“Innocuous” minimum quality standards

Paolo G. Garella

Dipartimento di Scienze Economiche, University of Bologna, Strada Maggiore 45, Bologna, Italy

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Abstract

The present note shows that “innocuous” minimum quality standards, namely below the lowest quality level in a market, may have effects on equilibrium outcomes. Such a MQS reduces the incentive to invest in R&D by the quality-leading firm.

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1. Introduction

The role of minimum quality standards (MQS) has received so far little attention in the theory of oligopoly. After Ronnen (1991), however, a small number of papers (for instance Crampes and Hollander, 1995, Ecchia and Lambertini, 1997, Scarpa, 1998) have analyzed the effects of MQS in markets with differentiated products. Usually, the analysis is confined to standards that lie between the lowest and highest quality and it is almost always built upon vertical differentiation models. So far, in no place, has ever been mentioned the possibility that standards that lie below the lowest quality in the market may have any impact on the industry outcome. I shall term such standards “innocuous”, due to their neutral appearance. In a duopoly, if a “leading” firm is able to invest resources in cost-reducing technologies, then an innocuous MQS may lead to lower investment of this sort. The result hinges upon qualities being strategic substitutes, where the firms’ need to differentiate is satisfied by horizontal
features. To be precise, qualities are substitutes also in the vertical differentiation model of Gabszewicz and Thisse (1979) and of Shaked and Sutton (1982), since a graph of the best reply in quality is a broken flat line with a high value for low levels of the rival’s quality and a zero valued portion at high levels of it. However, given a pre-ordering on qualities, marginal revenue from quality upgrading can be increasing in the rival’s quality (Choi and Shin, 1992) and, for positive costs of quality (Ronen, 1991). Strictly speaking, however, a quality pre-ordering does not allow the definition of substitutes or complements to apply globally. As an example of marginal revenue from quality upgrades decreasing in the rival’s quality, Eales and Binkley (2003) suggest to interpret persistent advertising and complementary information associated to baking mix product Bisquick as a quality attribute, to contrast it with no-advertising-strategy by Chelsea Milling’s for its Jiffy product, aimed to induce a low quality perception by consumers.\footnote{An interpretation of advertising as a complementary product, increasing utility from consuming a good, has been pioneered by Becker and Murphy (1993).} Also, one may think that a modest pizza-house restaurant may find it less profitable to invest in improvements of food quality if next door’s rival has just recruited a famous chef. The same may go for an Economics Department as to the recruitment of professors, especially if it has some differentiation of the horizontal kind with respect to its direct competitors. Also, the ability of sellers of unbranded goods to attract new consumers through improvements in quality may inversely vary with the quality of branded goods in the market, and the other way round.

Reduced incentives to invest are also found in Maxwell (1998), where firms anticipate a regulator to raise standards above the realized quality, after R&D occurs. The example below is a variant of Garella (2003) with a duopoly differentiated horizontally and vertically. In a different context, of political economy, it has been stressed the role of “quality leaders” (Lutz et al., 2000). In the present paper the quality “leader” is defined as the only firm that innovates, while the competitor is not able to innovate. This is an extreme case of asymmetry in R&D abilities. A general case would be obtained if both firms could invest in R&D with different abilities. Unfortunately, this proves algebraically irksome and would become tractable only at the cost of special assumptions.

The model below is a modified Hotelling (1929) city, with firms at the two opposite endpoints. The vertical dimension is represented by a parameter, $h_i$, affecting consumers’ utility. The basic game played in the absence of regulation and of investments is the following. At the first stage firms choose qualities, and at the second, prices. This game is analyzed only as a background to sketch the main argument. The regulation game is a shortcut to avoid a fully dynamic game: a regulator is called to decide whether to use or not a MQS, based upon the observed unregulated qualities, as after an investigation by experts. The modified game 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 stage 1, Firm 1 invests in R&D. Then, the second and third stages parallel those of the basic game. A comparison between the decision to have no standard and that of introducing an innocuous standard reveals that with no standard the investment in R&D by firm 1 is higher. The low quality firm is transformed in a constrained player and, if it could choose the MQS appropriately, would do it as a first mover that can commit to a given quality level. Not exceeding that threshold for quality, one may speculate, could improve its equilibrium profits. This could happen when the Nash equilibrium in quality investments has the character of a prisoner’s dilemma.
The one-shot interpretation of the investment in quality is one possibility. A second possibility would be that of a per-period investment, leading to fixed costs, determining the quality in each period (quality would drop down without investments).

2. Unregulated industry

There are two firms, 1 and 2. Products are horizontally differentiated, are “located” at the opposite endpoints of a Hotelling linear city (Hotelling, 1929), and each embodies a vertical quality dimension, \( \theta \). The production cost for the quantity \( q_i \) for firm 1 is \( C_1(q, \theta_1) = cq_1 + \theta_1^2/2 \), where \( c > 0 \) is independent of \( \theta \). For firm 2, \( C_2(q_2, \theta_2) = cq_2 + \theta_2^2/2 \), where \( z > 1 \) is a parameter for 2. Quality only affects fixed costs.

Consumers have an address \( x \in [0, 1] \), and are uniformly distributed, with unit mass. When buying at location \( i \), for \( i = 1,2 \), a consumer’s utility is decreased of the amount (“transportation cost”) \( t|x - (i - 1)| \). Given \( p_1, p_2 \), the utility from one unit of good \( i \) is

\[
\begin{align*}
   u_i(x; \theta_i) &= v + \theta_i - t|x - (i - 1)| - p_i, \quad \text{for } i = 1,2.
\end{align*}
\]

where \( v > 0 \) is a utility parameter, identical across consumers.

The basic game without regulation and R&D is: at stage 1 firms simultaneously choose qualities, \( \theta_1 \) and \( \theta_2 \); at stage 2 firms simultaneously choose prices.

Assumption 1.

(i) \( t > 2/9 \),

(ii) \( 1 < z < 2 \).

Assumption 2. \( v > 2t + c \).

Assumption 1 ensures that equilibrium quality levels be positive and Assumption 2 ensures that the market is entirely served.

The address, \( \tilde{x} \), such that \( u_1(x; \theta_1) = u_2(x; \theta_2) \) is:

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

The demand functions are: \( D_1(p_1, p_2; \theta_1, \theta_2) = \tilde{x} \) and \( D_2(p_1, p_2; \theta_1, \theta_2) = 1 - \tilde{x} \). Then, when \( \tilde{x}(p_1, p_2; \theta_1, \theta_2) \in (0,1) \), the firm 1 program at stage 2 is:

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

This provides the best replies

\[
\hat{p}_1(p_i) = \max \left[ \frac{p_j}{2} + \frac{(\theta_i - \theta_j) + t + c}{2}, 0 \right], \quad \text{for } i, j = 1,2; i \neq j.
\]
If \( \theta_2 \leq \theta_1 - 3(t+c) = \theta_1^0 \), then 2 is priced out and equilibrium prices are \( p_2=0 \), and \( p_1=p_1^m \), where \( p_1^m \) is the monopoly price for firm 1. Similarly, firm 1 can be priced out. We shall exclude that either firm uses a quality so low as to be priced out, so that the analysis of the case where \( \theta_2 \leq \theta_1^0 \) (or \( \theta_1 \leq \theta_1^0 \)) shall not be pursued. The study of a game where either firm can use a high quality so as to gain monopoly is out of the scope of the present work. Then, it is easy to calculate the Nash prices, \( p_1^* \) and \( p_2^* \), as:

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

Note that \( p_1^*(\theta_1, \theta_2) - p_2^*(\theta_1, \theta_2) = (2/3)(\theta_1 - \theta_2) > 0 \) for \( \theta_1 > \theta_2 \).

Now, solving\(^3\) for \( \theta' \)'s at stage 1, the best reply functions in qualities, are

\[
\theta_1(\theta_2) = \frac{3t - \theta_2}{9t - 1}, \quad \theta_2(\theta_1) = \max \left\{ \frac{3t - \theta_1}{9\alpha t - 1}, \theta_1 - 3(t + c) \right\}.
\]

Qualities are strategic substitutes. As noted, firm 2 cannot choose \( \theta_2 < \theta_1 - 3(t+c) \); this explains the V-shape of its best reply (obviously also the best reply of firm 1 is V-shaped, as firm 1 cannot choose \( \theta_1 < \theta_2 - 3(t+c) \), but the best replies are pictured so as to simplify the exposition).

If the best reply functions cross where they slope downward\(^4\) then the Nash qualities are

\[
\theta_1^* = \frac{9\alpha t - 2}{3(9\alpha t - \alpha - 1)}, \quad \theta_2^* = \frac{9t - 2}{3(9\alpha t - \alpha - 1)},
\]

where \( \theta_2^* > 0 \) from Assumption 1; if they cross where the best reply of 2 is increasing, this firm is priced out, and 1 remains a monopoly (since \( \alpha < 2 \) is assumed in Assumption 1, this case is excluded). Prices and demands at equilibrium, are

\[
p_i^* = t + c + (-1)^{i-1}\left(\frac{t(\alpha - 1)}{9\alpha t - \alpha - 1}\right), \quad D_i^* = \frac{1}{2} + (-1)^{i-1}\left(\frac{\alpha - 1}{2(9\alpha t - \alpha - 1)}\right)
\]

Further, it can be checked that \( D_2^* > 0 \) and \( p_i^* > 0 \) for \( t > 2/9 \). Therefore, under Assumption 1 the best replies in qualities cross where they are both downward sloping. The equilibrium demand for 2, \( \alpha (9t - 2)/(9\alpha t - \alpha - 1) \), is positive for \( \alpha > 1 \).

Profits are

\[
\pi_1^u = \left(\frac{9t - 1}{18}\right)\left(\frac{9\alpha t - 2}{9\alpha t - \alpha - 1}\right)^2 \quad \text{and} \quad \pi_2^u = \alpha \left(\frac{9t - 1}{18}\right)\left(\frac{9t - 2}{9\alpha t - \alpha - 1}\right)^2,
\]

with \( \pi_1^u > \pi_2^u > 0 \).

### 3. Incentives to invest and MQS

The regulator can set a MQS, defined by a real number, \( \theta \). For the sake of the argument, the regulator’s choice is assumed to be restricted such that either \( \theta = \theta_2^0 \) (“innocuous standard”) or \( \theta = 0 \) (no

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\(^2\) Namely if \( \theta_1 \leq \theta_2 - 3(t+c) = \theta_1^0 \).

\(^3\) The equilibrium demand functions are \( D_i^*(\theta_1, \theta_2) = (1/2) + (-1)^{i-1}[(\theta_1 - \theta_2)/(6t)] \). The reduced form profits, used to solve the first stage, are \( \pi_i^*(\theta_1, \theta_2) = \frac{[t(\alpha - 1)\theta_i^* - \alpha_0\theta_i^*]}{[t(\alpha - 1)\theta_i^* - \alpha_0\theta_i^*] - \alpha_0^2[(\theta_1^* - \theta_2^*)]^2} \).

\(^4\) The upward sloping parts are parallel and cannot cross therefore.
MQS). This decision is taken at stage “0” of the regulation game, given \((\theta_1, \theta_2) = (\theta_1^f, \theta_2^f)\) as in (6). At stage 1 of the regulation game, firm 1 invests the sum \(x\), so as to reduce the cost of quality improvement. Firm 2 cannot invest, as a simplifying assumption.

In particular, 
\[
C_1(q, \theta_1, x) = cq + g(x)[\theta_1]^2/2 + x: \text{ investing } x \geq 0, \text{ reduces fixed costs of quality according to the function } g(x), \text{ where: } g'(x) < 0, g''(x) < 0, \text{ for all } x \geq 0, \text{ and } g(0) = 1.
\]

In terms of best replies in Fig. 1, 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 \(H = 0\), the problem of 1 at the quality stage is
\[
\max_{\theta_1} \left( \frac{3t + (\theta_1 - \theta_2)}{18t} - g(x) \frac{[\theta_1]^2}{2} - x \right).
\]
This leads to the best reply
\[
\theta_1(\theta_2, x) = \frac{3t - \theta_2}{9g(x)t - 1}.
\]
Clearly \(\theta_1(\theta_2, x)\) increases in \(x\). Recalling that the best reply of 2 is \(\theta_2(\theta_1) = (3t - \theta_1)/(9\alpha t - 1)\), if there is no standard, the Nash qualities, denoted \(\theta_i^0\), are
\[
\theta_1^0 = \frac{9\alpha t - 2}{3(9\alpha t g(x) - x - g(x))} \text{ and } \theta_2^0 = \frac{9\alpha t - 2}{3(9\alpha t g(x) - x - g(x))}.
\]
Notice that when \(g = 1\), \((x = 0)\), the values of \(\theta_1^f\) and \(\theta_2\) coincide with \(\theta_1^f\) and \(\theta_2^f\) of Section 2.

Without a standard, firm 2 would lower quality\(^5\) below \(\theta_2^u\), namely \(\theta_2^0 < \theta_2^u\), implying that a lower \(g\) leads to a lower value for \(\theta_2\).

The R&D investment by firm 1 results from
\[
\max_x \pi(x) = \frac{3t + (\theta_1(x), \theta_2)}{18t} - g(x) \frac{[\theta_1(d)]^2}{2} - x.
\]
It is apparent that marginal net return to invest \(x\), decreases with \(\theta_2\). Therefore, since \(\theta_2\) is forced to remain at its pre-standard level, firm 1 will invest less in R&D under a “innocuous” MQS.

\(^5\) Indeed \(\frac{d\theta_1}{dq} = \frac{9\alpha t - 2}{3(9\alpha t g(x) - x - g(x))} > 0.\)
Provided the function \( p(x) \) 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.

**Proof.** Let \( p(x) = \left[3t + (\theta_1(x) - \theta_2^*)\right]^2/(18t) - (g(x)/2)\left[\theta_1(x)\right]^2 - x \). 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 \( p(x) \) is \( p'(x) = 0 \), where \( p'(x) = \theta_1'(x)\left[(3t + \theta_1 - \theta_2^*)/(9t)\right] - g'(x)\left[\theta_1(x)\right]^2(1/2) - g(x)\theta_1'(x)\theta_1(x) \). The second order condition, under the hypothesis that \( p(x) \) is concave, implies that \( p''(x) < 0 \). Then, differentiating the first order condition with respect to \( \theta_2^* \) and \( x \) gives

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

which completes the proof. \( \square \)

By continuity arguments, a MQS slightly below the lowest quality level has the same effects.

4. Conclusion

That minimum quality standards below the minimum produced quality bear effects on the industry outcome is the only issue of the present note. In particular, there is no indication here that MQS be a “wrong” policy, since the optimal level of R&D from the social point of view is not discussed. A welfare analysis requires a more general model. The main result has to be interpreted as a counter-example to the notion of innocuous standards. More work is needed to assess the general effects of MQS on R&D.

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