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EFFECTS OF MINIMUM QUALITY STANDARD UNDER HORIZONTAL PRODUCT DIFFERENTIATION

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This paper examines the effects of Minimum Quality Standard when the products concerned are differentiated horizontally as well as vertically. The effects critically depend on the nature of strategic competition between firms through quality choices. In particular, it is shown that some firm might decrease its quality level in response to the regulation.

JEL Classification: L13, L15
Keywords: Minimum Quality Standard, Horizontal Differentiation, Strategic Interaction

I. INTRODUCTION

Regulations have been imposed on firms by government for various reasons. Externalities are known to be one of the important causes for regulation. The government would like car manufacturers to produce fuel-efficient cars to reduce carbon dioxide emissions and dependency on foreign oil, nevertheless, there might not be enough incentives for car manufacturers. Safety products such as cyclists' helmets and fire alarms provide with a similar motivation for regulation the government that might find the market provision of qualities to be insufficient. It seems, therefore, that often the government's objective of minimum quality standard(MQS) would be to raise the qualities that are actually consumed, and that the adoption of MQS is not necessarily related to consumers' ability to observe quality prior to purchase as argued by several authors. In Leland(1979) and Shapiro(1983), sellers' qualities are not known to buyers while a seller can not distinguish consumer types in Besanko, Donnenfeld and White(1988, hereafter BDW). Ronnen(1991) looked at a complete information model to derive different results. These analyses were carried out in various frameworks. On the supply

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side, Leland and Shapiro looked at the problem under the market structure of perfect competition. BDW considered a monopolist while Ronnen investigated an oligopolistic market. On the demand side, most work dealt with vertical differentiation only. Accordingly, these authors derived different implications. Shapiro and BDW showed that those consumers who purchase qualities in excess of the standard in the absence of regulation will not change their quality selections in response to the standard and, furthermore, some consumers might no longer purchase the product as a result of the regulation because the imposition of the standard may lead to an increase in prices. On the other hand, by using the Shaked and Sutton(1982)'s model, Ronnen demonstrated that when production involves fixed costs, an appropriately chosen standard will actually increase consumers' participation and will cause all participating consumers to purchase higher qualities. Ronnen's analysis was based upon the motivation for firms to relax price competition through product differentiation.

Every product has its own characteristics (i.e. products are not homogeneous) and consumers have different tastes over the characteristics. In other words, consumers are differentiated *horizontally* as well as vertically. In this paper, we look at horizontally differentiated consumers with quality considerations at the same time. It is shown that it is crucial whether firms' quality choices are strategic substitutes or complements in analyzing the changes in qualities and profits of each firm in response to MQS. Interesting results are derived when the situation is asymmetric, for example, costs of quality production differ across firms.

In the next section, the model is set up. In section 3, a symmetric case is considered as a benchmark, followed by an asymmetric case in section 4. Section 5 concludes.

Ⅱ. THE MODEL

We consider two firms which produce differentiated products with some level of quality. Each firm offers only one quality and faces the costs of developing the technology that enables the provision of quality q.[1] These costs, $C_i(q_i)$, are assumed to satisfy the following assumptions: $C_i'(q_i)>0$, $C_i''(q_i)>0$ for all feasible qualities $q_i \in [0, \infty]$. For the sake of analysis, we also assume that there are no unit production costs. On the demand side, it is assumed that each firm faces its demand function,

$$x_i = a_i - p_i + s \cdot p_j + v \cdot q_i - w \cdot q_j \quad (i \neq j \text{ and } i, j = 1, 2)$$

where x_i denotes the output, p_i the price, q_i the quality of firm i and

[1] This kind of quality is of public nature in the sense that, once it is produced, it applies to all outputs supplied by the firm.

$0<s<1,\ 0<w<v$.[2]

The first part of the demand, $(a_i - p_i + s \cdot p_j)$, is a usual form for a horizontally differentiated market. The remaining part, $(v \cdot q_i - w \cdot q_j)$, describes interaction between firms through qualities. An increase in firm i's quality raises i's demand by a larger amount than it reduces j's demand, which captures new consumers who get to purchase this product as well as diversion of consumers from firm j to firm i.

The competition between firms takes place in two stages. At each stage, the firms make their decisions simultaneously. The first-stage decisions become observable before the second stage starts. At the first stage, each firm decides how much to invest in quality development. Price competition occurs at the second stage. We look for a subgame perfect equilibrium. The two-stage modeling captures the notion that a firm can change its price almost instantaneously, whereas technological changes take a nontrivial amount of time. Consumers are price and quality takers.

The equilibrium is solved in two steps. First, we find the second-stage price equilibrium. At the stage two, firm i's problem is

$$\max_{p_i} \ \pi_i = p_i x_i - C_i(q_i) = p_i(a_i - p_i + sp_j + vq_i - wq_j) - C_i(q_i).$$

The first-order condition is

$(a_i + vq_i - wq_j) - 2p_i^e + sp_j^e = 0$ $(i \neq j$ and $i, j = 1, 2)$ where p_i^e and p_j^e denote secondstage equilibrium prices.[3]

The second-stage price equilibrium is

$$p_i^e(q_1, q_2) = \frac{1}{4-s^2}\{2(a_i + vq_i - wq_j) + s(a_j + vq_j - wq_i)\} \quad (i \neq j\ i, j = 1, 2). \tag{1}$$

As is well known, when the products are horizontally differentiated, the two firms' prices are strategic complements, which implies that the reaction curves are upward-sloping.[4] When firm i's quality is increased, its price also rises : $\frac{\partial p_i^e(q_1, q_2)}{\partial q_i} = \frac{2v - sw}{4-s^2} > 0$ since $0<s<1$ and $0<w<v$, and the change in firm j's price depends on the magnitudes of parameters s, v and w : $\frac{\partial p_j^e(q_1, q_2)}{\partial q_i} = \frac{sv - 2w}{4-s^2}$.

[2] This kind of demand functions can be obtained, if not linear, by the Hotelling's line model with quality considerations of a simple kind. A representative consumer model, also, can be shown to yield this form of linear demands. This is a very simple form of demands which, however, enables us to get nice and clear implications.

[3] The second-order conditions are satisfied since $\begin{pmatrix} -2 & s \\ s & -2 \end{pmatrix}$ is negative definite.

[4] The terminologies, strategic complements and substitutes, are defined in Bulow et al(1985).

At the first stage where each firm chooses how much to invest in quality, understanding that the second-stage price equilibrium is given as (1), firm i's problem is

$$\max_{q_i} \quad \pi_i(q_1, q_2) = p_i^e(q_1, q_2) \cdot x_i^e(q_1, q_2) - C_i(q_i)$$

where $x_i^e(q_1, q_2)$ denotes firm i's second-stage equilibrium output.
The first-order condition is

$$2p_i(q_1^e, q_2^e)\frac{2v - ws}{4 - s^2} - C_i(q_i^e) = 0 \quad (i = 1, 2)$$

where q_i^e denotes first-stage equilibrium qualities.[5] (2)

Equation (2) yields the solution under no regulation. Firm i's best response function is implicitly defined by (2) from which the slope of the best response function can be derived as

$$\frac{dq_j}{dq_i} = -\frac{\dfrac{\partial^2 \pi_i(q_1, q_2)}{\partial q_i^2}}{\dfrac{\partial^2 \pi_i(q_1, q_2)}{\partial q_i \partial q_j}} = -\frac{\dfrac{\partial^2 \pi_i(q_1, q_2)}{\partial q_i^2}}{2\dfrac{(2v - ws)(sv - 2w)}{4 - s^2}}.$$

Therefore,

$$Sign\left[\frac{dq_j}{dq_i}\right] = Sign\left[\frac{\partial^2 \pi_i(q_1, q_2)}{\partial q_i \partial q_j}\right] = Sign\,[sv - 2w]. \tag{3}$$

(3) implies that when $(sv - 2w)$ is positive (negative), the two firms' qualities are strategic complements (strategic substitutes). When qualities are strategic complements, firm i's increase in quality induces firm j to raise its quality level, which is more likely, the higher is s. The parameter s represents substitutability between the two goods. In other words, higher s means that the two goods are less differentiated, which says that, at the second-stage competition, given the change in the price of one firm, the other firm responds more sensitively to the change. When firm i increases the quality level to raise its price, therefore, firm j's response would be more favorable with higher substitutability, making it more likely that firm j's marginal profit improves to increase j's quality. Similarly, higher v or lower w, given firm i's increase in quality, makes it more likely to induce the increase of the firm j's price so that firm j's marginal profitability goes up. In sum, at the first stage, when

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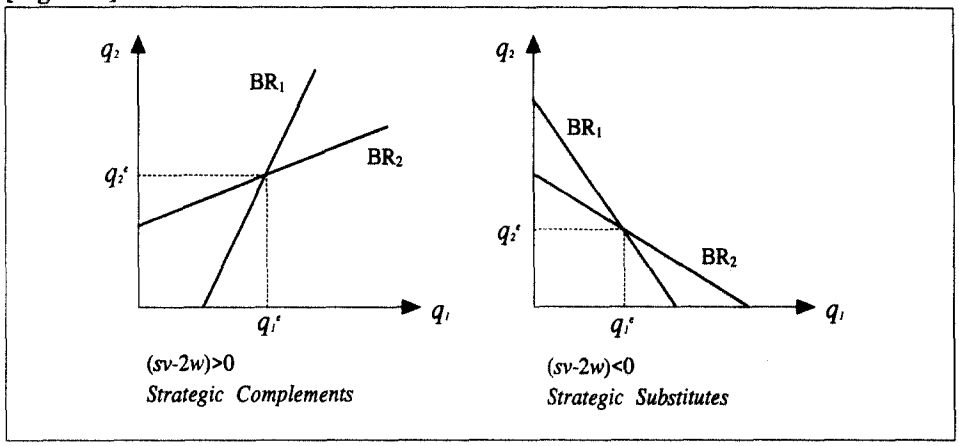
5 $\begin{pmatrix} 2(2v - ws)^2 - C_i''(q_i)(4 - s^2)^2 & 2(2v - ws)(sv - 2w) \\ 2(2v - ws)(sv - 2w) & 2(2v - ws)^2 - C_j''(q_j)(4 - s^2)^2 \end{pmatrix}$ is assumed to be negative semi-definite.

[Figure 1]



$(sv-2w)$ is positive (negative), we have upward-sloping (downward-sloping) reaction curves. Figure 1 shows the two cases.

We have characterized the unregulated market equilibrium so far. The following two sections analyses the regulation by MQS imposed on the firms.

Ⅲ. A SYMMETRIC CASE

A symmetric case is considered as a benchmark. Let us assume that $a_i = a_j$ and $C_i(\cdot) = C_j(\cdot) C(\cdot)$. MQS requires each firm to choose a quality level at least as high as q_m. Firm i's problem, at the first stage, is

$$\max_{q_i} \pi_i(q_1, q_2) = p_i^e(q_1, q_2) \cdot x_i^e(q_1, q_2) - C_i(q_i) \text{ subject to } q_i \geq q_m. \quad (4)$$

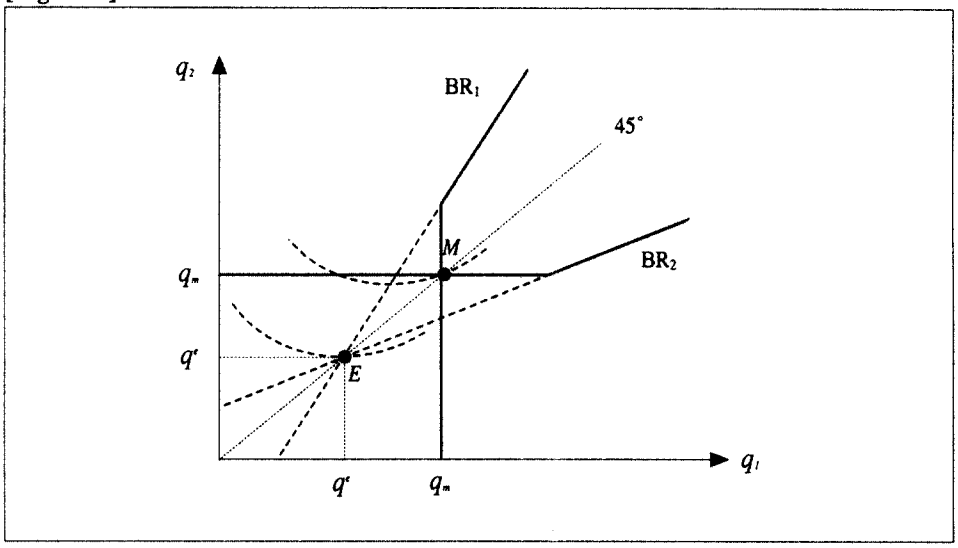
Note that $\frac{\partial \pi_i(q_1, q_2)}{\partial q_j} = 2p_i \frac{sv-2w}{4-s^2}$. (5)

Since we have a symmetry, $q_1^e = q_2^e \equiv q^e$. It would be more interesting to assume that $q_m \geq q^e$.

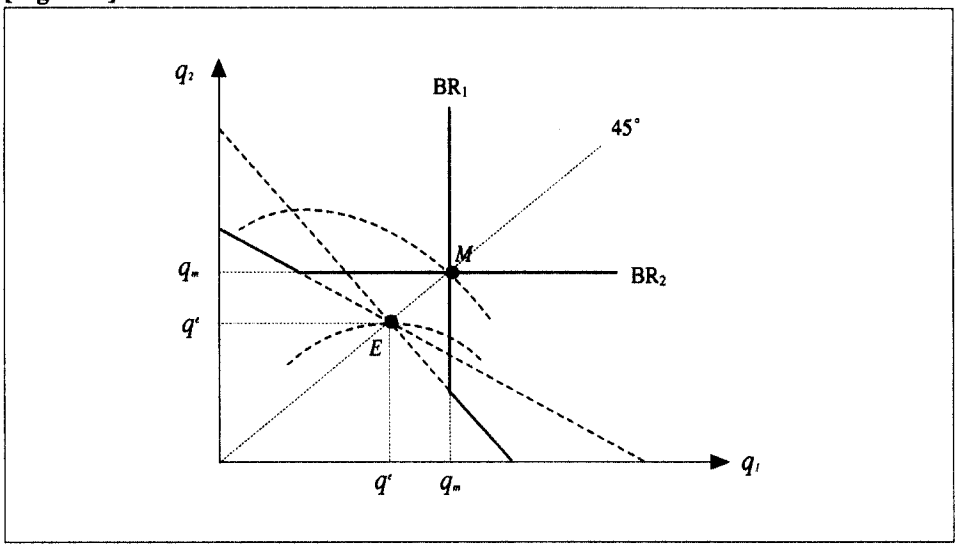
Rather than trying to solve the problem (4), we can graph it out to get the qualitative solution as in figure 2 and 3. The first-stage equilibrium without MQS is given at E and MQS requires $q_i \geq q_m (i = 1, 2)$. Now, the new reaction curves are shown by the solid lines and the new equilibrium occurs at M. The horizontal and vertical parts of the reaction curves reflect that firms are not allowed to choose a quality level below q_m. The quality levels of both firms rise to q_m as a result of MQS.

When the firms' qualities are strategic complements, (5) (i.e. $\partial \pi_i / \partial q_j > 0$) gives the shape of isoprofit curves as drawn in the figure 2 and we can see that both

[Figure 2]



[Figure 3]



firms' profits may improve. When qualities are strategic complements, MQS may act to yield a more cooperative outcome and firms are willing to accept the regulation in this case.[6] On the other hand, when the firms' qualities are strategic substitutes, (5) implies $\partial \pi_i / \partial q_j < 0$. In this case, the imposition of MQS

[6] In other words, MQS acts as a facilitating device for firms. See Salop(1986) for facilitating devices.

lowers firms' profits and there is an incentive for the firms to violate MQS. Therefore, the nature of competition at the first stage critically affects firms' position toward the imposition of MQS.[7]

Ⅳ. AN ASYMMETRIC CASE

Asymmetry may be a more natural phenomenon than is symmetry. Asymmetry might come from various sources such as differences in demand conditions, cost conditions etc. In this section, we investigate an asymmetry that results from different cost conditions, which brings qualitative modifications on the effects of MQS. We keep the assumption that $a_i = a_j = a$. Let us assume that, for simplicity, $C_i(q_i) = c_i q_i^2$ $(i = 1, 2)$ where $c_1 > c_2$.[8] Firm 1 has higher total and marginal costs.

4.1 Unregulated Equilibrium

To be compared with regulation, an equilibrium without MQS is considered, first. The second-stage equilibrium is not affected by this asymmetry and characterized by equation (1). Now, firm i's first-stage problem under no MQS is

$$\max_{q_i} \quad \pi_i(q_1, q_2) = p_i(q_1, q_2) \cdot x_i(q_1, q_2) - c_i q_i^2 \quad (i = 1, 2).$$

It can be shown that

$$q_i^e = (2+s)a \frac{(sv-2w) - \left\{(2v-sw) - c_j \frac{(4-s^2)^2}{2v-sw}\right\}}{\left\{(2v-sw) - c_i \frac{(4-s^2)^2}{2v-sw}\right\}\left\{(2v-sw) - c_j \frac{(4-s^2)^2}{2v-sw}\right\} - (sv-2w)^2}$$
$$i \neq j$$
$$i, j = 1, 2$$

which tells that $q_1^e < q_2^e$.[9] Equation (1) can be rewritten as

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[7] It can be shown that, upon the imposition of MQS, prices and outputs by the firms increase. Even if prices are higher under MQS, the fact that the higher qualities are supplied and more consumers are induced to participate in this market suggests that MQS plays a positive impact on consumers.

[8] The analysis is equally good even without this assumption which, additionally, gets us a clear and closed form solution.

[9] $\left\{(2v-sw) - c_i \frac{(4-s^2)^2}{2v-sw}\right\}\left\{(2v-sw) - c_j \frac{(4-s^2)^2}{2v-sw}\right\} - (sv-2w)^2 > 0$ is implied by stability conditions.

$$p_i^e(q_1, q_2) = \frac{1}{4-s^2}\{(2+s)a + (2v-sw)q_i + (sv-2w)q_j\} \quad (1)'$$

Note that $(2v-sw)>0>(sv-2w)$ and $|2v-sw|>|sv-2w|$. Therefore, $p_1^e - p_2^e = \frac{(2-s)(v+w)}{4-s^2}(q_1^e - q_2^e)<0$ which means that $p_1^e < p_2^e$. Similarly, it can be verified that $x_1^e < x_2^e$. In sum, the unregulated equilibrium where $c_1 > c_2$, can be described as $[q_1^e < q_2^e,\ p_1^e < p_2^e,\ x_1^e < x_2^e]$.

4.2 Regulated Equilibrium

Now, let us suppose that MQS requires each firm to choose a quality level at least as high as q_m. Then, the first-stage problem for firm i becomes

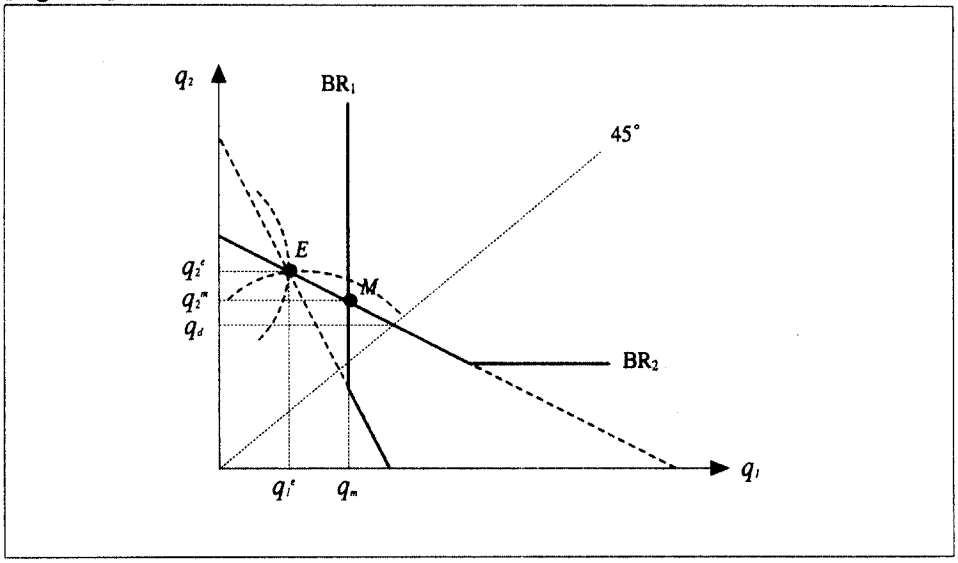
$$\max_{q_i} \pi_i(q_1, q_2) = p_i^e(q_1, q_2) \cdot x_i^e(q_1, q_2) - c_i q_i^2 \text{ subject to } q_i \geq q_m. \quad (i=1, 2)$$

Once again, rather than using kuhn-tucker conditions, we turn to figures to analyze qualitative features of this problem. According to the level of the standard q_m, we have outcomes of a different nature which stem from the *strategic interactions* between the firms.

A. Strategic substitutes: $(sv-2w)<0$

We look at three cases of q_m which yield equilibria with different properties.

[Figure 4]



Let q_d be defined by $p_2(q_d, q_d)\frac{2v-sw}{4-s^2} = c_2 q_d$. Therefore, $q_1^e < q_d < q_2^e$.

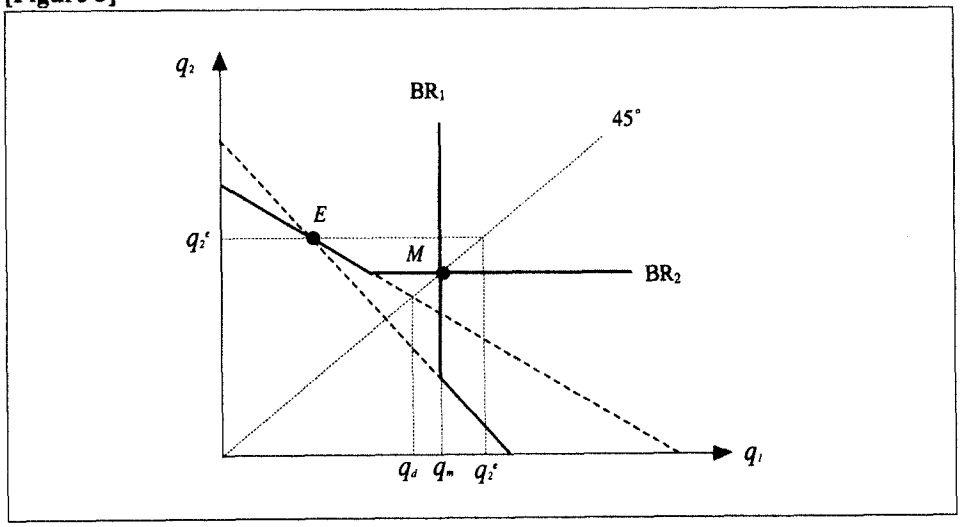
[case A-1] $q_1^e \leq q_m < q_d$

In the figure 4, q_m is set such that $q_m \in [q_1^e, q_d)$. The new reaction curves are depicted as solid lines. The new equilibrium occurs at M where $q_1^m = q_m$ and $q_2^m < q_2^e$. q_2^m is obtained by $p_2(q_m, q_2^m)\frac{2v-sw}{4-s^2} = c_2 q_2^m$. Compared with no regulation, the high-quality firm *lowers* its quality and the low-quality firm is driven up to raise its quality to the standard. MQS does not constrain firm 2's choice made under no MQS since $q_2^e > q_m$. Strategic considerations induce firm 2 to reduce its quality level.[10]

It has never been reported in the literature that the firm which produces a level of quality in excess of the standard lowers its quality level in response to MQS. In the models of Leland(1979) and Shapiro(1983), firms are price takers with qualities given exogenously under a perfectly competitive market, which means that the firms do not have any room for strategic interactions through either prices or qualities, while BDW(1988) dealt with a monopolist. On the other hand, in Ronnen(1990), the high-quality firm was shown to increase its quality even further in response to MQS to relax price competition at the second stage.

The low-quality firm becomes strictly better off and the high-quality firm may

[Figure 5]



[10] It should be noted, nevertheless, that even at the new equilibrium, the previously high-quality firm still produces higher qualities, i.e. $q_1^m < q_2^m$.

be worse off,[11] which we could not observe in the symmetric case with strategic substitutes. In this model, it is the *strategic interaction* between the firms through qualities that drives the outcome. The superiority of a firm's technology reveals itself as the high level of quality in the market. The fact that the qualities are strategic substitutes, implies that an increase in the quality level of one firm benefits the firm, inducing the other firm to reduce its quality level. The equilibrium action, however, prevents the firms from committing to a higher quality level *credibly*. The introduction of MQS offers the low-quality firm an official and credible mechanism to commit to the higher quality level, thereby doing a favor to the low-quality firm with the less efficient technology. On the other hand, the advantage of the high-quality firm with the more efficient technology is undermined by MQS that deteriorates the firm's profitability.[12]

[case A-2] $q_d \leq q_m < q_2^e$

In the figure 5, the new equilibrium is attained at M where $q_1^e < q_1^m = q_2^m = q_m < q_2^e$. The previously high-quality firm lowers its quality and the previously low-quality firm raises its quality such that they produce the same level of quality at the equilibrium. Even though q_m is not set too high (below q_2^e), i.e. the high-quality firm is not constrained by the imposition of MQS, MQS leads to the same level of quality chosen by both firms. The advantage of the firm which has the more efficient technology of quality production is offset by the introduction of MQS and firm 2 becomes strictly worse off. Firm 1 might be better off, depending on how high q_m is.

[case A-3] $q_m \geq q_2^e$

MQS is set so high that both firms' choices of qualities are constrained by the standard and there is no room for strategic interaction. The new equilibrium is entirely commanded by MQS so that we have an outcome which is similar to that of the symmetric case with strategic substitutes and both firms are strictly worse off.

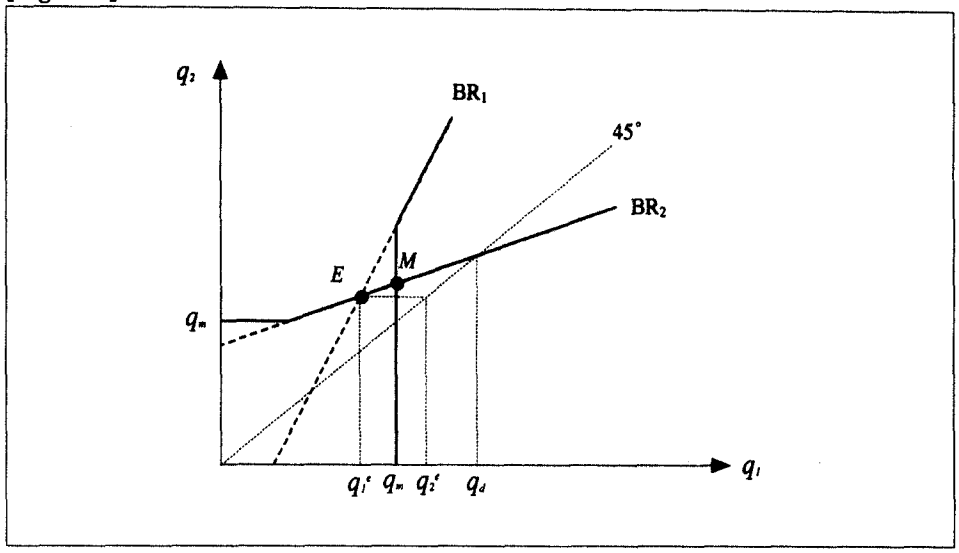
B. Strategic complements: $(sv - 2w) > 0$

q_d is defined as before, i.e. $p_2(q_d, q_d) \frac{2v - sw}{4 - s^2} = c_2 q_d$. Therefore, $q_1^e < q_2^e < q_d$.

[11] Similar results were reported in Ronnen(1990).

[12] It can be shown that, in all cases of strategic substitutes, the low-quality firm's price and output increase while the high-quality firm's price and output decrease, however, industry output increases as a result of MQS.

[Figure 6]



[case B-1] $q_1^e \leq q_m < q_d$

In the figure 6, the new equilibrium arises at M where $q_1^m = q_m$ and $q_2^m > q_2^e$. q_2^m is obtained by $p_2(q_m, q_2^m) \frac{2v - sw}{4 - s^2} = c_2 q_2^m$. The fact that the qualities are strategic complements, implies that, when one firm increases its quality, the other responds favorably by raising its own quality to improve its profits. When firm 1's quality is driven up to q_m by MQS, firm 2's strategic response induces firm 2 to raise its quality.[13]

Upon the imposition of MQS, the high-quality firm becomes strictly better off and the low-quality firm may be better off. As in the symmetric case, MQS may act as a facilitating device and be accepted willingly by the firms.[14]

[case B-2] $q_m \geq q_d$

This corresponds to [case A-3] of strategic substitutes. MQS requires too high a quality level that there is no room for strategic interaction and both firms' choices are totally commanded by the regulation. The nature of the new equilibrium is very similar to that of the symmetric case with strategic complements.

[13] The quality gap, however, is smaller than that under no MQS. In this case, even when MQS is set above the high quality in the market, i.e. $q_2^e < q_m (< q_d)$, the high quality firm, still, has room for strategic responses and pushes the quality level up above $q_m (q_1^m > q_m)$.

[14] It can be verified that, in all cases of strategic complements, both firms' prices and outputs increase.

V. CONCLUSION

This paper analyzes the effects of MQS when the products are horizontally differentiated and suggested other possibilities than those obtained in previous works that did not take horizontal differentiation into account. The results derived in this paper were shown to critically depend on the *nature of strategic competition* through qualities. In the symmetric case, this nature of competition determines the firms' position toward the regulation. In the asymmetric case, MQS offers an official mechanism for the less efficient firm of lower quality to *credibly commit* to a higher quality level and the more efficient firm of higher quality responds *strategically* to the commitment. In particular, it is shown that the high-quality firm in the absence of the regulation might decrease its quality level in response of the regulation. Obviously, a market has other characteristics than horizontal differentiation. What outcomes prevail in a market by the introduction of MQS, therefore, should be stated carefully after the characteristics of a specific market of interest is examined thoroughly.

REFERENCES

Besanko. D., Donnenfeld, S. and L. J. White(1988), "The Mulitproduct Firm, Quality Choice, and Regulation," Journal of Industrial Economics, vol. 3, 533-557.

Bulow, J., Geanakoplos J. and P. Klemperer(1985), "Multi-Market Oligopoly: Strategic Substitutes and Complements," Journal of Political Economy, vol. 93, 488-511.

Constantatos, C. and P. Stylianos(1998), "Minimum Quality Standard, Entry and the Timing of the Quality Decision," Journal of Regulatory Economics, vol.13, 47-58.

Crampes, C. and A. Hollander(1995), "Duopoly and Quality Standards," European Economic Review, vol. 39, 71-82.

Greenhut, M. L., Norman, G. and C. Hung(1987), The Economics of Imperfect Competition: a Spatial Approach, New York:Combridge University Press.

Hotelling, H.(1929), "Stability in Competition," Economic Journal, vol. 39, 41-57.

Leland, H. E.(1979), "Quacks, Lemons, and Licensing: A Theory of Minimum Quality Standards," Journal of Political Economy, vol. 87, 1328-1346.

Mussa, M. and S. Rosen(1978), "Monopoly and Product Quality," Journal of Economic Theory, vol. 18, 301-317.

Ronnen, U.(1991), "Minimum Quality Standards, Fixed Costs and Competition," Rand Journal of Economics, vol. 22, 490-504.

Salop, S.(1986), "Practices that (Credibly) Facilitate Oligopoly Coordination," In J. Stiglitz and F. Mathewson eds., New Developments in the Analysis of Market Structure, Cambridge:MIT Press.

Shaked, A. and J. Sutton(1982), "Relaxing Price Competition through Product Differentiation," Review of Economic Studies, vol. 49, 3-14.

Shapiro, C.(1983), "Premiums for High Quality Products as Returns to Reputations," Quarterly Journal of Economics, vol. 98, 659-679.

Spence, A. M.(1975), "Monopoly, Quality and Regulation," Bell Journal of Economics, vol. 6, 417-429.