Arms Export Controls and Proliferation

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Given that there are a relatively small number of suppliers of major weapons systems, control of arms exports is possible, and there are a variety of regulatory regimes striving to achieve this. Controls can stabilize regional arms races and reduce tensions. However, when buyers can develop the capability to produce conventional or unconventional weapons, arms export controls can increase the incentive for proliferation. The authors discuss a general framework for analyzing the arms trade and examine the dynamic decision problem faced by a country deciding whether to make an irreversible investment in arms production capability under conditions of uncertainty.

The arms trade is interesting because it is where foreign policy concerns such as security, human rights, and international order interact most directly with economic concerns such as trade, jobs, and profits. Explanations of the trade that emphasize just economics or just politics must be unsatisfactory; both matter. Of course, actually calculating the economic and political benefits and costs of the arms trade is difficult (Hartley 2000). The trade is quantitatively important, probably about $30 billion a year. After a period of decline, total exports of arms seem to be stabilizing, though the economic difficulties in East Asia, one of the main markets, may inhibit further growth in that area. Anderton (1995) and Sandler and Hartley (1995) provide general surveys of theoretical models of the arms trade. Levine and Smith (1997) provide a structured description of the evolution of the arms market in terms of the usual economic categories: the products and regulations to which they are subject, the data available, the pattern of supply and demand that shapes the quantities of arms transferred, and the determination of prices.

Arms exports are politically controversial, raising issues of proliferation and the diversion of resources from development needs, and are almost always subject to national regulation. There is also an international regulatory regime, and its evolution raises a number of important policy questions such as the implications of the
antipersonnel mine treaty, the role of the Wassenaar Arrangement, and the harmonization of European Union arms exports regulations. Regulation is possible because for major weapons systems, there are relatively few suppliers, and it is possible for them to act jointly. In these circumstances, arms exports controls can stabilize regional arms races and reduce tensions. However, when buyers can develop the capability to produce conventional or nonconventional weapons, then export controls can increase the incentive for proliferation, encouraging regional antagonists to acquire their own production capability (e.g., white South Africa’s development of a substantial arms industry and nuclear capability in response to restrictions of supply).

This article examines the dynamic problem faced by a country deciding whether to make an irreversible investment in arms production capability under conditions of uncertainty. The model used to analyze the proliferation decision takes as given many features of the arms race that have been analyzed elsewhere. For completeness, we first review a general framework for analyzing the arms trade. This is done in the next section, which describes the process by which optimization by buyers and sellers within a particular supply regime will result in the determination of prices and quantities. The ensuing section discusses the collective action problems suppliers face in establishing an arms export control regime. Given these decisions, we then discuss the incentives for proliferation by existing buyers, followed by a concluding section.

FRAMEWORK

Suppose the world can be divided into two groups of countries. There are a large number of buyers, each of whom are involved in a local arms race with a neighbor (e.g., India and Pakistan, Greece and Turkey). Arms races are indexed by \( b = 1, 2, \ldots, n \). There are a small number of suppliers, indexed \( s = 1, 2, \ldots, m \), who have the capability to build major weapons systems. The suppliers also have global security interests (e.g., through their foreign direct investment). On the demand side, buyers maximize multiperiod discounted welfare \( U_{bt} \) from time \( t \) into the future:

\[
U_{bt} = \sum_{t=0}^{\infty} (1 + r_b)^{-t} W(C_{b,t+1}, S_{b,t+1}),
\]

where \( W(\cdot) \) is a single-period utility function of security, \( S \), and consumption, \( C \), and \( r_b \) is their discount rate. Their antagonist in the \( b \)th arms race, denoted by a star, has a similar welfare function determining \( U_{bt}^* \). Security depends on the buyers’ own stock of arms and those of its antagonist:

\[
S_{bt} = S(K_{bt}, K_{bt}^*),
\]

with \( \frac{\partial S}{\partial K} > 0, \frac{\partial S}{\partial K^*} < 0 \). The stock of arms depends on investment in imported, \( M_b \), and domestic weapons, \( Q_b \), and depreciated previous stock:

\[
K_{bt} = f(M_{bt}, Q_{bt}) + (1 - \delta)K_{b,t-1}.
\]
\( f(M_{bt}, Q_{bt}) \) measures the contribution to the military stock from imported and domestic arms, respectively. A Cobb-Douglas function \( f(M_{bt}, Q_{bt}) = M_{bt}^{1} Q_{bt}^{1} \) would indicate that they are imperfect substitutes, but if they are perfect substitutes, which is assumed below, then \( f(M_{bt}, Q_{bt}) = M_{bt} + Q_{bt} \). The budget constraint is

\[
Y_{bt} = C_{bt} + P_{1} M_{bt} + p_{bt} Q_{bt} + F_{bt},
\]

where \( Y_{bt} \) is available output, \( P_{1} \) and \( p_{bt} \) are the per unit cost of imported and domestic arms, and \( F_{bt} \) is the fixed costs associated with domestic arms production.

The optimizing choices of the buyer and its antagonist, described in a similar way, then jointly determine a Nash equilibrium in arms subject to their available output and the price of imported and domestic weapons. This is discussed in Levine and Smith (1995), who, following Anderton (1990), assumed that equation (2) is linear, which gives rise to linear reaction functions and a unique equilibrium. If the reaction functions are nonlinear, there may be multiple equilibria. The Nash equilibrium will in general be inefficient because of coordination failure. Countries can increase their security by increasing military capability, but one country’s security is its rival’s insecurity. Security is a negative externality that both countries appreciate. The countries can do nothing to avoid this externality in the absence of a credible coordination mechanism. An arms control regime between regional rivals that jointly agreed on levels of military capability would internalize this externality and result in lower military expenditure and imports of arms, but given their antagonism, they cannot agree to such a regime. With multiple equilibria, there may be possibilities of moving from the highly armed to a lower armed Nash equilibrium.

This game generates a demand function by the buyers for imported arms as a function of price, the threat from the antagonist, and available output. Econometric estimates of such demand functions in Levine, Mouzakis, and Smith (1998) using cross-section data estimate a significant negative price elasticity of demand. Price is measured by the ratio of the Arms Control and Disarmament Agency (ACDA) to the Stockholm International Peace Research Institute (SIPRI) figures for arms imports because, by construction, the SIPRI measure is a constant price volume index, whereas the ACDA measure is a constant price value index. The ratio of the ACDA to SIPRI series thus provides an implicit price index and shows the qualitative movements one would expect (e.g., falling during the 1990s with the large drop in demand). Measurement error is a major problem (e.g., the SIPRI and ACDA measures cover different categories of weapons); however, the evidence for a negative price elasticity of demand is robust to the treatment of measurement error. Price is also important for the dynamics of the arms race. If increasing demand increases price (the usual case), the feedback would tend to stabilize the arms race. Of course, if there were significant increasing returns to scale in weapons production, increased demand could reduce price, causing destabilizing feedback or the multiple equilibria discussed by Brito and Intriligator (1999).

On the supply side, sellers maximize a similar welfare function:

\[
U_s = \sum_{i=0}^{\infty} (1+r_s)^{-1} W(C_{s,t+i}, S_{s,t+i}).
\]
However, because of their global rather than regional concerns, their security depends on stocks of arms throughout the world; that is, the stocks of each pair of buyers, $b = 1, 2, \ldots, n$, and each of the suppliers, $s = 1, 2, \ldots, m$, including itself:

$$S_{st} = S(\ldots, K_{st}, K_{st}^*, \ldots, K_{st}^*, \ldots).$$  

(6)

In many post–cold war situations (e.g., the Gulf War and former Yugoslavia), increased regional stocks of arms have a negative effect on supplier security, $\partial S_{st} / \partial K_{st} < 0$, and other suppliers are allies whose arms stocks have a positive effect, $\partial S_{st} / \partial K_{st} > 0$. In this case, from the suppliers’ point of view, both arms exports and military expenditure, by itself and by the other suppliers, have security externalities. The decisions of producers involving domestic military capability and the exports of arms result in a public good in the form of their common regional security. It is nonexcludable (no country can be excluded from “consuming” high regional security), and it is nonrival (its “consumption” does not reduce the amount available for others).

Suppliers produce their own arms domestically so stock is given by

$$K_{st} = Q_{st} + (1 - \delta)K_{st,t-1}.$$  

(7)

The supplier governments choose a level of exports, $X_{st}$, and set the domestic price of arms, $p_{st}$, to maintain domestic production capability given their demand, export demands, and costs:

$$p_{st}Q_{st} + p_{st}X_{st} - \alpha (Q_{st} + X_{st}) = 0,$$  

(8)

where $\alpha(\cdot)$ is the cost function. This specification of the cost function assumes that the same good is produced for domestic use and exports and that factor prices are given to suppliers when making decisions affecting arms production and trade (i.e., the model is of a partial equilibrium variety). The budget constraint is

$$Y_{st} = C_{st} + p_{st}Q_{st} + F_{st},$$  

(9)

where $F_{st}$ is the per-period fixed costs of arms production. Notice that the budget constraints (4) and (9) are balanced trade conditions. For buyers, exports of the consumption good finance arms imports; for sellers, arms exports finance imported consumption. Suppliers then jointly determine $X_{st}$ and $Q_{st}$, $s = 1, 2, \ldots, m$, subject to their outputs, demand, and market structure. The world price of arms, $P_{r}$, then adjusts to clear the market so that

$$\sum_{b=1}^{n} (M_{bt} + M_{bt}^*) = \sum_{s=1}^{m} X_{st}.$$  

(10)

This framework is too general to get explicit analytical solutions, but a number of special cases have been considered in the literature. These use specific forms for the various functions and can be solved numerically given particular values for the parameters of those functions.
Within the framework set out in the previous section, a central issue is the form of market structure or international regime, which influences the determination of $X_{st}$ and $Q_{st}$. The form of regime is determined by the suppliers’ choice to cooperate or not to cooperate along three dimensions. First, suppliers may or may not jointly regulate arms exports, operating as a suppliers cartel. Second, suppliers may or may not operate as allies, jointly determining their military expenditures. Third, suppliers may or may not collaborate in production, reducing $c(Q_{st} + X_{st})$ by benefiting from learning curves, increasing returns to scale, and sharing fixed costs.

Under the assumptions above, $\frac{\partial S_{st}}{\partial K_{st}} < 0$, arms exports are “bad” within this framework; therefore, monopoly (arms export control) is good because it restricts supply and raises prices. This has two effects on the buyers. The first is a terms of trade effect that clearly reduces the buyers’ welfare; they pay more for their arms and have less for other uses. The second effect is for the higher price of arms to cause a switch from military expenditure into consumption. This reduction in arms stocks in response to the price rise shifts the reaction functions in the arms race. This moves the Nash equilibrium closer to the efficient consumption–military expenditure mix that pairs of buyers would choose if they could cooperate through some process of arms control. This effect could outweigh the terms of trade loss, making the buyers better off as a result of the formation of the cartel and the higher prices. Suppliers also benefit from internalizing the regional stability externality if $\frac{\partial S_{st}}{\partial K_{st}} < 0$. These results suggest that the optimal market structure for the arms industry could be a cartel of cooperating producer countries. Under these assumptions, arms suppliers clearly have a common interest in forming a cartel. The results in Levine and Smith (1995) indicate that this could also be beneficial for recipients, particularly if combined with a tax on arms exports redistributed to recipients. Of course, the proposal for a supplier cartel plus transfers to recipients is both dependent on the specification of the model, particularly the form of the supplier security functions, and subject to obvious practical difficulties. Any proposal for cooperation must inevitably address the collective-action cartel stability problem of sustaining such a regime given the short-run incentives of any particular supplier to defect. Sandler (2000) discusses this collective action problem.

Suppose suppliers do solve the collective action problem and do cooperate in controlling the export of arms, acting as a joint monopolist. Then they face the credibility issues analyzed in Levine, Sen, and Smith (1994). If buyers are forward looking as implied by equation (1), and if the suppliers can credibly precommit to the quantities that they will export, in the future, they can use these announcements to change the recipients’ behavior. However, if they cannot precommit, they are forced to adopt the less efficient time-consistent strategy: doing what is optimal in each period. In the arms trade, the credibility of commitment to future supply or embargo is particularly important for the case of resupply of spares and munitions in a future conflict.

Even if suppliers solve both the collective action and credibility problems, they face the problem that to the extent export controls are effective, driving up price or reducing quantity, they provide incentives for proliferation: the acquisition of weapons production capability by the buyers. The U.S. embargoes on Latin American countries during
the Carter presidency proved a major incentive for countries such as Brazil to set up their own industries, partly financed by exports. To try and avoid this export control, regimes are usually associated with measures to prevent the diffusion of the relevant technology to other states (e.g., the missile technology control regime). This raises the cost of acquiring domestic production but rarely makes it completely impossible.

DOMESTIC PRODUCTION

Using a static version of the framework from section 2, Levine, Mouzakis, and Smith (2000) show that there is a threshold at which countries switch from depending completely on imports to establishing a domestic capability. A sufficiently high price can induce a pair of identical antagonistic buyers to switch from importing arms to domestic production. This switch causes higher levels of military expenditure, military capability, and inefficiency than does reliance on importing arms. Higher fixed costs of establishing domestic production increase the threshold level of military capability at which it is efficient to set up military production. The model assumes that domestic and imported arms are imperfect substitutes. The incentives for establishing a domestic industry also depend on the substitution between security and consumption.

To consider the dynamic issues involved in the proliferation or the acquisition of domestic weapons production, we will use the continuous time theory of investment under uncertainty (e.g., Dixit and Pindyck 1994, chap. 5). Consider a buyer country with no current arms production capability and suppose for simplicity that imported and domestically produced arms are perfect substitutes. The buyer calculates the optimal quantity of arms—say, \( m(t) \)—that it needs given available output and the threat. For the moment, treat this as exogenous, thus ignoring the feedback of price on demand for arms. Arms can either be imported at price \( P(t) \) or produced domestically at marginal cost \( p(t) \) subject to an initial investment \( I \) to establish the production capability. Typically, the investment is large but may be reduced by offsets on import deals that involve technology transfer. The relative marginal costs, \( c(t) = P(t) - p(t) \), will reflect political costs imposed to obtain arms imports and the relative advantage of the domestic and imported weapons, which may be of different forms (e.g., imported conventional vs. domestic nuclear). For instance, the marginal cost to Pakistan of taking delivery of the F16s it had already paid for would have meant giving up its nuclear weapons program, something it was unwilling to do. Relative costs may also reflect political economy factors such as lobbying by a domestic military industrial complex or bribery by foreign arms firms.

The benefit, per period, of investing in the domestic production capability is

\[
\pi(t) = (P(t) - p(t))m(t) = c(t)m(t).
\]  

Assume that the marginal cost of domestic production is below the import price, so the issue is whether the difference is large enough to justify the investment. Consider first the deterministic case, as viewed by the potential proliferator at time \( t \). Suppose the
benefit of domestic production is expected to grow exponentially because of a combination of import price growth at rate $\alpha_1$ or increasing demand for military expenditure at rate $\alpha_2$. Then, at time $s > t$, we have

$$\pi(s) = \left\{ c(t)e^{\alpha_1(s-t)} m(t)e^{\alpha_2(s-t)} \right\} = \pi(t)e^{\alpha(s-t)},$$

(12)

where $\alpha = \alpha_1 + \alpha_2$. The gross value of investing in domestic production is

$$V(t) = \int_t^{s} \pi(t)e^{(\alpha-r_b)(s-t)} ds = \frac{\pi(t)}{r_b - \alpha},$$

(13)

where $r_b$ is the buyer's discount rate introduced in equation (1). The conventional investment criterion is to invest immediately if $V(t) > I$; that is, if $\pi(t) > (r_b - \alpha)I$, assuming $\alpha < r_b$. If $\alpha > r_b$, the integral in (13) does not exist. However, the net present value (NPV) criterion is suboptimal even in the deterministic case because there is the option of investing at a later time $t + T$. Then given the current value $V(t)$, the net present value of this investment opportunity is given by

$$g(V(t)) = \int_{t+T}^{\infty} \pi(t)e^{(\alpha-r_b)(s-t)} ds - e^{-r_b T} I = (V(t)e^{r_b T} - I)e^{-r_b T}.$$

(14)

Suppose $\alpha \leq 0$. Then, $g(V(t))$ decreases with $T$. Thus, it is optimal to invest immediately if $V(t) > I$ or not at all. If, however, $\alpha > 0$, one should only invest immediately if

$$V \geq \frac{r_b}{r_b - \alpha} I > I,$$

(15)

a higher threshold than the conventional (incorrect) NPV criterion. For given $V$ and $I$, a larger $\alpha$ (due to faster import price growth or military demand growth) tends to discourage investment in domestic production because it raises the threshold; higher discount rates encourage it. Of course, $V$ is also a function of $\alpha$ and $r_b$. Offsets or technology transfer, which reduce $I$, tend to increase investment in domestic production capability.

Now allow for uncertainty and suppose that both the cost differential and weapons demand are stochastic following geometric Brownian motions:

$$dc = \alpha c dt + \sigma_c cdz,$$

$$dm = \alpha m dt + \sigma_m mdz,$$

(16)

with drifts $\alpha_i$ and variances $\sigma_i^2$, $i = 1, 2$, where $dz$ is the increment of a Wiener process, $dz = \varepsilon \sqrt{dt}$, and $\varepsilon$ is identically and independently distributed as a standard normal process. A Wiener stochastic process has three properties: first, the probability distribution for all future values depends only on its current value. Second, it has independent increments. Third, these increments are normally distributed with variance proportional to the time interval. One way of understanding a Wiener process is as the limit of a more familiar discrete time-stochastic process. In terms of logs, equations (16) are of the form $dx = \alpha dt + \sigma e \sqrt{dt}$, which is the limit of the discrete-time random
walk, \( x_t = x_{t-h} + \alpha h + \sigma \varepsilon_t \sqrt{h} \) as \( h \to 0 \). This discrete time process has the property that \( x_t - x_{t-1} = \alpha + \sigma (\varepsilon_t + \varepsilon_{t-h} + \varepsilon_{t-2h} + \ldots + \varepsilon_{t-1}) \sqrt{h} \). If we choose \( 1/h \) to be an integer, in this limiting process, the latter summation has \( 1/h \) terms. Hence, by choosing \( dx \) to depend on the square root of \( dt \), we ensure that the mean of \( x_t - x_{t-1} \) is \( \alpha \), the variance is \( \sigma^2 \), and both are independent of \( h \). Geometric Brownian motions, such as equation (16), are found to fit data on interest rates, wage rates, output prices, and securities prices.

Given equation (16), both the single-period benefit of investing in domestic production, \( \pi \), and the gross value, \( V \), also evolve according to geometric Brownian motions:

\[
d\pi = \alpha \pi dt + \sigma \pi dz,
\]

(17)

\[
dV = \alpha V dt + \sigma V dz
\]

(18)

where \( \alpha = \alpha_1 + \alpha_2 + \rho \sigma_1 \sigma_2 \) is the drift, and the variance \( \sigma^2 = \sigma_1^2 + \sigma_2^2 + 2 \rho \sigma_1 \sigma_2 \), where \( \rho \) is the correlation between the two processes. The correlation may be positive if a deteriorating security situation, needing more arms, provokes higher prices from suppliers or negative if the higher prices reduce the buyer’s demand for military spending. Notice that a positive correlation would increase both the drift and the variance, which, as is evident below, would have opposite effects on the decision to invest.

Current values of the benefit, \( \pi(t) \), are known; future values are log normally distributed with increasing variance. The main restriction here is that \( \pi \) must be positive, which is achieved by our assumption that marginal costs of domestic production are below imports. Given the current value, \( V(t) \), the value of investing in domestic production capacity at some unknown future date \( T \) is now the expected value:

\[
g(V(t)) = E_t [(V(t)e^{\alpha T} - I)e^{-\sigma V}].
\]

(19)

The maximization of \( g(V) \), given by equation (19), is an optimal “stopping problem.” Using dynamic programming and Itô calculus, it can be shown that, at the optimum, \( g(V) \) satisfies

\[
\frac{1}{2} \sigma^2 V^2 g''(V) + \alpha V g'(V) - r V = 0,
\]

(20)

plus the following boundary conditions:

\[
g(0) = 0; \ g(V^*) = V^* - I; \ g'(V^*) = 1.
\]

(21)

The first condition in equation (21) ensures that the option to invest is of no value when \( V = 0 \). The second condition says that on investing at the threshold value, \( V^* \), the firm receives a net payoff given by \( V^* - I \). The final condition is the optimality “smooth-pasting” condition. Once the irreversible nature of the investment is allowed for, there is an option value of waiting, even when \( \alpha \leq 0 \), because waiting provides new information. When the option value of waiting is allowed for, the optimal decision rule is to invest if

\[
V(t) \geq V^* = \phi I,
\]

(22)
where \( \phi = \beta(\beta - 1) \) and where \( \beta \) is given by

\[
\beta = \frac{1}{2} \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r_b}{\sigma^2}} > 1. 
\]

For full details, see Dixit and Pindyck (1994, chap. 5). Using the assumption that \( r_b > \alpha \), we can show from (23) that \( \phi = \beta(\beta - 1) > 1 \). Thus, \( \phi \) measures the wedge between \( V^* \) and the conventional investment rule.

This wedge increases with \( \sigma \). The larger the future uncertainty about the price of foreign arms and the security situation, the larger the excess return on domestic procurement the country will demand before committing to the irreversible investment in domestic production capacity. Waiting a little longer provides extra information on the shocks, and because the shocks are persistent, they contain information about the future. When importing, it is easy to adjust military expenditure in response to changes in costs and the threat. Having established a domestic capability, the sunk cost \( I \) cannot be recovered even when it becomes clear that a domestic capability was not necessary. This is a robust result in the literature and holds for many variants of the model. For parameters associated with standard investment projects in the United States, Dixit and Pyndick (1994) suggest \( \sigma = 2 \). Although it is difficult to be precise about the uncertainty associated with the national security calculations relevant to establishing a domestic military capability, it seems plausible that the uncertainty may be at least as large as that associated with commercial investments. This uncertainty is an obstacle to proliferation.

It may seem counterintuitive that greater uncertainty about future military demand and the relative costs of military capability should reduce the likelihood of a country investing in domestic production capability. The natural intuition would be that growing uncertainty about future supply and national security requirements would prompt the investment in domestic production capability as insurance. But the insurance effects are captured in the drift terms, which measure the likely worsening in the costs of dependence. The model, being cast in expected present value rather than expected utility terms, does assume risk neutrality. But the evaluation of risk (e.g., through the adoption of worst-case scenarios) would already be embodied in the calculation of \( m(t) \). Uncertainty reduces the incentives for more producers to enter, and existing producers clearly gain both economic and security benefits from this. The buyers benefit by staying at the better Nash equilibrium associated with imported weapons rather than the more militarized Nash equilibrium associated with domestic production.

There are various straightforward extensions to the model that can easily be applied to weapons production. For instance, suppose that it is possible to exit weapons production and return to importing at some fixed cost. One then gets two thresholds. One, \( V^* \), at which nonproducers become producers; another, \( V_* \), at which producers exit and return to importing, with \( V^* > V_* \). Dixit and Pindyck (1994, chap. 7) provide details of how the two thresholds are determined in this case. This framework can be used to analyze capabilities such as that for producing fast jet fighters. The United Kingdom has effectively surrendered that independent capability, now producing only collaboratively. France and Sweden seem likely to exit after Rafale and Gripen. Yet although
some countries were exiting, other countries have tried to acquire the capability (e.g., India and Japan), though as yet unsuccessfully. Although the framework provides insights, this is a more complex problem than those standard in the literature; because investment is not instantaneous, it takes time to build the capability. Furthermore, both the size of the investment and the time to build are stochastic. Thus, Israel, having suffered embargo by France, decided to develop its own fighter, the Lavi, but after much time and expenditure decided that it was not worth proceeding. Although we cannot show it directly, we would conjecture that uncertainty about time to build and the size of the investment required would also tend to delay the decision to develop production capability relative to the instantaneous known investment cost case discussed above.

Just because it is a cause for concern, proliferation tends to become the salient evidence that models are designed to account for. There is a tendency to focus on India and Pakistan acquiring nuclear capability and forget the countries that either could have easily acquired nuclear capability (such as Sweden, Germany, Japan, and Canada) but chose not to or those countries that chose to give up their nuclear capability (such as the former Soviet republics and South Africa). In these circumstances, changing the benefits from having a domestic capability, as the Cooperative Threat Reduction (Nunn-Lugar) program did, can be an effective incentive. There are also cases in which exporting, providing the countries the capability cheaply, gives you leverage over their behavior by changing the benefits of adopting an autonomous program. This is similar to the co-option case discussed in Levine, Sen, and Smith (1994). An example is the U.S. provision of Polaris nuclear delivery systems to the United Kingdom in the 1960s. In terms of preventing proliferation, although it is clearly a bad idea to signal that access to imported weapons technology will get more difficult through time, it may be optimal for suppliers to add uncertainty to signals about their future willingness to supply. In the case of the United States, Congress adds a suitably random element.

**CONCLUDING REMARKS**

The formal models, discussed above, provide a framework, integrating economic and security objectives, that allow the analysis of the institutions of the arms trade, particularly its national and international regulatory regimes and market structures. It may be argued that treating governments as individual agents who act rationally is a poor description of behavior in this area. But as Myerson (1999, 1069) argues,

> When our task is to look for potential flaws in a social institution it can be very helpful to analyze the institution under an assumption that the agents in the institution themselves are not flawed. Otherwise, if we find that flawed individuals may come to grief in this institutional structure, we cannot say whether our finding is an argument for reform of the institution or an argument for better education of individuals.

Because there is no lack of groups attempting to reeducate government policy in the area of arms imports and exports, it seems more useful for economists to concentrate
on the incentives rational actors would face and how the institutions shape those incentives. Of course, in any rational actor model, specifying the preferences or objectives of the actors is crucial. In this respect, the specification of security is central. For buyers, the specification in terms of an antagonistic but fairly peaceful arms race seems to capture many important cases, though it does not cover actual war or internal threats. Supplier security is more problematic, but a specification that recognizes that they may come into conflict with buyers, perhaps in alliance with other suppliers, captures many important reasons for arms export controls, though not human rights concerns.

The models include factors that are important but are often ignored. Budget constraints are clearly important as the fall in demand for arms after the 1985 oil price collapse and the 1997 East Asian crises indicates. Prices are important, as indicated both by econometric work and by the drop in prices for major weapon systems when demand fell in the 1990s for strategic reasons while supply did not. Price increases can be welfare enhancing by dampening arms races. However, regulatory regimes can generate perverse incentives. Controls can promote proliferation: by raising the price, they increase the incentive for domestic production. However, uncertainty about the future supply of imported weapons, prices, or quantities available can reduce the probability of proliferation. This is a feature that does not seem widely recognized in the literature, which has been more concerned with the need for sending clear signals.

REFERENCES


