Market Structure and Optimal Entry Cost When Quality of Product is Uncertain

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Abstract

We investigated the government's optimal intensity of product screening process prior to entry when the product's quality is uncertain, such as medical devices, and showed that the intensity that maximizes social welfare is greater than the intensity that maximizes the number of entrants. In recent empirical research about medical devices, implications of uncertainty of product's quality and screening process on consumer has been studied and it has been found that too weak screening intensity may not maximize the social welfare in some cases. We gave such empirical findings a theoretical form by using a general reduced form model, and we also provided a structural example that is an extension of static two stage entry model. The policy implication from our argument is that the government may have to increase the intensity to improve the social welfare even though the number of entrants decreases, in other words, reducing entry costs may not be always good for society.

1 Introduction

One of the central questions in industrial organization is what the desirable market structure for the society is and how to implement it. In light of discussions around these topics, economists and policy makers have discussed how much should the government reduce entry costs. A canonical answer is that entry costs should be set as low as possible to encourage enter that improves welfare. Along with this idea, in 2014, Japanese Pharmaceutical Affairs Act was amended such that the intensity of product screening process prior to entry which is said to be a major component of the entry costs is reduced for some medical devices such as central venous catheter. However, in this paper, we argued that when the product's quality is uncertain, consumers are risk averse and the screening process can reduce the uncertainty, it is not always optimal to reduce the intensity of the screening process or the entry costs.

Our argument is based on the peculiar characteristics of the screening process that affects both producers and consumers. Suppose the intensity of the process reduced. Producers perceive that the entry costs are also reduced, therefore more of them would enter the market. On the other hand, consumers may reckon that the risks of consuming low quality products increases, therefore, even though the price may drop due to the increase in market competition, their utility could decrease and even some consumers would stop consuming the goods. Hence, if the government reduces the screening intensity, the number of firms in the market may increase but the consumer surplus could decrease.

To fix this idea, we considered a social welfare function that is increasing in both the number of firms and the screening intensity. In this case, changes in the screening intensity has both direct and indirect effects. Suppose again the intensity is reduced. As a consequence of our assumption, this would reduce the consumer surplus directly. At the same time, through the change in the entry costs, this could increase the number of entrants which could improve the consumer surplus indirectly. The total change in the consumer surplus depends on the relative strength of these two effects. In other words, the optimal intensity of screening process must balance direct and indirect effects. By using this observation, we showed that the intensity that maximizes the number of firms is always smaller than that maximizes the social welfare.

Our argument might bridge two distinct research lines, one is theoretical research about market structure and the other is recent empirical literature about consumer learning. In particular, our result could be understood as a generalization of excess entry theorem (such as Mankiw and Whinston (1986)) that incorporates insights from recent empirical literatures. Both the excess entry theorem and our argument investigate the same question, namely, what is the number of firms that maximizes the social welfare. Moreover, they share a common policy implication that the social welfare could improve when the number of firms decreases. However there is a major difference between them. In the excess entry theorem, the government directly chooses the number of firms, while in our argument, the government indirectly affects the number of firms through controlling the entry costs. Therefore, we believe that our result imply that policy implications from the excess entry theorem could be still valid even when firms make entry decisions. Some recent empirical literature investigates consumers learning about product's quality. In particular, Grennan (2014) has studied how the length of screening process prior to entry affects consumer surplus and has found that a reduction in the length could reduce the surplus. However, they have not incorporated firms' entry decisions and they have not discussed their results theoretically. We believe that our result would give their empirical findings a theoretical form

The rest of this paper is organized as follows. In section 2, we develop our main argument by examining a general reduced form framework. In section 3, we present an example that satisfies assumptions made in section 2, which is an extension of conventional two-stage entry model.

2 Reduced Form Argument

To illuminate our main argument, we would like to compare our model and classical entry model. For clarity, we employ a simplified version of Mankiw and Whinston (1986) model where the goods is homogeneous and there is no heterogeneity in firms.

2.1 Optimal Entry Cost in Simple Classical Model

In this model, the consumer surplus is increasing in the number of firms and a firm's profit is decreasing in it. Firms enter the market if their profit exceeds the entry costs and, other things being equal, reducing entry costs encourages more firms to enter. In equilibrium, firms should earn zero profit, thus the social welfare is equal to the consumer surplus, and this implies that the lower the entry cost the greater the social welfare. In other words, the optimal entry costs is 0.

Let us be more specific. Let N be the number of firms, $\Pi(N)$ be a firm's profit, and E be an entry cost. We assume $\Pi'(N) < 0$ and N is continuous for simplicity. Then, the relationship between the entry costs and the number of firms is given by

$$\Pi(N) = E, \tag{1}$$

and this implies

$$\frac{dN}{dE} = \frac{1}{\Pi'(N)} < 0, \tag{2}$$

which means that the number of firms is a decreasing function of the entry costs.

Let $CS(N)$ be the consumer surplus, then the social welfare $SW(N)$ is denoted by

$$SW(N) = CS(N) + N[\Pi(N) - E)], \tag{3}$$

however, when (1) holds the second term on the right hand side disappears. Hence, the social welfare is equal to the consumer surplus. Suppose $CS'(N) > 0$, which is satisfied if firms compete a la Cournot, then we get

$$\frac{dSW}{dE} = \frac{dCS}{dN}\frac{dN}{dE} < 0, \tag{4}$$

which implies that the optimal entry cost E is equal to 0.

To sum up, in a simple classical model, the number of firms is a decreasing function of entry cost and the optimal entry cost is 0. This result may imply that the policy maker should reduce the entry costs to improve the social welfare.

2.2 The Model: Dual Role of Screening Intensity

In this subsection, we would like to present our main claim that reducing entry costs does not necessarily improve the social welfare when the products' quality is uncertain and the screening process prior to entry can reduce the uncertainty. As we have argued in the introduction, the screening process has two distinct roles, which is the entry costs for producers and the uncertainty reducing process for consumers. To capture this idea, we extended the previous model. Let $\Pi(N, E)$ be the firms profit where $\Pi_E > 0$, $\Pi_N < 0$ and here E represents screening intensity. $\Pi_E > 0$ means that the demand for this goods shifts upwards as the screening intensity increases and this captures that increase in E reduces uncertainty in product's quality. Let $C(E)$ be the entry costs where $C'(E) > 0$ and $C''(E) > 0$. This means that the entry cost is an increasing function of the screening intensity. As in the previous model, the following free entry condition must hold in equilibrium:

$$\Pi(N, E) = C(E). \tag{5}$$

By the implicit function theorem, N and E are related in the following manner:

$$\frac{dN}{dE} = \frac{-\frac{\partial \Pi}{\partial E} + \frac{dC}{dE}}{\frac{\partial \Pi}{\partial N}}. \tag{6}$$

Since the denominator in (6) is always negative, the sign of equation (6) is positive when

$$\frac{\partial \Pi}{\partial E} > \frac{dC}{dE}, \tag{7}$$

and negative when

$$\frac{\partial \Pi}{\partial E} < \frac{dC}{dE}. \tag{8}$$

The equation (7) means that, if the marginal increase in profit is greater than the marginal increase in entry cost, the number of firms increases. If we further assume that $\lim_{E \to 0} \Pi_E = \infty$, then with $C'' > 0$, equation (8) holds when E is large enough. The screening intensity that maximizes the number of firms satisfies $dN/dE = 0$. Intriguingly, unlike the previous model, the number of firms can be a nonlinear function of the screening intensity. The intuition is given in the following section when we give a numerical example.

Let us turn to the social welfare, which is equivalent to the consumer surplus as in the previous model. Let $CS(N, E)$ be the consumer surplus where $CS_N > 0$, $CS_E > 0$. This means that, as we have emphasized, consumers appreciates the increase in the screening intensity because it reduces uncertainty in product's quality. If we differentiate CS with respect to E, we get

$$\frac{dCS}{dE} = \frac{\partial CS}{\partial N}\frac{dN}{dE} + \frac{\partial CS}{\partial E}. \tag{9}$$

In equation (9), we can see that the change in E has both indirect and direct effects. The first term represents the indirect effect which means that the change in screening intensity affects consumer surplus via the changes in the number of firms. The second term represents the direct effect which means that the change in screening intensity directly affects the consumer surplus.

Since the optimal E^* must satisfy $dCS/dE = 0$, the following inequality must hold;

$$\left.\frac{dN}{dE}\right|_{E=E^*} < 0. \tag{10}$$

The above equation is our main claim. At the optimal E^*, the number of firms is not maximized and equation (8) holds. At E^*, the reduction in the screening intensity leads the increase in the number of firms because the reduction in the entry costs is greater than the drop in the profit. The mathematical reason why inequality (10) must hold is as follows. Suppose $dN/dE \geq 0$. Then, by $CS_E > 0$ and $CS_N > 0$, if E increases, CS increases as well. Thus, the optimal entry cost must satisfy inequality (10). To give the condition at E^* an economic interpretation, consider the following equality:

$$\frac{\partial CS}{\partial N}\frac{dN}{dE}\Big|_{E=E^*} = -\frac{\partial CS}{\partial E}\Big|_{E=E^*}. \tag{11}$$

The left hand side represents the marginal gain from reducing E which is derived from the indirect effect, and the right hand side represents the marginal loss from doing so which stems from the direct effect. Equation (11) implies that the optimal screening intensity must strike a balance between these two effects.

The policy implication from our result remarkably differs from the one from the previous model. Our claim implies that, in some circumstances, reduction in the entry costs may not improve the consumer surplus. There may be a case where the policy maker should increase the screening process that could result in reduction in the number of firms.

2.3 On the Difference with the Excess Entry Theorem

Even though we emphasized the similarity between our claim and the excess entry theorem such as Mankiw and Whinston (1986), there are mathematical and economical differences between them. The typical excess entry theorem asks the following question which is whether the number of firms that are achieved in a free entry equilibrium optimal or not. Mathematically, it compares N' that satisfies

$$\Pi(N') = E$$

and N^* that is a solution to

$$\max_N CS(N) + [\Pi(N) - E]N.$$

N^* means that the number of firms that the government chooses when it can directly control that. However, our model considers E^* that is a solution to

$$\max_E CS(N(E), E)$$

where $N(E)$ means that the number of firms N is determined by the free entry condition given E. In other words, we consider a case that entry decision are made by firms. Some may say we could have studied the N^* and E^* that is a solution to

$$\max_{N,E} CS(N, E) + [\Pi(N, E) - E]N$$

however, we cannot get such N^* and E^*. The mathematical reason is that there are many pairs of N and E that satisfies

$$CS(N, E) + [\Pi(N, E) - E]N = W$$

where W is fixed. This means that, even if the number of firms (N) decreases we can keep the social welfare constant by increasing the intensity (E). To sum up, our argument and the excess entry theorem investigate different questions and the assumed economic environments are distinct.

3 An Example

We would like to present a simple extension to a two-stage entry model with homogeneous goods that satisfies assumptions that are imposed in the previous section. The timing of game is as follows; at stage 0, the government decides the intensity of screening process prior to entry, at stage 1, firms decide whether enter or not, and at stage 2 firms competes a la Cournot. In this example, firms produce homogeneous goods, the quality of goods, which is the same across manufacturers, is uncertain and consumers are risk averse.

3.1 Consumer's Preference and Demand Function

Each consumers consumes one unit of goods and their utility is given by;

$$u_i = a_i - \frac{\sigma^2}{E} - p, \tag{12}$$

where a_i is consumer i's valuation of the goods and follows uniform distribution over $[0, A]$, σ^2 represents the uncertainty in product's quality, E is the screening intensity. We assume A is large enough relative to σ. As we can see, consumer dislikes uncertainty but E reduces it. We assume that policy makers, consumers, and producers know σ^2.

Since the demand for this good Q is equal to the number of consumers who buys the product, Q is given by

$$Q = \int_0^A 1\{a_i - \frac{\sigma^2}{E} - p \geq 0\} da_i, \tag{13}$$

where $1\{\cdot\}$ is an indicator function. This means that a consumer buys the product if the utility from consuming the product is greater than the utility from not consuming the goods, which is normalized to 0. To get the demand function, we need to know the marginal buyer's valuation a^*. By the above equation, a^* satisfies

$$0 = a^* - \frac{\sigma^2}{E} - p. \tag{14}$$

Since the consumer whose a_i is greater than a^* buys this product and a_i follows the uniform distribution over $[0, A]$, the demand function becomes

$$Q = A - a^* = A - \frac{\sigma^2}{E} - p. \tag{15}$$

3.2 Firms' Payoff at Stage 2

Firms decides how much to produce q_i given the demand function. Suppose there are $N \geq 2$ firms. For simplicity, we assume N is continuous. Then, the firms' problem is

$$\max_{q_i} \Pi_i = q_i(p(Q) - c) = q_i(A - \frac{\sigma^2}{E} - Q - c). \tag{16}$$

We assume c is equal to 0 in the rest of this paper. Let Q_{-i} be the sum of output of all firms but i, the first order condition of the equation (15) is

$$\frac{\partial \Pi_i}{\partial q_i} = A - \frac{\sigma^2}{E} - Q_{-i} - 2q_i = 0.$$

Thus, each firms produces

$$q_i = \frac{1}{2}\left(A - \frac{\sigma^2}{E} - Q_{-i}\right).$$

In a symmetric equilibrium, $Q_{-i} = (N-1)q_i$, so

$$q_i = \frac{1}{N+1}\left(A - \frac{\sigma^2}{E}\right), \tag{17}$$

hence

$$Q = Nq_i = \frac{N}{N+1}\left(A - \frac{\sigma^2}{E}\right). \tag{18}$$

As we can see, the higher the E the greater the Q. This means that the increase in the screening intensity reduces uncertainty and the demand curve shifts upwards. Since the price in equilibrium is given by

$$p = A - \frac{\sigma^2}{E} - Q = \frac{1}{N+1}\left(A - \frac{\sigma^2}{E}\right), \tag{19}$$

the profit becomes

$$\Pi_i = pq_i = \left(\frac{1}{N+1}\left(A - \frac{\sigma^2}{E}\right)\right)^2. \tag{20}$$

The payoff function is the same as basic quantity competition model except for σ^2/E part.

3.2.1 Properties of the Payoff Function

As we can see, properties that are assumed in the previous section are satisfied:

$$\frac{\partial \Pi}{\partial N} = -2\left(A - \frac{\sigma^2}{E}\right)^2 \frac{1}{(N+1)^3} < 0,$$

$$\frac{\partial \Pi}{\partial E} = 2\left(A - \frac{\sigma^2}{E}\right) \frac{1}{(N+1)^2} \frac{\sigma^2}{E^2} > 0.$$

Also, $\lim_{E\to\infty} \Pi_E = 0$ holds.

3.3 Firms' Decision at Stage 1

Firms decide whether to enter or not. Firms enter if the payoff Π is greater than the entry costs $C(E)$, and stay out otherwise. Let us specify $C(E)$ as E^2. In free entry equilibrium, $\Pi = E^2$ must hold, thus

$$\left(\frac{1}{N+1}\left(A - \frac{\sigma^2}{E}\right)\right)^2 = E^2. \tag{21}$$

Since $N > 0$ and $E > 0$ must hold,

$$\frac{1}{N+1}\left(A - \frac{\sigma^2}{E}\right) = E,$$

and we get

$$N = \frac{A}{E} - \frac{\sigma^2}{E^2} - 1. \tag{22}$$

We would like to give a numerical example of the equation (22). Suppose $A = 10$ and $\sigma^2 = 2$. If we take N on the vertical axis and E on the horizontal axis, (22) becomes as the Figure 1.

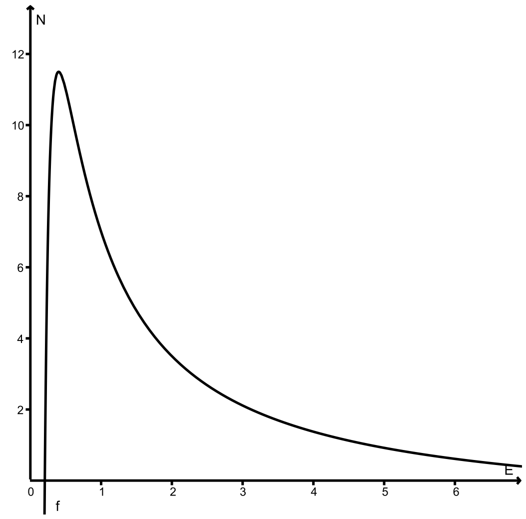

Figure 1

The reason why N is a nonlinear function is as follows. When E is small, the demand for the product is so weak that the payoff from entry is small. Therefore, even though the entry costs is small, only a few firms enter. When E is large, even though the demand is strong, the entry costs is so large that a small number of firms end up entering the market.

The E that maximizes N is given by

$$\frac{dN}{dE} = -\frac{A}{E^2} + \frac{2\sigma^2}{E^3} = 0$$

which is,

$$E = \frac{2\sigma^2}{A}. \tag{23}$$

3.4 Optimal Screening Intensity

In this subsection, we provide an analytical expression of E that maximizes the consumer surplus. The consumer surplus is the shaded area in the figure below,

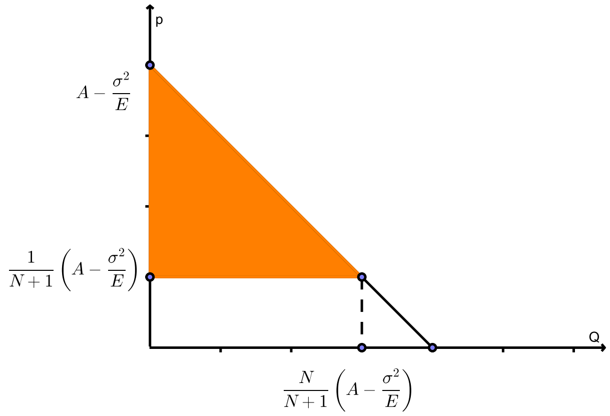

Figure 2

which is expressed by

$$CS = \frac{1}{2}\left(\frac{N}{N+1}\right)^2\left(A-\frac{\sigma^2}{E}\right)^2. \tag{24}$$

In the appendix, we showed that

$$CS = \frac{1}{2}N^2E^2$$

thus, it is clear that $CS_E > 0$ and $CS_N > 0$ holds. The optimal E is given by

$$E^* = \sigma. \tag{25}$$

See the appendix for derivation.

If $A > 2\sigma$holds, E that satisfies equation (23), hereafter E_N, is always smaller than E^*. Here is the numerical example of E_N and E^*. Suppose $A = 10$, $\sigma = 1$. Then, E, N, CS becomes as follows.

	E_N	E^*
E	0.2	1
N	24	8
CS	11.52	32

In this example, screening intensity that maximizes the social welfare is five times as large as that maximizes the number of firms. If we set $E = 1$, though the number of firms becomes a third, the consumer surplus doubles.

4 Concluding Remarks

We showed that the optimal intensity of product screening prior to entry is greater than that maximizes the number of firms when the product's quality is uncertain. We firstly showed this claim in a general framework and provided an example of structural model. The policy implication is that it may be desirable to increase the intensity of product screening or the entry costs even though the number of firms decreases.

In our example the quality of the product was exogenously given and we reckon that this is a drawback. Future works could enrich our example by allowing firms to decide their product's quality and its variance. Nonetheless, our main claim will hold as long as assumptions on firm's profit function and the consumer surplus are satisfied.

We reckon that the medical devices fits into our argument but there could be many industries that we can apply our argument such as laser-assisted in-situ keratomileusis or LASIK. We hope that our result will be verified in future empirical works.

References

[1] Grennan, M. (2014). Regulating Innovation with Uncertain Quality: Information, Risk, and Access in Medical Devices. working paper

[2] Mankiw, G., & Whinston, M. (1986). Free Entry and Social Inefficienty. *The RAND Journal of Economics, 17(1)*, 48-58.

5 (Appendix) Derivation of E^*

Put (21) into (23),

$$\begin{aligned} CS &= \frac{1}{2}\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)^2 \left(\frac{A}{E} - \frac{\sigma^2}{E^2}\right)^{-2} \left(A - \frac{\sigma^2}{E}\right)^2 \\ &= \frac{1}{2}\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)^2 \left(\frac{A}{E} - \frac{\sigma^2}{E^2}\right)^{-2} \left(\frac{A}{E} - \frac{\sigma^2}{E^2}\right)^2 E^2 \\ &= \frac{1}{2}\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)^2 E^2. \end{aligned} \tag{26}$$

By differentiating (25),

$$\begin{aligned} \frac{dCS}{dE} &= E\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)^2 + E^2\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)\left(-\frac{A}{E^2} + \frac{2\sigma^2}{E^3}\right) \\ &= E\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1 - \frac{A}{E} + \frac{2\sigma^2}{E^2}\right) \\ &= E\left(\frac{A}{E} - \frac{\sigma^2}{E^2} - 1\right)\left(\frac{\sigma^2}{E^2} - 1\right) \\ &= EN\left(\frac{\sigma^2}{E^2} - 1\right). \end{aligned} \tag{27}$$

At E^*, (26) must be 0. However, we are not interested in a case where the first and second terms are 0. So we only have to consider the third term. Hence, E^* satisfies

$$\frac{\sigma^2}{E^{*2}} - 1 = 0. \tag{28}$$

Since $E > 0$ and $\sigma > 0$, $E^* = \sigma$.

We can see that E^* satisfies the second order condition when A is large enough compared to σ. Since

$$\frac{dCS^2}{d^2E} = \left(\frac{\sigma^2}{E^2} - 1\right)^2 + \left(A - \frac{\sigma^2}{E} - E\right)\left(-2\frac{\sigma^2}{E^3}\right)$$

if $A > 2\sigma$,

$$\frac{dCS^2}{d^2E}\Big|_{E=\sigma} = (A - 2\sigma)\left(\frac{-2}{\sigma}\right) < 0 \tag{29}$$