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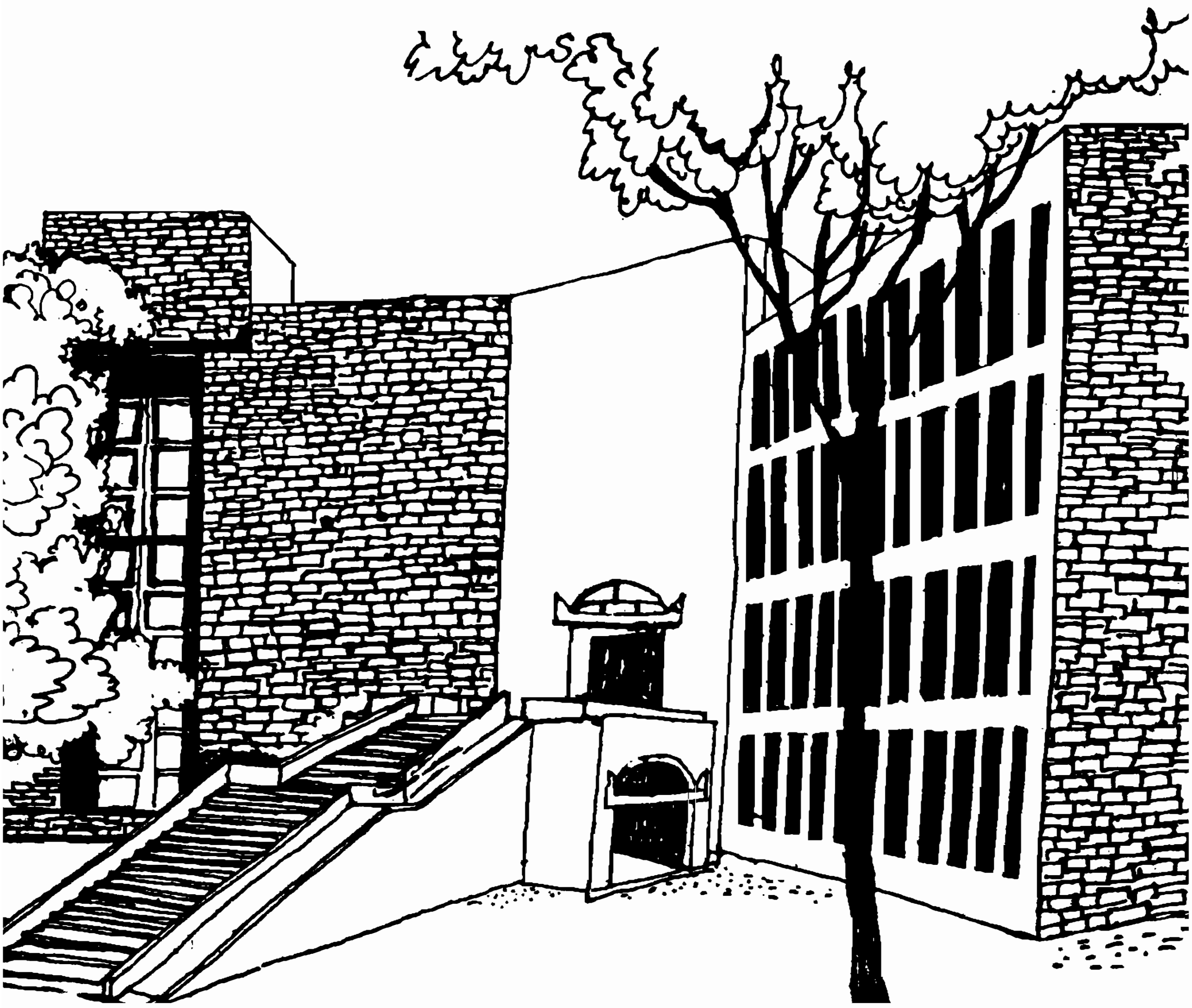

CONSUMPTION EXTERNALITIES AND PRODUCT QUALITY: THE MARKET FOR MILITARY HARDWARE

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CONSUMPTION EXTERNALITIES AND PRODUCT QUALITY: THE MARKET FOR MILITARY HARDWARE

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This paper considers arms race between two rival nations and arms trade between these buyer countries and a number of producers. All the parties are completely informed, and the sellers manufacture differentiated products. It is shown that intensified competition among the producers leads the buyer countries to step up their military buildup but has no effect on the buyers' national welfare if they have symmetric demand for arms. We also find the conditions under which increased competition among the sellers induces all of them to produce goods of higher qualities in equilibrium.

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1. INTRODUCTION

Arms trade between the North and the South amounts to billions of dollars each year, yet there are few economic analyses of arms trade. Unlike most products, the demand for military equipment depends on the extent of rivalry between buyer countries and on the amount of weapons the rival nations purchase. This paper examines an interaction between arms trade and arms races and its welfare implications.

Up until the 1960s, the two superpowers supplied military assistance and equipment to their recipient nations. The superpowers based their arms exports primarily on political considerations and dictated the terms of trade. But since the 1970s, a number of new arms producers has emerged in Europe, Asia, and Latin America. As development and production in the weapons industry require a large scale operation, the suppliers began promoting exports harder in order to support the viability of their defense production. Fierce competition among the growing number of exporters has increased the bargaining power of the recipient nations. Consequently, the trend in arms trade has gone through some major changes over the last couple of decades.

First, the buyer nations now acquire far more advanced and state-of-the art weapons (as opposed to the dated equipment they used to receive). Procurement of such modernized equipment by one country puts pressure on its rivals to purchase comparable systems. Second, competition drives the suppliers to offer more attractive financing arrangements to the buyers. The cost of such financing are often subsidized by the governments of the exporters. Third, arms deals frequently involve transfer of technology and know-how via licensing. Finally, the importing nations demand and obtain offset deals, e.g. coproduction, counter-trade, and joint ventures.[1]

In this paper, we set up a simple model of complete information that captures some of the major trends in arms races and arms trade. Two questions are addressed: first, how would the rivalry between the importing countries determine their demand for defense systems? Second, how would increased competition among the sellers affect their choice of product quality, the recipient nations' defense capacities, and their national welfare?

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[1] For more detailed accounts of the major trends in arms trade, see Gansler (1981) chapter 8, Pierre (1982), Bajusz and Louscher (1986) chapter 2, SIPRI Findings (1986) chapter 4, and SIPRI (1987) chapter 1.

The literature on arms races (see, for example, Bueno de Mesquita and Lalman 1988, Hirshleifer 1988 and 1991, and Skaperdas 1991) shed light on the factors that determine the levels of arms buildup and their effects on the likelihood of actual war. These studies on the technology of conflict, however, do not distinguish between arms producers and buyer nations. The last few years have seen drastic shifts in global politics where the equations of power have gone through major changes. Amid such turbulent political developments, the structure of arms trade has been reshaped. In order to analyze the implications of these changes, we extend the models developed by Hirshleifer and Skaperdas and incorporate arms trade into our setup. We find that the producers' market structure indeed has significant effects on the quality of weapons and on the degree of arms race between the importing nations.

As mentioned before, purchase of military equipment differs from most goods in that its demand depends upon (among others) the quantity and quality of weapons the rival nations possess. The models of product quality choice (see, for example, product differentiation models by Spence 1976, and Dixit and Stiglitz 1977; and models of vertical differentiation by Shaked and Sutton 1982) do not take consumption rivalry into account. On the other hand, the literature on consumption externalities (e.g. Farrell and Saloner 1985, and Katz and Shapiro 1985) does not consider the issue of product quality choice. This paper attempts to bridge the gap in the literature. We analyze arms trade and arms races jointly by studying the suppliers' choice of quality of weapons in the presence of rivalry between the buyers.

It is shown that increased competition among the producers (parameterized by the number of sellers and their cost efficiencies) leads the buyer countries to step up their military buildup. The higher levels of defense, however, have no effect on their welfare if the buyers have symmetric demand for arms. This is because the probability of winning a conflict is not affected by the levels of armament if both countries acquire the same defense capacities. Most interestingly, we find that when erstwhile inefficient producers (those with high fixed costs of developing new weapons) become more efficient and hence intensify the competition among the sellers, the recipient nations get higher quality of arms from *all* producers--if the firms with higher fixed costs have lower variable costs of production. This occurs despite the fact that quality and quantity of arms are substitutes in our set up. This finding contrasts with the standard results in the literature on firms' choice of product quality; the principle of differentiation in the models of vertical differentiation (e.g. Shaked and Sutton 1982) states that when one of the sellers supplies high product quality, the other firm optimally chooses low quality in order to mitigate the price competition that follows.

The rest of the paper is organized as follows: Section 2 sets up the model and solves for the buyer's decisions. Section 3 derives the sellers' pricing and product quality choices, and discusses the main findings. We conclude in Section 4.

2. THE MODEL

2.1 Sequence of events

There are two rival nations, A and B. They spend part of their initial endowment $R^j(j=A,B)$ on defense. Country j's defense capacity (preparedness) is measured by y^j. These countries do not produce arms domestically, however, and must import weapons.[2] There are n ($\geq$ 2) arms manufacturers outside the two nations. Each firm produces one type of good, and their products are differentiated. The sellers choose a_i, the quality of their products, and set prices p_i (i=1,..,n; throughout the paper, superscripts denote the importing nations, and subscripts denote the sellers). Country j purchases x^j_i (i=1,..,n; j=A,B) units of good i. Buyer j's preparedness y^j is a function of quality a_i and quantity x^j_i of the military equipments.

Let $G^j \equiv \sum_{i=1}^{n} p_i x_i^j$ be country j's total expenditure on defense.

The arms race between the two buyers follows the model analyzed by Hirshleifer (1988, 1991) and by Skaperdas (1991). The levels of armament y^A and y^B in turn determine $\pi^A(y^A,y^B)$, the probability that country A wins in conflict. Of course, country B wins with probability $\pi^B(y^A,y^B) = 1 - \pi^A(y^A,y^B)$. The winner receives fraction s of its own remaining resources, $R^j - G^j$, plus fraction t of the other nation's remaining resources, $R^h - G^h$ ($h \neq j$), where $0 \leq t \leq s \leq 1$. The loser gets nothing. That $t \leq s \leq 1$ is meant to capture the attrition of the resources lost to combat. In this interpretation, the countries are inevitably engaged in conflict. Alternatively, we may assume that instead of waging war, the two nations bargain

[2] We assume that countries A and B do not have the technology to develop and produce sophisticated military equipments. "The buyers" and "the importing nations" are used interchangeably.

over the share of the total resources, $s\{R^j - G^j\} + t\{R^h - G^h\}$. (Any deadweight loss associated with the bargaining is captured by $1 - s$ and $1 - t$.) Here, $\pi^j(y^A,y^B)$ is the share received by country j. Though the countries do not fight, they build up defense y^j in order to enhance their bargaining position. In either interpretation, the expected payoff to country j, U^j is

(1) $$U^j = \pi^j(y^A,y^B)\,[s\{R^j-G^j\} + t\{R^h-G^h\}].$$

Throughout the paper we assume that all parties are completely informed.

2.2 *Buyers' decisions*

Countries A and B simultaneously choose the defense levels y^A and y^B. In order to attain target y^j, country j also decides the amount of product i (i=1,..,n) it purchases. Country j's defense capacity is a function of a_i and x^j_i. For concreteness, suppose it takes a constant elasticity of substitution (CES) form:

(2) $$y^j = \left[\sum_{i=1}^{n} (a_i\, x_i^j)^\rho\right]^{1/\rho} \quad ; 0 < \rho \leq 1.$$

The products are differentiated so long as $\rho < 1$. Quality and quantity of each product are substitutable. The substitutability between quality and quantity of military equipments is well documented in Peck and Scherer (1962; chapter 10) and in Rogerson (1990, p.83).

The buyer's decisions are solved in two stages. First, given target y^j and the product quality a_i and prices p_i, country j chooses $\{x_1^j,x_2^j,..,x_n^j\}$ to minimize the cost, $G^j = \sum_{i=1}^{n} p_i x_i^j$, subject to (2).

The standard cost minimization problem yields j's demand for input i:

(3) $$x_i^j = y^j \frac{\left(\frac{a_i^{\rho}}{p_i}\right)^{\frac{1}{1-\rho}}}{\left[\sum_{k=1}^{n} \left(\frac{a_k}{p_k}\right)^{\rho} 1-\rho\right]^{\frac{1}{\rho}}}, \quad (i=1,..,n).$$ [3] 3

The minimized cost of attaining y^j is

(4) $$G^{j*} = y^j \left[\sum_{i=1}^{n} \left(\frac{a_i}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-\frac{1-\rho}{\rho}} \equiv g y^j ,$$

where g represents the term multiplied by y^j and is inversely related to the sum of the quality-price ratios, a_i/p_i.

Country j also chooses its level of defense y^j to maximize its expected payoff (1), taking the rival's defense y^h as given. The outcome depends on the probability of winning and on the prize to the winner. To explicitly derive the buyers' demand for inputs x^j_i, consider specific functions for the probability of winning. Following Hirshleifer (1988) and the literature on rent seeking (see, e.g. Baye, Kovenock, and de Vries 1992), suppose $\pi^j(y^A,y^B) = y^j/(y^A+y^B)$. This function has the properties that (i) the probability of winning is 1/2 if both countries have the same defense levels; (ii) it rises with its own preparedness y^j and falls with the rival's y^h; and (iii) the country has no chance of winning if it does not arm. The last property forces both nations to send positive amounts on defense.[4]

[3] The derivation can be found in microeconomics textbooks; see, for example, Varian (1984), pp.31-33.

[4] Although the buyer nations will spend positive amounts on defense, this does not imply that peace is impossible; as mentioned before, the countries may bargain with each other rather than wage war.

Assuming that an interior solution exists,[5] the first-order condition of (1) with respect to y^j yields

$$(5) \qquad y^A = -y^B + \left\{\left(1-\frac{t}{s}\right)(y^B)^2 + \frac{1}{g}y^B\left(R^A + \frac{t}{s}R^B\right)\right\}^{\frac{1}{2}} \quad \text{, for country A, and}$$

$$(5)' \qquad y^B = -y^A + \left\{\left(1-\frac{t}{s}\right)(y^A)^2 + \frac{1}{g}y^A\left(R^B + \frac{t}{s}R^A\right)\right\}^{\frac{1}{2}} \quad \text{, for country B.}$$

The second-order conditions for maximization are satisfied. Equations (5) and (5)' are a pair of the reactions functions. We can solve explicitly for Nash equilibrium in the levels of defense capacities $\{y^A,y^B\}$, if we assume symmetry between *s* and *t* or between the country sizes, R^A and R^B:

$$(6) \qquad \begin{cases} y^A = y^B = \dfrac{(R^A + R^B)}{4g} & \text{if } s=t \\ y^A = y^B = \dfrac{s+t}{3s+t}\cdot\dfrac{R^A}{g} & \text{if } R^A = R^B \end{cases}$$

Recall that *s* is the fraction of a country's own productive resources and *t* is the fraction of the rival's remaining resources the winner receives. If s = t, the expected payoff to both countries are the same, so both choose the same level of defense regardless of their initial endowments. (This case was analyzed by Hirshleifer 1988.) If t < s but the countries have the same initial resources, then equation (6) states that their demand for arms are positively related to (s+t)/(3s+t). Since this term increased with *t* and falls with *s*, each country becomes more aggressive when *t* (the booty) is large and *s* is small (the latter implies a low opportunity cost of arming). In both cases, $y^A + y^B$ is proportional to $(R^A + R^B)/g$. For ease

[5] Hirshleifer (1988) examines corner solutions, as well as the solutions when the probability of winning takes a logistic form. In this paper, we consider the simplest ratio form for the probability of winning, in order to focus on the effect of the sellers' market structure on the buyers' actions.

of notation, let $R \equiv (s+t)\{R^A+R^B\}/(3s+t)$. R is a constant and is proportional to the total initial endowments. Combining (3) and (6), the total demand for product i by the two buyer nations is

$$(7) \qquad X_i = x_i^A + x_i^B = R \frac{\left(\frac{a_i^\rho}{p_i}\right)^{\frac{1}{1-\rho}}}{\sum_{k=1}^{n}\left(\frac{a_k}{p_k}\right)^{\frac{\rho}{1-\rho}}}, \quad (i=1,..,n).$$

2.3 Sellers' decisions

There are n arms manufacturers. Each chooses the product quality, taking the other firms' actions as given. The choice of a_i determines firm i's fixed cost $F_i(a_i)$ of developing a weapon and its (constant) unit cost of production, $c_i(a_i)$. They then set prices simultaneously. The sellers' decisions are solved backwards from the final stage.

In the price setting stage, the product quality and the costs, F_i and c_i $(i = 1,..,n)$, are fixed. Using the demand function (7), seller i sets its price p_i to maximize its profit P_i:

$$(8) \qquad \text{Max } P_i = X_i\,(p_1,..,p_n)\,\{p_i - c_i\} - F_i$$

$$= -F_i + R\{p_i - c_i\} \frac{\left(\frac{a_i^\rho}{p_i}\right)^{\frac{1}{1-\rho}}}{\sum_{k=1}^{n}\left(\frac{a_k}{p_k}\right)^{\frac{\rho}{1-\rho}}}$$

The objective function is similar to the monopolistic competition models by Dixit and Siglitz (1977). Unlike in monopolistic competition, however, the number of producers is small, so each seller recognizes the effect of its action, a_i/p_i, on the sum of these terms; there is a strategic interaction among the sellers.

Again assuming an interior solution, first-order condition of (8) with respect to p_i yields the reaction function for firm i:

$$(9) \qquad \left(\frac{a_i}{p_i}\right)^{\frac{\rho}{1-\rho}} = \sum_{k\neq i}^{n} \left(\frac{a_k}{p_k}\right)^{\frac{\rho}{1-\rho}} \frac{\left[\rho\cdot\frac{p_i}{c_i} - 1\right]}{1-\rho} \quad , (i = 1,2,\ldots,n).$$

The second-order conditions for maximization are satisfied.

Solving these n reaction functions, we get a Nash equilibrium in prices:

$$(10) \qquad p_i = \frac{n-\rho}{(n-1)\rho}c_i \quad , (i = 1,2,\ldots,n).$$

It is easy to show that the term $(n-\rho)/((n-1)\rho)$ decreases with both n and ρ; the larger the number of sellers and the higher the elasticity of demand, lower the price-cost margin.

In the quality-setting stage, we are interested in how asymmetry among the producers affects arms race between the buyers. To make the analysis tractable, we will henceforth assume that $\rho = 1/2$. Then

$$(10)' \qquad p_i = \frac{(2n-1)c_i}{n-1}$$

It can be shown that this is a unique Nash equilibrium in prices if n=2.[6] By substituting (10)' and ρ=1/2 into (8), firm i's profit can now be expressed as a function of the vector of qualities, $a_1, a_2, \ldots, a_n$:

$$P_i = \frac{R\left(\frac{nc_i(a_i)}{n-1}\right)\left(\frac{a_i}{c_i(a_i)^2}\right)\left(\frac{n-1}{2n-1}\right)^2}{\sum_{k=1}^{n}\left(\frac{a_k}{c_k(a_k)}\right)\left(\frac{n-1}{2n-1}\right)} - F_i(a_i) \qquad \Rightarrow$$

[6] The proof is omitted, but is available upon request.

$$(11) \qquad P_i = \frac{nR}{2n-1}\left(\frac{r_i(a_i)}{r_i(a_i) + \sum_{k\neq i}^{n} r_k(a_k)}\right) - F_i(a_i) \quad , (i=1,2,...,n).$$

where $r_i(a_i) \equiv a_i/c_i(a_i)$ is the quality/cost ratio for firm i.

We are again interested in an interior solution. At an interior solution, the first-order condition of (11) with respect to a_i is set equal to zero, and the second-order condition must be negative. The following assumption ensures these conditions:

[A.1] $r'_i(a_i) > 0$, $r''_i(a_i) < 0$; and $F'_i(a_i) > 0$, $F''_i(a_i) > 0 \;\; \forall$ i.

If $r'_i(a_i) \leq 0$ so that the unit cost $c_i(a_i)$ is not a concave function of a_i, the first-order condition is always negative; firm i would find it optimal to choose the minimum level of quality.

We will use the following example that satisfies assumption [A.1]:

(ex 1) $F_i(a) = \alpha_i a^2$, and $c_i(a) = \beta_i a^\gamma$ ($\alpha_i>0$, $\beta_i>0 \forall i$, $0 \leq \gamma < 1$).

Then $r_i(a) = a/c_i(a) = a^{1-\gamma}/\beta_i$.

Given [A.1], the optimum is found by setting the first-order condition of (11) with respect to a_i equal to zero:

$$(12) \qquad \frac{nR}{2n-1}\left[\frac{\left(\sum_{k\neq i}^{n} r_k(a_k)\right)}{\left(\sum_{l=1}^{n} r_l(a_l)\right)^2}\right] - \frac{F'_i(a_i)}{r'_i(a_i)} = 0 (i=1,2,...,n).$$

3. CHARACTERIZATION OF ARMS TRADE AND ARMS RACES

3.1 Outcomes when all firms are identical

We first consider a symmetric solution. Suppose all n producers have the same technology so that $c_1(a)=c_2(a)=...=c_n(a)=c(a)$; and $F_1(a)=F_2(a)=...=F_n(a)=F(a)$. Then there is a symmetric solution $a_1=a_2=...=a_n=a$, that satisfies the following first order condition for all n firms:

$$(13) \qquad \frac{(n-1)R}{n(2n-1)} = \frac{F'(a)r(a)}{r'(a)}$$

The left-hand side of equation (13) decreases with n, while assumption [A.1] implies that the right-hand side increases with a. Thus each firm lowers the quality of its product when there are more competitors, as the marginal revenue of quality gets smaller. We now examine how the overall defense capacity of an importing country is affected as a result. Substituting (ex 1) into (13) and solving for a symmetric equilibrium quality, we get:

$$(14) \qquad a = \left[\frac{(1-\gamma)(n-1)R}{2\alpha n(2n-1)}\right]^{1/2}$$

Combining (10)' and (14) we get

$$(15) \qquad \frac{a}{p} = \left(\frac{n-1}{2n-1}\right)\frac{a}{c} = \frac{1}{\beta}\left(\frac{(1-\gamma)R}{2\alpha n}\right)^{\frac{(1-\gamma)}{2}}\left(\frac{n-1}{2n-1}\right)^{\frac{3-\gamma}{2}}$$

The expression (15) is in turn substituted into (7) to yield

$$(16) \qquad ax = R\frac{(a/p)^2}{n(a/p)} = \frac{1}{\beta}\left(\frac{1-\gamma}{2\alpha}\right)^{\frac{1-\gamma}{2}}\left(\frac{(n-1)R}{n(2n-1)}\right)^{\frac{3-\gamma}{2}}$$

and

$$(17) \qquad px = R\frac{(a/p)}{n(a/p)} = \frac{R}{n}$$

Therefore country A's defense capacity is

(18) $y^A = \left[n(ax)^{1/2}\right]^2 = \frac{1}{\beta}(n)^{\frac{1-\gamma}{2}}\left(\frac{1-\gamma}{2\alpha}\right)^{\frac{1-\gamma}{2}}\left(\frac{(n-1)R}{2n-1}\right)^{\frac{3-\gamma}{2}}$

Recall from (6) that $y^A=y^B$ in equilibrium. Each country's total expenditure on defense is:

(19) $G^A = npx = R$

Clearly, the importing nations' defense spending is independent of producers' market structure. This is due to the fact that the demand for each product, (7), is of the constant elasticity of substitution (CES) form. On the other hand, a country's preparedness is inversely related to the sellers' cost parameters α and β, and is positively related to the number of sellers, n; the right-hand side of equation (18) increases with n. A rise in the number of arms producers results in higher levels of defense for both buyers.

The welfare effects of a change in the number of sellers on the importing nations are easy to derive (the sellers' profits fall as n rises). Recall from (1) that each country's expected payoff is the probability it wins, $\pi^j(y^A,y^B)$, times the prize, $s(R^j-G^j)+t(R^h-G^h)$. The probability of winning remains the same when n changes, since y^A and y^B increase by the same amount. Nor does the prize change, because the defense expenditures G^A and G^B are independent of the sellers' market structure. It follows that an increase in the number of producers does not affect the welfare of the importing countries in our setup, even though they both acquire higher levels of defense without spending more on it.

3.2 *The outcome with asymmetric firms: a numerical example*

The previous analysis is extended to a case in which firms have different cost structures. Suppose there are two types of producers. The first m ($\leq$ n) firms have low fixed costs of developing weapons, and the last n-m sellers have high fixed costs. Using (ex 1), $\alpha_1 = \alpha_2 = ... = \alpha_m < \alpha_{m+1} = \alpha_{m+2} = ... = \alpha_n$.

The firms in each group also have the same variable costs, but no assumption is made about their relative sizes:

$\beta_1 = \beta_2 = ... = \beta_m <> \beta_{m+1} = \beta_{m+2} = ... = \beta_n$.

Let $\alpha \equiv \alpha_n/\alpha_1$ be the ratio of the fixed costs of a high cost firm and a low cost firm ($\alpha > 1$), and $\beta \equiv \beta_n/\beta_1$ be the ratio of the variable costs.

Each firm chooses quality a_i according to (12). We again focus on a symmetric solution in which all firms with the same costs select the same qualities: $a_1 = a_2 = \ldots = a_m < a_{m+1} = a_{m+2} = \ldots = a_n$.

Let firm 1 be a representative low-cost seller and firm n be a representative high-cost producer. The first-order condition for firm 1 is

$$(20) \qquad \frac{nR}{2n-1} \frac{\left\{ \sum_{i=1}^{n} r_i(a_i) \right\}^{-2} - F'_1(a_1)}{\left\{ r'_i(a_1) \sum_{k=2}^{n} r_k(a_k) \right\}} =$$

$$\frac{nR}{2n-1} \left\{ m\frac{a_1^{1-\gamma}}{\beta_1} + (n-m)\frac{a_n^{1-\gamma}}{\beta_n} \right\}^{-2} - \left[\frac{\alpha_1\beta_1 a_1^{1-\gamma}}{(m-1)(a_1^{1-\gamma}/\beta_1) + (n-m)(a_n^{1-\gamma}/\beta_n)} \right] = 0.$$

Likewise, high cost firm n chooses a_n so that

$$(21) \qquad \frac{nR}{2n-1} \left\{ m\frac{a_1^{1-\gamma}}{\beta_1} + (n-m)\frac{a_n^{1-\gamma}}{\beta_n} \right\}^{-2} - \left[\frac{\alpha_n\beta_n a_n^{1-\gamma}}{m(a_1^{1-\gamma}/\beta_1) + (n-m-1)(a_n^{1-\gamma}/\beta_n)} \right] = 0.$$

Because the first-order conditions (20) and (21) are complex nonlinear functions, it is difficult to solve explicitly for $\{a_1, a_n\}$ except when $\gamma = 0$. When $\gamma = 0$, calculation shows that

$$(22) \qquad a_n = \left[\frac{2n\beta R}{(2n-1)\alpha_1\tau} \frac{(m-1)\beta\tau + 2m(n-m)}{[\beta\tau + 2(n-m)]^2} \right]^{1/2},$$

where $\tau \equiv (m-1)\alpha\beta - \frac{1}{\beta}(n-m-1) + \sqrt{\left\{(m-1)\alpha\beta - (\frac{1}{\beta}(n-m-1)\right\}^2 + 4\alpha m(n-m)}$ for ease of notation, and

(23) $a_1 = \tau a_n / 2m$.

Following the same steps as in equation (18), the importing country's defense level in equilibrium is

$$(24) \qquad y^A = y^B = \left[\frac{R^3}{2\alpha_1\beta_1^2}\right]^{1/2} V ,$$

$$\text{where} \quad V = \left[\frac{n(n-1)^2}{(2n-1)^3}\left\{m-1 + \frac{2m}{\beta\tau}(n-m)\right\}\right]^{1/2} .$$

If α_1 and β_1 are normalized at 1, equation (24) states that the importer's preparedness is a function of their total initial endowments, R, and the sellers' market structure, which in turn is a function of α, β, m, and n.

To characterize how the outcome changes with the sellers' market structure, we calculate in Tables 1 through 4 below some numerical values of a_1 and a_n. In these tables, γ is set equal to 0; α_1, β_1, and R are normalized at 1; and the values of α, β, m, and n are varied.

[Insert Tables 1 through 4 about here]

From the numerical examples in Tables 1 through 4, we note that:

1) Holding α and β (the ratios of the fixed and the variable costs of the two types of producers) and n (the total number of sellers) constant, an increase in m decreases a_1

and a_n, and raises the ratio a_1/a_n and y^A if the firms with low fixed costs also have lower variable costs (see Table 1). But the results are reversed when the firms with lower fixed costs have higher variable costs (see Table 2): As the total number of firms remain the same but more sellers start developing weapons at low fixed (R & D) costs, both types of firms supply higher quality goods if the sellers with lower fixed costs have higher variable costs (due to higher labor costs, for example).

This observation is consistent with the recent developments in the market for weapons. The new arms manufacturers are likely to have higher development costs but lower variable costs than the superpowers. Brzoska and Ohlson (1987) document that "...the period [since the early and mid-1970s] saw many structural changes in the arms market: While the USA and the USSR were the dominant suppliers, their combined share declined throughout this period. Instead, the shares of West European suppliers, most notably France, and new exporters from the Third World rose. In addition shares of second-hand and refurbished weapons in Third World arms imports decreased in favour of more new and highly sophisticated weapons systems." (Brzoska and Ohlson, p.14). And "More than 90 per cent of the total volume of transfers of major weapons was made up of new weapons by the mid-1980s." (ibid., p.10.) Pierre (1982) also reports striking improvements in the qualities of arms transferred to developing countries, most notably for fighter aircrafts and anti-tank missiles, since the 1970s (Pierre, pp.10-11).

2) Holding α, β, and m constant, an increase in n reduces a_1 and a_n, and increases a_1/a_n and $y^A(= y^B)$ (see Tables 3 and 4): As more high cost sellers enter the market, both types of firms lower their product qualities. But the impact is greater for the high-cost sellers, resulting in a greater disparity in the quality ratio, a_1/a_n. The importing countries acquire a higher level of defense.

3) Holding β, m, and n constant, a fall in α_n (which is equivalent to a fall in $\alpha \equiv \alpha_n/\alpha_1$, since α_1 is normalized at 1) results in a decrease in a_1, an increase in a_n, a decrease in the ratio a_1/a_n, and a rise in y^A (compare the upper and the lower blocks in each table): As the high cost producers become more efficient, their fixed costs of developing weapons fall and approach that of the low cost firms (α_1). As a result, the

high cost firms start producing more advanced weapons and narrow the quality gap, a_1/a_n. The level of preparedness of the importing countries again rises.

4) Holding α, m, and n constant, a decrease in β_n (equivalent to a fall in $\beta \equiv \beta_n/\beta_1$) results in a decrease in a_1, a rise in a_n, a fall in the ratio a_1/a_n, and an increase in y^A (compare the upper blocks in Tables 1 and 2; the lower blocks in Tables 1 and 2; the upper blocks in Tables 3 and 4; and the lower blocks in Tables 3 and 4). This case is analogous to 3.

Although the numerical examples are certainly not the same as general results, these observations indicate that greater competition among sellers (in the form of increases in n and m, or decreases in the cost ratios α, and β) tend to make each producer select a lower product quality, but the defense levels of the importing countries rise as a result. We also found an instance in which an increase in the number of low fixed cost sellers results in higher equilibrium quality levels. This was the case when the firms with higher fixed costs have the lower variable costs of production.

Finally, the effect of the sellers' market structure on the buyers' national welfare is calculated below. Following the same reasoning as the end of Section 3.1, it can be readily shown that the buyer's total expenditure on defense is

$$(25) \qquad G^A = G^B = \sum_{i=1}^{n} p_i x_i^A = R.$$

And each country's national welfare is given by

$$(26) \qquad U^A = \frac{y^A}{y^A + y^B}\left[s\{R^A - G^A\} + t\{R^B - G^B\}\right],$$

and likewise for country B. Since $y^A = y^B$ in equilibrium, the probability of winning does not vary with the sellers' market structure. Nor do G^A and G^B. Once again, competition among the sellers leads both importing countries to acquire higher levels of defense but does not alter their national welfare levels. This is due to the fact that both countries select the same level of preparedness and that the demand for inputs is of the constant elasticity of substitution form.

4. CONCLUSIONS

This paper examined the demand for arms by the two rival nations and arms trade between these buyers and weapons producers in a complete information framework. It was shown that the nature of rivalry between the importing countries will determine the intensity of arms race. The main contribution of the paper is in demonstrating that the market structure of the weapons suppliers has important bearings on the defense capacities of the recipient countries. We showed in our simple model that as competition among the sellers intensifies, the buyer nations step up their levels of military buildup. But given symmetric demand for arms, they both increase their armament by the same extent. Thus the probability of winning a conflict is unchanged for each country. Nor are their defense expenditures affected, since their demand for each military equipment is of the constant elasticity of substitution form. As a result, increased competition among the sellers has no effect on the buyer nations' welfare levels in our set up.

When the arms market consists of sellers with different cost structures, it is difficult to obtain closed-form solutions to the model; but numerical computations support our previous result that greater competition between low and high-cost sellers intensifies arms race. We also obtained the conditions for the producers' costs under which greater competition induces *all* sellers to supply higher product qualities in equilibrium. This finding contrasts with the principle of differentiation---the standard result in the literature on product quality choice.

In order to jointly consider the rivalry between the buyers and the sellers' product quality choice, we used a highly simplified model. It would be desirable to examine whether our results will continue to hold in a more general framework---particularly for more general production costs. A natural extension of this work will be to analyze asymmetric information between the buyer nations about their levels of military buildup.

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Table 1: The Effect of a Change in the Number of Low Fixed Cost Sellers (m) (Holding β_n/β_1 at 1.2, and n at 5)*

α_n/α_1	m	a_1	a_n	a_1/a_n	y^A
1.2	1	0.236	0.185	1.272	0.379
	2	0.229	0.178	1.286	0.402
	3	0.223	0.172	1.298	0.424
	4	0.217	0.166	1.309	0.447
1.0	5	0.211	0.211	1.000	0.468**
1.5	1	0.244	0.163	1.500	0.349
	2	0.235	0.154	1.534	0.380
	3	0.227	0.145	1.562	0.410
	4	0.219	0.138	1.586	0.440

* α_n/α_1 is the relative fixed costs of a high and a low cost firms, β_n/β_1 is the relative unit costs of a high and a low cost firms.

n is the total number of firms, of which m is the low cost.

a_1 and a_n are the quality choices of the low and high cost firms, defined in equations (23) and (22) in the text.

y^A=y^B is the importing nation's defense level, defined in (24).
(In calculating a's and y's, α_1, β_1, and R are normalized at 1.)

** When all firms have the same cost (m = n), α_n/α_1 = β_n/β_1 = 1.

Table 2: The Effect of a Change in the Number of Low Fixed Cost Sellers(m) (Holding β_n/β_1 at 0.8, and n at 5)*

α_n/α_1	m	a_1	a_n	a_1/a_n	y^A
1.2	1	0.197	0.195	1.009	0.522
	2	0.200	0.198	1.011	0.508
	3	0.204	0.201	1.013	0.495
	4	0.207	0.204	1.015	0.482
1.0	5	0.211	0.211	1.000	0.468*
1.5	1	0.2087	0.1725	1.2097	0.476
	2	0.2093	0.1730	1.2098	0.474
	3	0.2098	0.1734	1.20987	0.472
	4	0.2103	0.1738	1.20993	0.470

Note:

* When all firms have the same cost (m = n), $\alpha_n/\alpha_1 = \beta_n/\beta_1 = 1$.

Table 3: The Effect of a Change in the Total Number of Sellers (n) (Holding β_n/β_1 at 1.2, and m at 2)*

α_n/α_1	n	a_1	a_n	a_1/a_n	y^A
1.0	2	0.289	0.289	1.000	0.192*
1.2	3	0.265	0.218	1.214	0.285
	4	0.245	0.195	1.258	0.349
	5	0.230	0.178	1.286	0.402
	6	0.216	0.165	1.307	0.447
	10	0.180	0.133	1.352	0.592
	100	0.065	0.045	1.430	1.901
	1,000	0.021	0.014	1.439	6.014
1.5	3	0.267	0.187	1.426	0.276
	4	0.249	0.167	1.490	0.333
	5	0.235	0.154	1.534	0.380
	6	0.224	0.143	1.566	0.420
	10	0.190	0.116	1.641	0.547
	100	0.072	0.040	1.780	1.707
	1,000	0.023	0.013	1.798	5.381

Note:

* When all firms have the same cost (m = n), $\alpha_n/\alpha_1 = \beta_n/\beta_1 = 1$.

Table 4: The Effect of a Change in the Total Number of Sellers (n) (Holding β_n/β_1 at 1.2, and m at 2)*

α_n/α_1	n	a_1	a_n	a_1/a_n	y^A
1.0	2	0.289	0.289	1.000	0.192*
1.2	3	0.254	0.242	1.051	0.324
	4	0.223	0.218	1.025	0.425
	5	0.200	0.198	1.011	0.508
	6	0.183	0.183	1.001	0.581
	10	0.141	0.143	0.984	0.812
	100	0.044	0.046	0.962	2.825
	1,000	0.0139	0.0144	0.960	9.012
1.5	3	0.258	0.212	1.217	0.312
	4	0.230	0.190	1.212	0.401
	5	0.209	0.173	1.210	0.474
	6	0.193	0.160	1.208	0.538
	10	0.152	0.126	1.205	0.741
	100	0.049	0.041	1.2005	2.531
	1,000	0.015	0.013	1.2000	8.062

Note:

When all firms have the same cost (m = n), $\alpha_n/\alpha_1 = \beta_n/\beta_1 = 1$.