Standards and Market Entry

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Introduction

- Standards become beneficial when there are network effects
  - Consumer Value
  - Price of inputs

Standards are pro-innovation

- However, strategic use of standards is possible
  - Switching cost
  - Rival cost

Standards may be anti-innovation

What is the relationship between standards and innovation?

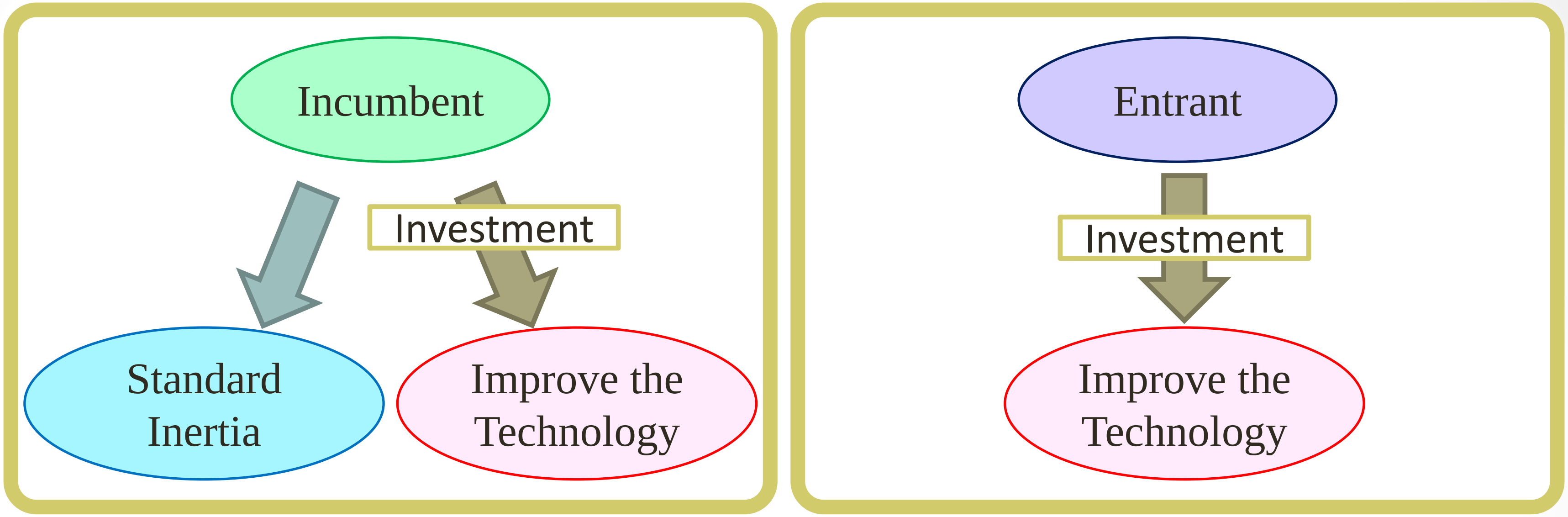
Standards and Innovation

- Relationship between standards and innovation
  - Patent pools and innovation
    Lampe and Moser (2012)
  - Standards and innovation
    Farrell & Saloner (1985), Cabral & Salant (2013)

- Entry Deterrence
  - Entry Deterrence by Increasing standard inertia
    Farrel and Saloner (1987)
  - Entry Deterrence by Increasing switching cost
    Klemperer (1987), Chen (1997)

Focus of this Paper

- There is a standard in place.



- Incumbent can improve his technology to deter the entry.
- Entrant can also invest to improve his technology to counter the deterrence.

Framework: Timing

- Player

  Firm 0 :incumbent

  Firm 1 :new entrant

  Consumers

- Timing of this game

  1. Invest in technology (sequential)

     I. Firm 0 invests in technology

     II. Firm 1 invests in technology

  2. Market competition (Bertrand competition)

- We examine how investments relate to second stage subgame equilibria.

Framework: Consumer

- Consumers are located over unit interval (Hotelling)
  - The surplus of a consumer $x \in [0,1]$ is given by

$$v_0 - p_0 - tx \quad \text{:when he purchases from firm 0}$$

$$v_1 - p_1 - S - t(1-x) \quad \text{:when he purchases from firm 1}$$

v_i: the value of products
p_i: price of the product
S: cost of changing to different standard (switching cost).
t: the per unit transportation cost

- We define the bench marks $\hat{x}_0(p_0), \hat{x}_1(p_1)$and $\hat{x}(p_0, p_1)$ by

$$v_0 - p_0 - t\hat{x}_0(p_0) = 0$$

$$v_1 - p_1 - S - t\big(1 - \hat{x}_1(p_1)\big) = 0$$

$$v_0 - p_0 - t\hat{x}(p_0, p_1) = v_1 - p_1 - S - t\big(1 - \hat{x}(p_0, p_1)\big)$$

- We assume $v_i \geq 2t$.

Hotelling Model

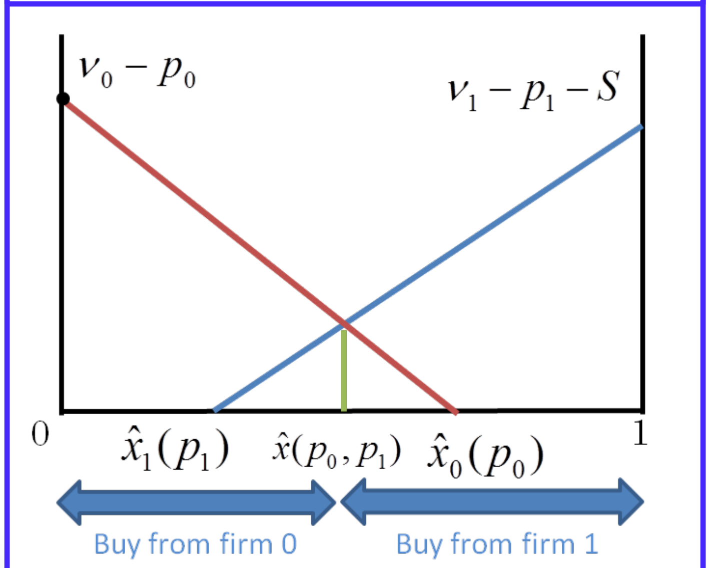
- Then

$$\hat{x}_0(p_0) = \frac{v_0 - p_0}{t}, 1 - \hat{x}_1(p_1) = \frac{v_1 - p_1}{t},$$

$$\hat{x}(p_0, p_1) = \frac{v_0 - v_1 - p_0 + p_1 + S + t}{2t}$$

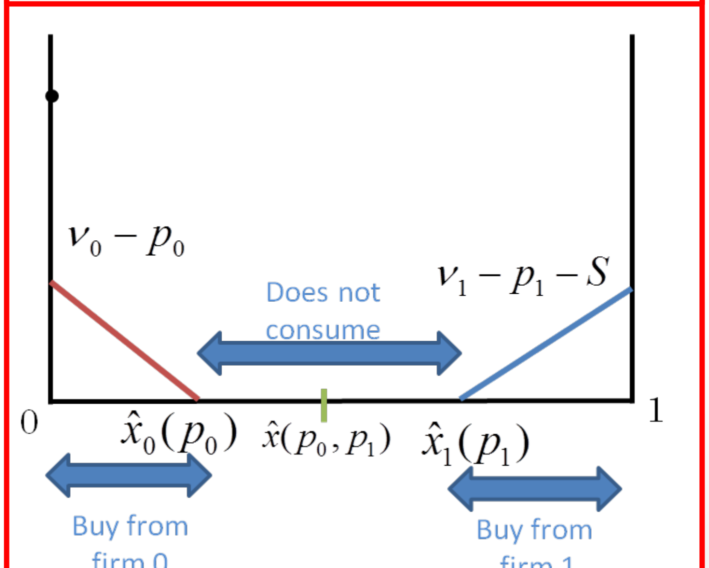
- By definition, it must be that either

$\hat{x}_1(p_1) < \hat{x}(p_0, p_1) < \hat{x}_0(p_0)$



or

$\hat{x}_0(p_0) < \hat{x}(p_0, p_1) < \hat{x}_1(p_1)$



Framework : Optimization in Market

- Firm 0 chooses p_0 to maximize his profit

$$\pi_0 = \begin{cases} \pi_0^A = p_0\hat{x}_0 = \dfrac{p_0(v_0 - p_0)}{t} & \text{for } v_0 - p_0 \le t - v_1 + S + p_1 \\ \pi_0^B = p_0\hat{x} = \dfrac{p_0(v_0 - v_1 - p_0 + p_1 + S + t)}{t} & \text{for } t - v_1 + S + p_1 < v_0 - p_0 \le t + v_1 - S - p_1 \\ \pi_0^C = p_0 & \text{for } t + v_1 - S - p_1 < v_0 - p_0 \end{cases}$$

- Firm 1 chooses p_1 to maximize his profit

$$\pi_1 = \begin{cases} \pi_1^A = p_1(1 - \hat{x}_1) = \dfrac{p_1(v_1 - S - p_1)}{t} & \text{for } v_1 - S - p_1 \le t - v_0 + p_0 \\ \pi_1^B = p_1(1 - \hat{x}) = \dfrac{p_1(t - v_0 + p_0 + v_1 - S - p_1)}{t} & \text{for } t - v_0 + p_0 < v_1 - S - p_1 \le t + v_0 - p_0 \\ \pi_1^C = p_1 & \text{for } t + v_0 - p_0 < v_1 - S - p_1 \end{cases}$$

Framework : Optimization in Market

- Firm 0's best response correspondence $p_0 = R_0(p_1)$

i. *If* $3t < v_0, then$

$$R_0(p_1) = \begin{cases} v_0 - v_1 + S + p_1 - t & \text{for } v_1 - S - p_1 \le v_0 - 3t \\ \dfrac{v_0 - v_1 + S + p_1 + t}{2} & \text{for } v_1 - S - p_1 \ge v_0 - 3t \end{cases}$$

ii. *If* $3t > v_0, then$

$$R_0(p_1) = \begin{cases} v_0 + v_1 - S - p_1 - t & \text{for } v_1 - S - p_1 \le t - \dfrac{v_0}{3} \\ \dfrac{v_0 - v_1 + S + p_1 + t}{2} & \text{for } v_1 - S - p_1 \ge t - \dfrac{v_0}{3} \end{cases}$$

iii. *If* $3t = v_0, then$

$$R_0(p_1) = \frac{v_0 - v_1 + S + p_1 + t}{2} \quad \text{for all } v_1 - S - p_1 \ge 0$$

Framework : Optimization in Market

- Firm 1's best response correspondence $p_1 = R_1(p_0)$

i. If $3t < v_1 - S$, then

$$R_1(p_0) = \begin{cases} \boldsymbol{\frac{v_1 - S}{2}} \text{ or } p_0 - t - v_0 + v_1 - S & \text{for } v_0 - p_0 \le t - \frac{v_1 - S}{2} \\ p_0 - t - v_0 + v_1 - S & \text{for } t - \frac{v_1 - S}{2} < v_0 - p_0 \le v_1 - S - 3t \\ \frac{t - v_0 + p_0 + v_1 - S}{2} & \text{for } v_1 - S - 3t < v_0 - p_0 \end{cases}$$

ii. If $3t > v_1 - S$, then

$$R_1(p_0) = \begin{cases} \boldsymbol{\frac{v_1 - S}{2}} & \text{for } v_0 - p_0 \le t - \frac{v_1 - S}{2} \\ v_1 - S - t + v_0 - p_0 & \text{for } t - \frac{v_1 - S}{2} < v_0 - p_0 \le t - \frac{v_1 - S}{3} \\ \frac{t - v_0 + p_0 + v_1 - S}{2} & \text{for } t - \frac{v_1 - S}{3} < v_0 - p_0 \end{cases}$$

Framework : Optimization in Market

- Firm 1's best response correspondence $p_1 = R_1(p_0)$

iii. *If* $3t = v_0, then$

$$R_0(p_1) = \frac{t - v_0 + p_0 + v_1 - S}{2} \qquad \text{for all } v_0 - p_0 \geq 0$$

Market Equilibrium

I. Only Firm 0 (Deter Entry): $v_1 - S \leq v_0 + 3t$

➡ All consumers purchase from firm 0

$$p_0^* = v_0 - v_1 + S - t, \quad p_1^* = S$$

$$\pi_0^* = v_0 - v_1 + S - t, \quad \pi_1^* = 0$$

II. Only Firm 1 (Standard Replaced): $v_1 - S \geq v_0 - 3t$

➡ All consumers purchase from firm 1

$$p_0^* = 0, \quad p_1^* = v_1 - v_0 - S - t$$

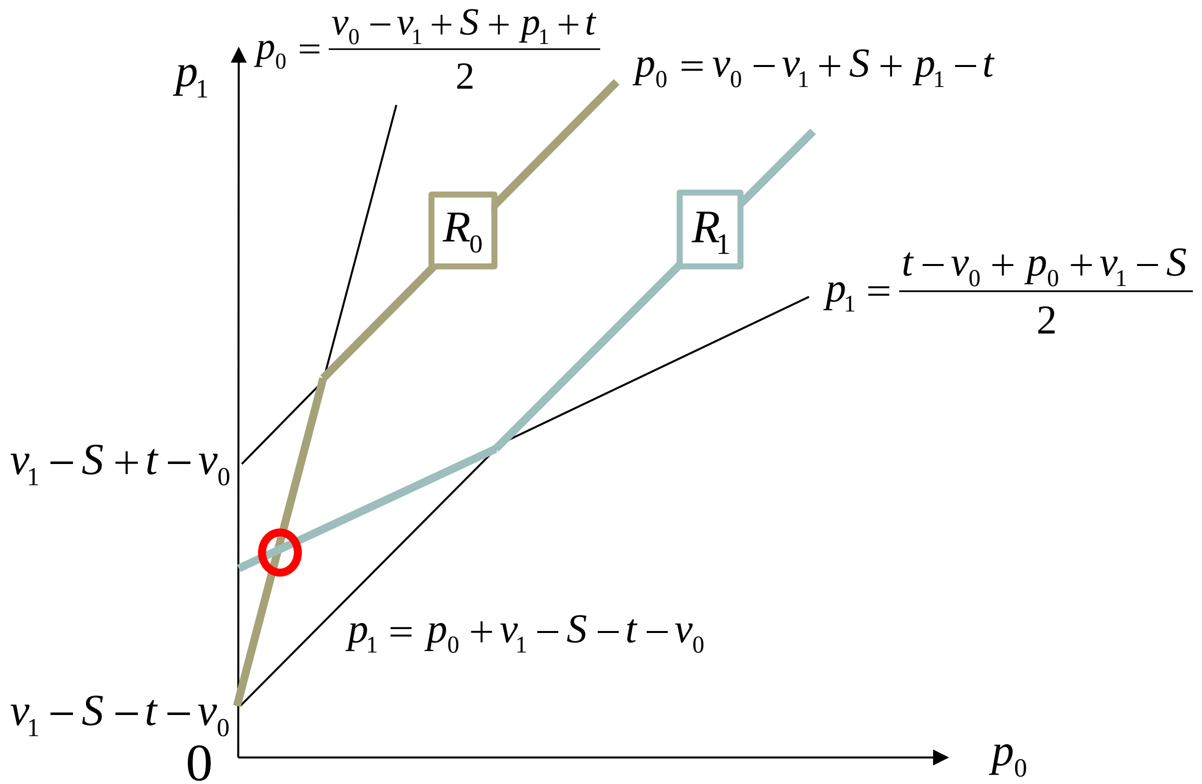
$$\pi_0^* = 0, \quad \pi_1^* = v_1 - v_0 - S - t$$

III. Two firms co-exist in the market (unique equilibrium):

$$v_0 + v_1 - S \geq 3t \text{ and } v_0 - 3t < v_1 - S < v_0 + 3t$$

$$p_0^* = \frac{v_0 - v_1 + S + 3t}{3}, \quad p_1^* = \frac{v_1 - v_0 - S + 3t}{3}$$

$$\pi_0^* = \frac{1}{2t}\left(\frac{v_0 - v_1 + S + 3t}{3}\right)^2, \quad \pi_1^* = \frac{1}{2t}\left(\frac{v_1 - v_0 - S + 3t}{3}\right)^2$$

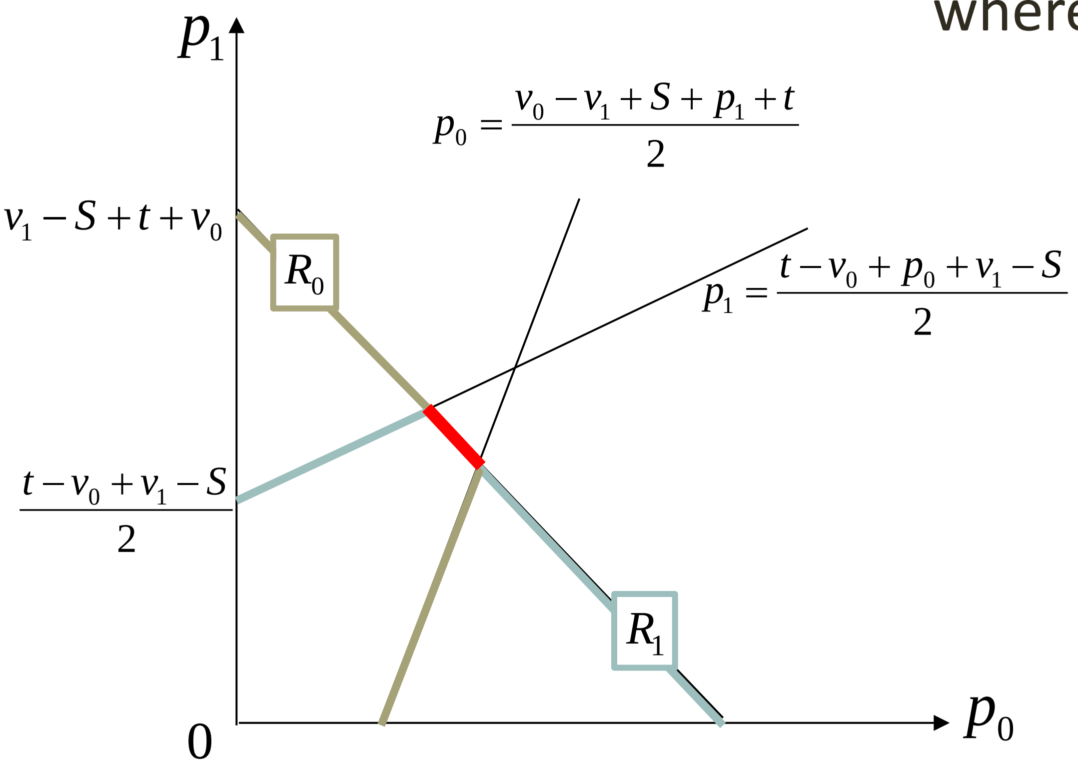


IV. Two firms co-exist in the market (multiple equilibria):

$v_0 + v_1 - S < 3t$

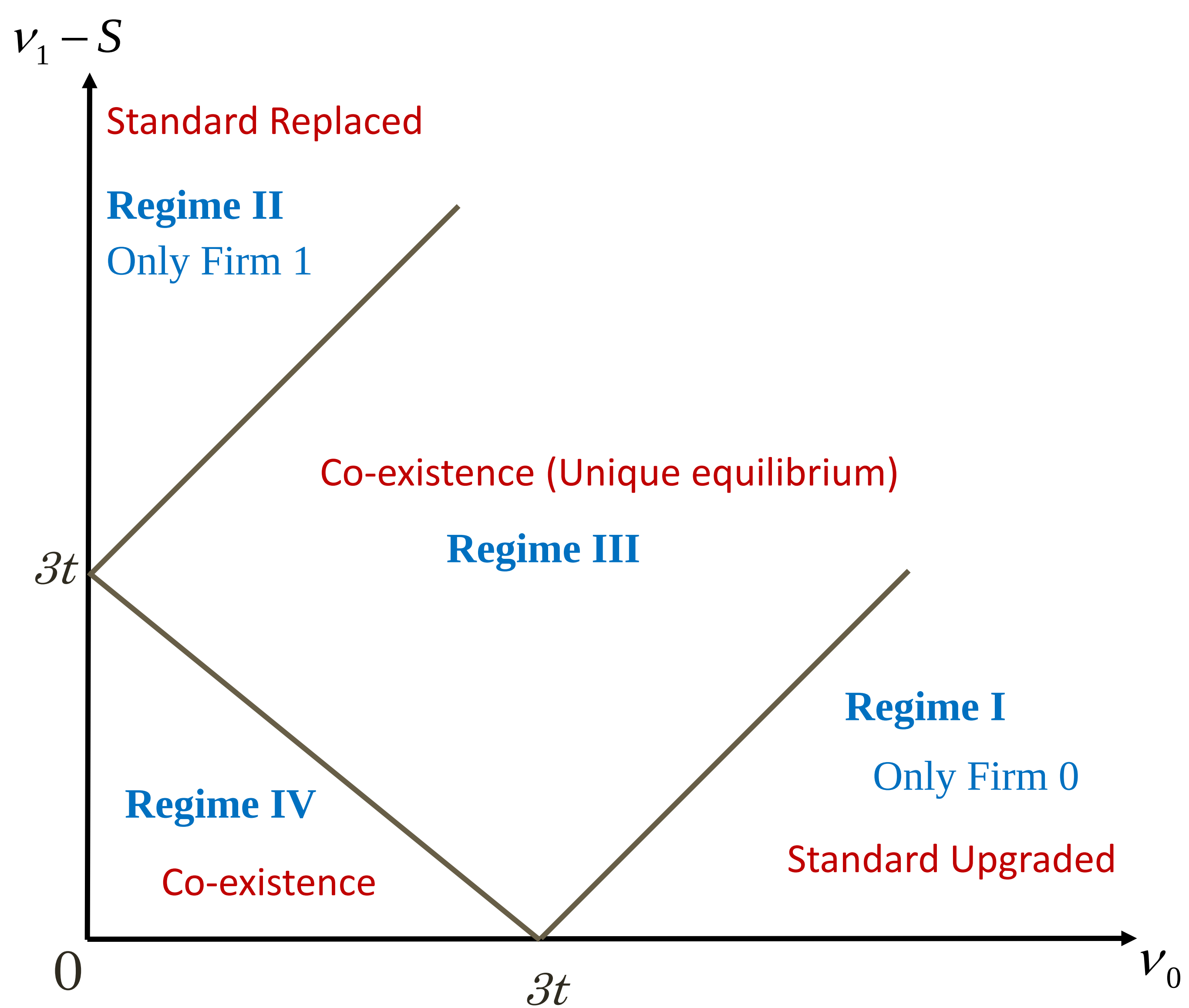
$$p_0^* = \frac{(3-\alpha)v_0}{3} - (1-\alpha)\left(t - \frac{v_1 - S}{3}\right) \quad , p_1^* = \frac{(2+\alpha)(v_1 - S)}{3} - \alpha\left(t - \frac{v_0}{3}\right)$$

where $\alpha \in [0,1]$



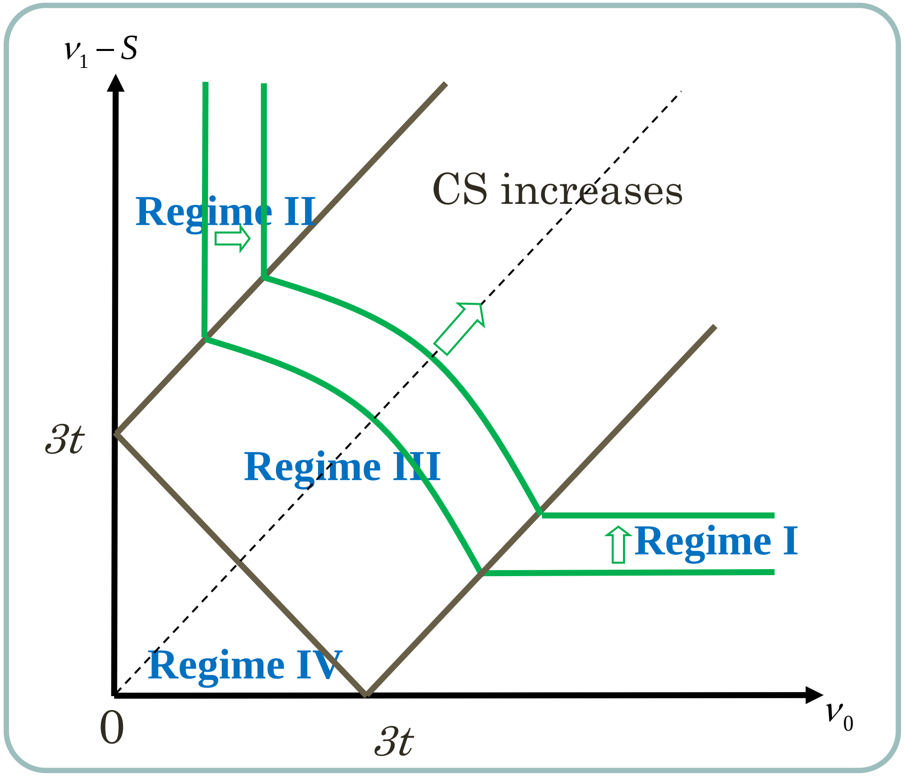
If we also assume that the entrant is sufficiently efficient ($v_1 - S \geq 2t$), then this regime never occurs.

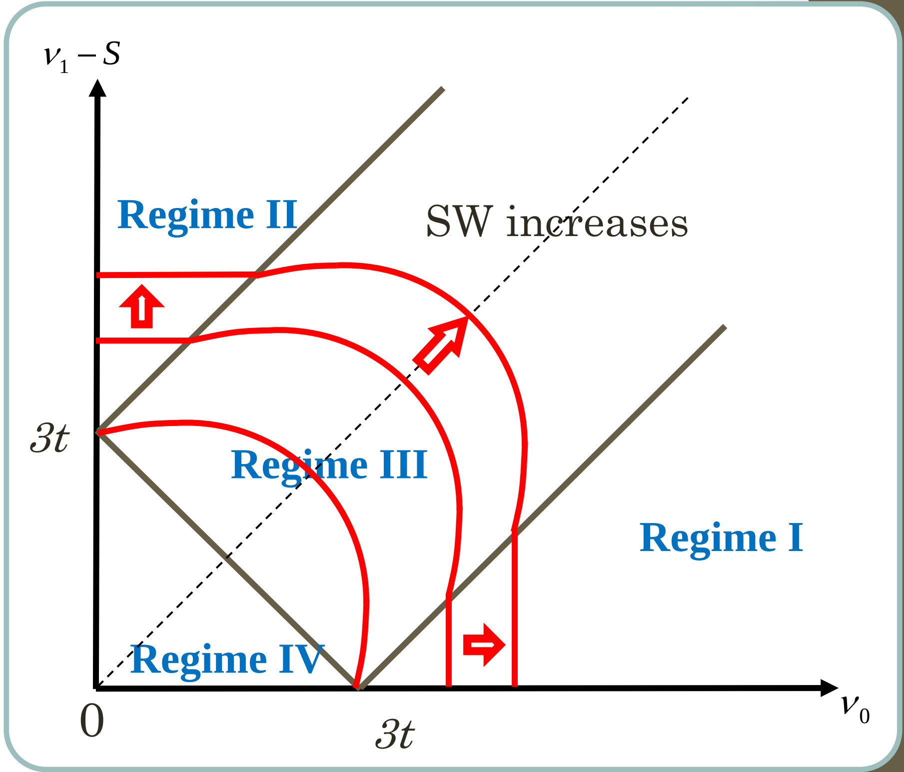
Market Equilibrium



Iso-consumer surplus curve

Iso-social surplus curve





Investment

- We examine how investments relate to second stage subgame equilibria.
  - Firm 0 (Incumbent) can invest in technology, Δ_0

$$v_0 = \bar{v} + \Delta_0 \text{ (Upgrade)}$$

$$\max_{\Delta_0} \pi_0(\Delta_0, \Delta_1, S) - C_0(\Delta_0)$$

  - Firm 1 (Entrant) can invest in technology,Δ_1

$$v_0 = \bar{v} + \Delta_1 \text{ (Replace)}$$

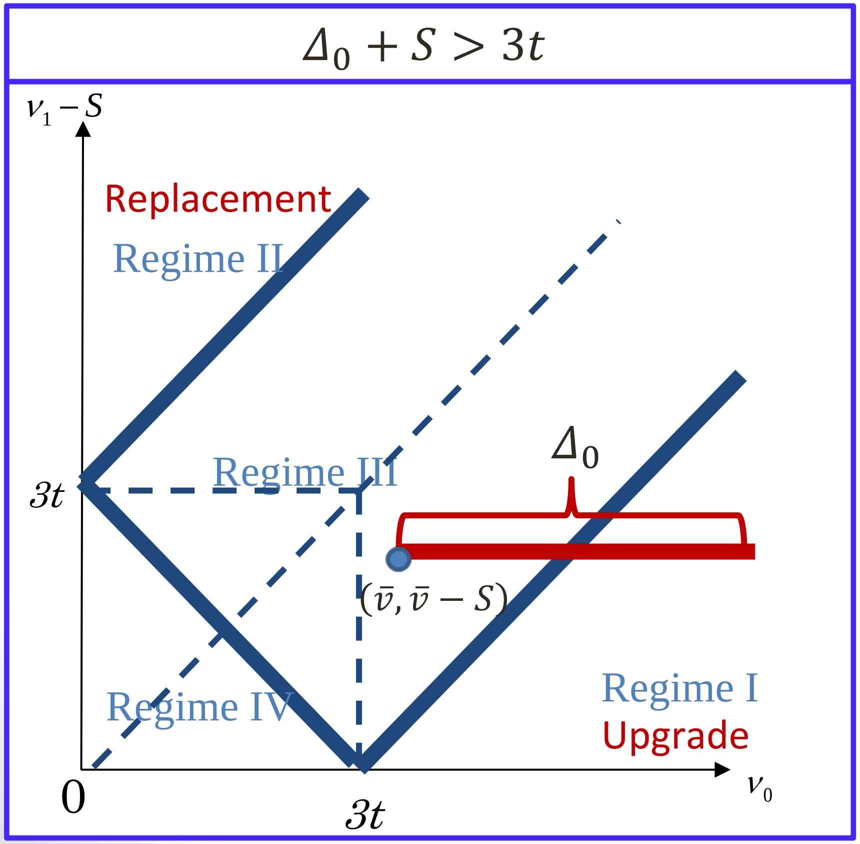
$$\max_{\Delta_1} \pi_1(\Delta_0, \Delta_1, S) - C_1(\Delta_0)$$

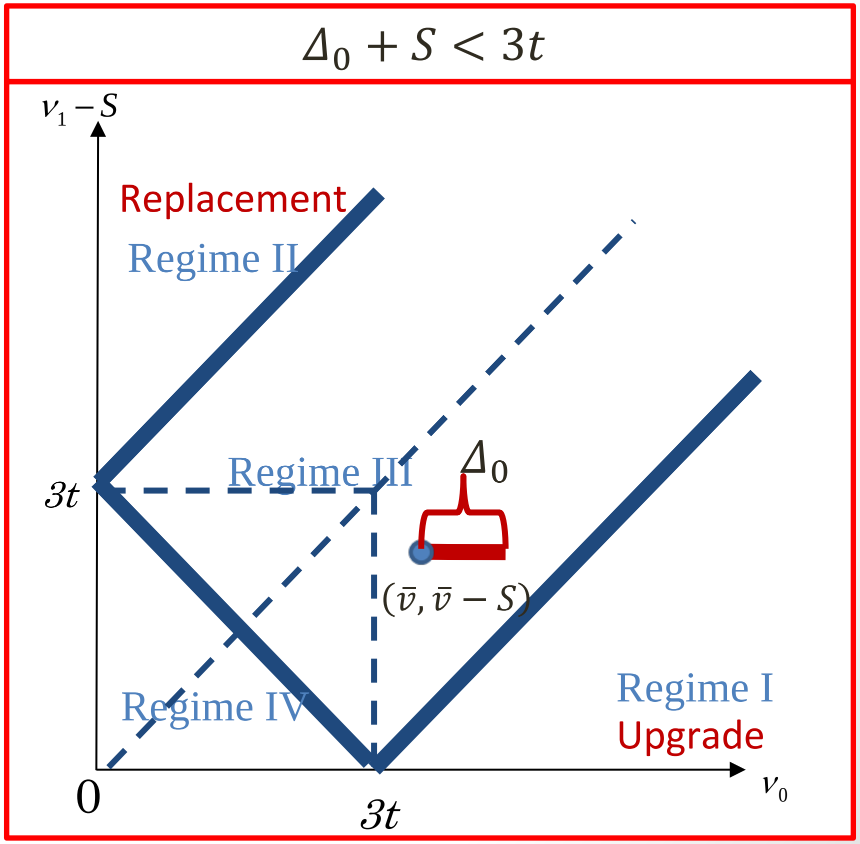
  - Costs of investment are

$$C_0(\Delta_0) = \frac{\delta \Delta_0^2}{2}, C_1(\Delta_1) = \frac{\delta \Delta_1^2}{2}$$

Subgame

- For simplicity, we assume that $\bar{v} > 3t$
- If there is no investment $(\Delta_0 = \Delta_1 = 0), v_0 = v_1 = \bar{v}$ and regime (III) will transpire
- There are two possible regimes after Firm 0 has its investment choice.





Subgame

- The final outcome depends on firm 1's investment choice. Next Proposition shows the equilibrium outcome of this game.

Proposition 2

In equilibrium,

if $\delta \leq 1/3t$ or $9t(3t\delta - 1)/(9t\delta - 1) < S$,

$$\Delta_0^* + S > 3t \text{ and } \Delta_1^* = 0$$

⇨ Final outcome is regime I (Upgrade)

if $\delta > 1/3t$ and $9t(3t\delta - 1)/(9t\delta - 1) > S$,

$$\Delta_0^* + S < 3t \text{ and } \Delta_1^* > 0$$

⇨ Final outcome is regime III (Co-existence)

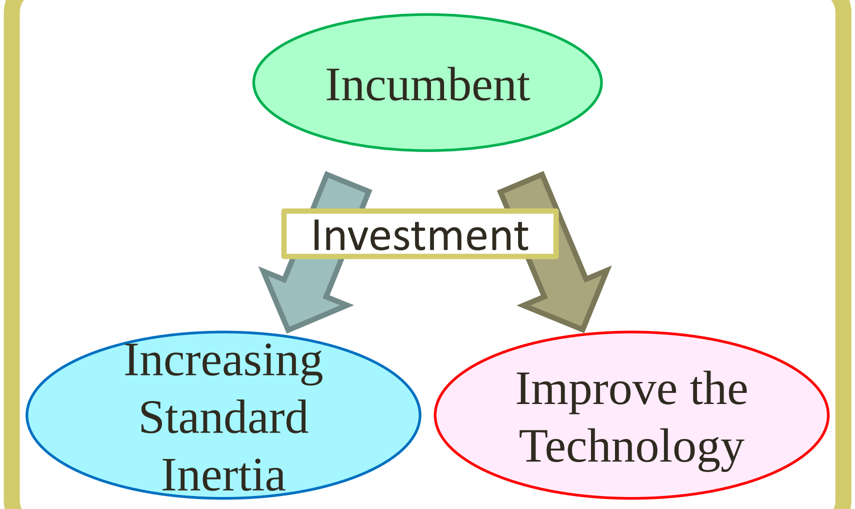
Conclusion

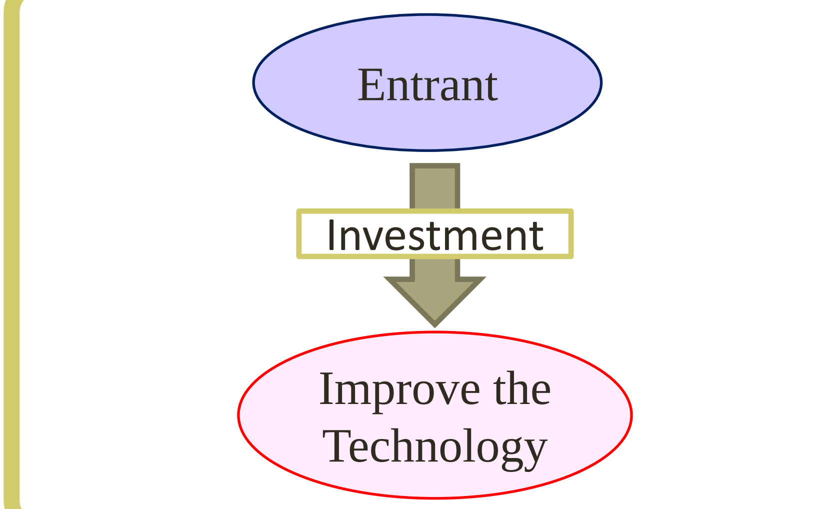
- Policy (competition, standardization) should be technology life cycle dependent
- Incumbent improving technology (upgrade) always makes consumer better-off
- Investment in installed base can reduce consumer surplus

- When technology is in infancy, entry deterrence (upgrade, switching cost) and persistence of single standard
- When technology matures, co-existence of new and old standards
- There will never be replacement in equilibrium (entrant never dominates)

Appendix:Dual Investment

- There is a standard in place.





- Incumbent can invest in two things
  1. Increase standard inertia
     - Invest in installed base
     - Improve complementary technology
     - Increase switching cost
  2. Improve the standard (technology)
- Entrant only invests to improve technology

Appendix:Dual Investment

- We examine how investments relate to second stage subgame equilibria.
  - Firm 0 (Incumbent) can invest in
    1. Technology improvement, Δ_0

       $$v_0 = \bar{v} + \Delta_0 \text{(Upgrade)}$$

    2. Installed base = increase switching cost S

$$\max_{\Delta_0, S} \pi_0(\Delta_0, \Delta_1, S) - C_0(\Delta_0, S)$$

  - Firm 1 (Entrant) invests in technology, Δ_1

$$v_1 = \bar{v} + \Delta_1 \text{ (Replace)}$$

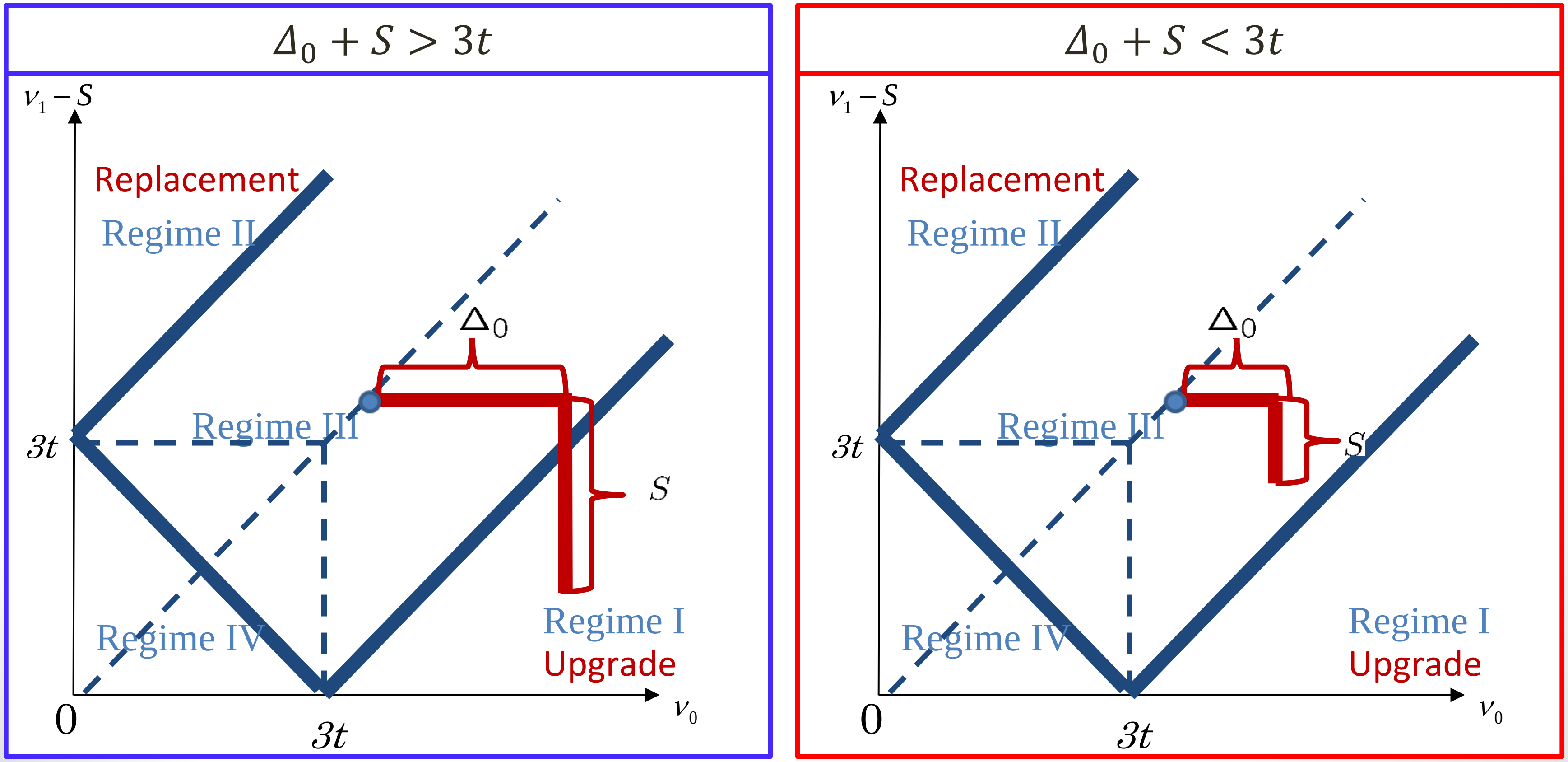
$$\max_{\Delta_1} \pi_1(\Delta_0, \Delta_1, S) - C_1(\Delta_1)$$

  - Costs of investment are

$$C_0(\Delta_0, S) = \frac{\delta(\Delta_0 + S)^2}{2}, \qquad C_1(\Delta_1) = \frac{\delta \Delta_1^2}{2}$$

Subgame

- For simplicity, we assume that $\bar{v} > 3t$
- If there is no investment $(\Delta_0 = \Delta_1 = S = 0)$, $v_0 = v_1 = \bar{v}$ and regime (III) will transpire
- There are two possible regimes after Firm 0 has its investment choice.



Subgame

- The final outcome depends on firm 1's investment choice. Next Proposition shows the equilibrium outcome of this game.

Proposition 2

In equilibrium,

if $\delta \leq 1/3t$,

$$\Delta_0^* + S^* \equiv \Delta^* > 3t \text{ and } \Delta_1^* = 0$$

⇨ Final outcome is regime I (Upgrade)

if $\delta > 1/3t$,

$$\Delta_0^* + S^* \equiv \Delta^* < 3t \text{ and } \Delta_1^* > 0$$

⇨ Final outcome is regime III (Co-existence)