Welfare Effects of Process Innovation in Two-Sided Markets: The Role of Compatibility Decisions

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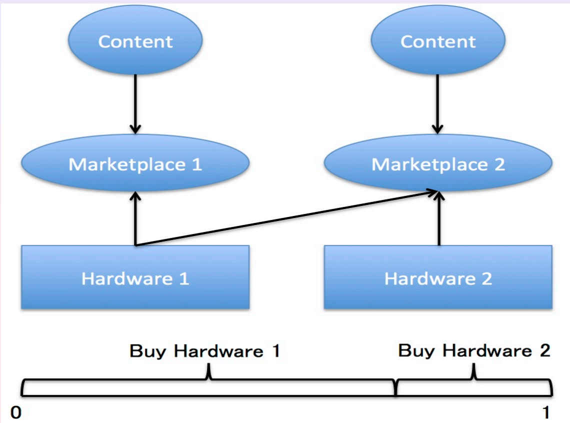
Two-Sided markets?

What is the two-sided markets?

Two-sided (or, more generally, multi-sided) markets are roughly defined as markets in which one or several platforms enable interactions between end-users and try to get the two (or multiple) sides "on board" by appropriately charging each side. (Rochet and Tirole, 2006)
(e.g. shopping mall, video game, and e-book reader)

Compatibility?



The aim of this paper I

- We extend the arguments of R&D investment competition into the two-sided markets.
- Particularly in the markets of system goods such as video game, digital music, and e-book, 'razor-razor blade model' is a well-known business model, which involves pricing hardware devices inexpensively, usually at a normal level, insufficient to cover costs, but forcing up software prices to cover remaining costs plus provide a profit.
- It is important for these platforms to make a substantial investment in reducing hardware costs.

The aim of this paper II

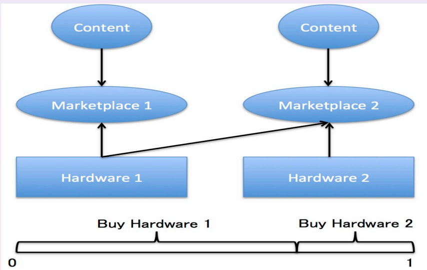
- Additionally, in two-sided markets of hardware-software system, compatibility decisions as to whether to make its software compatible with the other's device are very important for platforms.
- The aim of this paper is to provide a framework that accounts for R&D investment competition in the two-sided markets, and incorporates another important feature of compatibility decisions by competing platforms.

Our assertion and contribution

- We argue that process innovation (the increased efficiency of cost-reducing investment) of hardware device can hurt the social surplus in two-sided markets.
- Contrary to the previous literature, the unique contribution of this paper lies in examining the welfare effects of process innovation in the model of two-sided markets which endogenizes the determination of compatibility structure among platforms.
- To the best our knowledge, this is the first paper which explores the possibility of welfare-reducing process innovation in two-side markets mediated by strategic compatibility decisions of platforms.

Main Results and Intuition

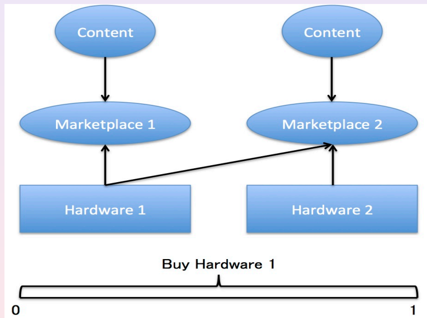
When the efficiency of investment is low,



- Consider the parameter space in which equilibrium market structure becomes $(\mathbf{IC}, \mathbf{C})$.

Main Results and Intuition

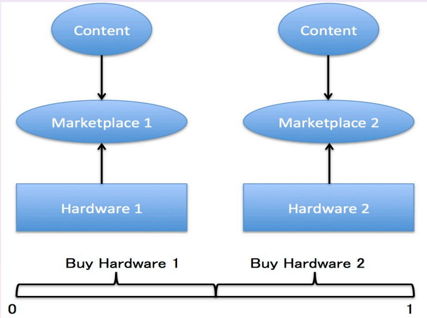
When the efficiency of investment is high,



process innovation helps platform 1 to monopolize the hardware market.

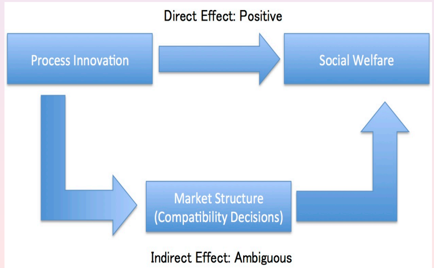
Main Results and Intuition

Platform 2 has an incentive to choose incompatibility.



Main Results and Intuition

1. Process innovation may change the compatibility decisions of platforms.
2. The change of platforms' strategy about compatibility leads the different equilibrium market structure.
3. Different market structure may reduce the social welfare.



R&D investment with licensing

- The technology licensing literatures show licensing may reduce welfare.
  - induces competitors to exit the market (Kabiraj and Marjit, 1992; Lin, 1996),
  - facilitates collusion (Fauli-Oller and Sandonis, 2002),
  - changes R&D organization (Mukherjee, 2005),
  - induces excessive entry (Mukherjee and Mukherjee, 2008).
- These papers don't consider how the increased efficiency of R&D investment affects social welfare.
- Chang et al. (2013) focus this point, and finds that the availability of licensing leads to lower social surplus, if the "efficiency of R&D investment" is high.

R&D investment in two-sided markets

Focusing on the argument comparing the incentive for R&D investment under different market structures in two-sided markets, there are two strands in the recent literature.

- Open-source or Proprietary Platform
  - Casadesus-Masanell and Llanes (2013)
- Net-Neutrality Platform
  - Musacchio et al. (2009)
  - Choi and Kim (2010)
  - Economides and Hermalin (2012)

Compatibility

The literature on compatibility in two-sided markets.

- Doganoglu and Wright (2006)
- Casadesus-Masanell and Ruiz-Aliseda (2008)
- Miao (2009)
- Viecens (2011)
- Maruyama and Zennyo (2013)

However, these papers do not treat the R&D investment by platforms.

Platforms I

- There are two platforms, $i = 1, 2$, who sell hardware device i at price p_i.
- Each platform operates its marketplace i that distributes content for its own hardware device.
- There are two kinds of content, $i = 1, 2$, and content i is exclusively supplied to marketplace i at price ρ_i. Each unit of content provides an equal benefit for any consumer, and that the price of a unit of content is the same for any content, $\rho_i = \rho$ $(i = 1, 2)$.

Platforms II

- Each platform chooses whether to make its content compatible with the other ' s hardware device. (Compatibility decisions)
- Each platform charges a royalty rate r $(0 \leq r \leq 1)$ for each unit of content sold at its marketplace.
- Suppose that marginal cost of hardware device is c. Each platform decide the level of cost-reducing investment, y_i $(y_i < c)$. Each platform inccurs ky_i^2 from this investment. The parameter k expresses the efficiency of innovation.

Platforms III

- The profit function of platform is

$$\Pi_i = (p_i - c + y_i)D_i + r\rho D_i + \delta_i r\rho D_j - ky_i^2, \quad i = 1, 2, j \neq i.$$

where D_i denotes the demand of hardware device i and δ_i is following function.

$$\delta_i = \begin{cases} 0 & \textbf{if platform } i \textbf{ chooses incompatibility.} \\ 1 & \textbf{if platform } i \textbf{ chooses compatibility.} \end{cases}$$

Consumers I

- Use a Hotelling model of product differentiation.
- Hardware 1 located at 0, and hardware 2 at 1.
- Ideal points of consumers are distributed uniformly on the unit interval with a unit density.
- Each consumer incurs a constant proportional disutility t per unit length.
- The benefit derived from consumption of the hardware device is v. $(v = 0)$
- Denote by B the utility that any consumer derives from a unit of content, which is assumed to be the same for any content and for any consumer, and satisfies the condition $B > \rho$.

Consumers II

- The utility function of a customer who is located at x, buys a hardware device i, and uses its available contents is written as

$$u_i = N_i(B - \rho) - p_i - t|x - x_i|,$$

where denotes N_i the variety of contents on hardware device i and x_i the location of hardware device i.
- We will use the notation, $b = B - \rho$.

Timing of game

Consider the following three-stage game.

1. Each platform chooses between compatibility and incompatibility. (C or IC)
2. Each platform decides the level of investment. (y_i)
3. Each platform sets the price of hardware device (p_i)

Incompatible platforms I

The utility function of a customer who is located at x can be written as

$$u_i = b - p_i - t|x - x_i|, \quad (i = 1, 2).$$

The proportion of consumers who buy hardware 1:

$$u_1 = u_2 \quad \Rightarrow \quad \hat{x} = \frac{t - p_1 + p_2}{2t}.$$

Hence, the demand for hardware device i is

$$D_i = \frac{t - p_i + p_j}{2t} \quad (i = 1, 2, \; j \neq i).$$

Incompatible platforms II

Platform i maximizes its profit

$$\begin{aligned}\Pi_i &= (p_i - c + y_i)\, D_i + r\rho\, D_i - k y_i^2 \\ &= (p_i - c + y_i + r\rho) \cdot \frac{t - p_i + p_j}{2t} - k y_i^2\end{aligned}$$

with respect to its hardware price p_i.
Taking the first-order conditions with respect to price and solving, we have the prices as follows:

$$p_i(y_1, y_2) = t + c - r\rho - \frac{2y_i + y_j}{3}.$$

Incompatible platforms III

Substitute this price in the profit function.

$$\Pi_i = \frac{(3t + y_i - y_j)^2}{18t} - k y_i^2.$$

Next, we consider the decisions at stage 2.
Taking the first-order conditions with respect to investment and solving, we have the investments as follows:

$$y_i(\mathrm{IC}, \mathrm{IC}) = \frac{1}{6k}.$$

where, we assume for second-order condition with respect to investment that $18kt - 1 > 0$ holds.

Incompatible platforms IV

From this equilibrium investment level, we can derive the hardware price, demand, profit of platform.

$$\begin{aligned}p_i(\mathrm{IC}, \mathrm{IC}) &= t + c - r\rho - \frac{1}{6k} \\ D_i(\mathrm{IC}, \mathrm{IC}) &= \frac{1}{2} \\ \Pi_i(\mathrm{IC}, \mathrm{IC}) &= \frac{t}{2} - \frac{1}{36k}\end{aligned}$$

And, profit of content provider i is

$$\pi_i(\mathrm{IC}, \mathrm{IC}) = (1 - r)\rho \cdot (D_i(\mathrm{IC}, \mathrm{IC}) + \delta_i D_j(\mathrm{IC}, \mathrm{IC})) = \frac{(1 - r)\rho}{2}.$$

Incompatible platforms V

Consumer surplus is

$$\begin{aligned}CS(\mathrm{IC}, \mathrm{IC}) &= \int_0^{D_1(\mathrm{IC},\mathrm{IC})} u_1(x)\, dx + \int_{D_1(\mathrm{IC},\mathrm{IC})}^1 u_2(x)\, dx \\ &= \frac{1}{6k} + b - \frac{5}{4}t - c + r.\rho\end{aligned}$$

Social surplus is

$$\begin{aligned}SS(\mathrm{IC}, \mathrm{IC}) &= CS(\mathrm{IC}, \mathrm{IC}) + \sum_i \pi_i(\mathrm{IC}, \mathrm{IC}) + \sum_i \Pi_i(\mathrm{IC}, \mathrm{IC}) \\ &= \frac{1}{9k} + b - \frac{t}{4} - c + \rho.\end{aligned}$$

Compatible platforms

- Skip.

Incompatible-compatible platforms without tipping

- Skip.
- We need the condition for the interior solution.

Lemma 1

If the efficiency of investment is low enough to satisfy the condition $k > 1/(3(3t - b - r\rho)) \equiv \hat{k}$ and the degree of hardware differentiation is large enough to satisfy the condition $t > (b + r\rho)/3$, then there exist interior solutions under the asymmetric market structures.

Incompatible-compatible platforms with tipping I

We can derive the following equilibrium outcome (corner solution).

$$y_1(\mathrm{IC},\mathrm{C})^T = \frac{1}{2k}\,,\ y_2(\mathrm{IC},\mathrm{C})^T = 0$$

$$p_1(\mathrm{IC},\mathrm{C})^T = b - t + c\,,\ p_2(\mathrm{IC},\mathrm{C})^T = c$$

$$\Pi_1(\mathrm{IC},\mathrm{C})^T = \frac{1}{4k} - t + b + r\rho\,,\ \Pi_2(\mathrm{IC},\mathrm{C})^T = r\rho$$

$$SS(\mathrm{IC},\mathrm{C})^T = \frac{1}{4k} - \frac{t}{2} + 2(b + \rho) - c$$

- We need the condition for the corner solution.

Incompatible-compatible platforms with tipping II

Lemma 2

If the efficiency of investment and the degree of hardware differentiation are large enough to satisfy the conditions $k < 1/(2(3t - b - r\rho)) \equiv \bar{k}$ and $t > (b + r\rho)/3$, then there exist the following corner solutions under asymmetric market structure.

Incompatible-compatible platforms with tipping III

Proof

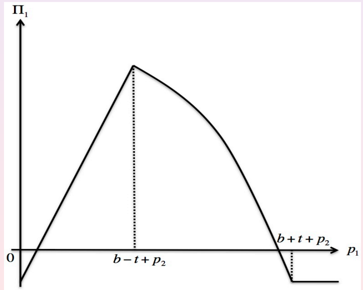
The demand and profit function of platform 1 can be written as

$$D_1 = \begin{cases} 1 & \text{if } \; p_1 \leq b - t + p_2 \\ \frac{b+t-p_1+p_2}{2t} & \text{if } \; b - t + p_2 \leq p_1 \leq b + t + p_2 \\ 0 & \text{if } \; b + t + p_2 \leq p_1 \end{cases}$$

$$\Pi_1 = \begin{cases} (p_1 - c + y_1 + r\rho) \cdot 1 - ky_1^2 & \text{if } \; p_1 \leq b - t + p_2 \\ (p_1 - c + y_1 + r\rho) \cdot \frac{b+t-p_1+p_2}{2t} - ky_1^2 & \text{if } \; b - t + p_2 \leq p_1 \leq b \\ -ky_1^2 & \text{if } \; b + t + p_2 \leq p_1 \end{cases}$$

Incompatible-compatible platforms with tipping IV

The platform 1 chooses the price that leads to the tipping by its own ($D_1 = 1$) when the profit function can be drawn as below.



Incompatible-compatible platforms with tipping V

The condition that tipping is a best-response strategy for platform 1 is given by:

$$\lim_{p_1 \to (b-t+p_2)+0} \frac{\partial \Pi_1}{\partial p_1} = 1 - \frac{b - t + p_2 - c + y_1 + r\rho}{2t} \leq 0$$
$$\iff y_1 \geq 3t - b - r\rho + c - p_2 \qquad (1)$$

Then the best response function of platform 1 can be written as

$$BR_1(p_2) = b - t + p_2.$$

Incompatible-compatible platforms with tipping VI

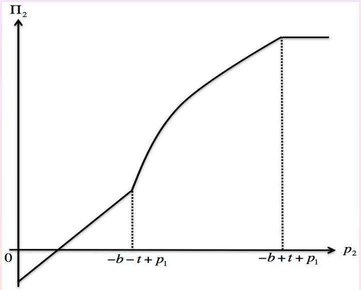
The demand and profit function of platform 2 can be written as

$$D_2 = \begin{cases} 1 & \text{if } \; p_2 \leq -b - t + p_1 \\ \frac{t-b+p_1-p_2}{2t} & \text{if } \; -b - t + p_1 \leq p_2 \leq -b + t + p_1 \\ 0 & \text{if } \; -b + t + p_1 \leq p_2 \end{cases}$$

$$\Pi_2 = \begin{cases} (p_2 - c + y_2) \cdot 1 + r\rho - ky_2^2 & p_2 \leq -b - t + p_1 \\ (p_2 - c + y_2) \cdot \frac{t-b+p_1-p_2}{2t} + r\rho - ky_2^2 & -b - t + p_1 \leq p_2 \leq -b \\ +r\rho - ky_2^2 & -b + t + p_1 \leq p_2 \end{cases}$$

Incompatible-compatible platforms with tipping VII

The platform 2 accepts the price that leads to tipping by rival platform ($D_1 = 1$) when the profit function of platform 2 is shown as below.



Incompatible-compatible platforms with tipping VIII

The condition that being tipped is a best-response strategy for platform 2 is given by:

$$\lim_{p_2 \to (-b+t+p_1)-0} \frac{\partial \Pi_2}{\partial p_2} = -\frac{-b+t+p_1-c+y_2}{2t} \geq 0$$
$$\iff y_2 \leq b-t+c-p_1 \qquad (2)$$

Then the best response function of platform 2 can be written as

$$BR_2(p_1) = \{p_2 | p_2 \geq -b+t+p_1\}.$$

Here, when there exists an equilibrium with tipping, the profit of platform 2 can be written as $\Pi_2 = r\rho - ky_2^2$. Therefore, we

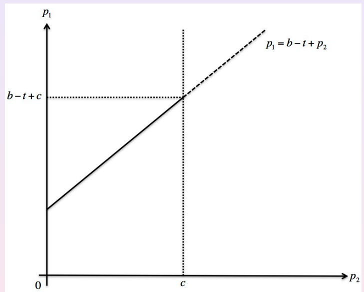
Incompatible-compatible platforms with tipping IX

can immediately get the following investment level of platform 2.

$$y_2(\mathrm{IC}, \mathrm{C})^T = 0$$

From this investment level, we can rewrite the condition (2) as $p_1 \leq -t+b+c$.

Incompatible-compatible platforms with tipping X



- We have the line $p_2 = -b+t+p_1$ ($p_1 \leq b-t+c$) as the set of common point of both platforms' best response functions. So we cannot derive the unique equilibrium.

Incompatible-compatible platforms with tipping XI

- Using the *trembling hand perfect equilibrium* as equilibrium concept, we have the following unique equilibrium.

$$p_1 = b - t + c\ ,\ p_2 = c$$

- The profit of platform 1 can be written as $\Pi_1 = b - t + y_1 + r\rho - ky_1^2$.
- Taking the first-order conditions and solve for the investment level, we can derive the following investment level.

$$\frac{\partial \Pi}{\partial y_1} = 1 - 2by_1 = 0 \iff y_1(\mathrm{IC}, \mathrm{C})^T = \frac{1}{2k}$$

Incompatible-compatible platforms with tipping XII

- Using this, we can get the equilibrium prices. But, it needs that $p_1(\mathrm{IC}, \mathrm{C})^T,\ p_2(\mathrm{IC}, \mathrm{C})^T,\ y_1(\mathrm{IC}, \mathrm{C})^T,\ y_2(\mathrm{IC}, \mathrm{C})^T$ satisfy the equation (1) and (2).
- The condition for the existence of this corner solution: $k < 1/(2(3t - b - r\rho)) \equiv \bar{k},\ t > (b + r\rho)/3$. □

Comparative statics

Compare the social surplus among the different market structures.

Proposition 4

If the efficiency of investment is low enough to satisfy the condition $k > \hat{k}$ and the degree of hardware differentiation and the benefit from a unit of content are large enough to satisfy the conditions $t > (b + r\rho)/3$ and $b > 3r\rho$, then the equilibrium social surpluses are ordered as follows:

$$SS(\mathrm{IC}, \mathrm{IC}) < SS(\mathrm{IC}, \mathrm{C})^{\mathrm{NT}} = SS(\mathrm{C}, \mathrm{IC})^{\mathrm{NT}}.$$

Subgame-perfect equilibrium I

Proposition 7

If both the degree of hardware differentiation and the benefit of content are at the intermediate levels that satisfy the conditions $\frac{b+r\rho}{3} < t < \frac{b+r\rho}{2}$ and $2r\rho < b < 5r\rho$, then for all $k > \hat{k}$, the equilibrium market structures are the asymmetric ones without tipping, $(\mathrm{IC}, \mathrm{C})^{\mathrm{NT}}$ and $(\mathrm{C}, \mathrm{IC})^{\mathrm{NT}}$.

Subgame-perfect equilibrium II

Intuition

- Suppose that the rival chooses incompatibility and the degree of hardware differentiation is not very large. Then, choosing incompatibility leads to a price competition in hardware devices, which reduces the profit from selling hardware devices.
- If the rival chooses compatibility, then by choosing incompatibility the platform gains the advantage of available content and gets more profit from selling hardware devices.

Subgame-perfect equilibrium III

Proposition 8

If both the degree of hardware differentiation and the benefit from content are large enough to satisfy the conditions $t > (b + r\rho)/3$ and $b > r\rho$, then the equilibrium market structure is given by

$$\begin{cases} (\mathrm{IC},\mathrm{IC}) & \text{if} \quad t > 2r\rho \text{ and } \tilde{k} < k < \bar{k}, \\ (\mathrm{IC},\mathrm{C})^{\mathrm{T}} \text{ or } (\mathrm{C},\mathrm{IC})^{\mathrm{T}} & \text{if} \quad (t < 2r\rho \text{ and } 1/(18t) < k < \bar{k}) \text{ or} \\ & \quad (t > 2r\rho \text{ and } 1/(18t) < k < \min\{\tilde{k},\ \bar{k}\}). \end{cases}$$

Subgame-perfect equilibrium IV

Intuition

- Given that a rival platform chooses incompatibility, choosing compatibility makes the market for hardware devices will be monopolized by the rival platform. So, it is the best-response strategy for a platform to choose incompatibility under the following parameter space.
  - Choosing incompatibility does not lead fierce competition in the hardware market. (The parameter k and t are not vary small.)
  - The royalty revenue from the sale of content is small. (The parameter $r\rho$ is small.)

Subgame-perfect equilibrium V

When both of Proposition 7 and 8 holds, that is, $(b + r\rho)/3 < t < (b + r\rho)/2,\ b/5 < r\rho < b/2$, we can show the partition of equilibrium market structure.

Corollary 1

Suppose that $(b + r\rho)/3 < t < (b + r\rho)/2$. When the royalty revenue from a unit of content is large enough to satisfy the condition $2b/7 < r\rho < b/2$, we can derive the partition of equilibrium market structure in the parameter space as shown in Figure 1. The equilibrium market structure is $(\mathrm{IC},\mathrm{C})^{\mathrm{NT}},\ (\mathrm{C},\mathrm{IC})^{\mathrm{NT}}$ in the range framed in by the yellow line and $(\mathrm{IC},\mathrm{C})^{\mathrm{T}},\ (\mathrm{C},\mathrm{IC})^{\mathrm{T}}$ in the range framed in by the blue line.

Subgame-perfect equilibrium VI

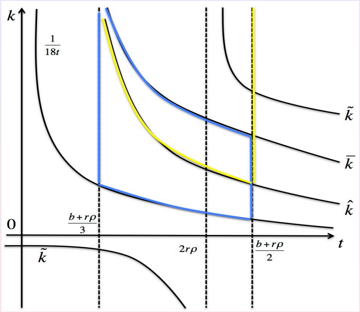


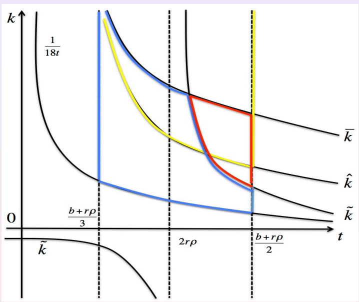
Figure 1: $\frac{2}{7}b < r\rho < \frac{b}{2}$
Yellow: $(\mathbf{IC}, \mathbf{C})^{NT}$, $(\mathbf{C}, \mathbf{IC})^{NT}$ Blue: $(\mathbf{IC}, \mathbf{C})^{T}$, $(\mathbf{C}, \mathbf{IC})^{T}$

Subgame-perfect equilibrium VII

Corollary 2

Suppose that $(b + r\rho)/3 < t < (b + r\rho)/2$. When the royalty revenue from a unit of content is small enough to satisfy the condition $b/5 < r\rho < 2b/7$, we can derive the partition of equilibrium market structure in the parameter space as shown in Figures 2 and 3. The equilibrium market structure is $(\mathbf{IC}, \mathbf{C})^{\mathbf{NT}}$, $(\mathbf{C}, \mathbf{IC})^{\mathbf{NT}}$ in the range framed in by the yellow line, $(\mathbf{IC}, \mathbf{C})^{\mathbf{T}}$, $(\mathbf{C}, \mathbf{IC})^{\mathbf{T}}$ in the range framed in by the blue line, and $(\mathbf{IC}, \mathbf{IC})$ in the range framed in by the red line.

Subgame-perfect equilibrium VIII



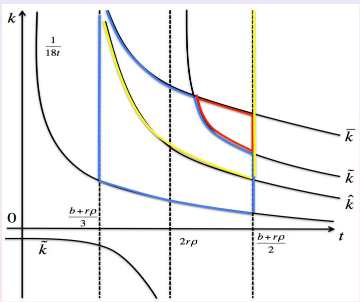
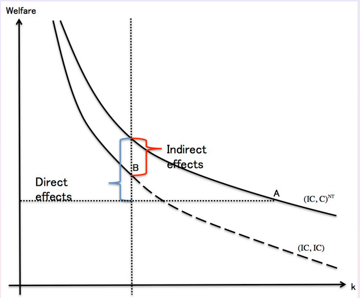


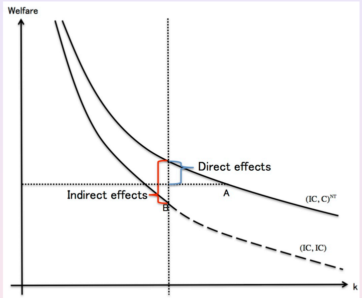
Figure 2: $\frac{b}{5} < r\rho < \frac{5}{19}b$ Figure 3: $\frac{5}{19}b < r\rho < \frac{2}{7}b$
Yellow: $(\mathbf{IC}, \mathbf{C})^{NT}$, $(\mathbf{C}, \mathbf{IC})^{NT}$ Blue: $(\mathbf{IC}, \mathbf{C})^{T}$, $(\mathbf{C}, \mathbf{IC})^{T}$
Red: $(\mathbf{IC}, \mathbf{IC})$

Conclusion I

- In the range by the flamed by the red line, (IC,IC) becomes the equilibrium.
- (IC,IC) has the smallest social welfare in four market structures.
- The process innovation has a positive direct effect on social welfare.
- But, it also lead to an equilibrium with inefficient market structure, (IC, IC) by affecting the compatibility decisions.

Conclusion II





- If the positive direct effect exceeds, the process innovation increases welfare.
- If the negative indirect effect exceeds, the process innovation reduces welfare.

Conclusion III

- While process innovation directly confers socially benefits, we have shown that it might nevertheless reduce social welfare by inducing change of market structure.
- Indeed, attaining a first-best might actually require taxing investment, to prevent the platforms from choosing inefficient market structures.

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Table 1: Equilibrium investment, price, demands, profits of platform, profit of content provider, consumer surplus, and social surplus.

	(IC, IC)	(C, C)	$(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}$	$(\mathrm{IC},\mathrm{C})^{T}$
y_1	$\frac{1}{6k}$	$\frac{1}{6k}$	$\frac{3k(3t+b+r\rho)-1}{6k(9kt-1)}$	$\frac{1}{2k}$
y_2	$\frac{1}{6k}$	$\frac{1}{6k}$	$\frac{3k(3t-b-r\rho)-1}{6k(9kt-1)}$	0
p_1	$t+c-r\rho-\frac{1}{6k}$	$t+c-\frac{1}{6k}$	$t+c+\frac{b}{3}-\frac{2}{3}r\rho-\frac{1}{6k}-\frac{b+r\rho}{6k(9kt-1)}$	$c-t+b$
p_2	$t+c-r\rho-\frac{1}{6k}$	$t+c-\frac{1}{6k}$	$t+c-\frac{b}{3}-\frac{1}{3}r\rho-\frac{1}{6k}+\frac{b+r\rho}{6k(9kt-1)}$	c
D_1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}+\frac{3k(b+r\rho)}{2(9kt-1)}$	1
D_2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}-\frac{3k(b+r\rho)}{2(9kt-1)}$	0
Π_1	$\frac{t}{2}-\frac{1}{36k}$	$\frac{t}{2}+r\rho-\frac{1}{36k}$	$\left(\frac{t}{2}-\frac{1}{36k}\right)\left(\frac{3k(3t+b+r\rho)-1}{9kt-1}\right)^2$	$\frac{1}{4k}-t+b+r\rho$
Π_2	$\frac{t}{2}-\frac{1}{36k}$	$\frac{t}{2}+r\rho-\frac{1}{36k}$	$\left(\frac{t}{2}-\frac{1}{36k}\right)\left(\frac{3k(3t-b-r\rho)-1}{9kt-1}\right)^2+r\rho$	$r\rho$
π_1	$\frac{(1-r)\rho}{2}$	$(1-r)\rho$	$(1-r)\rho\cdot D_1(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}$	$(1-r)\rho$
π_2	$\frac{(1-r)\rho}{2}$	$(1-r)\rho$	$(1-r)\rho$	$(1-r)\rho$
CS	$\frac{1}{6k}+b-\frac{5}{4}t-c+r\rho$	$\frac{1}{6k}+2b-\frac{5}{4}t-c$	$\int_0^{D_1(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}}u_1(x)\ dx+\int_{D_1(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}}^1 u_2(x)\ dx$	$b+\frac{t}{2}-c$
SS	$\frac{1}{9k}+b-\frac{t}{4}-c+\rho$	$\frac{1}{9k}+2b-\frac{t}{4}-c+2\rho$	$CS(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}+\sum_i\pi_i(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}+\sum_i\Pi_i(\mathrm{IC},\mathrm{C})^{\mathrm{NT}}$	$\frac{1}{4k}-\frac{t}{2}+2(b+\rho)-c$