Are "innocuous" Minimum Quality Standards really innocuous?

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Abstract

The present note shows that "innocuous" Minimum Quality Standards, namely standards that are below the lowest quality level observed in the market, may have effects on equilibrium outcomes. In particular this is true in a duopoly where one high quality firm invests in R&D to lower its cost of quality improvements. A Standard that is below, but close to, the lowest quality observed in the market reduces the incentive to invest by the quality leading firm.

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1. Introduction

The role of Minimum Quality Standards (MQS) as a regulatory instrument has received so far little attention in the theory of oligopoly competition. Starting with Ronnen (1991), however, a small number of papers (see, for instance, Crampes and Hollander 1995, Scarpa 1998) have analyzed the effects of MQS in situations where firms produce, before the introduction of the standard, different qualities of a product. Then, usually, the analysis is confined to standards that lie between the lowest and the highest quality in the market and that force low quality firms to a higher quality. The models in the literature almost always build upon the vertical differentiation models of Gabszewicz and Thisse (1979) and Shaked and Sutton (1981) So far, in no place in the literature, has even been mentioned the possibility that standards that lie below the lowest quality in the market may have any impact on the industry outcome. In what follows I shall term these standards as "innocuous standards", due to their unintrusive appearance, although indeed I shall show precisely that they may not be innocuous at all. In particular, in a duopoly, if the leading firm is assumed to be able to invest resources in cost reducing technologies, then an innocuous MQS may lead to lower investment of this sort than it would result in an unregulated industry. The example I use is a variant of Garella (2003) with a duopoly where firms produce products that are differentiated both, horizontally and vertically. Furthermore, firms differ in their ability to improve upon the vertical dimension of their products quality, so that at an unregulated equilibrium the two qualities are not identical. In a different context, of a political economy game, it has been stressed the role of firms acting as quality leaders in industries (Lutz, Lion and Maxwell (2000). In the present paper, by contrast, quality leaders do not play a game with the regulatory authorities, but have the role of spurring quality innovation[1]. The quality leader, in particular, is assumed to be able to reduce the fixed cost of quality, while the other firm is not able to do so. This is an extreme case of asymmetry in R&D abilities. A much more general case would be obtained if both firms could invest in R&D albeit with different abilities. Unfortunately, this case proves algebraically irksome and would become tractable only at the cost of special assumptions on the relation between R&D investment and cost reduction (thereby loosing in generality).

The model below is a modified Hotelling (1929) linear city of unit length, where two firms are located at the two opposite endpoints of the spectrum of horizontal characteristics. The vertical dimension is represented by a one-to-one relation between a parameter, θ_i, and the gross consumers' surplus from the purchase of product i. The basic game played by the two firms in the absence of regulation and of investments in new technologies is the following. At the first stage both firms choose their qualities. At the second and final stage they select prices. This game is analyzed only in order to have the background on which to sketch the main argument and it contains no new insights. When the possibility of introducing regulation is added to the set-up, a regulator is called to decide whether to use or not a MQS, based upon the observed qualities, as after an investigation by experts. If the regulator introduces a MQS then both firms must abide and cannot lower their quality below the standard. The modified game played is the following. Firms inherit their qualities from the situation with no R&D investment and no regulation. At stage 0, the regulator's choice is restricted to a binary choice, for the sake of the argument: it can either set a MQS equal to the lowest produced quality (innocuous standard) or no MQS at all. At the stage 1 Firm 1 invests in R&D, while firm 2 invests zero. Then the second and third stages parallel those of the basic game. A comparison between the decision to leave the industry with no standard and that of introducing an innocuous standard reveals that with no standard the investment in R&D by the high quality firm is higher than with the standard.

2. Unregulated industry equilibrium

There are two firms, indexed 1 and 2. Products are horizontally differentiated and, by hypothesis, the two firms are located at the opposite endpoints of a Hotelling linear city (Hotelling 1929). Each product embodies a vertical quality dimension, θ, which is costly to obtain. Firms are asymmetric, in the sense that firm 1 is assumed to be more efficient than firm 2 in improving the vertical dimension of its quality. The production cost for the quantity of output q_1 for firm 1 is $C_1(q_1, \theta_1) = cq_1 + \theta_1^2/2$, where $c > 0$ is a constant marginal cost independent of θ. The cost for firm 2 is $C_2(q_2, \theta_2) = cq_2 + \alpha\theta_2^2/2$, where $\alpha > 1$ is a cost parameter for firm 2. The quality θ

[1] Other policy-oriented papers are Ecchia and Lambertini (1997) and Boom (1995).

only affects fixed costs.

Consumers have an address $x \in [0,1]$, and the distribution of consumers is uniform with unit density. When buying at location $i-1$, for $i = 1,2$, a consumer obtains a lower utility than if it was buying her own preferred brand. This transportation cost is $t\,|x-(i-1)|$, where $|\cdot|$ denotes absolute value and t is a parameter. Then, given the prices p_1 and p_2, the utility derived from consumption of one unit good 1 and 2 is

$$u_i(x,\theta_i) = v + \theta_i - t\,|x-(i-1)| - p_i, \text{ for } i = 1,2. \tag{2.1}$$

The basic game without regulation and without R&D opportunities is a two stage game. At the first stage firms simultaneously choose their quality levels θ_1 and θ_2; at the second and final stage firms simultaneously choose their prices. It is assumed that t is high enough, or

Assumption 1. $t > 2/9$.

Furthermore, it shall be assumed that v is large enough so that the market is always entirely served.

Assumption 2. $v > 2t + c$.

The address, $\tilde{x}$, of the consumer for which $u_1(x,\theta_1) = u_2(x,\theta_2)$ holds is:

$$\tilde{x}(p_1,p_2;\theta_1,\theta_2) = \max\left\{0, \min\left\{1, \frac{1}{2} + \frac{(p_2-p_1)+(\theta_1-\theta_2)}{2t}\right\}\right\}. \tag{2.2}$$

Accordingly, the demand functions at the second stage of the game are defined as $D_1(p_1,p_2;\theta_1,\theta_2) = \tilde{x}$ and $D_2(p_1,p_2;\theta_1,\theta_2) = 1-\tilde{x}$. Then, when $\tilde{x}(p_1,p_2;\theta_1,\theta_2)$ is not equal to either 0 or 1, the profit maximization problem for firm 1 at the second stage can be written as

$$\max_{p_1}(p_1-c)\left[\frac{1}{2} + \frac{(p_2-p_1)+(\theta_1-\theta_2)}{2t}\right] - \frac{\theta_1^2}{2}.$$

This provides the best reply function for firm 1 and 2 at the second stage

$$\check{p}_i(p_j) = \max\left[\frac{p_j}{2} + \frac{(\theta_i-\theta_j)+t+c}{2}, 0\right], \text{ for } i,j = 1,2\ ;\ i \neq j. \tag{2.3}$$

One can show that if $\theta_2 \leq \theta_1 - 3(t+c) \equiv \theta_2^0$, then firm 2 is priced out of the market and the equilibrium prices are $p_2 = 0$, and $p_1 = p_1^m$, where p_1^m is the monopoly price for firm 1. Similarly, if the quality of firm 1 is too low this firm would be priced out[2]. We shall exclude that either firm uses a quality so low as to be priced out, so that the analysis of the case where $\theta_2 \leq \theta_2^0$ (or $\theta_1 \leq \theta_1^0$) shall not be further pursued. The study of a game where either firm can use a high quality policy so as to gain monopoly power is out of the scope of the present work.

Then, it easy to calculate the Nash equilibrium prices, p_1^* and p_2^*, at the second stage, as:

$$p_i^*(\theta_1,\theta_2) = t + c + (-1)^{i-1}\left[(\theta_1-\theta_2)/3\right], \text{ for } i = 1,2. \tag{2.4}$$

[2] Namely if θ_1 is lower or equal to $\theta_2 - 3(t+c) \equiv \theta_1^0$.

Notice that $p_1^*(\theta_1,\theta_2) - p_2^*(\theta_1,\theta_2) = (2/3)(\theta_1 - \theta_2)$ is positive if the quality of firm 1 is higher than that of firm 2.

Now, solving[3] for the values of θ_1 and θ_2 at the first stage one gets the following best reply functions in terms of qualities,

$$\theta_1(\theta_2) = \frac{3t - \theta_2}{9t - 1}, \qquad \theta_2(\theta_1) = \max\left\{\frac{3t - \theta_1}{9\alpha t - 1}, \theta_1 - 3(t + c)\right\}. \tag{2.5}$$

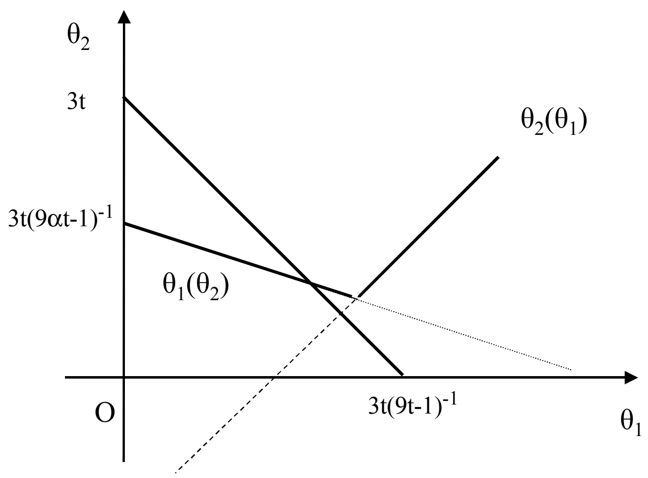

Figure 1: quality best replies

Vertical qualities are strategic substitutes. Note that firm 2 cannot choose a quality lower than $\theta_1 - 3(t + c)$ otherwise it is priced out of the market at the second stage, this explains the V-shape of its best reply function (obviously also the best

[3]The equilibrium demand functions are $D_i^*(\theta_1,\theta_2) = (1/2) + (-1)^{(i-1)}\,[(\theta_1 - \theta_2)/(6t)]$, for $i = 1, 2$. The reduced form profits, that shall be used to solve the first stage of the game, are $\pi_i^*(\theta_1,\theta_2) = \frac{\left[3t+(-1)^{(i-1)}(\theta_1-\theta_2)\right]^2}{18t} - \frac{(\theta_1)}{2}^2$.

reply of firm 1 is V-shaped if α is not too large, but the best replies are defined so as so as to simply the exposition). If the best reply functions cross where they are both downward sloping then both firms shall enjoy a positive market share at equilibrium, with positive prices (irrespective of profits). One obtains, then, the Nash equilibrium values for the qualities of the two firms as,

$$\theta_1^* = \frac{9\alpha t - 2}{3(9\alpha t - \alpha - 1)}; \quad \theta_2^* = \frac{9t - 2}{3(9\alpha t - \alpha - 1)}. \tag{2.6}$$

The assumptions that $t > 2/9$ (A.1) and $\alpha > 1$ together imply that $\theta_2^* > 0$ holds[4]. Prices and demands at equilibrium, for $i = 1, 2$, are

$$p_i^* = t + c + (-1)^{i-1} \left(\frac{t(\alpha - 1)}{9\alpha t - \alpha - 1} \right), \qquad D_i^* = \frac{1}{2} + (-1)^{i-1} \left(\frac{\alpha - 1}{2\,(9\alpha t - \alpha - 1)} \right) \tag{2.7}$$

It is possible that if t is too high, then the intervals defining the market shares of the two firms do not touch and firms behave as separate monopolists. To exclude this possibility it is assumed that even for consumer with address $x = 0$ one has $u_2 > 0$ at an equilibrium. This is true if the inequality $v + \theta_2^* - p_2^* > t$ holds, which is guaranteed by A.2, as it can be easily checked.

Further, it can be checked that $D_2^* > 0$ and that $p_2^* > 0$ for $t > 2/9$. Therefore, under the assumption that $t \geq 2/9$ the best reply function in qualities of the two firms cross where they are both downward sloping. The equilibrium demand for firm 2, which can also be written as $\alpha(9t - 2)/(9\alpha t - \alpha - 1)$, is positive for $\alpha > 1$.

The equilibrium profits for the unregulated industry are,

$$\pi_1^u = \left(\frac{9t - 1}{18} \right) \left(\frac{9\alpha t - 2}{9\alpha t - \alpha - 1} \right)^2 \text{ and } \pi_2^u = \alpha \left(\frac{9t - 1}{18} \right) \left(\frac{9t - 2}{9\alpha t - \alpha - 1} \right)^2 \tag{2.8}$$

Both profits are nonnegative and that of firm 1 is always larger than that of firm 2.

3. Innocuous Standards and Incentives to Invest

Given a historically determined equilibrium situation the regulator can set a Minimum Quality Standard, defined by the real number Θ. For the sake of the argument, the regulator's choice is assumed to be restricted such that either $\Theta = \theta_2^*$ (an "innocuous standard") or $\Theta = 0$, no standard. Note that under the assumptions 1, 2 and $\alpha > 1$, The regulator's decision is taken at stage "0" of the regulation game, given $\theta_2 = \theta_2^*$ as given by (2.6).

Suppose that the cost function of firm 1 can be modified by some R&D investment. At stage 1, of the regulation game, that is, firm 1 can invest the sum x, so as to reduce the cost of quality improvement. Firm 2 cannot invest, as a simplifying assumption.

[4] Note, again, that it is implicitly assumed that α is not so large as to allow monopolization by firm 1.

It shall be assumed in particular, $C_1(q, \theta_1, d) = cq + g(x)[\theta]^2/2 + x$. In other terms, investing $x \geq 0$ in money terms, provides a reduction in the fixed cost of producing quality θ according to the function $g(x)$, where: $g'(x) < 0$ and $g''(x) < 0$, for all $x \geq 0$, and $g(0) = 1$.

In terms of the reaction functions in **Figure 1** above, an increase in x leads to an outward rotation of the reaction function $\theta_1(\theta_2)$, with the point $(0, 3t)$ on the vertical axis, as a pivot.

Under no regulation, namely with $\Theta = 0$, the maximization problem of firm 1 at the quality choice stage is rewritten as

$$\max_{\theta_1} \frac{[3t + (\theta_1 - \theta_2)]^2}{18t} - g(x)\frac{[\theta_1]^2}{2} - x. \tag{3.1}$$

This leads to the following best reply function for firm 1

$$\theta_1 = \frac{3t - \theta_2}{9g(x)t - 1}. \tag{3.2}$$

This best reply is clearly increasing in x, given the assumptions on $g(x)$. Recalling that the best reply function of firm 2 is $\theta_2(\theta_1) = (3t - \theta_1)/(9\alpha t - 1)$, if there is no standard, the Nash solutions in terms of qualities, denoted by θ_i^0, are

$$\theta_1^0 = \frac{9\alpha t - 2}{3(9\alpha t g(x) - \alpha - g(x))} \text{ and } \theta_2^0 = \frac{9gt - 2}{3(9\alpha t g(x) - \alpha - g(x))}. \tag{3.3}$$

Notice that when $g = 1$, namely when $x = 0$, the values of θ_1^g and θ_2 coincide with θ_1^* and θ_2^* of section 2 above.

Without a standard, firm 2 would lower its quality[5] with respect to θ_2^u, that is, one obtains the inequality: $\theta_2^0 < \theta_2^u$, implying that a lower g leads to a lower value for θ_2 at equilibrium.

Analyzing now the choice of the R&D investment by firm 1, one can write the program for this firm as

$$\max_x \pi(x) = \frac{[3t + (\theta_1(x) - \theta_2)]^2}{18t} - g(x)\frac{[\theta_1(d)]^2}{2} - x. \tag{3.4}$$

It is apparent that the marginal net return to invest in a reduction in cost $g(x)$, decreases with θ_2. Therefore, since θ_2 is forced to remain at its pre-standard equilibrium level, firm 1 will invest less in R&D when a standard is imposed than without it.

Formally, one can state the following result.

Proposition 1. *Provided the function $\pi(x)$ is concave, in a game where a MQS equal to the lowest quality in the market prevails the level of cost-reducing R&D investment, x, by the high quality firm 1 is lower than in a game where there is no standard.*

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[5] This can be seen observing that $\frac{d\theta_2^0}{dg} = \frac{9\alpha t - 2}{3(9\alpha t g - \alpha - g)^2} > 0$ under the assumptions on t and α.

Proof: Let $\pi(x) = \left[3t + (\theta_1(x) - \theta_2^*)\right]^2 / (18t) - (g(x)/2)\left[\theta_1(x)\right]^2 - x$. Furthermore, let $\theta'(x)$ denote the derivative of $\theta_1(x)$ with respect to x. Note first that $\theta'(x)$ is positive for $x \geq 0$. Then the first order condition for a maximum of $\pi(x)$ is $\pi'(x) = 0$, where $\pi'(x) = \theta_1'(x)\left[(3t + \theta_1 - \theta_2^*)/(9t)\right] - g'(x)\left[\theta_1(x)\right]^2(1/2) - g(x)\theta_1'(x)$. The second order condition, under the hypothesis that $\pi(x)$ is concave, implies that $\pi''(x) < 0$ where $\pi''(x) = \dfrac{\theta_1''(x)}{9t}(3t + \theta_1 - \theta_2^*) + \dfrac{\left[\theta_1'(x)\right]^2}{9t} - g''(x)\frac{[\theta_1(x)]^2}{2} - 2g'(x)\theta_1'(x) - g(x)\theta_1''(x)$. Then, differentiating the first order condition with respect to θ_2^* and to x gives

$$\frac{dx}{d\theta_2^*} = \frac{\theta_1'(x)}{\pi''(x)} < 0, \text{ for } x \geq 0,$$

which completes the proof.

The incentive to invest for firm 1 is reduced if a MQS is introduced, this implies that regulation may become an obstacle to quality improvements that would have occurred over time by the leading firm. By continuity arguments, a MQS that lies slightly below the lowest quality level has the same effects.

4. Conclusion

The idea that Minimum Quality Standards that lie below the minimum produced quality bear effects on the industry outcome is the only issue of the present note. In particular, there is no clear indication here that a MQS be a "wrong" policy, since the optimal level of R&D from the social point of view is not discussed here. Such an analysis requires a more general model than what has been used above. The main result, therefore, has to be interpreted as a counter-example rather than as an attempt to derive general insights. More work is needed to assess the effects of MQS when R&D investments are available. This is a topic that may become more and more relevant as regulation in hi-tech and in information technology industries is increased.

REFERENCES

Crampes, C. and Hollander A. 1995, Duopoly and quality standards, *European Economic Review* 39, 71-82.

Boom, A., 1995, Asymmetric international minimum quality standards and vertical differentiation, *Journal of Industrial Economics* 43, 101-119.

Ecchia, G. and L. Lambertini, 1997. Minimum Quality Standards and Collusion, *Journal of Industrial Economics* 44, 101-

Gabszewicz,J.J. and J-F, Thisse, 1979. Price competition, qualities and income disparities, *Journal of Economic Theory* 20, 340-359.

Garella P.G. (2003), The effects of Minimum Quality Standards in oligopoly: better or worse products? Working Paper 484, Dipartimento di Scienze Economiche, University of Bologna, http://www.dse.unibo.it/ricerca

Hotelling, H. 1929, Stability in competition, *Economic Journal* 39, 41-57.

Lutz, S.; Lyon, T., Maxwell, J.W. 2000. Quality leadership when regulatory standards are forthcoming, *Journal of Industrial Economics*, 48, 331-48.

Scarpa, C., 1998. Minimum quality standards with more than two firms, *International Journal of Industrial Organization* 16, 665-676.

Shaked A. and J. Sutton (1982), Relaxing price competition through product differentiation, *Review of Economic Studies* 49, 3-14.

Ronnen, U. , 1991. Minimum quality standards, fixed costs, and competition, *Rand Journal of Economics* 22, 490-504.