+2w)(1+8w+8w^2)^2(-1+\alpha) + 2(1+2w)\alpha \\ (1+8w+8w^2 + \frac{(1+2w)^2(1+8w(1+w))\alpha}{2kt(1+4w)^2(3+4w)^2(1+2nw) - (1+2w)(1+8w(1+w))^2\alpha} + \\ \frac{2w(1+2w)^2(1+8w(1+w))\alpha}{2kt(1+4w)^2(3+4w)^2(1+2nw) - (1+2w)(1+8w(1+w))^2\alpha})^2 \end{array}\right)}{2(t+2ntw)(3+16w+16w^2)^2} < 0$$

. Then we substitute the leader's new marginal cost into the follower's response functions and get the follower's new marginal costs if his implementation is successful.

$$
c_{F,s}^{K}=\frac{\left(\begin{aligned}
&(3+4w)\left(-(1+2w)(t+2Uw)(1+8w(1+w))\alpha+2kt(1+4w)^{2}(3+4w)(1+2nw)c_{O}\right)-\\
&((1+2w)^{2}(1+8w(1+w))\alpha(\frac{(1+2w)(t+2Uw)(1+8w+8w^{2})\alpha}{t(1+4w)^{2}(3+4w)(1+2nw)}-\frac{(1+2w)(t+2Uw)(1+8w+8w^{2})\alpha^{2}}{t(1+4w)^{2}(3+4w)(1+2nw)}+\\
&\frac{2(1+2w)(t+2Uw)(1+8w+8w^{2})\alpha^{2}\left(kt(1+2nw)(3+16w+16w^{2})-2w(1+3w+2w^{2})\alpha\right)}{t(1+4w)(1+2nw)\left(2kt(1+2nw)(3+16w+16w^{2})^{2}-(1+2w)(1+8w+8w^{2})^{2}\alpha\right)}-\\
&2k(-1+\alpha)^{2}c_{O}-2k\alpha c_{O}+\frac{(1+2w)(1+8w+8w^{2})\alpha c_{O}}{(t+2ntw)(3+16w+16w^{2})^{2}}+\frac{2w(1+2w)(1+8w+8w^{2})\alpha c_{O}}{(t+2ntw)(3+16w+16w^{2})^{2}}+\\
&2k(-1+\alpha)\alpha c_{O}+\frac{(1+2w)(-1-8w-8w^{2})\alpha^{2}c_{O}}{(t+2ntw)(3+16w+16w^{2})^{2}}+\frac{2w(1+2w)(-1-8w-8w^{2})\alpha^{2}c_{O}}{(t+2ntw)(3+16w+16w^{2})^{2}}-\\
&(2(1+2w)(1+8w+8w^{2})\alpha^{2}\left(kt(1+2nw)(3+16w+16w^{2})-2w(1+3w+2w^{2})\alpha\right)\\
&\left((t+2Uw)(1+10w+24w^{2}+16w^{3})\alpha-2kt(1+4w)^{2}(3+4w)(1+2nw)c_{O}\right))/\\
&\left(t(1+4w)(1+2nw)\left(-2kt(1+2nw)(3+16w+16w^{2})^{2}+(1+2w)(1+8w+8w^{2})^{2}\alpha\right)^{2}\right)-\\
&(4w(1+2w)(1+8w+8w^{2})\alpha^{2}\left(kt(1+2nw)(3+16w+16w^{2})-2w(1+3w+2w^{2})\alpha\right)\\
&\left((t+2Uw)(1+10w+24w^{2}+16w^{3})\alpha-2kt(1+4w)^{2}(3+4w)(1+2nw)c_{O}\right))/\\
&\left(t(1+4w)(1+2nw)\left(-2kt(1+2nw)(3+16w+16w^{2})^{2}+(1+2w)(1+8w+8w^{2})^{2}\alpha\right)^{2}\right)))/\\
&(-2k(-1+\alpha)^{2}-2k\alpha+\frac{(1+2w)(1+8w+8w^{2})^{2}\alpha}{(t+2ntw)(3+16w+16w^{2})^{2}}+2k(-1+\alpha)\alpha-\frac{(1+2w)(1+8w+8w^{2})^{2}\alpha^{2}}{(t+2ntw)(3+16w+16w^{2})^{2}}+\\
&\frac{2(1+2w)(1+8w+8w^{2})^{2}\alpha^{2}\left(kt(1+2nw)(3+16w+16w^{2})-2w(1+3w+2w^{2})\alpha\right)}{t(1+2nw)(3+16w+16w^{2})\left(2kt(1+2nw)(3+16w+16w^{2})^{2}-(1+2w)(1+8w+8w^{2})^{2}\alpha\right)}+\\
&\frac{2(1+8w+8w^{2})^{2}(\alpha+2w\alpha)^{3}\left(kt(1+2nw)(3+16w+16w^{2})-2w(1+3w+2w^{2})\alpha\right)}{t(1+2nw)(3+16w+16w^{2})\left(-2kt(1+2nw)(3+16w+16w^{2})^{2}+(1+2w)(1+8w+8w^{2})^{2}\alpha\right)^{2}}+\\
&\frac{4w(1+8w+8w^{2})^{2}(\alpha+2w\alpha)^{3}\left(kt(1+2nw)(3+16w+16w^{2})-2w(1+3w+2w^{2})\alpha\right)}{t(1+2nw)(3+16w+16w^{2})\left(-2kt(1+2nw)(3+16w+16w^{2})^{2}+(1+2w)(1+8w+8w^{2})^{2}\alpha\right)^{2}})
\end{aligned}\right)}{2kt(1+4w)^{2}(3+4w)^{2}(1+2nw)-(1+2w)(1+8w(1+w))^{2}\alpha}
$$
and

$$
c_{F,f}^{K}=\frac{\left(\begin{aligned}
&\alpha(1+2w)^{2}(1+8w(1+w))c_{O}-2kt(1+4w)^{2}(3+4w)^{2}(1+2nw)c_{O}+\\
&\alpha(1+2w)(3+4w)(t+2Uw)(1+8w(1+w))
\end{aligned}\right)}{\alpha(1+2w)(1+8w(1+w))^{2}-2kt(1+4w)^{2}(3+4w)^{2}(1+2nw)}.
$$

Proof of PROPOSITION E5.1:

With the parameter sets, $k = 0.48, c_O = 1, t = 0.4, U = 1.35, w = 0.5, n = 1.5$, firms' profit without IT investment is $\frac{(1+2w)(t+2(U-c_O)w)^2}{2(1+4w)^2(t+2ntw)} = 0.0625$; the leader's profit is $E(\pi_L^U \mid \alpha = 0.6) = 0.0677$ and the follower's profit is $E(\pi_F^U \mid \alpha = 0.6) = 0.0675$ in the outcome unknown case; the leader's profit is $E(\pi_L^K \mid \alpha = 0.6) = 0.0678$ and the follower's profit is $E(\pi_F^K \mid \alpha = 0.6) = 0.0675$ in the outcome known case. Thus, the firms' profits can be higher than when they do not invest in IT.

Q.E.D.

Proof of PROPOSITION E5.2:

a) With the following set of parameters, $k = 0.48, c_O = 1, t = 0.4, U = 1.35, w = 0.001, n = 1.5$, the leader's profit's first derivative with respect to probability of success in the Case 1 $\frac{dE(\pi_L^U)}{d\alpha} = 0$ at $\alpha = 0.9291$. We further check that $E(\pi_L^U)|_{\alpha=0.5} = 0.184805$, $E(\pi_L^U)|_{\alpha=0.8} = 0.16524$, $E(\pi_L^U)|_{\alpha=0.93} = 0.15997$ and $E(\pi_L^U)|_{\alpha=0.98} = 0.161761$. Thus, $E(\pi_L^U)$ can decrease first and then increase as α decreases.

b) With the following set of parameters, $k = 0.48, c_O = 1, t = 0.4, U = 1.35, w = 0.001, n = 1.5$, the first derivative of the follower's marginal cost in the event of a successful implementation with respect to probability of success in the Case 1 $\frac{dc_F^U}{d\alpha} = 0$ at $\alpha = 0.8495$. We further check that $c_F^U|_{\alpha=0.5} = 0.81416$, $c_F^U|_{\alpha=0.7} = 0.7507$, $c_F^U|_{\alpha=0.85} = 0.72836$ and $c_F^U|_{\alpha=0.9} = 0.73268$. Thus, f_F^U can increase first and then decrease as α decreases.

Q.E.D.

Proof of PROPOSITION E5.3:

a)

The difference between the expected profit of the leader and that of the follower in Case 1 is:

$$E(\pi_L^U)-E(\pi_F^U)=\frac{\begin{pmatrix}4(1+2w)^6(t+2(-c_O+U)w)^2(1+8w(1+w))\alpha^4\\(kt(1+4w)(3+4w)^2(1+2nw)+(1+w)(1+2w)(1+8w(1+w))(-1+\alpha)\alpha)^2\\(4(1+4w)^4(3+4w)^4(kt+2ktnw)^2-kt(1+2w)(1+4w)^2(3+4w)^2(1+2nw)\\(1+8w(1+w))\alpha(4+32w(1+w)+3\alpha+6w\alpha)+(1+8w(1+w))(\alpha+2w\alpha)^2\\((1+8w(1+w))^3+(1+2w)(1+6w(1+w))(1+16w(1+w))\alpha))\end{pmatrix}}{\begin{pmatrix}(t+2ntw)(8(1+4w)^6(3+4w)^6(kt+2ktnw)^3\\-12kt^2(1+2w)(1+4w)^4(3+4w)^4(1+2nw)^2(1+8w(1+w))^2\alpha-\\(1+8w(1+w))^6(\alpha+2w\alpha)^3+(1+8w(1+w))^2(1+4w(1+w)(7+32w(1+w)))(\alpha+2w\alpha)^5+2kt\\(1+2w)^2(1+4w)^2(3+4w)^2(1+2nw)(1+8w(1+w))^2\alpha^2(3(1+8w(1+w))^2-2(\alpha+2w\alpha)^2))^2\end{pmatrix}}$$

Since $kt>1/6$, and by assumption, the market is sufficiently large so that it is not fully covered without IT investment (or $n>\frac{2-3kt}{6kt}$), one can show that the numerator and the denominator of $E(\pi_L^U)-E(\pi_F^U)$ are positive. Thus, $E(\pi_L^U)-E(\pi_F^U)>0$ and the leader's expected profit is higher than the follower's expected profit in Case 1.

b)

With the parameter sets, $k=0.48, c_O=1, t=0.34, U=1.35, w=0.001, n=1.6$, the follower's profit $E(\pi_F^U \mid \alpha=0.9)=0.0571$ and $E(\pi_F^U \mid \alpha=0.975)=0.0067$ in the outcome unknown case; and the follower's profit $E(\pi_F^K \mid \alpha=0.9)=0.0519$ and $E(\pi_F^K \mid \alpha=0.975)=0.0071$ in the outcome known case. Thus, the follower's profit can be higher in Case 1 than in Case 2, or it can be higher in Case 2 than in Case 1.

Q.E.D.

LEMMA E1.1:

Firm *i*'s decision problem in the Outcome Unknown Case 1 can be formulated as:

$$\max_{c_i^U} E(\pi_i^U)=\max_{c_i^U}\begin{pmatrix}\alpha^2(e\pi_{i,s,t1}^U+(1-e)\pi_{i,ss,t2}^U)+\alpha(1-\alpha)(e\pi_{i,s,t1}^U+(1-e)\pi_{i,sf,t2}^U)\\+(1-\alpha)\alpha(e\pi_{i,f,t1}^U+(1-e)\pi_{i,fs,t2}^U)+(1-\alpha)^2(e\pi_{i,f,t1}^U+(1-e)\pi_{i,ff,t2}^U)-k(c_O-c_i)^2\end{pmatrix}$$

$$s.t., c_i^U\in[0,c_O].$$

where $\pi_{i,k,t1}^U$ denotes firm *i*'s payoff given leader's implementation outcome k after the leader's implementation completes but before the follower's implementation completes, and $\pi_{i,j,t2}^U$ denotes firm *i*'s payoff given both firms' implementation outcome j after the follower's implementation completes, $i\in\{L,F\}$, $k=s,f$, and $j=ss,sf,fs,ff$.

The two firms' expected profits can be characterized as follows:

$$E(\pi_L^U)=\frac{\begin{pmatrix}9t^2-6\left(c_L^U+c_F^U(-1+e)\right)t\alpha+\alpha\left(c_L^{U2}-c_F^U(-1+e)\left(c_F^U-2c_L^U\alpha\right)\right)-\\2\alpha\left(c_F^U+c_L^U-c_F^Ue-3et+\left(cfII+c_L^U\right)(-1+e)\alpha\right)c_O+\alpha\left(2-e+2(-1+e)\alpha\right)c_O^2\end{pmatrix}}{18t}-k(c_O-c_L^U)^2$$

$$E(\pi_F^U)=\frac{\begin{pmatrix}9t^2+6\left(c_L^U+c_F^U(-1+e)\right)t\alpha+\alpha\left(c_L^{U2}-c_F^U(-1+e)\left(c_F^U-2c_L^U\alpha\right)\right)-\\2\alpha\left(c_F^U+c_L^U-c_F^Ue+3et+\left(c_F^U+c_L^U\right)(-1+e)\alpha\right)c_O+\alpha\left(2-e+2(-1+e)\alpha\right)c_O^2\end{pmatrix}}{18t}-k(c_O-c_F^U)^2$$

By taking the first derivative of the follower's expected profit w.r.t. the follower's new marginal cost in the event of a successful implementation, c_F^U, and solving its first order condition, we get $c_F^U(c_L^U)=\frac{(-1+e)\alpha\left(c_L^U\alpha+3t\right)+c_O\left((-1+e)\alpha-(-1+e)\alpha^2+18kt\right)}{(-1+e)\alpha+18kt}$, which is the response function of the follower conditioning on the leader's investment level. Then, we substitute the follower's response function into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c_L^U, and solving its first order condition, we get the leader's new marginal cost if his implementation is successful

$$c_L^U=c_O-\frac{3t\alpha\left(36(1-e)kt\alpha+(1-e)^2\alpha^2\left((1-e)\alpha-1\right)-324k^2t^2\right)}{-5832k^3t^3+324(3-2e)k^2t^2\alpha+(-1+e)^2\alpha^3\left(1+(-1+e)\alpha^2\right)+18(-1+e)kt\alpha^2\left(3-e+2(-1+e)\alpha^2\right)}.$$

Then check the second order condition, and with the assumption $kt>1/6$, one can show that

$$\frac{\delta^2E(\pi_L^U)}{\delta c_L^{U2}}=\frac{2\alpha-36kt+\frac{2(-1+e)^2\alpha^4(\alpha-e\alpha)}{\left((-1+e)\alpha+18kt\right)^2}+\frac{4(-1+e)^2\alpha^4}{(-1+e)\alpha+18kt}}{18t}<0.$$

Then we substitute the leader's new marginal cost into the follower's response function and get the follower's new marginal cost if his implementation is successful

$$c_F^U=c_O-\frac{3(1-e)t\alpha\left(18kt\alpha(2-e+\alpha)-(1-e)\alpha^2\left(1+\alpha-2(1-e)\alpha^2\right)-324k^2t^2\right)}{-5832k^3t^3+324(3-2e)k^2t^2\alpha+(1-e)^2\alpha^3\left(1-(1-e)\alpha^2\right)-18(1-e)kt\alpha^2\left(3-e-2(1-e)\alpha^2\right)}.$$

We also check the second order condition, and with the assumption $kt>1/6$, one can show that $\frac{\delta^2E(\pi_F^U)}{\delta c_F^{U2}}=\frac{\alpha-e\alpha-18kt}{9t}<0$.

LEMMA E1.2:

In the Outcome Known case, the leader's expected profit can be characterized as follows:

$$E(\pi_L^K)=\frac{(-1+\alpha)t\left((-1+e)^2\alpha^2\left(-1+3(-1+e)\alpha\right)+36(-1+e)k\alpha\left(-1+(-1+e)\alpha\right)t-324k^2t^2\right)}{18t}-k(c_O-c_L^K)^2$$

And the follower's expected profits depending on the outcome of leader's implementation can be characterized as follows:

$$E(\pi^K_{F,s}) = \frac{(1-e)\left(-c_O{}^2(-1+\alpha)+c^K_{F,ss}{}^2\alpha+2c_O(-1+\alpha)\left(c^K_L+3t\right)+\left(c^K_L+3t\right)\left(cIII-2c^K_{F,ss}\alpha+3t\right)\right)}{18t}-k(c_O-c^K_{F,ss})^2$$

if the leader's implementation is successful;

$$E(\pi^K_{F,f}) = \frac{(1-e)\left(\left(c^K_{F,fs}-c_O\right)^2\alpha+6\left(-c^K_{F,fs}+c_O\right)\alpha t+9t^2\right)}{18t}-k(c_O-c^K_{F,fs})^2$$ if the leader's implementation is unsuccessful.

By taking the first derivative of the follower's expected profits, $E(\pi^K_{F,s})$ and $E(\pi^K_{F,f})$ w.r.t. the follower's new marginal costs if his implementation is successful, $c^K_{F,s}$ and $c^K_{F,f}$, and solving its first order conditions, we get $c^K_{F,s} = \frac{18c_O kt+(-1+e)\alpha\left(c^K_L+3t\right)}{(-1+e)\alpha+18kt}$ and $c^K_{F,f} = c_O - \frac{3(1-e)t\alpha}{18kt-(1-e)\alpha}$, which are the response functions of the follower conditioning on the leader's investment level and implementation outcome. We also check the second order condition, with assumption $kt > 1/6$, one can show that $\frac{\delta^2 E(\pi^K_{F,s})}{\delta c^{K\ 2}_{F,s}} = \frac{\delta^2 E(\pi^K_{F,f})}{\delta c^{K\ 2}_{F,f}} = -2k - \frac{(-1+e)\alpha}{9t} < 0$. Then, we substitute the follower's response functions into the leader's expected profit. By taking the first derivative of the leader's expected profit w.r.t. the leader's new marginal cost if his implementation is successful, c^K_L, and solving its first order condition,

we get $c^K_L = \frac{\begin{pmatrix} 18ktc_O-(1-e)\alpha(3t+(3t\alpha(324k^2t^2-36(1-e)kt\alpha+(1-e)^2\alpha^2(1-(1-e)\alpha)))\ / \\ (-5832k^3t^3+324(3-2e)k^2t^2\alpha+(1-e)^2\alpha^3(1-(1-e)\alpha)-18(1-e)kt\alpha^2(3-e-2(1-e)\alpha))+c_O) \end{pmatrix}}{18kt-(1-e)\alpha}$.

Then we check the second order condition, and with the assumption $kt > 1/6$, one can show that

$$\frac{\delta^2 E(\pi^K_L)}{\delta c^{K2}_L} = -2k + \frac{\alpha\left((-1+e)^2\alpha^2\left(1+(-1+e)\alpha\right)+36(-1+e)k\alpha\left(1+(-1+e)\alpha\right)t+324k^2t^2\right)}{9t\left((-1+e)\alpha+18kt\right)^2} < 0$$

Then we substitute the leader's new marginal cost if his implementation is successful into the follower's response functions and get the follower's new marginal costs if his implementation is successful

$$c^K_{F,s} = c_O - \frac{3t\alpha(324k^2t^2-36(1-e)kt\alpha+(1-e)^2\alpha^2(1-(1-e)\alpha))}{5832k^3t^3+324(2e-3)k^2t^2\alpha-(1-e)^2\alpha^3(1-(1-e)\alpha)+18(1-e)kt\alpha^2(3-e-2(1-e)\alpha)}$$ and

$$c^K_{F,f} = c_O - \frac{3(1-e)t\alpha}{18kt-(1-e)\alpha}.$$

Proof of PROPOSITION E1.1:

Note, when $e=0$, we have the baseline setup where the two firms' implementations complete at the same time.

We take the first order derivative of the Leader's profit in Case 1 with respect to e.

$$\frac{\delta E(\pi_L^U)}{\delta e} = \frac{\begin{pmatrix} (1-e)\alpha^2(-324k^2t^2+18kt\alpha(2-e+\alpha)+(-1+e)\alpha^2(1+\alpha+2(-1+e)\alpha^2)) \\ (-23328k^3t^3-324k^2t^2\alpha(-13+9e+4\alpha)+18(-1+e)kt\alpha^2(-3(-4+e)-3\alpha+8(-1+e)\alpha^2) \\ +(-1+e)^2\alpha^3(3+\alpha(-1+2(-1+e)\alpha))) \end{pmatrix}}{2(-5832k^3t^3+324(3-2e)k^2t^2\alpha+(-1+e)^2\alpha^3(1+(-1+e)\alpha^2)+18(-1+e)kt\alpha^2(3-e+2(-1+e)\alpha^2))^2}$$

It is easy to see that the denominator of $\frac{\delta E(\pi_L^U)}{\delta e}$ is positive, and since $kt > 1/6$, $0 < \alpha < 1$ and $0 < e < 1$, the numerator of $\frac{\delta E(\pi_L^U)}{\delta e}$ also is positive. Thus, $\frac{\delta E(\pi_L^U)}{\delta e} > 0$ and the leader's profit in Case 1 in this extension ($e > 0$) is higher than in the baseline setup ($e = 0$).

We take the first order derivative of the Leader's profit in Case 2 with respect to e.

$$\frac{\delta E(\pi_L^K)}{\delta e}$$

$$= (-1+e)\alpha^2 t \frac{\begin{pmatrix} -44079842304k^8t^8 - 612220032(-33+25e)k^7t^7\alpha - (-1+e)^6\alpha^8(3+\alpha)(1+(-1+e)\alpha)^2 \\ -18(-1+e)^5kt\alpha^7(3+\alpha)(1+(-1+e)\alpha)(9-2e+7(-1+e)\alpha) - 5832(-1+e)^3k^3t^3\alpha^5(219+e(-158+21e) \\ -202\alpha+2(159-55e)e\alpha+2(-1+e)(-10+19e)\alpha^2) - \\ 324(-1+e)^4k^2t^2\alpha^6(103+3(-16+e)e-124\alpha+6(30-7e)e\alpha+2(-1+e)(-8+21e)\alpha^2+8(-1+e)^2\alpha^3) - \\ 104976(-1+e)^2k^4t^4\alpha^4(3(95+\alpha(-59+2\alpha))-4e(70+\alpha(-75+4\alpha))+2e^2(29+\alpha(-67+5\alpha))) + \\ 34012224kt^6\alpha^2(-117+14\alpha+e(176-26\alpha+e(-63+16\alpha))) + \\ 1889568(-1+e)k^5t^5\alpha^3(-233+79\alpha+2e(145-71\alpha+e(-41+38\alpha))) \end{pmatrix}}{2((-1+e)\alpha+18kt)^3((-1+e)^3\alpha^4-18(-3+e)(-1+e)\alpha^2kt+324(3-2e)\alpha kt^2-5832kt^3+(-1+e)^2\alpha^3(1+36kt))^2}$$

It is easy to see that the denominator of $\frac{\delta E(\pi_L^K)}{\delta e}$ is positive, and since $kt > 1/6$, $0 < \alpha < 1$ and $0 < e < 1$, the numerator of $\frac{\delta E(\pi_L^K)}{\delta e}$ is also positive. Thus, $\frac{\delta E(\pi_L^K)}{\delta e} > 0$ and the leader's profit in Case 2 in this extension ($e > 0$) is higher than in the baseline setup ($e = 0$).

We take the first order derivative of the Leader's IT investment in Case 2 with respect to e.

$$\frac{\delta f_L^K}{\delta e} = \frac{\begin{pmatrix} t324(-1+e)kt^2\alpha^5(324(1+3e)kt^2+72(-1+e)ekt\alpha-(-1+e)^3\alpha^2(-1+2\alpha)) \\ (324kt^2+36(-1+e)kt\alpha+(-1+e)^2\alpha^2(1+(-1+e)\alpha)) \end{pmatrix}}{(5832kt^3+324(-3+2e)kt^2\alpha-(-1+e)^2\alpha^3(1+(-1+e)\alpha)-18(-1+e)kt\alpha^2(3-e+2(-1+e)\alpha))^3}$$

One can show that the since $kt > 1/6$, $0 < \alpha < 1$ and $0 < e < 1$, $\frac{\delta f_L^K}{\delta e} < 0$. Thus, the Leader's investment in Case 2 in this extension ($e > 0$) is lower than in the baseline setup ($e = 0$).

With the parameter sets, $k=0.48, c_O=1, t=0.34, e=0.2$, the leader's profit without investing in IT is $t/2=0.17$. We can check that the leader's profit $E(\pi_L^U \mid \alpha=0.8)=0.17123$ in the outcome unknown, and $E(\pi_L^K \mid \alpha=0.8)=0.17354$ in the outcome known case. Thus, the leader's profits can be higher in Case 1 and Case 2 than in the case where firms do not invest in IT.

Q.E.D.

Proof of PROPOSITION E1.2:

a) The first derivative of the leader's investment level with respect to the probability of success is

$$\frac{df_L^U}{d\alpha}=\frac{\begin{pmatrix} 18kt^2\alpha\left(324k^2t^2+36(-1+e)kt\alpha+(-1+e)^2\alpha^2\left(1+(-1+e)\alpha\right)\right) \\ (1889568k^5t^5+419904(-1+e)k^4t^4\alpha+ \\ 11664(-1+e)^2k^3t^3\alpha^2\left(3+\alpha(-2+2e+3\alpha)\right)+ \\ 18(-1+e)^4kt\alpha^4\left(1+2\alpha(-3+e+4\alpha)\right)+324(-1+e)^3k^2t^2\alpha^3 \\ \left(4+3\alpha(-3+2e+4\alpha)\right)+(-1+e)^5\alpha^6\left(-1+\alpha\left(2+(-1+e)\alpha\right)\right)) \end{pmatrix}}{\begin{pmatrix} 5832k^3t^3+324(-3+2e)k^2t^2\alpha-(-1+e)^2\alpha^3\left(1+(-1+e)\alpha^2\right)- \\ 18(-1+e)kt\alpha^2\left(3-e+2(-1+e)\alpha^2\right) \end{pmatrix}^3}$$

One can prove that the numerator and the denominator of $\frac{df_L^U}{d\alpha}$ are positive since $kt>1/6$. Thus, $\frac{df_L^U}{d\alpha}>0$.

With the parameter sets, $k=0.48, c_O=1, t=0.34, e=0.01$, in the outcome unknown case the first derivative of the leader's profit with respect to probability of success $\frac{dE(\pi_L^U)}{d\alpha}=0$ at $\alpha=0.846$. Further, we can check that $E(\pi_L^U \mid \alpha=0.7)=0.1449$, $E(\pi_L^U \mid \alpha=0.85)=0.1393$, and $E(\pi_L^U \mid \alpha=0.9)=0.1416$ in the outcome unknown case. Thus, the leader's profit can first decrease and then increase when probability of implementation success decreases.

b) The first derivative of the follower's profit with respect to the probability of success is

$$\frac{dE(\pi_F^U)}{d\alpha} = \frac{\left(\begin{array}{l} t\alpha(-22039921152\left(-1+\left(-2+e\right)e\right)k^8t^8 + \\ 612220032k^7t^7\alpha\left(-3\left(6+e\left(5+e\left(-11+3e\right)\right)\right)+8\left(-1+e\right)^2\alpha\right)+ \\ 34012224k^6t^6\alpha^2(68-17e-123e^2+91e^3-16e^4+2\left(-1+e\right)^2\left(-31+24e\right)\alpha+ \\ 6\left(-1+e\right)^2\left(1+2\left(-2+e\right)e\right)\alpha^2)+1889568\left(-1+e\right)k^5t^5\alpha^3 \\ (142-e\left(39+e\left(175+2e\left(-52+7e\right)\right)\right)-210\alpha+6e\left(87+2e\left(-35+9e\right)\right)\alpha+ \\ \left(-1+e\right)\left(-49+e\left(163+2e\left(-87+25e\right)\right)\right)\alpha^2-16\left(-1+e\right)^3\alpha^3)+ \\ 104976\left(-1+e\right)^2k^4t^4\alpha^4(180-3e\left(15+2e\left(25+\left(-11+e\right)e\right)\right)+ \\ 4\left(-1+e\right)\left(98+29\left(-4+e\right)e\right)\alpha+\left(-1+e\right)\left(-141+e\left(357+e\left(-323+75e\right)\right)\right)\alpha^2- \\ 12\left(-1+e\right)^2\left(-9+8e\right)\alpha^3-4\left(-1+e\right)^2\left(11+6\left(-2+e\right)e\right)\alpha^4)+ \\ 5832\left(-1+e\right)^3k^3t^3\alpha^5(142-e\left(25+e\left(78+\left(-22+e\right)e\right)\right)-428\alpha+ \\ 4e\left(202+5e\left(-22+3e\right)\right)\alpha+3\left(-1+e\right)\left(-69+\left(-4+e\right)e\left(-35+16e\right)\right)\alpha^2- \\ 2\left(-1+e\right)^2\left(-115+82e\right)\alpha^3-2\left(-1+e\right)^2\left(73-88e+38e^2\right)\alpha^4)+ \\ \left(-1+e\right)^6\alpha^8(2+e+12\left(-1+e\right)\alpha+12\left(-1+e\right)^2\alpha^2+12\left(-1+e\right)^2\alpha^3+ \\ 3\left(-1+e\right)^2\left(-6+5e\right)\alpha^4+4\left(-1+e\right)^4\alpha^6)+ \\ 324\left(-1+e\right)^4k^2t^2\alpha^6(68-3e-23e^2+3e^3+6\left(-1+e\right)\left(45+e\left(-27+2e\right)\right)\alpha+ \\ \left(-1+e\right)\left(-169+e\left(279+e\left(-137+11e\right)\right)\right)\alpha^2-108\left(-2+e\right)\left(-1+e\right)^2\alpha^3- \\ 3\left(-1+e\right)^2\left(61+24\left(-3+e\right)e\right)\alpha^4+16\left(-1+e\right)^3\alpha^5+16\left(-1+e\right)^4\alpha^6)+ \\ 18\left(-1+e\right)^5kt\alpha^7(-3\left(-3+e\right)\left(2+e\right)-2\left(-1+e\right)\left(-45+14e\right)\alpha- \\ \left(-1+e\right)\left(72+5e\left(-19+5e\right)\right)\alpha^2-6\left(-1+e\right)^2\left(-15+4e\right)\alpha^3- \\ 2\left(-1+e\right)^2\left(51+e\left(-53+10e\right)\right)\alpha^4+12\left(-1+e\right)^3\alpha^5+24\left(-1+e\right)^4\alpha^6)) \end{array}\right)}{2\left(\begin{array}{l} -5832k^3t^3+324\left(3-2e\right)k^2t^2\alpha+\left(-1+e\right)^2\alpha^3\left(1+\left(-1+e\right)\alpha^2\right)+ \\ 18\left(-1+e\right)kt\alpha^2\left(3-e+2\left(-1+e\right)\alpha^2\right) \end{array}\right)^3}$$

First we can show the denominator of $\frac{dE(\pi_F^U)}{d\alpha}$ is negative since $\frac{1}{6} < kt$. Then we can take the fourth derivative of the numerator of $\frac{dE(\pi_F^U)}{d\alpha}$, and we can show it is positive since $\frac{1}{6} < kt$. Then we evaluate the third derivative, the second derivative, and the first derivative of the numerator of $\frac{dE(\pi_F^U)}{d\alpha}$ at

$kt = \frac{1}{6}$, and we can show they are positive. Then we evaluate the numerator of $\frac{dE(\pi_F^U)}{d\alpha}$ at $kt = \frac{1}{6}$, and we can show it is positive. Thus, the numerator of $\frac{dE(\pi_F^U)}{d\alpha}$ is positive. Therefore, $\frac{dE(\pi_F^U)}{d\alpha} < 0$ and the follower's expected profit increases as α decreases.

With the parameter sets, $k = 0.48, c_O = 1, t = 0.34, e = 0.01$, in the outcome unknown case the first derivative of the follower's investment level with respect to probability of success $\frac{df_F^U}{d\alpha} = 0$ at $\alpha = 0.777$. Further, we can check that $f_F^U |_{\alpha=0.6} = 0.0228$, $f_F^U |_{\alpha=0.78} = 0.0301$, and $f_F^U |_{\alpha=0.9} = 0.0210$ in the outcome unknown case. Thus, the follower's investment level can first increase and then decrease when probability of implementation success decreases.

Q.E.D.

Proof of PROPOSITION E1.3:

a) The difference between the leader's investment level and the follower's investment level in Case 1 is:

$$f_L^U - f_F^U = \frac{\begin{pmatrix} 9kt^2\alpha^2((324k^2t^2 + 36(-1+e)kt\alpha + (-1+e)^2\alpha^2(1+(-1+e)\alpha))^2 - \\ (-1+e)^2(-324k^2t^2 + 18kt\alpha(2-e+\alpha) + (-1+e)\alpha^2(1+\alpha+2(-1+e)\alpha^2))^2) \end{pmatrix}}{(-5832k^3t^3 + 324(3-2e)k^2t^2\alpha + (-1+e)^2\alpha^3(1+(-1+e)\alpha^2) + 18(-1+e)kt\alpha^2(3-e+2(-1+e)\alpha^2))^2}$$

It is easy to see that the dominator of $f_L^U - f_F^U$ is positive. Since $kt > 1/6$, the numerator of $f_L^U - f_F^U$ is also positive. Thus, $f_L^U > f_F^U$ and the leader's investment level is higher than the follower's investment level in Case 1.

The difference between the leader's expected profit and the follower's expected profit in Case 1 is:

$$E(\pi_L^U) - E(\pi_F^U) = \frac{\begin{pmatrix} \alpha^2(-2834352(-2+e)ekt^5 - 104976e(15+e(-18+5e))kt^4\alpha - 2916(-1+e)kt^3(e(58+e(-53+11e)) - 36(-1+e)kt)\alpha^2 - 324(-1+e)^2kt^2(e(27+e(-17+2e)) \\ +18(6-5e)kt)\alpha^3 + 36(-1+e)^2kt(2(-3+e)(-1+e)e + 9(-1+e)(-13+7e)kt + 81(5+12(-2+e)e)kt^2)\alpha^4 + 2(-1+e)^3(-(-1+e)e \\ +27(-4+e)(-1+e)kt + 486(3+2e(-5+2e))kt^2)\alpha^5 + (-1+e)^4(4+99e^2kt + 36(5-18kt)kt - 2e(2+207kt))\alpha^6 - 2(-1+e)^5(-2+3e+72kt)\alpha^7 \\ -4(-1+e)^6(1+27kt)\alpha^8 - 4(-1+e)^7\alpha^9) \end{pmatrix}}{(5832kt^3 + 324(-3+2e)kt^2\alpha - (-1+e)^2\alpha^3(1+(-1+e)\alpha^2) + 18kt\alpha^2(3-4e+e^2-2(-1+e)^2\alpha^2))^2}$$

It is easy to see that the dominator of $E(\pi_L^U) - E(\pi_F^U)$ is positive. Since $kt > 1/6$, the numerator of $E(\pi_L^U) - E(\pi_F^U)$ is also positive. Thus, $E(\pi_L^U) > E(\pi_F^U)$ and the leader's expected profit is higher than the follower's expected profit in Case 1.

b)

The difference between the leader's investment levels in the outcome known case and in the outcome unknown case is

$$f_L^K - f_L^U = \left(\frac{9kt^2\alpha^2\left(324k^2t^2+36(-1+e)kt\alpha+(-1+e)^2\alpha^2\left(1+(-1+e)\alpha\right)\right)^2}{\left(\begin{array}{l}-5832k^3t^3+324(3-2e)k^2t^2\alpha+(-1+e)^2\alpha^3\left(1+(-1+e)\alpha\right)+\\ 18(-1+e)kt\alpha^2\left(3-e+2(-1+e)\alpha\right)\end{array}\right)^2} - \frac{9kt^2\alpha^2\left(324k^2t^2+36(-1+e)kt\alpha+(-1+e)^2\alpha^2\left(1+(-1+e)\alpha\right)\right)^2}{\left(\begin{array}{l}-5832k^3t^3+324(3-2e)k^2t^2\alpha+(-1+e)^2\alpha^3\left(1+(-1+e)\alpha^2\right)+\\ 18(-1+e)kt\alpha^2\left(3-e+2(-1+e)\alpha^2\right)\end{array}\right)^2} \right)$$

We can prove that since $kt > 1/6$, $f_L^K - f_L^U > 0$.

The difference between the leader's expected profits in the outcome known case and in the outcome unknown case is

$$E(\pi_L^K) - E(\pi_L^U) = \frac{\left(\begin{array}{l}(1-e)^2 t(1-\alpha)\alpha^5\left(36kt+(-1+e)\alpha\right)\\ \left(324k^2t^2+36(-1+e)kt\alpha+(-1+e)^2\alpha^2\left(1+(-1+e)\alpha\right)\right)^2\end{array}\right)}{\left(\begin{array}{l}2\left(18kt+(-1+e)\alpha\right)^2(5832k^3t^3+324(-3+2e)k^2t^2\alpha-\\ (-1+e)^2\alpha^3\left(1+(-1+e)\alpha\right)-18(-1+e)kt\alpha^2\left(3-e+2(-1+e)\alpha\right))\\ (5832k^3t^3+324(-3+2e)k^2t^2\alpha+(-1+e)^2\alpha^3\left(-1-(-1+e)\alpha^2\right)+\\ 18kt\alpha^2\left(3-4e+e^2-2(-1+e)^2\alpha^2\right))\end{array}\right)}$$

We can prove that the numerator and the denominator of $E(\pi_L^K) - E(\pi_L^U)$ are positive since $kt > 1/6$. Thus, $E(\pi_L^K) - E(\pi_L^U) > 0$.

c) With the parameter sets, $k = 0.48, c_O = 1, t = 0.34, e = 0.01$, the follower's profit $E(\pi_F^U \mid \alpha = 0.9) = 0.0576$ and $E(\pi_F^U \mid \alpha = 0.975) = 0.00781$ in the outcome unknown case; and the follower's profit $E(\pi_F^K \mid \alpha = 0.9) = 0.0527$ and $E(\pi_F^K \mid \alpha = 0.975) = 0.00788$ in the outcome known case. Thus, the follower's profit can be higher in Case 1 than in Case 2, or it can be higher in Case 2 than in Case 1.

Q.E.D.