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THE ELIMINATION OF PRICE DISCRIMINATION AND STRATEGIC INCENTIVE OF R&D

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This article investigates the welfare consequences of the elimination of price discrimination and points out the firm's strategic incentive of R&D against the regulator. It is shown that discrimination regulation aimed at preventing welfare-reducing price discrimination may induce the monopolist to invest a lower R&D and make the final outcome that is socially suboptimal compared to the case of no regulation. This article also discusses the second-best way of achieving an efficient regulatory policy by considering the firm's opportunistic behaviors and the regulator's possibility of commitment.

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I. INTRODUCTION

In the economics of price discrimination, it is well-known that a move by a monopolist from uniform pricing to third-degree price discrimination - charging different prices in different exogenously identifiable markets - reduces the welfare if total output decreases.[1] Schmalensee(1981), for instance, proves this conclusion assuming that monopolist can perfectly separate markets when marginal cost is constant. Varian(1985, 1989) extends this result in a more general setting when marginal cost is non-decreasing, by allowing imperfect arbitrage so that demand in any market can depend on prices in other markets, and Schwartz(1990) does

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[1] A necessary condition for welfare to increase under price discrimination is that total outputs increase. See, Varian(1992; p. 251).

for any cost function. For example, in the typical example with linear demands and constant marginal cost, the total output is the same under price discrimination as under uniform price. This implies that welfare must decrease under price discrimination.

However, as described in Varian(1985, 1989) and Tirole(1988), this result relies on the assumption that both markets are served in the uniform price regime, which is actually quite strong. When forced to charge a uniform price, the monopolist raises the price in high-elasticity markets and lowers that in low-elasticity markets. The increase in price in the high-elasticity markets may induce consumers in those markets to stop purchasing. Therefore, the elimination of price discrimination may be partially dangerous if it leads to the closure of markets. Based on these standard results in third-degree price discrimination literature, one may obtain the policy-relevant conclusion that if the elimination of discrimination does not lead to the closure of markets, output criteria can be a useful condition for welfare to increase.[2] Notice that in the simplest example with linear demands and constant cost, it is easy to show that if both markets are served in the uniform price regime, the elimination of price discrimination must increase welfare.

The purpose of this article is to examine this type of policy recommendation in a dynamic setting and test the validity of the static-based conclusion. The point is that ex post regulatory incentives generally deviate from ex ante incentives in dynamic models. Specifically, in order to rectify the incompleteness of the static analysis, the model presented in this article explicitly includes the strategic R&D behavior of the firm against the regulator. Using the simplest example with linear demands and constant marginal cost, this article investigates the R&D behavior of profit-maximizing monopolist under the threat of discrimination regulation and analyzes the welfare consequences of regulation. It is shown that discrimination regulation aimed at preventing welfare-reducing price discrimination may induce the monopolist to lower R&D investment and make the final outcome that is socially suboptimal compared to the case of no regulation. This is so because the monopolist would have the first-mover advantage over the regulator. This article also discusses the second-best way of achieving an efficient regulatory policy by considering the firm's opportunistic behaviors and the regulator's possibility of commitment.

The remains are the organization of the study: Section II specifies the basic model of price discrimination in order to examine the static-based policy recommendations by the existing literature. Section III analyzes firm's strategic incentive of R&D under the regulation of price discrimination and shows that the elimination of discrimination may mislead the R&D investment. Section IV

[2] Industrial policy for a regulated utility to overcome such profit-seeking activity may be in forms of average-price regulation, i.e., price caps. Armstrong and Vickers(1991) and Ireland(1992) examined the welfare consequences of allowing price discrimination by a monopolist, who is constrained to the forms of price regulation.

discusses some relevant extensions and policy-relevant implications, and the final section concludes the discussion.

II. THE BASIC MODEL OF PRICE DISCRIMINATION

Consider a monopolist selling to two exogenously identifiable markets. Let p_i and q_i respectively denotes the price and output sold in market $i(i=1, 2)$. Assume that the demand curve in market $q_i = a_i - bp_i$ where $3a_1 > a_2 > a_1 > 0$ and $0 < b < 1$.[3] The monopolist has constant marginal cost function, $C(\Sigma q_i) = c\Sigma q_i$ where $0 < c < a_1/b$. It ensures that under price discrimination all markets can be served.

The monopolist, if he can discriminate, chooses a price $\tilde{p}_i$ in market i so as to maximize $(\tilde{p}_i - c)(a_i - b\tilde{p}_i)$. Straightforward computations show that

$$\tilde{p}_i = (a_i + bc)/2b \quad \text{and} \quad \tilde{q}_i = (a_i - bc)/2.$$

The monopolist's profit under price discrimination $\tilde{\Pi} = \Sigma(a_i - bc)^2/4b$ and consumers' surplus $\tilde{S} = \Sigma(a_i - bc)^2/8b$. Thus, social welfare, which is defined as the unweighted sum of profit and consumers' surplus, $\tilde{W} = \Sigma 3(a_i - bc)^2/8b$.

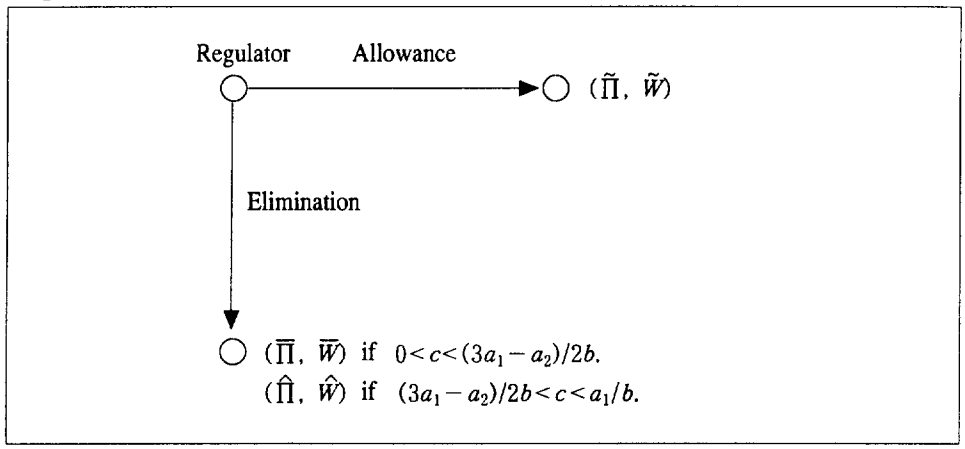
Suppose next that the monopolist is forced to charge a uniform price across

markets.[4] Consider the first case that $0 < c < (3a_1 - a_2)/2b$ in which all markets are served at the optimum. The monopolist chooses $\bar{p}$ so as to maximize $(\bar{p} - c)(\Sigma a_i - 2b\bar{p})$. This leads to

$$\bar{p} = \left(\sum_{i=1}^{2} a_i + 2bc\right)/4b \quad \text{and} \quad \sum_{i=1}^{2} \bar{q}_i = \left(\sum_{i=1}^{2} a_i - 2bc\right)/2.$$

In this case, the monopolist's profit $\bar{\Pi} = (\Sigma a_i - 2bc)^2/8b$ and consumers' surplus $\bar{S} = \Sigma_{j \neq i}(3a_i - a_j - 2bc)^2/16b$. Thus, social welfare $\bar{W} = (\Sigma a_i - 2bc)^2/8b + \Sigma_{j \neq i}(3a_i - a_j - 2bc)^2/16b$. Notice that total output is the same in the two arrangement: $\Sigma \tilde{q}_i = \Sigma \bar{q}_i$. Then, social welfare is lower under price discrimination: $\tilde{W} \leq \bar{W}$,

[Figure 1]



Next consider the other case that the first market is not served under a uniform price: $(3a_1-a_2)/2b \leq c < a_1/b$. The uniform price is then equal to the monopoly price for the second market. It yields that

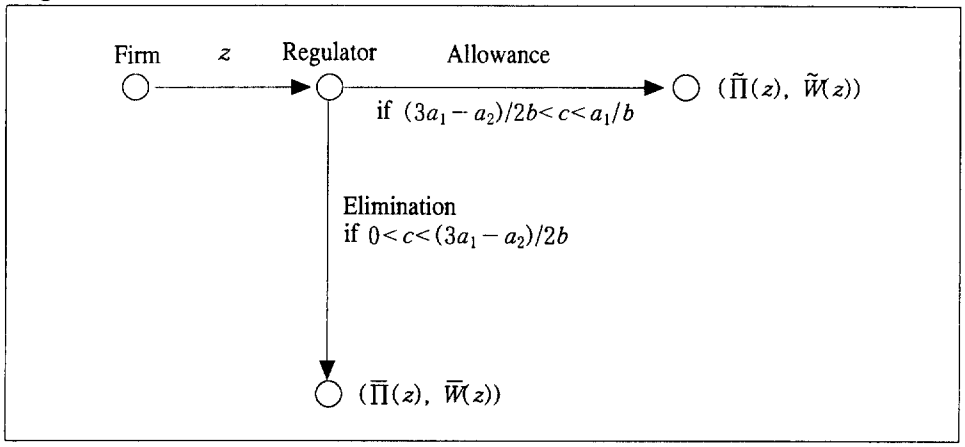
$$\hat{p}=(a_2+bc)/2b \quad \text{and} \quad \hat{q}_2=(a_2-bc)/2.$$

The obtained social welfare $\hat{W}=3(a_2-bc)^2/8b$, which is the sum of monopolist's profit $\hat{\Pi}=(a_2-bc)^2/4b$ and consumers' surplus $\hat{S}=(a_2-bc)^2/8b$. This level is lower than that under price discrimination, which is a result by Tirole (1988). Notice that social welfare in this case is the lowest among three arrangements: $\hat{W} \leq \tilde{W} \leq \bar{W}$. Notice also that the monopolist can achieve higher profit under price discrimination: $\hat{\Pi} < \tilde{\Pi}$. Figure 1 depicts such a situation.

Since it is assumed that the regulator's intervention is only through discrimination regulation, the choice of the regulator will be either the allowance of price discrimination or the elimination of discrimination. Notice here that the regulator's optimal decision on price discrimination depends on the marginal cost level of the firm. The standard conclusion in price discrimination literature is as follows: While the elimination of discrimination is a better policy when $0<c<(3a_1-a_2)/2b$, the allowance of discrimination is when $(3a_1-a_2)/2b \leq c < a_1/b$. The monopolist, on the other hand, wants to discriminate for all c without regulation on discrimination. Therefore, there is a difference between the social incentives and private incentives when $0<c<(3a_1-a_2)/2b$.

III. THE STRATEGIC INCENTIVE OF R&D

[Figure 2]



static analysis described above may call into question. This is so because before the regulator decides discrimination regulation, the monopolist can change its cost level through cost-reducing innovation. In order to analyze this situation, consider a two-stage model, in which monopolist chooses the level of research activity in the first stage and determine price levels in the second stage. The firm has a production function with constant marginal cost, which is a linear function of research. That is, $c = d - z$, where $z\,(0 < z < d)$ denotes the amount of research level of the firm. The cost of R&D is assumed to be quadratic, reflecting the existence of diminishing returns to R&D expenditures.[5] Figure 2 summarizes such a two-period, two-person game. Since the regulator's intervention is only through prohibition of price discrimination in the subgame, the firm as a first-mover finds its best responses to the regulator in the whole game.

As a benchmark case, suppose that the firm is under no discrimination regulation and thus he can freely discriminate the markets in the second price choice stage. Using the envelope theorem, the monopolist's objective is then to maximize

$$\tilde{\Pi}(z) = \tilde{\Pi} - z^2/2 = \Sigma(a_i - b)(d - z))^2/4b - z^2/2.$$

It yields the profit-maximizing R&D level,

$$z^* = \Big(\sum_{i=1}^{2} a_i - 2bd \Big)/2(1 - b).$$

Next, suppose that the monopolist decides research activity level under the

[5] The assumption on the relationship between R&D and cost follows the pioneering paper by d'Aspremont and Jacquemin(1988).

threat of price discrimination regulation. In the context of the static analysis with price discrimination regulation, the monopolist's profit in the second stage is given by:

$$\bar{\Pi} = \left(\sum_{i=1}^{2} a_i - 2bc \right)^2 / 8b \quad \text{when} \quad 0 < c < (3a_1 - a_2)/2b,$$

and

$$\tilde{\Pi} = \left(\sum_{i=1}^{2} a_i - bc \right)^2 / 4b \quad \text{when} \quad (3a_1 - a_2)/2b \leq c < a_1/b.$$

Using the envelope theorem and substituting $c = d - z$ yield the following monopolist's profit under regulation:

$$\bar{\Pi}(z) = \left(\sum_{i=1}^{2} a_i - 2b(d-z) \right)^2 / 8b - z^2/2 \quad \text{when} \quad \bar{z} < z < d,$$

and

$$\tilde{\Pi}(z) = \left(\sum_{i=1}^{2} a_i - b(d-z) \right)^2 / 4b - z^2/2 \quad \text{when} \quad 0 < z \leq \bar{z},$$

where $\bar{z} = d - (3a_1 - a_2)/2b$, which represents a threshold for discrimination regulation.

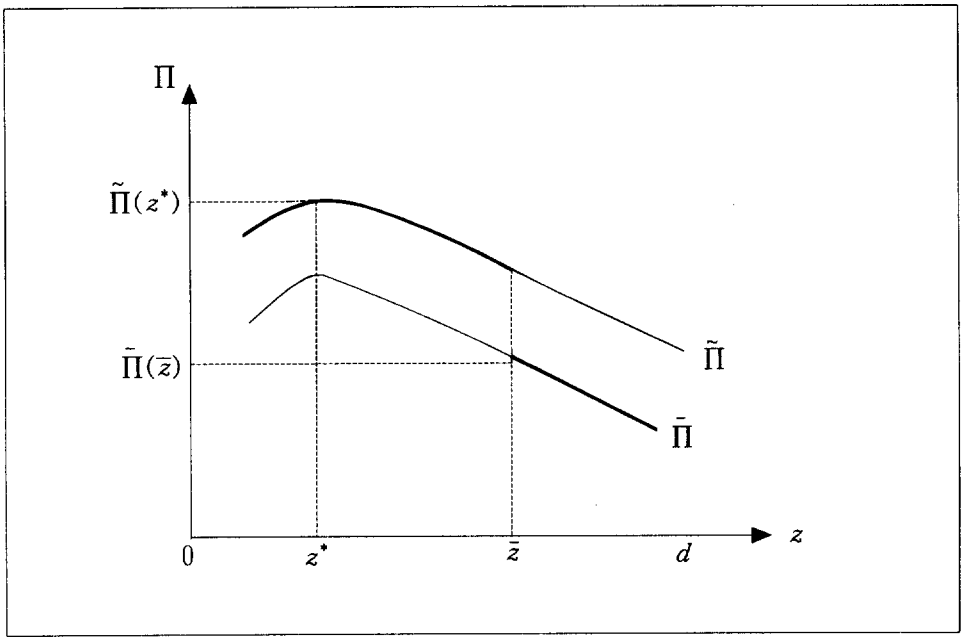
I can now investigate the relationship between discrimination regulation and the incentive of R&D, and examine its welfare consequences. First of all, it is noteworthy to know that

$$\tilde{\Pi}(z) - \bar{\Pi}(z) = \Sigma a_i^2 / 8b \quad \text{for all} \quad z.$$

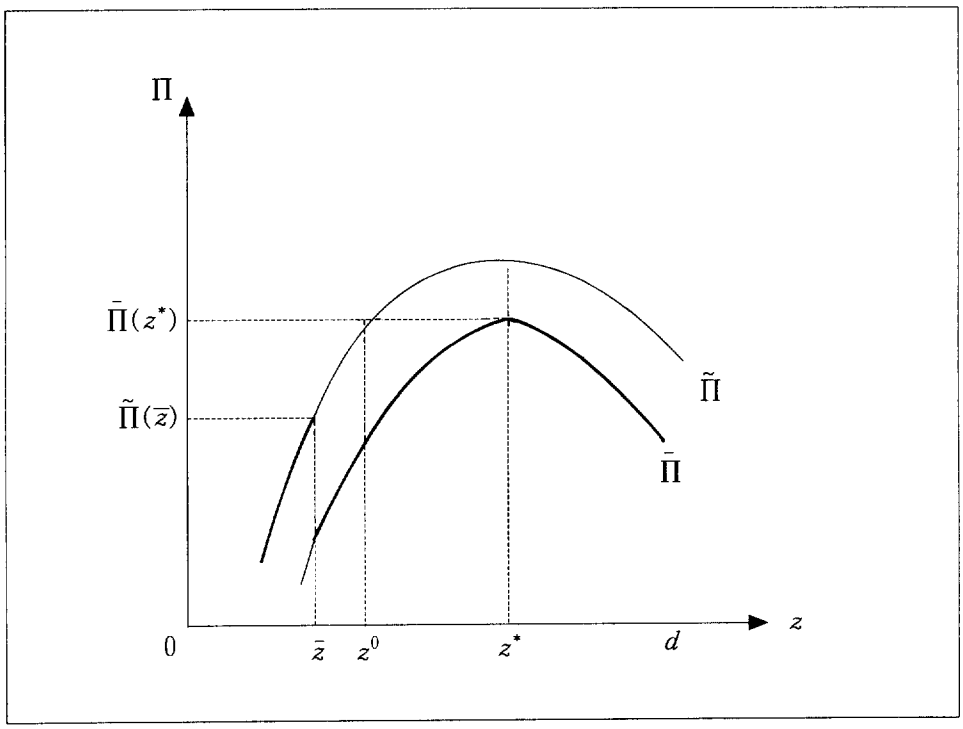
It implies that $\tilde{\Pi}(z) > \bar{\Pi}(z)$ for all z since $\Sigma a_i^2/8b > 0$. This is so because price discrimination is always profitable to the monopolist for all cases. Otherwise, he can charge a uniform pricing across markets. It also represents that the difference between two function is independent to the amount of research level of the firm. Thus, the maximal level of z for $\tilde{\Pi}(z)$ is the same to that for $\bar{\Pi}(z)$, i.e., $argmax_z \tilde{\Pi}(z) = argmax_z \bar{\Pi}(z)$.

I will distinguish three cases in order to determine the optimal R&D value of z. First, consider a case that $z^* \leq \bar{z}$. Since the optimal R&D level is lower than the threshold for regulation, the monopolist expects that he can discriminate the markets when he chooses the optimal R&D level z^*, so that he can earn the highest profit through price discrimination. This result is shown in Figure 3. In the figure, bold line indicates the monopolist's regulated profit under discrimina-

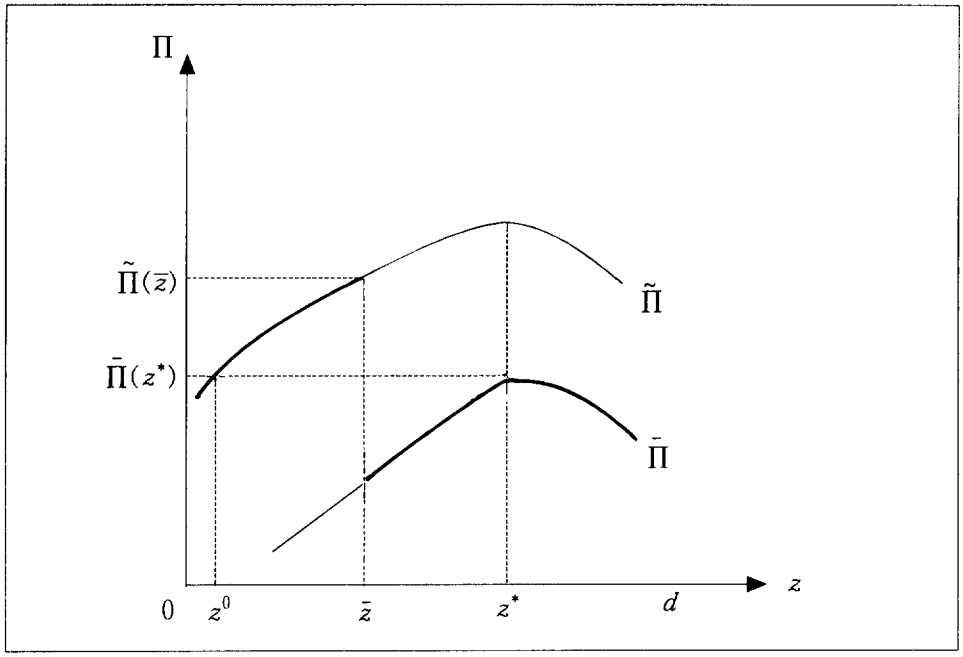
[Figure 3]



[Figure 4]



[Figure 5]



tion regulation. In fact, the regulator can obtain a better result by allowing discrimination rather than prohibiting discrimination, i.e., $\hat{W} < \tilde{W}$: the output criteria for social welfare to increase is still valid.

Next, consider the other case where the optimal R&D level is higher than the threshold for regulation, i.e., $z^* > \bar{z}$. Then, the result depends on the response of the monopolist. The monopolist in this case expects the regulator's choice of the elimination of discrimination when he chooses z^*, while he expects the allowance of discrimination when he chooses $\bar{z}$. The monopolist therefore have to compare the regulated profit with the optimal R&D level, z^*, and the unregulated profit with the strategic R&D level, $\bar{z}$. When $z^* > \bar{z}$ and $\tilde{\Pi}(\bar{z}) \leq \bar{\Pi}(z^*)$, firstly, the monopolist can earn larger profit with the optimal R&D level and thus the incentive of strategic R&D disappears. This result is shown in Figure 4. The regulator therefore can obtain a better result through the elimination of discrimination rather than the allowance of discrimination, i.e., $\tilde{W} < \bar{W}$: social welfare increases under discrimination regulation.

On the other hand, consider the other case where $z^* > \bar{z}$ and $\tilde{\Pi}(\bar{z}) > \bar{\Pi}(z^*)$. If the regulator allows price discrimination, the monopolist can earn the highest profit $\tilde{\Pi}(z^*)$ by choosing z^*, but the resulting welfare will be $\tilde{W}(z^*)$. From the viewpoint of regulator, it is thought that the elimination of price discrimination is a better policy so that the highest welfare $\bar{W}(z^*)$ will be obtained under regulation. This, of course, is wrong. From the viewpoint of the monopolist, since $\tilde{\Pi}(\bar{z}) > \bar{\Pi}(z^*)$, he chooses $\bar{z}$ strategically so as to achieve the allowance of

discrimination. Therefore, the resulting welfare level will be $\tilde{W}(\bar{z})$. The result is shown in Figure 5.

Finally, I compare the size of $\tilde{W}(\bar{z})$ and $\tilde{W}(z^*)$. Using the envelope theorem, it is obtained that $\tilde{W}(z)=\tilde{W}-z^2/2=\Sigma 3(a_i-b(d-z))^2/8b-z^2/2$ and thus, $\partial\tilde{W}/\partial z=3(\Sigma a_i-2bd)/4+(3b-2)z/2$. This yields that

$$\frac{\partial\tilde{W}}{\partial z}\Big|_{z^*}=3\Big(\sum_{i=1}^{2}a_i-2bd\Big)/4+(3b-2)\Big(\sum_{i=1}^{2}a_i-2bd\Big)/4(1-b)$$
$$=\Big(\sum_{i=1}^{2}a_i-2bd\Big)/4(1-b)>0.$$

It states that since $\tilde{W}$ is strictly concave function in z, the maximal level of R&D for $\tilde{W}$ is greater than z^*. Since $z^*>\bar{z}$, it follows that $\tilde{W}(\bar{z})<\tilde{W}(z^*)$. That is, the welfare level under discrimination regulation will be lower than that under no regulation. Thus, if the incentive of strategic R&D behavior occurs under discrimination regulation, the regulator will obtain a worse result rather than the allowance of discrimination. It means that the policy implication of the standard results in price discrimination literature can be misleading: social welfare decreases under price discrimination regulation. It also supports that ex post regulatory incentives generally deviate from ex post incentives in dynamic models if future prices are related to realized costs. This is so because before the regulator decides on the elimination of price discrimination, the monopolist as a first-mover can higher its cost level strategically against the regulator through less efforts on cost-reducing innovation, which will lead a regulator ex post to allow price discrimination and thus he can discriminate the markets; otherwise, he would just withdraw from the low price market under the elimination of discrimination. Therefore, at high levels of cost, under-investment is likely to occur in order to induce the regulator to permit price discrimination since more investment yields less marginal cost and thus prohibition of price discrimination.

[Table 1] The Effects of Price Discrimination Regulation

Case	Choice of z	profit	welfare	ΔW
No Regulation	z^*	$\tilde{\Pi}(z^*)$	$\tilde{W}(z^*)$	
Case 1: $z^*\le\bar{z}$	z^*	$\tilde{\Pi}(z^*)$	$\tilde{W}(z^*)$	0
Case 2: $z^*>\bar{z}$ and $\tilde{\Pi}(\bar{z})\le\bar{\Pi}(z^*)$	z^*	$\bar{\Pi}(z^*)$	$W(z^*)$	+
Case 3: $z^*>\bar{z}$ and $\tilde{\Pi}(\bar{z})>\bar{\Pi}(z^*)$	$\bar{z}$	$\bar{\Pi}(\bar{z})$	$W(\bar{z})$	−

The analysis is summarized in Table 1. In the table, ΔW implies the difference between welfare with regulation and without regulation. Notice that the social welfare without regulation is $\tilde{W}(z^*)$. Notice also that under Case 1 the result is the same to that under no regulation since the optimal regulation in Case 1 is no intervention. However, discrimination regulation based on the output criteria induces different R&D incentive of the firm depending upon market condition. While regulation is efficient when it does not affect firm's choice of R&D, as in Case 2, inefficient regulation reduces the welfare when the strategic incentive of the firm appears, as in Case 3.

IV. SOME DISCUSSIONS

In the previous section, where the analysis is extended to a multiperiod game, it is revealed that the elimination rule which the regulator is able to implement is restricted by the firm's opportunism. In principle, this is so because the nature of the game played by the regulator and the firm changes dramatically when both make decisions over time. Since the firm knows that the regulator can use some observations of firm performance to decide its price discrimination regulation rule, he has an incentive to try to fool the regulator, even raising costs and sacrificing profits today in order to make tomorrow's discrimination rule more favorable. It implies that the standard policy-relevant recommendation for optimal price discrimination regulation should be reconsidered.

In this section, I first consider the regulator's opportunism in a second-best sense and provide a modified discrimination regulation rule. First, suppose that the initial cost level is sufficiently high: $z^* \leq \bar{z}$ or $a_2 - a_1 + (3a_1 - a_2)/2b \leq d < \sum a_i/2b$. Then, there exists an opportunity to cut down the cost drastically when there is no intervention. In this case the optimal policy is to allow price discrimination.

Second, suppose that the initial cost level is low: $z^* > \bar{z}$ or $d < a_2 - a_1 + (3a_1 - a_2)/2b$, where a minor cost reduction occurs. Then, I have two different cases for and against discrimination regulation. The determinant for the optimal regulation depends on the difference between $\tilde{\Pi}(\bar{z})$ and $\bar{\Pi}(z^*)$. If $\tilde{\Pi}(\bar{z}) \leq \bar{\Pi}(\bar{z}^*)$, the elimination of price discrimination is efficient. This is so because the initial cost level is sufficiently low so that uniform pricing covers both markets. On the other hand, if $\tilde{\Pi}(z) > \bar{\Pi}(\bar{z}^*)$, the allowance of price discrimination is efficient in a second-best sense. It means that no regulation yields a better efficient outcome when the strategic incentive is taken into consideration: $\tilde{W}(z^*) > \bar{W}(\bar{z})$.

For a concrete analysis, I will examine this suggestion and find a determinant, which is determining the difference between $\tilde{\Pi}(\bar{z})$ and $\bar{\Pi}(z^*)$. Under the assumption that $d < \bar{K}$, where $\bar{K} = a_2 - a_1 + (3a_1 - a_2)/2b$, I have

$$\bar{z} = z^* - \frac{1}{1-b}(\bar{K} - d).$$

I can next find z^0 such that $\tilde{\Pi}(z^0) = \bar{\Pi}(z^*)$. Recall that $\tilde{\Pi}(z) = \bar{\Pi}(z) + \Sigma a_i^2/8b$. It implies that I need to find z^0 such that $\bar{\Pi}(z^0) - \bar{\Pi}(z^*) + \Sigma a_i^2/8b = 0$. With some necessary calculations with the restriction of $z^0 < z^*$, I obtain

$$z^0 = z^* - \sqrt{\frac{\Sigma a_i^2}{4b(1-b)}}.$$

In sum, if $\bar{z} \leq z^0$ or $0 < d \leq \underline{K}$ where $\underline{K} = \bar{K} - \sqrt{\Sigma a_i^2/4b(1-b)}$, then $\bar{\Pi}(z^*) \geq \tilde{\Pi}(\bar{z})$ so that the elimination of price discrimination would raise the welfare. This is so because the initial cost level is sufficiently low to cover both markets. On the other hand, if $z^0 < \bar{z}$ or $\underline{K} < d < \bar{K}$, then $\bar{\Pi}(z^*) < \tilde{\Pi}(\bar{z})$ so that the regulation would reduce the welfare. Thus, the allowance of price discrimination would be efficient strategy for a second-best regulator. Notice that this case of reducing welfare more occurs as d increases.

However, these second-best considerations may also induce the regulator's other opportunism. For instance, in the above description, there exists opportunism between the firm and the regulator when the initial cost level is not sufficiently high or $z^0 < \bar{z}$ or $\underline{K} < d < \bar{K}$. In this case, if the regulator can commit that if the firm reduces costs by too much, he will not remove the firm's right to price discrimination, as in the suggested elimination rule, this commitment eliminates the possibility of the strategic behavior of the firm. Then, under credible commitment the resulting outcome will be $\tilde{W}(z^*)$ rather than $\tilde{W}(\bar{z})$, since the firm chooses its optimal investment level when he can discriminate. Of course, $\tilde{W}(z^*)$ is greater than $\tilde{W}(\bar{z})$ so that the regulator can improve the social welfare under commitment. Yet, this outcome is the second-best in that after the firm chooses the optimal investment level, z^*, if the regulator ex post regulates price discrimination opportunistically, then the regulator can achieve the first-best outcome, $\bar{W}(z^*)$, which is larger than $\tilde{W}(z^*)$. Knowing this possibility, however, the firm would not choose z^* under the suggested elimination rule, and thus the second-best rule may be not workable. Thus, when the regulator is unable to commit credibly to the whole game, the firm may act opportunistically to take advantage of sunk investments. This analysis implies that the multiperiod game outcome depends on the regulator's ability to commitment.[6] This is so because when the regulator and the firm make decisions in a multiperiod game situation, the set of policies the regulator is able to implement is restricted by its opportunism and by the consequent opportunism of the firm.

In conclusion, an important factor affecting the efficiency of the elimination of

[6] Commitment refers to the ability of the regulator to specify credible policies for each future period at the beginning of the regulatory horizon. For a discussion on the commitment in regulatory mechanisms, see Joskow and Schmalensee(1986) and Baron(1991).

price discrimination is the regulator's ability to commit credibly to the whole game. As I have shown, if credible commitment can be made, the second-best framework presented in the above analysis provides the basis for the evaluation. If credible commitments cannot be made, however, the cause of that inability must be assessed. If it is due to the policies of the regulator, then the consequences are attributable to the efficiency of regulation so that the other second-best rule should be considered. If, however, the source of the inability to make credible commitments is due to other factors, such as opportunism by a

legislature or politics, then its consequences should be evaluated separately.

V. CONCLUDING REMARKS

This article has investigated the welfare consequences of the elimination of price discrimination and has indicated the strategic incentive of R&D.[7] In particular, it has shown that discrimination regulation based on the static analysis may mislead efficient policy, and discrimination regulation aimed at preventing welfare-reducing price discrimination might induce the monopolist to invest a lower R&D strategically against the regulator and could result in a final outcome that is socially suboptimal compared to the case of no regulation. Therefore, standard policy recommendations on the regulation of price discrimination based on the static model is fundamentally limited since it can be subgame rational against the actions of the monopolist. In a dynamic model, it has also pointed out that the monopolist has the first-mover advantage over the second-moving regulator and thus the ex post regulatory incentives generally deviate from ex ante incentives. On balance, the most important way of achieving an efficient regulatory policy is by considering the firm's opportunistic behaviors and the regulator's possibility of commitment when the second-best regulation is imposed on the specific theme.

This study supports that although economic analysis reveals that there are some cases in which prohibiting price discrimination is socially beneficial, there

outcome depends on the market condition, such as demands and cost conditions, the ability to commit, information, and the degree of differences between the social incentives and private incentives.

Finally, the robustness of the results needs to be tested under more general conditions. It is also important to verify whether the results still hold with composite regulations such as price level regulation or rate-of-return regulation for public utilities. These rather challenging issues are left for future research.

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