

QUALITY CHOICE, SALES RESTRICTION AND THE MODE OF COMPETITION

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A regulator imposing sales restrictions or capacity limitation on firms competing in oligopolistic markets may enhance quality provision by these firms. The instrument amounts to protecting entrants or low-quality firms; this in turn makes it profitable to sink money into quality upgrades. Moreover, for most restrictions levels, the impact on quality selection is invariant to the mode of competition.

1 INTRODUCTION

Many consumer markets are subject to quality regulation with minimum requirements of ‘product safety’ or ‘environmental standard’,¹ either because of externalities or more simply for paternalistic reasons. This is, for instance, the case in the automobile industry where fuel-economy standards and emission maxima must be met by producers. In the regulated health sector, child care centers must meet drastic criteria to obtain accreditation. More generally, many service industries see their access conditioned and limited by various forms of certification aimed at controlling for adequate professional training. Again, the aim is to ensure, by regulation, that ‘quality’ is large enough.

The fact that quality must be ensured through regulation might be surprising at first sight in a market economy where, in theory, rivalry between firms takes place in terms of price, quality, service or combinations of these and other factors which customers may value.² In such a competitive world, only high-quality products are apt to survive. However, real markets are rather oligopolistic than perfectly competitive and in that situation it has long been shown by the literature dealing with quality product differentiation that low-quality products can last. Worse, Crampes and Hollander (1995) show that entering a market with a low-quality product can often be an optimal

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¹ Environmental requirements are becoming more and more pervasive in mass product industries and tend to be assimilated to quality.

² Taken from the glossary of the Competition Directorate at the European Commission.

strategy. Moreover, in the case of entry, it might be optimal for an incumbent to downgrade its own quality as shown by Yong (1999). The general idea behind these negative results is that competition erodes profits margins; thus if quality provision is costly, quality upgrades tend to be less valuable at the margin. More generally, quality choices are governed by strategic considerations and, in this respect, quality downgrades are often valuable at the margin because they relax competition, in addition to decreasing costs.

In regulated industries (natural monopolies), ensuring quality provision has also long been a concern for public authorities. However, in this asymmetric information context, it is well known that the regulator has to mix incentives and monitoring to ensure quality provision. The regulation literature that started with Baron and Myerson (1982) has shown the inherent limits of this approach in terms of efficiency and the cost of public funds. In this context, competition has often been viewed as a way out of the dilemma. One could indeed hope that lower-quality products would not resist the challenge of higher-quality products entering the (now) deregulated industry. However, the aforementioned theory has not reached a definite conclusion and some widely publicized failures like the accidents of privatized railways in the UK or the power crisis in California have shocked the population and led policy makers to realize that increased competition does not necessarily ensure quality provision but could actually undermine it. For instance, Kennet (1993) shows empirically that a lowering of quality initially followed the deregulation of the airline industry in the USA.

Accordingly, introducing or enhancing competition may call for complementary public intervention aimed at ensuring quality provision. Two basic instruments have been studied in the literature: minimum quality standards (MQS hereafter) and tax/subsidy schemes. We shall henceforth argue against them and offer a novel mechanism to sustain high quality in deregulated industries.

Obviously, by imposing MQS, we increase quality at the bottom of the quality range. Ronnen (1991) provides a detailed analysis of the effects of MQS and concludes that these may indeed increase welfare as well as increase quality. However, other papers (see, for instance, Maxwell, 1998; Scarpa, 1998) have studied the impact of MQS and yielded more ambiguous results regarding welfare. A major drawback of MQS is that they undermine firms' profit by intensifying price competition. Moreover, as shown by Valletti (2000), Ronnen's conclusions regarding the positive impact of MQS are not robust to the mode of competition. All in all, theoretical approaches provide at best a mixed support for MQS policies, even when monitoring costs are neglected.³ On the other hand, empirical evidence suggests that MQS might

³Notice that monitoring is mandatory in the case of effective MQS since by definition the MQS impose a *binding* constraint on the low-quality firm. As recently argued by Glaeser and Shleifer (2001), quantity regulation might be optimal simply because it would be less costly to enforce due to smaller monitoring costs.

not induce quality upgrading. For instance, Chippy and Witte (1997) empirically investigate health care providers and conclude that minimum standards increase the probability that firms exit certain markets, thereby reducing competition.

Instead of regulating quality by altering directly the quality space, the regulator may provide firms with incentives to upgrade quality. Tax/subsidy schemes might be effective in this respect, as shown, for instance, by Cremer and Thisse (1994). Such instruments do not require strict monitoring of qualities since they give the right incentives to firms. However, the particular instrument to be used depends on the mode of competition prevailing in the oligopolistic industry as shown by Brander and Spencer (1983). In many instances, this information might be hard to identify accurately. The government must then cope with the risk of using the wrong instrument.

All in all, the two instruments most often studied, and used, in the field of quality regulation display some drawbacks which might call for investigating alternative tools. The present paper analyzes sales restrictions as an alternative instrument aimed at regulating quality provision. Its most appealing feature is that it overcomes the weaknesses of the two preceding ones. In opposition with MQS, sales restrictions provide firms with direct incentives to upgrade quality while preserving firms' margins. Also it is much easier to check whether a quota has been met than to verify a quality index.⁴ In opposition to tax/subsidy schemes, sales restrictions do not weigh on scarce public funds. Finally, contrary to tax/subsidy schemes and MQS, the impact of sales restrictions on optimal quality choices is largely invariant to the mode of competition.

The key intuition underlying our analysis is the following: a sales restriction relaxes competition, whatever the mode of competition; therefore it increases the marginal profitability of quality upgrades and restores for all firms the incentive to select higher qualities. This is especially true for the low-quality producer. Of course, a smoother competition might be detrimental to industry welfare but we show that, in equilibrium, the positive impact of quality upgrades on welfare more than compensates the negative impact of reduced competition.

Clearly enough, sales restriction is not yet very frequently used to regulate quality. In this respect our contribution can be viewed as a purely speculative exercise. It is our contention that, given the limitations of MQS and taxes, there is room for such an exercise. Moreover, it should be stressed that there are already many industries in which various forms of quantity regulations actually apply, although for competition enhancing reasons. For instance, supermarkets in most European countries face restrictions both on sizes and opening hours which actually limit their ability to pre-empt the

⁴In several industries the quota would apply to production capacities or geographical territories while in others sales would be readily available from the accounting books.

market. In the Italian electricity market, generation companies are prohibited from installing too large production capacities (their capacity is actually limited to half of the national market). A similar disposition can be found in the European regulation on the award of public service contracts passenger transport. According to this regulation, a public authority may indeed decide not to award contracts to an operator should this operator cover more than a quarter of the relevant market. The basic motivation for such regulations consists of guaranteeing through quantitative restrictions that there is enough room for competitors to (enter and) survive in the market. We show that in concentrated industries this also relaxes competition and therefore promotes quality provision by all firms.

To capture formally the intuition underlying our proposal, we develop a very simple model. Suppose a government wishes to offer protection to an entrant facing competition by an incumbent firm. We assume that the incumbent is already committed to its quality when the government implements a sales restriction. This allows us to concentrate on the quality selection of the entrant only. To analyze the role of the competition mode, we compare the optimal quality selection of the entrant under Cournot and Bertrand competition at the market stage, as a function of the 'sales restriction' level. We show that for most values of this quota, the optimal quality selection of the entrant is the same under Cournot and Bertrand competition, and is greater than the optimal quality selected in the unconstrained game. Most often, the optimal quality level is negatively related to the tightness of the sales restriction. However, compared with Cournot, the range where the quota is effective is larger under Bertrand competition.⁵

We present the model in Section 2. Section 3 deals with Cournot competition whereas Section 4 studies the Bertrand case. After comparing the two models in Section 5, we conclude in Section 6.

2 THE MODEL

Consumers' preferences are derived from the model of Mussa and Rosen (1978). Consumer j exhibits a taste for quality θ_j and derives an indirect utility $\theta_j s - p$ when consuming a product of quality s , bought at price p . Not consuming yields a utility of 0. Consumers' types are uniformly distributed in the $[0, 1]$ interval. The density is 1, and is taken as a measure of the market size. To produce a quality level s , a firm has to incur a sunk cost $c(s) = s^2/8$.⁶ Marginal cost is assumed to be zero for simplicity.

⁵Notice that the impact of sales restrictions on quality selection has been studied recently in a specific context. Herguera *et al.* (2000) study the impact of a trade quota imposed on a foreign firm on equilibrium quality selection. However, their analysis is confined to Cournot competition. We compare our results with theirs in the last section of the paper.

⁶The analysis can be carried out with a more general convex cost. See Boccard and Wauthy (2001).

An *incumbent* (denoted by i) originally sells as a monopolist in the market a product of quality $s_i = 1$.⁷ We assume the producer is committed to this quality level.

The sequence of decisions is the following. The government chooses a sales restriction for the incumbent (a quota) from an interval $[q, 1]$ with $q > 0$.⁸ Given the quota, the *entrant* (denoted by e) firm selects its quality s_e before both firms compete in the last stage of the game. We consider in turn Cournot and Bertrand competition. Notice that, given the specification of the sunk cost, we may restrict the analysis of entrant's quality selection to $s_e \leq 1$. Since the incumbent is committed to its quality, it is immediate to check that, under our assumption about quality costs, entering the market with $s_e > 1$ cannot be a best reply for the entrant. In other words, quality leapfrogging is not an issue in our basic model. The equilibrium concept is a Nash subgame perfect equilibrium.

3 COURNOT COMPETITION

We study the quality decision of the entrant in two situations: first when the ensuing quantity competition is free from governmental intervention (hereafter unconstrained) and second when the regulation authority imposes a binding sales restriction (hereafter quota) to the incumbent firm.

3.1 Unconstrained Competition

We first solve the last stage of the game, and then we go backward to study quality selection. The analysis of this Cournot game is a standard exercise.⁹ Given qualities and prices, demands are

$$x_i = 1 - \frac{p_i - p_e}{1 - s_e} \quad (1)$$

$$x_e = \frac{p_i s_e - p_e}{s_e(1 - s_e)} \quad (2)$$

Thus, the inverse demands characterizing Cournot competition are given by

$$p_i = 1 - x_i - x_e s_e \quad (3)$$

$$p_e = (1 - x_i - x_e) s_e \quad (4)$$

⁷Note that $s_i = 1$ is indeed the optimal choice of a monopolist under the cost assumption $c(s) = s^2/8$. The case for endogenous quality selection where the incumbent might not have the highest quality is the object of a more involved paper (Boccard and Wauthy, 2001).

⁸The introduction of a lower bound for the quota is made to avoid technical problems in the derivation of equilibria in the pricing games. The importance of this assumption is discussed below.

⁹We may refer the reader unfamiliar with these models to Herguera *et al.* (2000) for a formal derivation of the demand functions.

The best replies in quantities are immediately derived as $BR_i^c(x_e) \equiv (1 - x_e s_e)/2$ and $BR_e^c(x_i) \equiv (1 - x_i)/2$. The unconstrained Cournot equilibrium is thus

$$x_e^c(s_e) \equiv \frac{1}{4 - s_e} \quad \text{and} \quad x_i^c(s_e) \equiv \frac{2 - s_e}{4 - s_e} \quad (5)$$

leading to equilibrium prices

$$p_i^c = \frac{2 - s_e}{4 - s_e} \quad \text{and} \quad p_e^c = \frac{s_e}{4 - s_e} \quad (6)$$

Notice that x_e^c is increasing with s_e while x_i^c is decreasing. The entrant's profits at the Cournot equilibrium are given by

$$\pi_e^c(s_e) \equiv \frac{s_e}{(4 - s_e)^2} - \frac{s_e^2}{8} \quad (7)$$

The first-order condition for maximization of π_e^c is $0 = 16 - 60s_e + 48s_e^2 - 12s_e^3 + s_e^4$ and letting

$$z = \frac{2 + (33 - \frac{1}{9}\sqrt{22353})^{1/3} + (33 + \frac{1}{9}\sqrt{22353})^{1/3}}{2}$$

the only relevant real root is

$$s_e^c \equiv 3 - \sqrt{z - (3 - z + 3z^{-1/2})^{1/2}} \approx 0.36261 \quad (8)$$

This defines the optimal quality selection by the entrant when no sales restriction is imposed. Demand addressed to the incumbent at the unconstrained subgame perfect equilibrium is¹⁰ $D_i^c \equiv x_i^c(s_e^c) \approx 0.4502$ and the profit of the entrant is $\pi_e^c(s_e^c)$.

3.2 Constrained Competition

The regulation authority now imposes a sales restriction at the level q on the sales of the incumbent firm. In the analysis to follow, we shall distinguish between two notions of effectiveness for the sales restriction.

Definition 1: A sales restriction is

- short-run effective if it alters the price equilibrium outcome, given qualities;
- long-run effective if it also alters the quality selection.

¹⁰In the remainder of the paper, we shall often appeal to approximate values for equilibrium outcomes. Note, however, that these approximations correspond to exact analytical values that we have chosen not to report systematically because of their length.

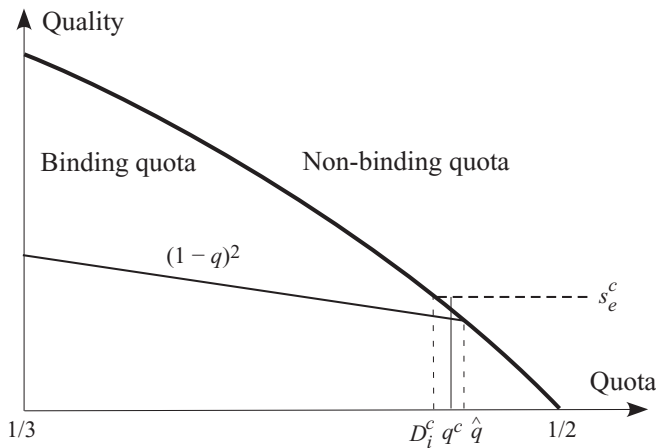


FIG. 1 Cournot Competition

Suppose the quota is binding at the Cournot stage (after quality has been set), so that we have $x_i = q$. Against this quantity, the entrant's best reply is then $x_e = \text{BR}_e^c(q) = (1 - q)/2$. Conditional on these quantities forming the constrained Cournot equilibrium, the first-period profit of the entrant is

$$\pi_e^{cq}(s_e) \equiv \frac{(1 - q)^2 s_e}{4} - \frac{s_e^2}{8} \quad (9)$$

and is maximum for $s_e = (1 - q)^2$ which is the optimal 'quota-constrained' quality. We observe that this optimal quality is decreasing in the sales restriction, i.e. the tougher the protection granted to the entrant, the greater the quality it can elicit.

Given the choice of quality s_e by the entrant, the quota is *short-run* effective if the incumbent's unrestricted sales $x_i^c(s_e)$ are greater than q so that a necessary condition for this to happen is $q < 0.5$ (since $x_i^c \leq 0.5$). A quota below half of the market size is *short-run* effective if the subsequent quality choice satisfies $x_i^c(s_e) > q \Leftrightarrow s_e < 2(1 - 2q)/(1 - q)$. This condition partitions the quality–quota space in two regions as shown in Fig. 1 where the frontier is drawn in bold face. Notice that, given $q < \frac{1}{2}$, there always exists a value for quality below which the quota is short-run effective. Exploiting this property, we may state a preliminary result.

Lemma 1: Under Cournot competition, a quota set above the free trade level D_i^c fails to be short-run effective whenever the quality is higher than s_e^c .

To identify the parameter space where the sales restriction is long-run effective, it remains to determine when it is optimal for the entrant to force

a constrained Cournot competition, i.e. when he takes advantage of the sales restriction. Figure 1 shows indeed that it is always possible. However, it does not mean that it is a wise strategy to follow since it often leads to quality downgrade and possibly lower profits.

The optimal quality choice in the non-binding regime is the frontier for $q < D_i^c \approx 0.450$ and s_e^c for larger qs . Likewise, the optimal quality choice in the binding regime is $(1 - q)^2$ for low qs and the frontier for larger qs . The intersection of the frontier $s_e = 2(1 - 2q)/(1 - q)$ and the best reply $s_e = (1 - q)^2$ determines the threshold $\hat{q}$ which solves $x_i^c[(1 - q)^2] = q$; more precisely,

$$\hat{q} \equiv 1 - \frac{1}{\sqrt{3}} 2 \cos \left[\frac{1}{3} \arctan \left(\frac{\sqrt{111}}{9} \right) \right] + 2 \sin \left[\frac{1}{3} \arctan \left(\frac{\sqrt{111}}{9} \right) \right] \approx 0.461$$

It is easy to see in Fig. 1 that the overall optimal choice is thus $(1 - q)^2$ if $q < D_i^c$ and s_e^c if $q > \hat{q}$. For $q \in [D_i^c; \hat{q}]$, we have two candidate equilibria; thus we need to compare their respective profits $\pi_e^c(s_e^c)$ and $\pi_e^{cq}[(1 - q)^2] = (1 - q)^4/8$ to identify the overall optimal quality choice. Solving for q , we obtain as the unique relevant real root

$$q^c \equiv 1 - [8\pi_e^c(s_e^c)]^{1/4} \approx 0.4557 \in]D_i^c; \hat{q}[$$

The threshold q^c defines the critical value below which the sales restriction is long-run effective when committed to before the entrant's quality is selected. The next proposition characterizes the impact of a sales restriction under Cournot competition.

Proposition 1: The equilibrium of the Cournot competition game depends on the sales restriction level q .

- If $q \geq q^c$, the sales restriction is not effective and the unconstrained equilibrium obtains.
- If $q \leq q^c$, the sales restriction is long-run effective and the entrant's quality is $(1 - q)^2$.

Corollary 1: When the sales restriction q becomes long-run effective, the entrant's quality falls from $s_e^c \approx 0.363$ to $(1 - q^c)^2 \approx 0.296$ (cf. Fig. 1).

Since government intervention tends to distort the competitive framework, it is instructive to explore the effect of the sales restriction upon the total welfare generated in this market. Notice first that the first-best can be assimilated to a configuration where the incumbent sells a product of maximal quality at marginal cost (here zero) to obtain a consumer surplus of $\frac{1}{2}$ (see equation (A1) in the Appendix). Since there is a cost for quality of $\frac{1}{8}$, the maximal total welfare is 0.375. The following corollary is proved in the Appendix.

Corollary 2: Welfare analysis for Cournot competition.

- If $q > q^c$, the entrant quality is s_e^c and industry welfare is independent of the sales restriction at $\bar{W}^c \approx 0.2485$.
- If $q \leq q^c$, welfare increases with the quota and reaches the maximal value $\bar{W}^{cq} \approx 0.2488$ for $q = q^c$.

The inequality $\bar{W}^{cq} > \bar{W}^c$ in a neighborhood of q^c is due to the fact that the quality downgrading boosts profits by increasing product differentiation more than the loss of consumer surplus which falls from 0.1599 to 0.1515.

As mentioned in the introduction, Herguera *et al.* (2000) consider a similar problem in the specific context of international trade. Compared with the free trade equilibrium, they show that the entrant is likely to select a higher quality in the presence of a binding quota (less than the entrant's sales under free trade). However, if the quota is set just above the entrant's sales under free trade, the entrant selects a lower quality, compared with free trade. This is precisely what we obtain. However, as we shall see in Section 5, our analysis shows that the risk of a local quality downgrading is entirely specific to the Cournot framework.

4 BERTRAND COMPETITION

The analysis of Bertrand competition is slightly more complex than the Cournot one; it is divided in four parts. We first re-derive the unconstrained benchmark equilibrium, and then tackle the implications of a sales restriction in a pricing game before solving it. Finally, we turn to the choice of the optimal quality by the entrant.

4.1 Free Trade

Under Bertrand competition, demands (1) and (2) enable us to compute firms' best reply in the unconstrained pricing game as

$$\Phi_i(p_e) = \frac{1 - s_e + p_e}{2} \quad \text{and} \quad \Phi_e(p_i) = \frac{p_i s_e}{2} \quad (10)$$

Straightforward computations yield the unique Nash equilibrium:

$$p_e^b = \frac{s_e(1 - s_e)}{4 - s_e} \quad \text{and} \quad p_i^b = \frac{2(1 - s_e)}{4 - s_e} \quad (11)$$

Using these values, we compute the equilibrium sales: $x_e^b \equiv 1/(4 - s_e)$ and $x_i^b \equiv 2/(4 - s_e)$. The entrant's equilibrium profit is

$$\pi_e^b(s_e) \equiv \frac{s_e(1 - s_e)}{(4 - s_e)^2} - \frac{s_e^2}{8} \quad (12)$$

Using equation (12), the optimal quality selection of the entrant, maximizing $\pi_e^b(s_e)$, is computed as

$$s_e^b \equiv 3 + \sqrt{y - (3 - y + 5y^{-1/2})^{1/2}} \approx 0.1923$$

where $y \equiv 1 + 3^{-2/3} 2^{-1} (5\sqrt{44889} - 423)^{1/3} - 34(5\sqrt{44889} - 423)^{-1/3} 3^{-1/3}$.

The associated demand for the incumbent is $D_i^b \equiv x_i^b(s_e^b) \approx 0.525$ while the profit of the entrant is $\pi_e^b(s_e^b)$. We observe that the tougher price competition forces the entrant, who is a quality follower, to differentiate more than under Cournot; this in turn enables the incumbent to increase sales with respect to the Cournot situation.

4.2 Effect of a Sales Restriction

Let us then consider the presence of a sales restriction. The first analysis of a quota constrained pricing game with differentiated products has been developed by Krishna (1989) in a trade context:¹¹ the first key difference between Cournot and Bertrand competition is that, under price competition, sales restrictions above the unconstrained equilibrium demand of the incumbent are (almost) always 'short-run' effective. This is so because a sales restriction deeply alters the structure of the pricing game. Therefore, we first have to study in detail the implication of the sales restriction on price competition itself before turning to the analysis of quality selection.

The underlying phenomenon is that, under price competition, consumers may be rationed by the incumbent if its demand exceeds the level of the sales restriction. Rationed consumers may then take their purchase to the entrant, whose effective sales increase. These rationing spillovers destroy the global concavity of the entrant's payoff and thereby make the existence of a pure strategy equilibrium problematic. Thus, the presence of the sales restriction induces Bertrand–Edgeworth competition at the market stage.¹²

A peculiarity of the present model is that, if the entrant sells the low quality, any consumer that is rationed by the high-quality incumbent prefers to make his purchase with the entrant's product rather than refrain from buying. Accordingly, whenever $x_i(p_e, p_i) > q$, the number of consumers who make their purchase with firm e is given by $x_i(p_e, p_i) - q$. It is then direct to show that the residual demand addressed to the entrant is

$$x_e^q(p_e) \equiv 1 - q - \frac{p_e}{s_e} \quad (13)$$

¹¹We refer the interested reader to her paper for the full analysis of such cases. Regarding price equilibrium, the present analysis is a direct application of the methodology proposed by Krishna (1989).

¹²See Vives (2000) for a presentation of Bertrand–Edgeworth competition versus Bertrand competition and why it makes sense to adopt the former in the present setting.

Using (13) we may define $p_e^q(p_i) \equiv p_i - (1 - q)(1 - s_e)$ by solving $x_i(p_e, p_i) > q$ for p_e to obtain $p_e > p_e^q(p_i)$. Whenever $p_e \leq p_e^q(p_i)$, the free trade analysis applies and firms' demands are given by (1) and (2). On the other hand, if $p_e \geq p_e^q$, the potential demand of the incumbent exceeds the legal limit q so that final sales are $x_e^q(p_e)$ and q respectively. Comparing the derivatives of the entrant's demand function using (1) and (13), we observe that the entrant's demand exhibits an outward kink at $p_e = p_e^q(p_i)$. This kink destroys the quasi-concavity of its profits. Thus, the existence of a pure strategy equilibrium is not guaranteed.

4.3 Price Equilibrium

We now characterize the nature of equilibrium in the pricing game. The incumbent's best reply is denoted Ω_i . Over the non-binding domain, the best reply is $\Phi_i(p_e)$ as defined by (10), if it belongs to this domain. Over the binding domain, the incumbent is better off selling q at the highest possible price, which is precisely the frontier price $p_i^q(p_e)$. The formal best reply is thus the minimum of $\Phi_i(p_e)$ and $p_i^q(p_e)$. Solving $\Phi_i(p_e) = p_i^q(p_e)$ for p_e we obtain $\tilde{p}_e = \max[(1 - s_e)(2q - 1), 0]$. Thus

$$\varphi_i(p_e) = \begin{cases} \Phi_i(p_e) & \text{iff } p_e < \tilde{p}_e \\ p_i^q(p_e) & \text{iff } p_e \geq \tilde{p}_e \end{cases} \quad (14)$$

Notice that the best reply is kinked and continuous, reflecting the fact that the incumbent's profit is concave in own price.

We turn to the entrant whose profit when he benefits from spillovers is

$$p_e x_e^q(p_e) = p_e \left(1 - q - \frac{p_e}{s_e} \right)$$

The maximum of this expression is reached for $p_e^s \equiv (1 - q)s_e/2$. Associated profits are equal to $\pi_e(q) = (1 - q)s_e/4$. If the sales restriction is not binding, the best reply is $\Phi_e(p_i)$ as defined by (10), yielding a payoff $\pi_e(p_i) = p_i^2 s_e / 4(1 - s_e)$. Solving for equality among $\pi_e(q)$ and $\pi_e(p_i)$ in the variable p_i , we obtain the critical value $\tilde{p}_i \equiv (1 - q)(1 - s_e)^{1/2}$ for which the entrant is indifferent between the two strategies. The best reply is therefore

$$\varphi_e(p_i) = \begin{cases} p_e^s & \text{iff } p_i \leq \tilde{p}_i \\ \Phi_e(p_i) & \text{iff } p_i \geq \tilde{p}_i \end{cases} \quad (15)$$

Combining (14) and (15), we observe that there is only one candidate for a pure strategy equilibrium: the unconstrained equilibrium (p_i^b, p_e^b) as defined by (11).¹³ A necessary and sufficient condition for this candidate to be an

¹³It is indeed immediate to check that $\tilde{p}_i < p_i^q(p_e^s)$, which is sufficient to rule out any pure strategy equilibrium candidate in the sales restriction binding domain of prices. Therefore, the only remaining candidates must lie in the unconstrained region. There is only one such candidate: the unconstrained equilibrium.

equilibrium is that $p_i^b > \tilde{p}_i$. Direct computations show that this condition is satisfied if and only if $q > \bar{q}(s_e) \equiv 1 - 2(1 - s_e)^{1/2} / (4 - s_e)$. When this condition is not satisfied, there exists no pure strategy equilibrium. However, the continuity of payoffs ensures the existence of a mixed strategy equilibrium.

The natural candidate for a mixed strategy equilibrium is then the following one: the entrant randomizes between p_e^s and $\Phi_e(\tilde{p}_i)$ and chooses the weight to put on each pure strategy so as to ensure that $\tilde{p}_i$ is indeed a best reply for the foreign firm against the mixture. We call this equilibrium the Krishna equilibrium.¹⁴ The following lemma summarizes the key difference between quantity and price competition in the presence of quantitative constraints. This result is central to the analysis originally proposed by Krishna (1989).

Lemma 2: As opposed to the Cournot case, a sales restriction above the unconstrained equilibrium level can be short-run effective in the Bertrand game whatever the quality level of the entrant.

Proof: Direct computations show that $\bar{q}(s_e) > x_i^b(s_e) = 2/(4 - s_e)$ is satisfied for all s_e . Accordingly, whatever the entrant's quality level s_e , any sales restriction $q \in [x_i^b(s_e); \bar{q}(s_e)]$ is such that the price equilibrium is a mixed strategy equilibrium involving prices greater than those of the unconstrained equilibrium. In particular, at the unconstrained subgame perfect equilibrium quality level s_e^b we have $\bar{q}(s_e^b) \approx 0.528 > x_i^b(s_e^b) \approx 0.525$. ■

4.4 Quality Selection

Let us assume for the moment that the Krishna equilibrium always exists when the unconstrained one does not and study the issue of quality selection. It is not necessary to compute the mixed strategy explicitly for our present purpose. Indeed, the key point here is to note that in this equilibrium the entrant earns exactly¹⁵ $\pi_e^s = (1 - q)^2 s_e / 4 - s_e^2 / 8$. Notice that this is exactly equivalent to the Cournot equilibrium payoffs under a binding sales restriction. Therefore, if the Krishna equilibrium is played at the price competition stage, the optimal quality is $(1 - q)^2$, yielding the net payoff $(1 - q)^4 / 8$.

In order to delineate the domain in which the sales restriction affects quality selection, consider the optimal quality selection in the unconstrained equilibrium: $s_e^b \approx 0.192$. As noted above, we need $q > q^b(s_e^b) = 0.528$ for the unconstrained equilibrium to exist in the pricing game. On the other hand,

¹⁴We refer the interested reader to Krishna (1989), Theorem 2, for the detailed construction of this equilibrium.

¹⁵In a mixed strategy, the equilibrium payoff can be computed at any of the firm's pure strategies. We do it for the entrant with p_e^s taking into account that the incumbent plays the pure strategy $\tilde{p}_i$.

it is always possible for the entrant to enforce the Krishna equilibrium by choosing a high enough quality. In order to identify the optimal strategy, we compare the corresponding payoffs. Direct computations indicate that $\pi_e^b(s_e^b) < (1 - q)^4/8$ whenever

$$q < q^b \equiv 1 - [8\pi_e^b(s_e^b)]^{1/4} \approx 0.530$$

where q^b defines the critical value above which the sales restriction is neither long-run nor short-run effective under Bertrand competition. Our findings are summarized in the following proposition.

Proposition 2: The equilibrium of the Bertrand competition depends on the sales restriction level:

- if $q \geq q^b$, the sales restriction is not effective and the unconstrained equilibrium s_e^b obtains;
- if $q \leq q^b$, the sales restriction is long-run effective and the entrant's quality is $(1 - q)^2$.

Let us then briefly comment on the existence of the Krishna equilibrium. Indeed, this equilibrium does not always exist. For this equilibrium to exist, the incumbent's demand must satisfy the non-negativity constraint $x_i[\Phi_e(\tilde{p}_i), \tilde{p}_i] > 0$. Direct computations show that this is the case if and only if

$$q > 1 - 2(1 - s_e)^{1/2} \quad (16)$$

In other words, there exists a lower bound on the sales restriction value below which the Krishna equilibrium fails to exist. If $s_e < \frac{3}{4}$, then (16) is satisfied since its right-hand side is negative. For $s_e \geq \frac{3}{4}$, we need to check condition (16) applied to the equilibrium quality $(1 - q)^2$. We obtain

$$(1 - q)^2 < 1 - \frac{(1 - q)^2}{4} \Leftrightarrow q > 1 - \frac{2}{\sqrt{5}} \approx 0.106$$

As a consequence, our previous analysis is fully compelling if we assume $q \geq 0.106$. Hence our initial assumption of a lower bound on the admissible values for the sales restriction.¹⁶ Since competition is tougher under the Bertrand regime, differentiation is greater than under the Cournot regime ($s_e^b < s_e^c$). One interesting difference between the two regimes is the fact that a sales restriction (whenever effective) gives protection to the entrant who can therefore increase its quality.

¹⁶When the Krishna equilibrium does not exist, there exists fully mixed strategy equilibria involving a finite number of atoms. We have not been able to fully characterize them. However, Levitan and Shubik (1972) provide a characterization for the particular case where $s_e = 1$. For the relevant domain of sales restriction values, the payoff of the entrant at $s_e = 1$ dominates the unconstrained benchmark. Hence, in this domain, it must be the case that the equilibrium quality is larger than the unconstrained one.

Corollary 3: When the sales restriction q becomes long-run effective, the entrant's quality rises from $s_e^b \approx 0.192$ to $(1 - q^b)^2 \approx 0.221$.

As in the previous section, we can perform a welfare analysis. It is more involved than in the Cournot case because the equilibrium is in mixed strategies when the quota is binding and this makes the computation of profits and consumer surplus lengthier. The algebra is deferred to the Appendix; it yields an interesting result: setting an effective sales restriction strongly increases welfare by enabling the entrant to upgrade its quality.

Corollary 4: Welfare analysis for Bertrand competition.

- If $q \geq q^b$, the entrant quality is s_e^b and welfare is independent of the sales restriction at $W^b \approx 0.275$.
- If $q \leq q^b$, welfare increases with the quota and reaches the maximal value $\bar{W}^{bq} \approx 0.286$ for $q = q^b$.

5 COMPARING COURNOT AND BERTRAND

As shown by Krishna (1989), the impact of a sales restriction at the market stage depends on the mode of competition. This result is best observed in our framework by noting that a sales restriction set slightly above the unconstrained subgame perfect equilibrium sales of the incumbent $D_i^c \approx 0.450$ is never short-run effective under Cournot while it is always short-run effective under Bertrand (provided the entrant's quality is optimally set). However, a sales restriction has also long-run implications. By comparing quality selection by the entrant in the two competition frameworks, we may now assess the long-run effectiveness of sales restrictions with the help of Fig. 2.

We obtain two results. First $q^b \approx 0.530 > q^c \approx 0.456$ implies that the range for an effective sales restriction is larger under Bertrand than under Cournot. Second, the quality selection is invariant to the mode of competition for a large domain of sales restrictions ($q < q^c$). Our claim that imposing a 'sales restriction' on an incumbent firm can enhance the quality provision of entrants is best understood with the help of Fig. 2: it is enough to set a quota q^o to guarantee that, whatever the mode of competition, the lowest quality is s_e^c . The regulator can increase quality simply by making the sales restriction tighter.

Compared with their respective unconstrained values, the optimal quality cannot decrease because of the sales restriction under Bertrand competition while there exists a domain of sales restriction values, above the free trade benchmark, for which the sales restriction induces quality downgrading under Cournot. The intuition underlying our result is easy to summarize. The presence of the sales restriction softens competition, especially from the point of view of a low-quality firm. Under Cournot competition,

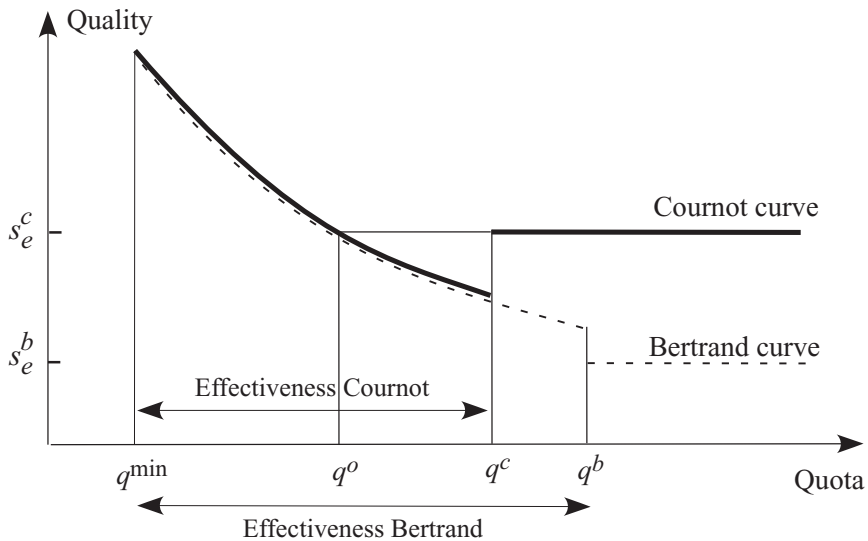


FIG. 2 Comparing the Two Modes of Competition

this increases the marginal values of quality upgrading. Under Bertrand competition, the effect is even more striking. Sales restrictions relax price competition so drastically that they remove any strategic incentives to select a low-quality level. There is indeed no need to relax price competition further.

The welfare analysis has followed the utilitarian approach where 1€ of profits counts like 1€ of consumer surplus. If the good or service delivered in this market is believed to produce positive externalities, as would be the case for education or health, then the consumer surplus should receive a greater weight; this would only reinforce our argument that the sales restriction is a helpful policy instrument to achieve the optimal quality without jeopardizing the survival of firms. Indeed, whatever the mode of competition, the quota smoothes out rivalry by guaranteeing minimal market shares.

6 CONCLUSION

The present paper aimed at providing a simplified example in which the role of 'sales restrictions' as a means to regulate quality provision could be exposed. Compared with MQS or tax instruments, sales restrictions exhibit two advantages: first, they are effective whatever the mode of competition and, second, they do not depress firms' margins.

This mechanism might seem rather unusual at first sight and is clearly at odds with most regulation actually in force regarding quality provision. At a theoretical level our analysis shows, however, that it is very effective because it alters competition in a way that provides firms with the desired incentives regarding quality choice. Regarding the actual applicability of this instrument, it is first useful to recall that regulation authorities often use quantity regulation instruments (although for different purposes). For instance, trade quotas have a long tradition which in particular suggests that monitoring sales is often a feasible option. Glaeser and Shleifer (2001) argue that such instruments might be superior because they are less costly to enforce. Whether monitoring capacities rather than quality levels is easier should be assessed on an empirical basis. Notice, however, that our mechanism requires controlling for installed capacities, not for actual sales. This form of control admittedly requires less sophisticated inquiries than the control of quantity sold or quality produced in all industries where installed capacities correspond to some relevant constraint.

Quantitative restrictions have also been enforced in recently deregulated industries. As reported, for instance, by McDaniel and Neuhoﬀ (2002), the British Monopolies and Mergers Commission forced British Gas to contract no more than 90 per cent of new gas fields in order to favor competition. Clearly, we do not argue that energy or basic services industries should be regulated by drastically limiting the size of operators. Instead, we should stress that the level of sales restriction which is necessary to enforce quality upgrading is actually quite loose, so that at the price equilibrium the restriction appears most often to be non-binding. By limiting the capacity of the incumbent operator, the regulator actually oﬀers protection to the entrant, which in turn finds it profitable to sink money into quality upgrades.

Therefore, it is our belief that such a mechanism is more than a theoretical curiosity and worth being investigated further. Indeed, our results have been obtained in a highly stylized framework. Several generalizations of our example can be considered. Shouldn't the two firms be constrained? Would a firm, or two, voluntarily choose to constrain its sales? A common feature of these generalizations is that they require a more general analysis of sales-constrained pricing games with differentiated products. The characterization of price equilibria in such settings is on our research agenda.

Assuming that only two firms are active is also a limitation. This is especially important if we want to assess the dynamic impact of regulation on entry. For instance, it has been argued that a drawback of MQS was that they reinforce entry barriers (Maxwell, 1998). In this respect, observe that sales restrictions may lead to lower market covering (but since average quality increases, the consumer surplus also increases). Regarding entry, this might be good news because the larger the non-covered segment, the larger the incentive for a third firm to enter this market. Entry deterrence might therefore become costlier.

Fairly enough, assuming that the incumbent does not alter its quality selection as a response to the sales restriction considerably eases the analysis. However, it is our belief that these results capture some basic implications of sales restrictions on quality selection in more general settings. In Boccard and Wauthy (2001), we consider a trade game where the domestic and the foreign firms are free to choose any quality level, and thus induce any quality ranking between the domestic and the foreign product after the sales restriction is implemented. We reach qualitatively similar conclusions: incentives to quality selection under Bertrand competition are in line with those prevailing under Cournot whenever the sales restriction is effective. The degree of product differentiation decreases when the sales restriction becomes tighter. When it becomes long-run effective, a sales restriction induces a marked quality upgrading under Bertrand. In other words, the impact of a quantitative restriction on quality selection seems to be qualitatively robust.

APPENDIX

In this Appendix we derive the welfare analysis.

Welfare Analysis for Cournot Competition

The consumer surplus in a vertical differentiation model is

$$CS = \int_{1-x_i}^1 (x - p_i) dx + \int_{1-x_i-x_e}^{1-x_i} (xs_e - p_e) dx$$

and is equal to

$$\int_0^1 x dx = \frac{1}{2} \quad (A1)$$

if sold at marginal cost (here zero) to all consumers by the top-quality firm.

Non-binding Restriction. When $q \geq q^c$, quantities are $x_e^c(s_e) = 1/(4 - s_e)$, $x_i^c(s_e) = (2 - s_e)/(4 - s_e)$, prices are $p_i^c = (2 - s_e)/(4 - s_e)$ and $p_e^c = s_e/(4 - s_e)$; hence

$$\begin{aligned} CS^c(s) &= \int_{1-(2-s)/(4-s)}^1 \left(x - \frac{2-s}{4-s} \right) dx + \int_{1-(2-s)/(4-s)-1/(4-s)}^{1-(2-s)/(4-s)} s \left(x - \frac{1}{4-s} \right) dx \\ &= \frac{4 + s(1-s)}{2(4-s)^2} \end{aligned}$$

Since $\pi_i^c(s_e) = [(2 - s_e)/(4 - s_e)]^2 - \frac{1}{8}$ and $\pi_e^c(s_e) \equiv s_e/(4 - s_e)^2 - s_e^2/8$, total welfare is

$$\begin{aligned} W^c(s) &= CS^c(s) + \pi_e^c(s) + \pi_i^c(s) \\ &= \frac{48 - 20s - 12s^2 + 8s^3 - s^4}{8(s-4)^2} - \frac{1}{8} \end{aligned}$$

Given the entrant's optimal quality selection s_e^c , welfare is $\bar{W}^c \approx 0.24851$.

Binding Restriction. When $q \leq q^c$, quantities are $x_i = q$ and $x_e = (1 - q)/2$, prices are $p_i^{cq} = (1 - q)(1 - s_e/2)$ and $p_e^{cq} = (1 - q)s_e/2$; thus

$$\begin{aligned} \text{CS}^{cq}(s) &= \int_{1-q}^1 \left[x - (1-q) \left(1 - \frac{s}{2} \right) \right] dx + \int_{(1-q)/2}^{1-q} s \left(x - \frac{1-q}{2} \right) dx \\ &= \frac{s}{8} (2q - 3q^2 + 1) + \frac{1}{2} q^2 \end{aligned}$$

As $\pi_e^{cq}(s_e) = (1 - q)^2 s_e/4 - s_e^2/8$ and $\pi_i^{cq}(s_e) = q(1 - q)(1 - s_e/2) - \frac{1}{8}$, total welfare is

$$\begin{aligned} W^{cq}(s) &= \text{CS}^{cq}(s) + \pi_e^{cq}(s) + \pi_i^{cq}(s) \\ &= \frac{3(1-q)^2 s - s^2 + 3 - 4(1-q)^2}{8} \end{aligned}$$

and since the entrant optimal quality is $s_e^{cq} = (1 - q)^2$, welfare, as a function of the sales restriction q , is

$$W^{cq} = W^{cq}(s_e^{cq}) = \frac{1}{8} + q^2 - q^3 + \frac{1}{4} q^4$$

It is increasing over $[0; q^c]$ and reaches the maximal value $\bar{W}^{cq} \approx 0.24881$ for $q = q^c \approx 0.4557$.

Welfare Analysis for Bertrand Competition

Non-binding Restriction. When $q \geq q^b$, equilibrium prices are $p_e^b = s_e(1 - s_e)/(4 - s_e)$ and $p_i^b = 2(1 - s_e)/(4 - s_e)$ and sales are $x_e^b = 1/(4 - s_e)$ and $x_i^b = 2/(4 - s_e)$; thus the consumer surplus is

$$\text{CS}^b(s) = \int_{1-2/(4-s)}^1 \left[x - \frac{2(1-s)}{4-s} \right] dx + \int_{1-2/(4-s)-1/(4-s)}^{1-2/(4-s)} s \left(x - \frac{1-s}{4-s} \right) dx = \frac{5s + 4}{2(s - 4)^2}$$

Since profits are $\pi_e^b(s_e) = s_e(1 - s_e)/(4 - s_e)^2 - s_e^2/8$ and $\pi_i^b(s_e) = 4(1 - s_e)/(4 - s_e)^2 - \frac{1}{8}$, total welfare is

$$\begin{aligned} W^b(s) &= \text{CS}^b(s) + \pi_e^b(s) + \pi_i^b(s) \\ &= \frac{4s + 32 - 25s^2 + 8s^3 - s^4}{8(4 - s)^2} \end{aligned}$$

Thus, $W^b = W^b(s_e^b) = 0.27503 > W^c$.

Binding Restriction. When $q \leq q^b$, the analysis is more involved because to compute the profit of the incumbent and the consumer surplus we must derive the mixed strategy equilibrium precisely. The entrant randomizes between $p_e^s = (1 - q)s_e/2$ (probability α) and $\Phi_e(\tilde{p}_i) = \tilde{p}_i s_e/2$ (probability $1 - \alpha$) while choosing the weight α to ensure that $\tilde{p}_i$ is indeed a best reply for the foreign firm against the mixture.

When facing p_e^s the demand addressed to firm i is $x_i = q$ while it is $x_i = 1 - [p_i - \Phi_e(\tilde{p}_i)]/(1 - s_e)$ when facing $\Phi_e(\tilde{p}_i)$. The expected profit is thus

$$\begin{aligned}\pi_i^b(s_e, p_i) &= p_i \{ \alpha x_i(p_i, p_e^s) + (1-\alpha) x_i[p_i, \Phi_e(\tilde{p}_i)] \} - \frac{s_e^2}{8} \\ &= p_i \left\{ \alpha q + (1-\alpha) \left[1 - \frac{p_i - \Phi_e(\tilde{p}_i)}{1-s_e} \right] \right\} - \frac{s_e^2}{8}\end{aligned}$$

and is maximum when

$$\alpha q = (1-\alpha) \left[1 - \frac{2p_i - \Phi_e(\tilde{p}_i)}{1-s_e} \right] = 0$$

i.e. for

$$p_i = \frac{\Phi_e(\tilde{p}_i)}{2} + \frac{1-s_e}{2} \left(\frac{\alpha q}{1-\alpha} + 1 \right) = \frac{\tilde{p}_i s}{4} + \frac{1-s}{2} \left(\frac{\alpha q}{1-\alpha} + 1 \right)$$

Now, in equilibrium, α is such that this best reply is exactly $\tilde{p}_i$; hence

$$\alpha = \frac{\tilde{p}_i(4-s)/[2(1-s)]-1}{\tilde{p}_i(4-s)/[2(1-s)]-1+q}$$

The equilibrium profit is then

$$\begin{aligned}\pi_i^b(s_e) &= \frac{2q\tilde{p}_i^2}{\tilde{p}_i(4-s_e)-2(1-q)(1-s_e)} - \frac{s_e^2}{8} \\ &= \frac{2q(1-q)(1-s_e)^{1/2}}{4-s_e-2(1-s_e)^{1/2}} - \frac{s_e^2}{8}\end{aligned}$$

using the precise expression of $\tilde{p}_i = (1-q)(1-s_e)^{1/2}$.

We can also compute the expected consumer surplus

$$CS^b(s_e) = \alpha CS(s_e, \tilde{p}_i, p_e^s) + (1-\alpha) CS[s_e, \tilde{p}_i, \Phi_e(\tilde{p}_i)]$$

where

$$CS(s_e, p_i, p_e) = \int_{1-x_i}^1 (x-p_i)dx + \int_{1-x_i-x_e}^{1-x_i} (xs_e - p_e)dx$$

Hence

$$\begin{aligned}CS(s_e, \tilde{p}_i, p_e^s) &= \int_{1-q}^1 (x-\tilde{p}_i)dx + \int_{\tilde{p}_i^2/s_e}^{1-q} (xs_e - p_e^s)dx \\ &= \frac{q}{2}(2-q-2\tilde{p}_i) + \frac{s_e}{8}(1-q)^2\end{aligned}$$

and

$$\begin{aligned}CS[s_e, \tilde{p}_i, \Phi_e(\tilde{p}_i)] &= \int_{(p_i-p_e)/(1-s_e)}^1 (x-\tilde{p}_i)dx + \int_{(p_i-p_e)/(1-s_e)-(p_i s_e - p_e)/[s_e(1-s_e)]}^{(p_i-p_e)/(1-s_e)} \left(xs_e - \frac{\tilde{p}_i s_e}{2} \right) dx \\ &= \int_{\tilde{p}_i(2-s_e)/2(1-s_e)}^1 (x-\tilde{p}_i)dx + s_e \int_{\tilde{p}_i/2}^{\tilde{p}_i(2-s_e)/2(1-s_e)} \left(x - \frac{\tilde{p}_i s_e}{2} \right) dx \\ &= \frac{1}{2} - \tilde{p}_i - \frac{(2s_e^2 + s_e - 4)\tilde{p}_i^2}{8(1-s_e)}\end{aligned}$$

so that, using the precise expression of $\tilde{p}_i = (1-q)(1-s_e)^{1/2}$, we obtain

$$CS^b(s) =$$

$$\frac{1}{8} \frac{(4-s)[q(2-q)(4-s)+s](1-s)^{1/2} + 2(1-s)(-2qs^2 + 2q^2s^2 + 4qs - 3q^2s - s + 12q^2 - 16q)}{(1-s)^{1/2}(4-s) - 2(1-s)}$$

Finally total welfare $W^b(s_e) = CS^b(s_e) + \pi_i^b(s_e) + \pi_e^b(s_e)$ can be computed for the optimal quality choice $(1-q)^2$ to yield an increasing function of the quota, reaching approximately 0.286 at q^b .

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