# Enforcing Quality Leapfrogging through Quotas

Nicolas Boccard* & Xavier Wauthy†

November 2000

**Abstract**

Under price competition between a domestic and a foreign producer on a domestic market, an import quota can enforce the equilibrium quality ranking that favours the domestic producer and thereby increase domestic welfare.

JEL codes: L13

Keywords: Vertical Differentiation, Capacity, Bertrand Competition

## 0.1 Introduction

Several papers in the recent literature on international trade address the impact of trade policies on quality choice by the firms (e.g., Herguera & Lutz [1998], Zhou et al. [2000]). In particular, Herguera, Kujal & Petrakis [2000] study the impact of quotas on quality choice within a *Cournot* framework. In their model, quotas that would be ineffective at the free trade equilibrium in terms of quantity reactions are shown to be effective through their impact on quality choices. Because of the quota, firms tend to downgrade their qualities for quotas set in the vicinity of the free trade equilibrium.

Yet, the effect of the quota depends on the initial products' hierarchy which is not uniquely defined on a priori grounds. Indeed, standard duopoly models of vertical differentiation display *two* equilibria in pure strategies: one sees the domestic firm selling the high quality product and the other displays the reverse quality ranking. These two equilibria coexist even under relatively large costs asymmetries. Needless to say, these two hierarchies are not equivalent from a domestic welfare point of view. Indeed, even

*CSEF, University of Salerno, Italy and CORE, UCL, Belgium.

†CEREC, Facultés universitaires Saint-Louis, Bruxelles and CORE, UCL, Belgium

if costs are identical (so that equilibrium prices, sales and quality levels are the same in both equilibria), the domestic welfare is larger if the domestic producer sells the high quality good, simply because the high quality firm is the high profit firm (cf. Lehmann-Grube [1997]). In this respect, a trade policy whose main effect would be to select the domestic firm as the unique possible quality leader in equilibrium seems particularly desirable. Such a policy could be viewed as inducing *leapfrogging* by removing from the set of possible equilibrium outcomes the configuration where the foreign firm acts as a quality leader.

We show in this brief note that under price competition, the imposition of a quota has precisely this virtue. The strategic effect we underline here is in line with empirical papers such as those of Aw & Roberts [1986] on shoes and Feenstra [1988] on automobiles where such quality upgrading have been reported for the US market. Last, it is worth stressing that the level of the quota that is required to ensure these outcomes is to be set at a fair level, i.e. an apparently not too restrictive level.

In the sequel we establish this result with the help of a simple stage game where firms choose quality and price after the government has chosen the level of the quota.

## 0.2 Quota, Quality, Prices : a three stage game

Consumers' preferences are set according to the standard framework we use in our companion paper Boccard & Wauthy [2000] (hereafter BW). A domestic firm $d$ competes with a foreign one $f$ on the domestic market. The good with label $i = f, d$ has a quality index $s_i \in [0, 1]$. Consumers exhibit unit demand for the good and are characterized by a "taste for quality" $x$, $x$ is uniformly distributed in $[0; 1]$. The indirect utility function is $u(i, x) = xs_i - p_i$ for $i = d, f$. Not consuming yields a utility normalized to 0.

We consider a three-stage game $\Gamma$ : the domestic government chooses a quota $q$ then in the subgame $\Gamma(q)$ firms $i = d, f$ choose quality levels $s_i \in [0, 1]$ at a cost $\frac{s_i^2}{F}$.[1] The latter can be interpreted as the R&D investment that is required to yield the desired quality. In the last stage, a subgame $\Gamma(q, s_d, s_f)$ firms compete in prices $p_d$ and $p_f$.

In the present note, we retain the assumption made by Berry, Levinshon & Pakes [2000] for modelling the implementation of a quota: the foreign firm may sell in excess of the quota but a penalty $\theta$ is levied on these extra sales. We assume w.l.o.g. that

[1]Setting a finite common upper bound to qualities and consumers reservation price is not a severe limitation of our model (cf. Boccard & Wauthy [2000]).

the marginal cost of production is zero for both firms and for simplicity that $\theta > 1$ to guarantee that it is never profitable for the foreign firm to produce beyond the quota.[2] Hence in equilibrium the foreign firm respects the quota. Furthermore, firms produce to satisfy demand.[3] In other words, we assume that the foreign firm cannot turn consumers away if prices are such that her demand exceeds the quota level. The fact that *no rationing* takes place in this market considerably eases the formal analysis of the capacity game.

## 0.3 The Free Trade Benchmark

Let us first recall of the equilibrium analysis under free trade ($q = 1$) done in BW. Note that no firm would choose a quality identical to that of her opponent since this would yield the standard zero-profit Bertrand equilibrium in the price subgame. When the cost of choosing a positive quality is small ($F$ large) the incentives to differentiate are exclusively related to the price competition mechanism: one firm chooses the maximal quality 1 while the other accommodates with a lower quality $\frac{4}{7+\frac{100}{F}}$.[4] The ratio of differentiation decreases slowly towards $\frac{4}{7}$ as quality costs become negligible ($F \to +\infty$) while in equilibrium, sales converge to 29% of the market for the low quality firm and 58% of the market size for the high quality firm.

This quality-price game is similar to the "battle of the sexes" game where one player chooses his most preferred action, the high quality while the other accommodates with a lower quality. Which of the two players manages to achieve his preferred action is indeterminate, hence the existence of two subgame perfect equilibria. Since they only differ by the identity of the high quality firm, it should be clear domestic welfare is strictly larger when the domestic firm is the quality leader because it makes higher profits. The following proposition states that it is always possible to enforce this equilibrium by choosing adequately the level of the quota.

[2] The apparent penalty is around 10% of the price which is lower than our choice but we have to include the reputation effect for the firm if its sales exceed the quota and is prosecuted by the goverment.

[3] We follow in this respect the definition of Bertrand competition suggested by Vives [2000] in his recent book. This assumption is best view as a black-box for complex reputation effects not modeled here. We perform the analysis for case of rationing in a much more complex article : Boccard & Wauthy [1999].

[4] If $F < 8$, one firm chooses a high quality, increasing in $F$ but less than the upper bound. The other firm differentiates with a lower quality. Since analytic solutions are more complex to use we focus on $F > 8$.

## 0.4 The Price Equilibrium

We rely on the fact that a quota in a pricing game is formally equivalent to a capacity constraint and use the analysis of BW where firms choose capacity levels before competing in prices. The capacity constrained pricing game is denoted $G(k_l, k_h, s_l, s_h)$ where $k_i$ is the capacity level of firm $i$. We now recall a brief characterization of the equilibria that may obtain in such pricing games, starting with the configurations where products' qualities differ.

Under product differentiation, demands as a function of prices are defined by $D_l(p_l, p_h) = \frac{p_h s_l - p_l s_h}{s_l(s_h - s_l)}$ and $D_h(p_l, p_h) = 1 - \frac{p_h - p_l}{s_h - s_l}$. There exists a unique price equilibrium whose features depend on the particular capacity-quality constellation we are considering.

**Lemma 1** *The price equilibrium in $G(k_l, k_h, s_l, s_h)$ is*

| | | | |
|---|---|---|---|
| **[A]** | $p_l^A = \frac{s_l(s_h - s_l)}{4s_h - s_l}$, | $p_h^A = \frac{2s_h(s_h - s_l)}{4s_h - s_l}$ | *if* $k_l \geq \frac{s_h}{4s_h - s_l}$ *and* $k_h \geq \frac{2s_h}{4s_h - s_l}$ |
| **[B]** | $p_l^B = \frac{(1-k_h)s_l(s_h - s_l)}{2s_h - s_l}$, | $p_h^B = \frac{2(1-k_h)s_h(s_h - s_l)}{2s_h - s_l}$ | *if* $k_l \geq \frac{(1-k_h)s_h}{2s_h - s_l}$ *and* $k_h < \frac{2s_h}{4s_h - s_l}$ |
| **[C]** | $p_l^C = \frac{(1-2k_l)s_l(s_h - s_l)}{2s_h - s_l}$, | $p_h^C = \frac{(s_h - k_l s_l)(s_h - s_l)}{2s_h - s_l}$ | *if* $k_l < \frac{s_h}{4s_h - s_l}$ *and* $k_h \geq \frac{s_h - k_l s_l}{2s_h - s_l}$ |
| **[D]** | $p_l^D = (1 - k_h - k_l)s_l$, | $p_h^D = (1 - k_h)s_h - k_l s_l$ | *if* $k_l < \frac{(1-k_h)s_h}{2s_h - s_l}$ *and* $k_h < \frac{s_h - k_l s_l}{2s_h - s_l}$ |

Region $[A]$ applies in the domain where capacities are large enough for both firms to allow for the standard (i.e. unconstrained) Nash equilibrium. In region $[B]$, the low quality firm sells its capacity in equilibrium, while the low quality firm enjoys a large enough capacity. In region $[C]$, the contrary applies. Last, in region $[D]$, both firms capacities are low, so that both firms are constrained in equilibrium.

Whenever products are homogeneous, capacity constrained price competition under a no-rationing assumption yields a multiplicity of equilibria. The intuition for this result is as follows. Assume two firms face identical capacities and compete in price under our (Bertrand) no rationing assumption. If firm 1 names $0 < p_1 < p^m$ then, by naming $p_2 > p_1$ firm 2 captures no consumers (but inflicts losses to firm 1 which is forced to meet full demand, thereby selling beyond capacity). By naming $p_2 < p_1$, firm 2 captures all consumers, and is forced to serve all of them, thereby selling at loss beyond its capacity. In other words, because firm 2 is limited in capacity but nevertheless forced to meet full demand, undercutting the other's price may not be an attractive strategy.

The natural candidate best reply in the present case is thus to *match* the other's price. Since this argument is independent of $p_1$, a multiplicity of equilibria appears. Note also that in such equilibria, both firms enjoy strictly positive profits even though products are homogeneous. In case firms' capacities are highly asymmetric, there still exists a multiplicity of (asymmetric) equilibria where only the large capacity firm enjoys positive profits. The intuition here is that there exists a range of price which are such that even matching the other's price is costly for the low capacity firm, while undercutting is attractive for the high capacity one.

## 0.5 Inducing Leapfrogging

Analyzing pricing games in the presence of a quota amounts to consider a particular class of the capacity-constrained pricing games described above. More specifically, we consider $k_d = 1$ and $k_f = q$ , i.e. firm $d$, the domestic firm, is never constrained (since the quota does not constrain domestic sales) while the foreign firm is constrained at the level of the quota $q$.

In order to study the impact of the quota on firms' quality choices, we need to study the payoffs accruing to the firms, using the relevant equilibrium prices as defined by the previous equations. We will focus here on the case where quality cost is small ($F > 8$).[5] Recall that in order to prove our proposition it is sufficient to identify $\bar{q}(F)$ such that ($s_d = 1, s_f = \frac{4}{7}$) is the unique subgame perfect equilibrium of $\Gamma(q)$ for $q < \bar{q}(F)$.

**Proposition 1** *Given the cost for quality $\frac{1}{F}s^2$, there exists a critical quota level $\bar{q}(F)$ such that for $q < \bar{q}(F)$ the domestic firm is the quality leader in the unique subgame perfect equilibrium of $\Gamma(q)$.*

*Proof* First we study the quality choices in the case where $s_d > s_f$ and identify a lower bound on $q$ such that ($s_d = 1, s_f = \frac{4}{7}$) is indeed a feasible equilibrium. Second we study the quality game where $s_d < s_f$ and show that, irrespective of the quota level, the foreign firm always wants to maximize its own quality under this hierarchy. The best reply of the domestic firm in domain $s_d < s_f$ is then to differentiate (but less than in the standard case). Third, we consider the case where the domestic firm matches the foreign quality ($s_d = s_f$) . This case is relevant here because the domestic firm can secure positive profits in the pricing game even when products are homogeneous. We identify the critical level of the quota for which the domestic firm is indifferent between this imitation and differentiation. This level precisely defines $\bar{q}(F)$ since for any smaller

[5] Similar qualititative results hold when $F < 8$. The proofs for this case are available upon request from the corresponding author.

quota, the best reply of the domestic firm is to match the foreign quality, so that, in the face of this threat, the best reply of the foreign firm is to differentiate with a lower quality.

*Case i) The domestic firm has a strictly higher quality*

As $s_d > s_f$ we can set $k_h = 1, k_l = q$ and observe that $k_h \geq \frac{2s_h}{4s_h - s_l}$ and $k_l \geq \frac{(1-k_h)s_h}{2s_h - s_l}$ to conclude that the relevant price equilibrium is either in $[A]$ or $[C]$, depending on the quality choice made by the firms. Note first that the quota is effective if $s_l > \frac{4q-1}{q} s_h$ (region $[C]$). This is always satisfied for $q < \frac{1}{4}$ but never if $q > \frac{1}{3}$ as $s_l < s_h$ . Hence if the government chooses $q > \frac{1}{3}$ the price equilibrium is in region $[A]$. The equilibrium qualities under this particular hierarchy are therefore the standard ones: $s_d^A = 1$ and $s_f^A = \frac{4}{7}$. The choice of $q > \frac{1}{3}$ is obviously sufficient to ensure that $s_f = 1$ and $s_d = \frac{4}{7}$ is feasible as part of a subgame perfect equilibrium.

*Case ii) The foreign firm has a strictly higher quality*

Consider now the alternative hierarchy. Observe that $s_d < s_f \Rightarrow k_h = q, k_l = 1$. The price equilibrium is in area $[B]$ if $q < \frac{2s_h}{4s_h - s_l} \Leftrightarrow s_l > \frac{2q-1}{q} 2s_h$ (this is always true if $q \leq \frac{1}{2}$) and in region $[A]$ otherwise. In the latter region, the analysis is similar to that of *case i)* up to the firm's indices. We obtain $s_f^A = 1$ and $s_d^A = \frac{4}{7}$. The foreign firm sales in this equilibrium candidate are $\frac{7}{12}$ , which is also the lower limit of the quota for this price equilibrium to apply.

Consider then the case of a more restrictive quota. Region $[B]$ applies and profits are $\Pi_h^B = \frac{2(1-q)q(s_h - s_l)s_h}{2s_h - s_l}$ and $\Pi_l^B = \frac{(1-q)^2(s_h - s_l)s_h s_l}{(2s_h - s_l)^2}$. Note that $\frac{\partial^2 \Pi_h^B}{\partial s_h^2} < 0$ and $\frac{\partial \Pi_h^B}{\partial s_h} = 2(1-q)q\frac{s_h^2 + (s_h - s_l)^2}{(2s_h - s_l)^2} > 0$ in the relevant domain. This is sufficient to prove that the optimal choice of the foreign firm is the best available quality, irrespective of the quota level. As $\left.\frac{\partial \Pi_l^B}{\partial s_l}\right|_{s_h = 1} = \frac{(1-q)^2(2-3s_l)}{(2-s_l)^3}$ the best reply of the domestic firm is $\frac{2}{3}$. The condition for being in area $[B]$ is $q < \frac{3}{5}$.

*Case iii) Homogeneous products*

Because price competition is mitigated by the presence of the quota, it is necessary to consider the possibility that firms choose identical products. Under Bertrand competition, i.e. when the foreign firm must meet demand in any case and incur the penalty if selling beyond the quota, we can derive from BW that under $s_d = s_f = 1$, the set of equilibria is any $p_d$ in $\left[0; 1 - \sqrt{2q}\right]$ and any $p_f > p_d$; it yields nil profits for the foreign firm. The only stable equilibrium from this correspondence is the Pareto dominating one

$p_d = 1 - \sqrt{2q}$ yielding profit $\Pi_d^H(q) = \sqrt{2q}\left(1 - \sqrt{2q}\right)$.

It is a matter of computations to show that $q < .46 \Rightarrow \Pi_d^H(q,F) > \Pi_d^B(q,F)$ for $F$ large. This in turn means that the domestic firm always prefers imitation to optimal differentiation. Given that the domestic firm will choose $s_d = s_f$ it is optimal now for the foreign to differentiate to $s_f = \frac{4}{7}s_d$. Case *i)* therefore applies and leads to final equilibrium choices $s_d^A = 1$ and $s_f^A = \frac{4}{7}$. We have thus shown that $\overline{q}(+\infty) = .46$ More generally, the critical level ensuring this result is $\bar{q}(F) \simeq .32 + \frac{\sqrt{F}}{44} - \frac{F}{955}$ ; it is plotted on Figure 1 below for $F > 8$ (small quality cost). ■

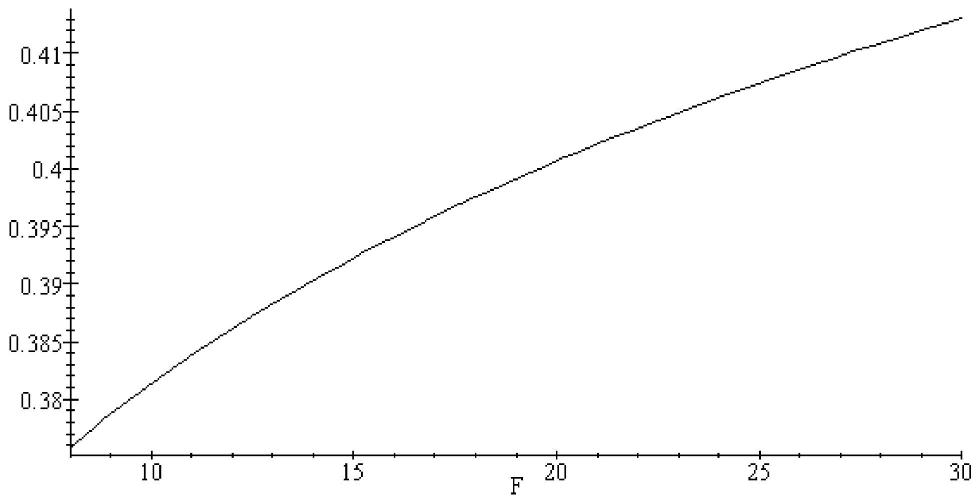


*Figure 1*

Let us summarize the argument behind our Proposition. The presence of the quota does not directly alters the willingness of the foreign firm to be the quality leader. Indeed, irrespective of the quota level, and whatever the quality level of the domestic firm, it remains true that in case he is the quality leader, the foreigner tends to choose the best available quality. However, the presence of the quota allows the domestic firm to be more aggressive at the quality stage. Indeed, the threat of matching foreign quality is a credible threat in the presence of a quota. This quota ensures indeed the domestic firm a positive profit, even if products are homogeneous at the price competition stage. Facing this threat, the foreign firm is better off accommodating in quality by optimally downgrading. It is therefore sufficient for the government to impose a quota at, or below, the level that makes the "quality matching" threat credible as a domestic best reply. It is noteworthy that the corresponding level of the quota is not highly restrictive. In particular, it is not binding in equilibrium.

Quality leapfrogging takes place here by enforcing domestic quality leadership as the unique equilibrium outcome. The reason why the quota selects the desirable equilibrium is now clear: by offering the domestic firm the credible threat of being very aggressive at the quality stage, it removes from the set of possible quality choices the whole set where the foreign firm would be the quality leader.

# References


[1] **Aw Y. & M. Roberts (1986)**, *Measuring quality change in Quota-Constrained Import Markets: the case of US Footwear*, Journal of International Economics, 21, pp. 45-60

[2] **Berry S., J. Levinshon & A. Pakes (2000),** *Voluntary Export Restraints on automobiles: Evaluating a Trade Policy***,** American Economic Review, 89, pp 400-430

[3] **Boccard N. & X. Wauthy (1999),** *Import quotas forster product imitation in vertically differentiated duopolies***,** mimeo

[4] **Boccard N. & X. Wauthy (2000),** *Vertical Differentiation: The Case of Capacity Commitment and Price Competition,* mimeo (also CORE DP 9956).

[5] **Zhou D., B.J. Spencer & I. Vertinsky**, *Strategic Trade Policy with Endogenous Choice of Quality and Asymmetric Costs*, NBER working paper 7536.

[6] **Feenstra R. (1988)**, *Quality change under trade restraints in Japanese autos*, Quarterly journal of Economics, 103, pp 131-146

[7] **Herguera I. & S. Lutz (1998)**, *Oligopoly and Quality Leapfrogging* , The World Economy, 21, pp. 75-94

[8] **Herguera I. , P. Kujal & E. Petrakis (2000),** *Quantity restrictions and endogenous quality choice*, forthcoming International Journal of Industrial Organization

[9] **Lehmann-Grube (1997)**, *Strategic choice of quality when quality is costly: the persistence of the high-quality advantage*, Rand Journal of Economics, 28, p. 372-384

[10] **Vives X. (2000)**, *Oligopoly pricing: old ideas, new tools*, MIT Press, Cambridge Massachusetts