Private Value of Innovation(Patents)

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Summary

Examining the relation between market structure and the value of innovation is important for competition and STI policy. If the value is large in a specific industry structure, government may lead the industry to take that form to enhance innovation.

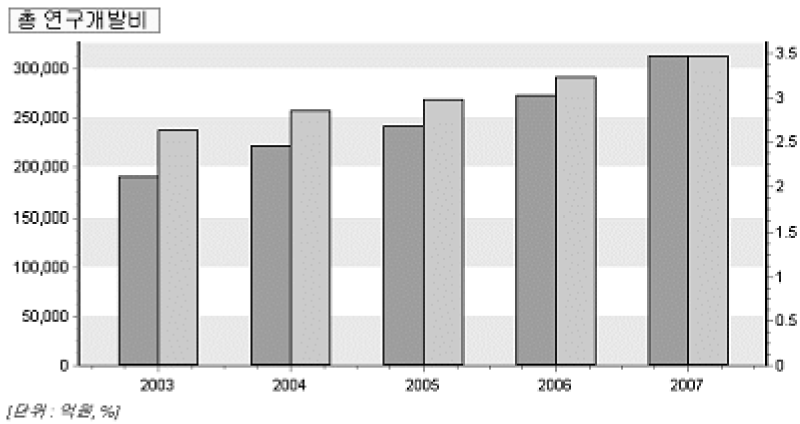
Our simple calibration in the case of linear demand and constant MC results in the conclusion that the incentive for R&D in the case of major and minor innovation in Cournot competition is less than that of merger and cooperative R&D.

This emphasizes again “necessary evil” as a monopoly for innovation.

Key Words: research, innovation, incentive or value of innovation.

I. Introduction

<Figure 1> depicts the trends in the ratio of R&D to value added in industry in the Korean economies.



<Figure 1> National Trend in R&D of Korea(Source: MOST)
[Right: percentage of GDP(%), Left: Total R&D expenditure(100 million Won)]

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In this study, we investigate how much this amount of R&D expenditures produce private values. We use simple oligopolistic models of Cournot(1838), Stackelberg(1934) and so on. We update the insights of Schumpeter(1942) incorporating Romer(1990)'s implication of endogeneous growth.

It was Dasgupta and Stiglitz (1980) who formalized the idea of private value of innovation in several market structures. They show that the value in the case of competitive market is higher than that of monopoly, which leads to support of Arrow hypothesis(1962).

We can ask the following question: what is the value of innovation(or patent) in diverse imperfect competition market?

Economists like Nordhaus(1969) computed the optimal patent duration assuming Bertrand competition. Dasgupta and Stiglitz (1980), Guesnerie and Tirole(1985) analyzed the value of patent where only one producer innovates, and the outcome is protected for unlimited time.

In this paper, we try to give answers to the following questions.

First, there are two kinds of process innovation: drastic(major) or nondrastic(minor). The former refers to the case where new monopoly price is lower than the previous monopoly price.[$pm(c2)<c1$] We compute the values of innovations for diverse cases.

Second, the value of drastic innovation was discussed in the framework of Cournot competition. Of course, those of monopoly, competitive market and social planner were analyzed by Arrow(1961) and Dasgupta and Stiglitz (1980). In this study, we compute those in the cases of diverse imperfect competiton structures: quantity leader, price leader, monopolistic competition and differentiated Nash price competition.

This article consists of the following sections. Section 2 introduces the basic model for discussing the extension of model. Section 3 considers and computes many kinds of values in numerous market structures. Section 4 concludes and gives some implications.

II. The Value of Drastic Innovation

2.1 The Model of R&D and Imperfect Competition

Arrow(1962) shows that incentives of innovation is largest in the case of social planner. Then, in competition, and smallest in the case of monopoly.

This value of innovation comes from reducing prices and increasing consumer's surplus. This conclusion leads to the famous Arrow hypothesis.(Tirole, 1988)

Social planner:

$Vs = (1/r)\int_{b*}^{b} D(c)dc$

He sets market price equal to marginal cost from b to b*.

Monopoly:

$Vm = (1/r)\int_{b*}^{b} pm(c)dc$

Pm(c): monopoly price when marginal cost is c

Competition(drastic)

$Vc = pm(b^*)D(pm)$

But, the value of innovation in the case of oligopoly is not firmly established. Our study aims to provide preliminary backgrounds for further research on this topic.

If two firms compete in price and only one firm succeeds in process innovation that reduces the marginal cost from b to b* and set monopoly price lower than that of competitor's cost, we say drastic or major innovation occurs.

In the case of minor or nondrastic innovation, the incentive to innovate in competitive market is:

$Vc = (1/r)(b-b^*)D(b)$

D( ): demand

In this paper, we analyze the effect of drastic innovation on the profit, performed by one firm and no innovation by the other firms. We allow R&D for process innovation and integration with respect to this quantity competition.

We may consider a two-stage game as follows.

First, firms in an industry decide whether to invest in R&D that lowers the next period's marginal cost. Then, all firms choose their quantity levels simultaneously at the second stage.

The two-stage solution is analyzed via backward induction. That is, firms first consider the situation in product market at the second stage. They forecast the competition as a function of research input at the first stage. Then, they determine R&D input considering the effect on profits at the second stage output market. This structure is similar to that of quantity or price leadership or forward trading game of duopoly(Allaz and Vila, 1993).

Finding sub-game perfect equilibrium for this sequential game needs two kinds of conditions: Nash equilibrium in overall and each of subgame. But, in this section, we only consider one shot game for simplicity.

2.2 Value of (Drastic) Innovation

Consider the case of n competitors engaged in quantity competition. In this case, the quantity is a strategic substitutes in that the second partial derivative for quantity is negative. The case of strategic complements is also interesting for R&D incentives, but we do not consider this in this paper.

If one of the competing firms succeeds in process innovation, it has now market power, in the viewpoint of the fact that its monopoly price is lower than the other firms' marginal cost.

We assume a linear (inverse) demand function for the total product $Q(=x_1+ x_2 +\ldots x_n)$ and for each product amount x_i, which we write as:

$$p = A - \Sigma x_i = A - x_1 - x_2 - \ldots x_n$$
$$Q = A - p \qquad (1)$$

Let the linear cost of supplying x_i be:

$$C(x_1) = b_1 x_1$$
$$\ldots$$
$$C(x_i) = b_i x_i$$
$$\ldots, (b_i = b) \qquad (2)$$

The production game is defined by the profit function of firm i:($X=\Sigma x$)

$\pi_i(x_i; X) = p(X)(x_i) - bx_i$
$= (A - X)(x_i) - bx_i$

Now, let $x_i(X_{-i})$ be the best-response function in the game. x_i is therefore given by $\partial\pi_i/\partial x_i=0$.($X_{-i} = \Sigma_{i\neq j} x_i$)

max $(A - b - X_{-i} - x_i)(x_i)$
$X=[n(A-b)]/(n+1)$,

Hence, in equilibrium,[1]

$$p_C=b + [(A-b)/(n+1)] \quad (3)$$

This price, p_C, is the equilibrium price of a simple Cournot model where there is no R&D. There are no R&D investments in period 1, but only a simultaneous quantity setting game occurs in period 2.

In the case of no R&D, we could derive the equilibrium production and profits [$\Pi C(n)$] of Cournot competition with n firms as follows:

$\Pi C(n)=(A-b)^2 / (n+1)^2$

If one firm succeeds in innovation, he then become a monopoly and get the following profits:

$\Pi M(n)=(A-b^*)^2 / 4$
Where, $b^*<b$

So, the value of patent is

$V=\Pi M(n) - \Pi C(n) =(A-b^*)^2 / 4 - \quad (A-b)^2 / (n+1)^2$
We can present simple numerical example; **minor invention**

If A=3, b=1, b*=1/2, RD=(1/2), n=2
then
$\Pi M(n) - \Pi C(n) =(A-b^*)^2 / 4 - \quad (A-b)^2 / (n+1)^2$
25 / 16 - 4 / 4 = 9/16=0.56
If we consider fixed costs, then $\Pi M(n) =(A-b^*)^2 / 4 - \quad RD^2$
$= 25 / 16 – RD^2$
=25/16 – 1/4
= 25/16 -4/16 = 21/16
So, V= 0.56 – 0.25=0.31

[1] $p(X)= (A+nb)/(n+1)$
$x_i =[(A-b)/2] – [(n-1)x/2]$
$=(A-b)/(n+1)=nX$

But, we should note that this linear example is not always applied to real world economy. And, new monopoly price is higher than the previous marginal cost, 1. This is minor innovation, so we consider another case: **major invention**

If A=3, b=1, b*=1/5, RD=(4/5), n=2
then
$\Pi M(n) - \Pi C(n) = 196 / 100 - 100/100$
$= 96/100 = 0.96$
$V = 0.96 - (16/25) = 96 - 64/100 = 0.32$

The main difference from the following section is we arbitrarily selected the level of innovation in the case of major innovation.

2.3 Noncooperative R&D of Firms: Simultaneous Success

In this oligopoly model, market performance depends on the costs faced by the competing firms (and market demand). We assume all firms have the ability to engage in R&D to lower their marginal costs rather than just only one form. This activity is generally known as process innovation and is not coincident with drastic or nondrastic innovation.

We consider R&D investment that reduces production costs in the next period.[2]

We assume that if the firm invests RD_i [i=1, 2,…, n] in R&D in the first period, its marginal cost in the second period will be [b_i-RD_i, i= 1, 2,…, n, b_i =b].

Reducing the unit cost by RD_i requires the following R&D costs:

$C_i (RD_i) = RD_i^2$

We can also derive the Cournot-Nash equilibrium[and profits ΠCR(n)] with noncooperative R&D by solving the following maximization problem:

$Max_x\ \pi_i(x_i; X, RD_i) = p(X)(x_i) - [(b-RD_i)x_i] - RD_i^{\ 2}$

In the case of noncooperative R&D, the equilibrium production, R&D input, market price, industry production and (individual) profits [ΠCR(n)] are:[3]

$$\Pi CR(n) = [3(A-b)]^2 / (2n+3)^2 \qquad (4)$$

$(RD^*_i) = n(A-b) / (2n+3)$
$V = \Pi M(n) - \Pi C(n) = [3(A-b)]^2 / (2n+3)^2 - (A-b)^2 / (n+1)^2$

2 In contrast, Farrel and Katz(2000) consider R&D that stochastically improves product quality.

3 $x^*_i = (A-b+RD_i)/(n+1)$
$p^* = A - [n(A-b+RD_i)/(n+1)]$
$X^* = n(A-b+RD_i)/(n+1)$

And, we can see that in noncooperative R&D and Cournot competition, R&D, output and profit is endogeneously determined by profit-maximization incentives.

We can present simple numerical example: **minor invention**

If A=3, b=1, b*=3/7, RD=(4/7), n=2

$(RD^*_i) = n(A-b) / (2n+3)=4/7$

$V=\Pi M(n) - \Pi C(n) =[3(A-b)]^2 / (2n+3)^2 - (A-b)^2 / (n+1)^2$

$=36/49 - 4/9 =0.29$

2.4 Stackelberg Leader and Noncooperative R&D of Firms

Quantity leadership model is sequential game, which is solved by backward induction. Leader first contempolates how the follower responds after he sets the quantity(or capacity) of output. So, to find equilibrium we should solve the follwer's maximization problem.

d'Aspremont and Jacquemin (1988) show that cooperation (monopoly) in both the R&D stage and the production stage results in more R&D input than does cooperation only in one stage.

This paper shows that there is much more R&D input under quantity leadership than in a monopoly, in the case of no spillovers.

In the case of no R&D, we can derive the equilibrium production and prices of the leader (firm1) and the followers with n firms (complements) as follows: [L(=1): leader, F(=2,3,4…): follower]

Max $\pi_L(x_1; X) = p(X) (x_1) - [bx_1]$

$= (A - X -b) (x_1)$

Such that $x_i=R(x_1)$, i=2,3,…n, R: response curve

$x_L =[(A-b)/2]$[4]

$x_{Fi} =[(A-b)/n] - (x_L/n)$

We can also derive the Stackelberg equilibrium quantity with R&D: <Appendix>

Max $\pi_L(x_1; X) = p(X) (x_1) - [(b-RD)x_1] - RD_L^2$

$= (A - X -(b-RD)) (x_1) - RD_L^2$

Such that $x_i=R(x_1)$, i=2,3,…n

$RD^{**}_L=[n(n+2)(A-b)] / [6n(n+1)-1]$[5]= 8*2/6*2*3-1=16/35=

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[4] $x_{Fi} =[(A-b)/2] - [(n-2)x/2] - [x_1/2]$

$=[(A-b)/n] - (x_L/n)$

$x =x_{F2} =x_{F3}=\cdots. =x_n$

$X=[(A-b)/2][(2n-1)/n]$

$p=[A+b(2n-1)]/2n$

[5] $x_L^{**} =[(A-b+RD_L)/2]$

$x_{Fi}^{**} = [(A-b+2RD_F- RD_L)/2n]$

RD^{**}_F= (A-b-[[n(n+2)(A-b)] / [6n(n+1)-1]] / 2(n^2 -1)

ΠM(n) - ΠC(n) = 0.68 - 4/9 =0.24

RD=16/35 b*=19/35

V=0.24-0.20=0.04

2.5 Collusion and cooperative R&D

If antitrust laws prohibit firms from colluding implicitly, firms choose to merge to increase their profits (Perloff, 2008). Mergers between firms can arise due to the following efficiency issues: increasing returns to scale, economies of scope, synergy effects and enhancing managerial efficiency.

In the case of no R&D, we can derive the equilibrium production and prices of a cartel with n firms as follows:

Max $\pi_L(x_1; X)$ = p(X) (X) - [b X]
= (A – X -b) (X)
Such that x_i= x_1, 2,3,…n

x_M = [(A-b)/(2n)] (5)

We can also derive the merger equilibrium quantity with R&D:

Max $\pi_L(x_1; X)$ = p(X) (X) - [(b-RD) X] –nRD^2
= (A – X –(b-RD)) (X) –nRD^2

(RD^{***}_i) = (A-b) / (4n-1) (6)

ΠM(n) - ΠC(n) = $(A-b^*)^2$ / 4n - $(A-b)^2$ / $(n+1)^2$
= 1.11 – 4/9=0.67
V=0.67-4/49=0.59

2.6 Numerical Examples (n=2)[6]

In the following examples, we focus on the case of two firms for simplicity. We can easily generalize the implications derived from this case to an n-firm economy.

The following table summarizes the previous results.

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p**=A-[(A-b+RD_L)/2] +n[(A-b+2RD_F- RD_L)/2n]
X=[(A-b+RD_L)/2] +n[(A-b+2RD_F- RD_L)/2n]

[6] We should note that these results do not always applied to real world economy, since we assumed only lenear demand and constant(linear) marginal cost.

<Table 1> Welfare Analysis without R&D (n=2)[A=3, $b_1=b_2=1$]

	Price	Profit(x)	Industry Production	Production	CS (Consumer Surplus)	Welfare (=Profit+CS)
*Stackelberg Leader	6/4=1.5	0.5	3/2	(1)	(3/2)(3/2)(1/2) = 9/8	13/8
Follower	6/4	0.25		(1/2)		2/8
**Collusion	2	1	1	1	(1)(1)(1/2)=1/2	3/2=1.5
*** Cournot 1	5/3	4/9	4/3	2/3	(4/3)(4/3)(1/2) =16/18	24/18=0.89
Cournot 2	5/3	4/9=0.44		2/3		8/18

* The sum of welfare with Stackelberg leadership is 15/8=1.875

** The sum of welfare in the Collusion model is 32/18=1.5

** The sum of welfare in the Cournot model is 32/18=1.78

<Table 2> Welfare Analysis with R&D (n=2) [A=3, $b_1=b_2=1$]

	Price	Profit (x)	Industry Production	Production	CS (Consumer Surplus)	Welfare (=Profit+CS)
*Stackelberg Leader	44/35=1.26	0.68	**61/35=1.74**	43/35 **ΣRD=(0.71)** (RD=16/35=0.46)	(61/35)(61/35)(1/2)=1.52	2.2
Follower	44/35	0.57		(18/35) RD=9/35=0.26		0.57
** Collusion	27/14=1.93	1.11	**15/14=1.07**	(15/14)=1.07 **2RD=4/7=0.58**	0.57	1.68
***Cooperative R&D 1	6/4=1.5	(1/2)	**3/2=1.5**	(3/4) **2RD=1/2=0.5**	(6/4) (6/4) (1/2) =9/8	13/8
Cooperative R&D 2	6/4	(1/2)		(3/4) RD=2/8		1/2
**** Noncooperative R&D Cournot 1	31/21=1.48	0.499	**32/21=1.52**	16/21=0.76 **2RD=8/7=1.14** RD=4/7=0.57	1.16	1.66
Noncooperative R&D Cournot 2	31/21	0.499		16/21 RD=4/7		0.499

2.7 Summary

We can summarize our calculation results for the private value of process innovation.

1. Cournot (major) V=0.32
2. Cournot (noncooperative R&D) V=0.29
3. Leader(first mover) V=0.04
4. Collusion (cooperative R&D) V=0.59

Implication 1

If two firms compete as Cournot competitiors in quantity, the private value from drastic innovation is smaller than that of horizontal merge and cooperative R&D.

Implication 2

By first moving adopting process innovation, the Schtackelberg leader gets private value, but this magnitude is very small.

Implication 3

In the case of Cournot competition, the value of drastic innovation, which is gain from being monopolist from reducing marginal cost, is larger than that of nondrastic innovation of simultaneous R&D.

Before discussing the relationship between natural resources and economic growth, we see the simplest Schumpeterian endogeneous growth model. This is because by glancing at the main structure of the theory, we can improve our insight for the relationship between growth and resources.

3. Conclusion

The conclusion from this study is that the incentive for innovation in the case of quantity competition is lower than that of monopoly.

Nordhaus(1969) derived optimal patent life from calculation value from process innovation. He assumed Bertrand competition and linear demand and quadratic costs for innovation. Maximization of profits from reducing costs shows that the longer the duration, the higher the degree of cost reduction.

The conclusion from this study is that the lower the elasticity of demand, the longer the duration. He argue that current patent system in the US is 90% efficient in that it attains about 90% of maximum possible consumers surplus from 17 years of duration.

But, in this study, we compared the private value of cost reduction in several market structures. This may complement his study in that he only considered price competition.

We used quantity competition model and derived optimal process innovation from the linear demand and quadratic costs of R&D. We can find the outcome coinciding with our intuition that private value of innovation of Cournot competitor is smaller than that of horizontally merged firm.

This conclusion implies the relaxation of anti-trust and regulation, but more sophisticated future research is needed.

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