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# A Rationale for Meeting Quotas Asymmetrically

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## Abstract

Under certain conditions, otherwise identical, competing firms may find it jointly preferable to face differing degrees of trade barriers on individual products rather than symmetric trade barriers. The key is the ability to reduce marginal production cost via research and development. The economic significance of this insight is that there could be a role for a market for quota allotments. This insight also has applications to Voluntary Export Restraints in which a priori symmetric, restricted firms may prefer to have individual production levels allocated asymmetrically. This indicates the need for detailed studies of how quotas are met by individual firms. (JEL F12, F13)

## Introduction

In the literature on quotas, there seems to be a dearth of detailed empirical investigation of how quotas are met by individual firms. The authors offer theoretical reasons why this void should be filled and suggestions how it should be filled. In the case of Voluntary Export Restraints (VERs) in particular (such as the U.S.-Japan automobile VER of the 1980s), one may guess that otherwise equivalent firms would meet the quota equally (or that quotas would be allocated strictly by market share). Also, the U.S. International Trade Commission (ITC) recently cleared the way for President George W. Bush to raise trade barriers to steel imports. Again, one may guess that otherwise equivalent firms would meet any quotas equally. About 40 countries from around the world had planned a meeting in December (2001) to have each country give specific plans on how best to cut steel production (see Matthews [2001]). In light of such activity and work on two-stage models such as Newberry [1990], Meister [1992], and Salant and Shaffer [1998; 1999], it seems imperative to examine how such quotas are met by constrained firms: not only at the firm level, but also by product classification. Such two-stage models may take the following form. Firms choose how much to spend on marginal cost (MC)-reducing research and development at stage one, and based on resulting MCs, firms then choose quantities (or prices) in stage two. Salant and Shaffer [1999] build on key insights pertaining to Cournot competition due to Bergstrom and Varian [1985a; b]. Salant and Shaffer [1999] summarize Bergstrom and Varian's insights by stating [p. 585]:

"Aggregate production costs strictly decline with no change in gross revenue or gross consumer surplus if the prior actions strictly increase the variance of marginal costs without changing the marginal cost stun."

Salant and Shaffer's [1999] contribution is that even when it is costly to induce asymmetries in marginal costs (for example, via research and development expenditures), private and social optima are asymmetric if the cost of inducing the second stage asymmetry is less than the reduction in aggregate production costs.

This work differs from Salant and Shaffer's in that the authors analyze the possibility of asymmetric quota allocations inducing differing levels of research and development expenditures among a priori identical firms. This paper finds that if it is possible to reduce marginal production costs via research and development, quota-constrained firms can see an increase in joint profits if quotas are met asymmetrically (unambiguously so if goods are perfect substitutes). The economic significance of this insight is that there could be a role for a market in which firms could trade quota allotments. Since joint profits of a priori symmetric firms are higher if a quota is met asymmetrically (rather than symmetrically), a firm would be willing to pay more for another firm's quota allocation than that other firm's reservation price. Further, joint profit maximization is a reasonable goal if side payments are costless. Allowing trade of quota allotments may be a close substitute for costless side payments.

If side payments are not costless or allowable, allocating a quota asymmetrically may still be of benefit to firms if they operate in multiple markets. For example, suppose two identical, competing firms in country A export to country B. If country B enacts a quota restricting imports from country A to a specified level, q, the two firms in country A may find joint profits will be higher if they meet the quota by allowing one firm to meet more than half the quota rather than having each firm produce half. This can hold if firms can reduce marginal production cost via research and development. Of course, the firm producing less than half the quota will not make as much profit as the firm producing more than half the quota; thus, one may wonder if both firms would ever be satisfied with such an arrangement. They may be if both firms produce two goods, y and z. Suppose country B places a restrictive quota, on both goods. If one firm is allowed to produce more than half the quota on good y while the other firm is allowed to produce more than half the quota, on good z, both firms' individual profits can be higher than if they both meet the quotas on goods y and z equally. (Richardson writes that VERs have the property of giving an "invitation to supernational regulation and cartel-like market sharing among incumbent firms" [Richardson, 1994, p. 644].) Therefore, it is important for empirical analysts to investigate precisely how quotas such as VERs are met: at the firm level and even by product classification. The remainder of the paper is organized as follows. In the second section, the model is specified and analyzed, and intuition is given for the results. The third section gives implications of the model and conclusions.

## The Model

The model employed is one in which firms choose levels of marginal-cost-reducing research and development, and then, based on these choices, decide how much output to produce (or what price to charge if price competition). Generally, this type of setup is specified as a two-stage game with research and development levels chosen in stage one and output levels (or prices) in stage two (see Spencer and Brander [1983]). In this paper, the two-stage specification is not necessary since firms are constrained by a quota.

## Elements of the Model

Suppose there are two countries in the model: A and B. Two firms (1 and 2), located in country A, are a priori identical (including selling perfect substitutes), and they export all output to country B. The remaining elements of the model are as follows:

| | |
|---|---|
| Firm i's output: | $q_i$ (i = 1, 2) |
| Total output: | $\Sigma_i q_i = Q$ |
| Firm i's level of research and development: | $x_i$ (where $x_i$ measures the number of dollars of reduction in the level of constant marginal cost) |
| i's cost of research and development: | $\varphi(x_i)$ ($\varphi^0$ > 0, $\varphi^{00}$ > 0, and $\varphi$ is twice continuously differentiable) |

| | |
|---|---|
| i's research and development-contingent constant MC: | $c_i = C - x_i$ (where C is a positive constant) |
| Inverse demand facing firm i: | $p = f(Q)$, $f^0(Q) < 0$, i = 1,2. |

The inverse demand facing both firms are the same since firms are identical (and they sell perfect substitutes). Also, the price, p, is a function of $Q(= q_1 + q_2)$, and both firms receive the same price for their product since goods are perfect substitutes.

Analysis of the Model (with quota)

Denote profit of the jth firm as:

(1) $\pi_j = pq_j - q_j[C - x_j] - \varphi(x_j) - F_j$,

where $q_j$ is the quota assigned to the jth firm, C is the constant marginal cost in the absence of research and development, φ symmetrically amortizes the cost of developing a production technique over the life of that technique, and $F_j$ is j's fixed cost. Further, the price, p, of the product will not change if the total quota is not changed, since firms produce perfect substitutes. The only means a firm has for maximizing profit in this setting is by varying the argument of φ. Therefore, differentiating $\pi_j$ with respect to x and setting the resulting expression equal to zero yields:

(2) $\varphi^0(x_j) = q_j$.

Equation (2) indicates that the firms should undertake research and development until the marginal research and development cost of reducing constant-marginal production cost ($\varphi^0(x_j)$) equals the marginal benefit ($q_j$). Intuitively, the marginal benefit of reducing marginal production cost is $q_j$ since if a firm were to reduce its constant marginal cost by $1, for example, it would enjoy a production cost savings of $q_j \cdot \$1$. Inverting (2) yields:

(3) $x_j = x(q_j)$,

where x is the inverse function of $\varphi^0$. Note, that if firm j were allowed a larger fraction of the quota (yet keeping total quota the same), it would have incentive to undertake more research and development since the marginal benefit ($q_j$) would rise. Intuitively, the firm would have a larger output base over which to reap the benefits of additional research and development expenditure.

Next, examine joint profit ($\Pi = \pi_1 + \pi_2$) for maxima and minima. Assume a planning board allocates the total quota (q) between the two firms so that $q = q_1 + q_2$(or $q_2 = q - q_1$). Note $dq_2/dq_1 = -1$. Therefore:

(4) $\Pi = pq - Cq + q_1x(q_1) - \varphi(x(q_1)) + q_2x(q_2) - \varphi(x(q_2)) - F_1 - F_2$.

Note that the first two terms on the right-hand side of (4) do not change with reallocation of the quota since the total quota, q, remains unchanged by assumption. Differentiating (4) with respect to $q_1$ yields:

(5) $d\Pi/dq_1 = q_1x^0(q_1) + x(q_1) - \varphi^0(x(q_1))x^0(q_1 - q_2x^0(q_2) - x(q_2) + \varphi^0(x(q_2))x^0(q_2)$.

Since $\varphi^0(x_j) = q_j$, from the first-order condition (in (2)), (5) can be written:

(6) $d\Pi/dq_1 = x(q_1) - x(q_2)$,

which is zero if $q_1 = q_2$. The second derivative of Π with respect to $q_1$ is:

$d2\Pi/dq^{2,\text{ sub }1} = x^0(q_1) + x^0(q_2) > 0$,

over the entire range of $q_1(q_1 \in [0, q])$. Since the first derivative is zero at $q_1 = q_2$ and the second derivative is positive everywhere, Π has a strong relative minimum at $q_1 = q_2$. In fact, equal division of the quota, is the only interior extremum. If there were another interior extremum, it would have to be a maximum, which is ruled out by the second-order condition (7). Therefore, the maximum of H is a corner solution, and Proposition 1 follows.

Proposition 1: If firms are a priori symmetric, sell perfect substitutes, and can reduce marginal production cost via. research and development, allowing them to meet a quota, of q asymmetrically rather than symmetrically increases joint profits.

Intuition

It may not be intuitively obvious that allowing two a priori symmetric firms to meet a quota asymmetrically results in joint profits being higher than if the quota were met symmetrically--especially when joint research and development spending will be higher in the asymmetric case. To gain intuition, consider the following scenario. Suppose the two symmetric firms were to meet the quota, equally. Suppose also that they have chosen individually optimal research and development levels (according to (3)). Thus, the firms would have identical constant marginal production costs. Now for comparison, let firm 1 be allowed Δ more output and firm 2 be allowed Δ less, and suppose initially that no changes in research and development levels are made. Firm 1's profit would increase by the same amount firm 2's profit would decrease (since there would be no change in the price due to firms selling perfect substitutes). However, firm 1 could achieve even higher profit by increasing research and development since its marginal benefit from research and development would now exceed the marginal cost of research and development. The marginal benefit is now higher due to firm 1 producing more.

Firm 2 can make its reduction in profit less if it does less research and development than in the symmetric case. If it were at the research and development level that would have been optimal in the symmetric case, marginal benefit of research and development would be less than marginal cost of research and development in the asymmetric case. This is due to firm 2 producing less than it would in the symmetric case. Thus, firm 2 should do less research and development than it would in the symmetric case. Then firm 2's profit will not be as much lower (than the symmetric case) as it otherwise would be. Therefore, firm 2's reduction in profit will be less than firm 1's gain in profit.

## Implications and Conclusions

The fact that the maximum is a corner solution has au important implication. There is a potential role for a market for quota allotments. With two a priori, symmetric firms, one firm could purchase another firm's quota, and both could be better off than if they meet the quota symmetrically. Since joint profit is higher in the symmetric case, the firm allowed more than half the quota gains more than the other firm loses. Therefore, a firm could purchase the other firm's quota for more than that firm would make from producing its own quota and still make more than it would producing just its own quota. Alternatively, a firm is willing to pay more to acquire the other firm's quota than that other firm is willing to sell it for. If the policy goal is to benefit business owners, the sale of quotas should be allowed since both firms can gain from such trade. Note also, that reallocating a quota would not affect the price if goods are perfect substitutes. Therefore, consumer welfare of the country importing products would not be affected. However, if the policy goal is to benefit the factors of production, then individual quotas should be assigned equally to maximize factor payments (since total production costs are higher when constant marginal costs are identical rather than asymmetric, ceteris paribus [Bergstrom and Varian, 1985]).

As Salant and Shaffer [1998] point out, "joint profit maximization is an appropriate objective when side payments are costless." Allowing firms to trade quota allocations conceivably could be a low cost substitute for side payments. If side payments are costly, allocating quotas asymmetrically may still be appropriate if firms operate in multiple markets. If two a priori, symmetric firms (1 and 2) produce two goods (y and z) subject to quotas, firm 1 may be allowed more than half the quota for good y while firm 2 is allowed more than half the quota for good z. In this case, joint profits would be higher than if both firms met both quotas symmetrically. Such an arrangement may substitute for side payments or allowing trade of quota allotments. Therefore, it is important for empirical analysts to investigate precisely how quotas such as VERs are met--at the firm level and even by product classification.

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