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MODELING THE PRODUCTION AND INTERNATIONAL TRADE OF ARMS: AN ECONOMIC FRAMEWORK FOR ANALYZING POLICY ALTERNATIVES

Arthur J. Alexander, William P. Butz, and Michael Mihalka

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THE FORD FOUNDATION

A SERIES IN INTERNATIONAL
SECURITY AND ARMS CONTROL

MARCH 1981

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PREFACE

This Note reports preliminary results of an investigation into the systematic influences on international arms transfers and indigenous arms production. This first phase of the investigation addressed both theoretical and empirical issues to test the feasibility of the approach. The product is unfinished and the mood of the presentation is often in the subjunctive, describing what would be done if the research were to continue. The conclusions are necessarily conjectural, though not without support. These initial results lead the authors to believe that integrating economic analysis with more traditional approaches can enhance understanding of international arms production and transfers.

This research was supported by a Ford Foundation grant (No. 790-0061), supplemented by research funds provided by The Rand Corporation. The Ford Foundation support is of special interest. In late 1978, the Foundation provided grants to The Rand Corporation and several university centers for research and training in international security and arms control. At Rand, the grant is supporting a diverse program. In the Rand Graduate Institute, which offers a doctorate in policy analysis, the grant is contributing to student fellowships for dissertation preparation, curriculum development, workshops and tutorials, and a series of visiting lecturers. In Rand's National Security Research Division, the Ford-sponsored projects are designed to extend beyond the immediate needs of government sponsors of research by investigating long-term or emerging problems and by developing and assessing new research methodologies. The grant also is being used to fund the publication of relevant sponsored research that would otherwise not be disseminated to the general public.

All research products are being made available to as wide an audience as possible through publication as unclassified Rand reports or notes, or in journals. The Rand documents may be obtained directly or may be found in the more than 330 libraries in the United States and 35 other countries that maintain collections of Rand publications.

SUMMARY

This Note analyzes international arms transfers and indigenous arms production as interrelated economic activities. The analysis embeds these activities in a framework of economic, diplomatic, and political incentives and constraints. A traditional economic model of trade is applied to the activities of arms production and transfer. Such factors as arms races, military threats, and drives for regional leadership are assumed to enter each country's *demand* function for arms. A country's domestic *supply* of arms depends on such economic factors as its supply of physical and financial capital, skilled personnel, technology, raw materials, and the price of arms. Each country's demand and supply, along with world market conditions, influence whether a country produces arms and whether it imports or exports them.

The basic model yields predictions that suggest certain empirical relationships. These are tested in preliminary attempts to assess both the reasonableness of the model and the availability of data. The model predicts that exports should be inversely related to domestic demand. Review of U.S. exports during the course of the Vietnam build-up and subsequent decline broadly supports the prediction. The second empirical application concerns the supply and demand influences on indigenous arms production. Using a cross-section of 30 countries, the size and technical capabilities of the manufacturing sector are shown to influence indigenous production on the supply side, and the level of military expenditures is weakly related to demand. Although these preliminary results are only suggestive, if confirmed in future research the prospect is that growing numbers of countries will produce arms as population growth and industrialization proceed in the Third World.

A final discussion considers ways in which the approach described in the Note could be extended and refined.

ACKNOWLEDGMENTS

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I. INTRODUCTION

This study analyzes international arms transactions and indigenous arms production as interrelated economic activities. It embeds the production, transfer, and accumulation of arms in a structured framework of diplomatic, economic, and political incentives and constraints, and assumes that countries act within this framework to maximize their own welfare. This approach yields a number of testable predictions.

Most previous analyses have either concentrated on particular country cases or focused on arms race dynamics or bureaucratic momentum as the inducement to arms accumulation. The case-by-case approach has tended to emphasize idiosyncratic factors and to obscure the systematic incentives and constraints that affect all countries similarly.

Although these studies frequently elucidate the complex policy environment in which particular countries make weapons decisions, they are poorly suited to predict the international effects of policies that apply generally: for example, a ceiling on the value of a supplying country's arms transfers. This weakness arises partly because such policies can affect many countries directly, but primarily because these policies have indirect effects on other countries through the reactive behavior of the countries first affected.

Analyses that emphasize arms race dynamics or bureaucratic momentum have tended to ignore the national and international economic factors that influence a nation's choice to buy, to sell, or to produce arms. Lacking the economic constraints that are binding in most countries, these models often predict that countries will acquire arms greatly in excess of economic feasibility. Models of the global market that include a systematic framework of economic constraints should complement this research already done on arms transfers and provide an additional tool for assessing policies to regulate that market.

This study sketches an economic framework for incorporating more traditional explanations of why states accumulate arms. Factors such as arms races, military threats, drives for regional leadership, domestic interservice rivalry, and modernization enter into each country's

demand function for arms. A country's domestic *supply* of arms depends on such economic factors as its supply (domestic and international) of physical and financial capital; its supply of engineers, skilled workers, and technology; its supply of raw materials; and the price of arms. Each country's own demand and supply functions, along with the price of arms established in the world market, then influence whether a country produces arms and whether it imports or exports them. If validated, this framework would allow an analyst to test the extent to which specific economic, diplomatic, political, and technological factors dominate a country's or region's level and mix of arms.

II. THE INTERNATIONAL SETTING

As countries gained their independence in the last three decades, many entered international markets to secure weapons for national security. Rising national incomes, and to a lesser extent international loans and grants, have provided the resources to participate in these markets. Simultaneously, poor countries have increased their industrial base. Many have increased their capability to produce arms indigenously. In the late 1970s, a score of countries exported arms and three score were importers. Twenty countries (primarily Third World) produced, but did not export, weapons.[1] These may soon export, following the pattern of many other countries that first imported, then produced for domestic use, and then exported, while still importing more advanced weapons and components. Continuing technological development has led in the 1970s to large and active markets for earlier-generation weapons, moving from regions where more advanced technology is important and affordable to regions where outdated, even used weapons will suffice. Cuba and Iran have been leading arms exporters among the less developed countries, though neither is a producer. This growth in the number of international suppliers and buyers encourages our presumption that arms markets, *as markets*, provide a fruitful focus for research. Recent case studies support this notion. Kolodziej, for example, describes the French approach to arms sales.[2]

> What began after World War II, and especially after the formation of the Fifth Republic, as an effort to develop an independent weapons production capability has assumed a life of its own, progressively detached from the strategic considerations that initially animated its creation. Arms transfers have been banalized. They are increasingly merchandized like other conventional

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[1] For a compiliation of arms trade and production see the International Institute for Strategic Studies (IISS), *The Military Balance 1979-80*, pp. 101-107.

[2] Edward A. Kolodziej, "Determinants of French Arms Sales: Security Implications," in Pat McGowan and Charles Kegley (eds.), *Threats, Weapons, and Foreign Policy*, Sage, Beverly Hills, California, 1980, p. 156.

capital and consumer products.... Arms are presented as goods and services, like machine tools or automobiles, to be bought and sold rather than as instruments of the nation's defense and security.

III. A MODEL OF ARMS PRODUCTION AND TRANSFERS

We begin by applying a traditional economic model of trade to the activities of arms production and transfer. We abstract at first from many considerations--diplomatic, economic and political--that are known to influence countries' arms decisions. By setting these factors aside, we derive a number of strong predictions about markets for arms. In the next section, we present preliminary evidence pertaining to several of these predictions. We then describe how the model might be extended to cover a wider range of phenomena.

Consider two allied countries. Each has its own demand and supply schedules for the composite good, arms. Trade in arms can occur. All arms produced in one period are traded or used in the same period: stockpiling does not exist. As a way of introducing policy instruments into the model, we assume that the exporting country can impose an export tax (or subsidy) which the importing country must pay (or can benefit from), apart from the price of arms that prevails in the exporting country. This tax or subsidy can have financial, diplomatic, and other components, although we assume at first that the value of the tax can be costed out in dollars.

An initial position of the two countries' demand and supply curves and the tax together determine each country's quantity of arms supplied and quantity demanded, as well as the value of arms traded, and the world price of arms.[1] The model's predictions then come from changing the four demand and supply curves and the tax. Some predictions are unambiguous, while others depend upon positions and elasticities of the curves.

The mechanics of this simple model are analyzed in the appendix. Table 1 summarizes some predictions for the case of an arms exporting country, Alpha, and an arms importing country, Beta. Along each row are pluses and minuses indicating whether the variable in each column

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[1] In this analysis, we look at the relationship between quantity and price--the traditional economic variables. Naturally, analysis need not be confined to these variables, although we focus on them for the present.

Table 1

PREDICTED CHANGES IN QUANTITIES AND PRICES RESULTING FROM CHANGES IN DEMANDS AND SUPPLIES OF ARMS AND IN AN EXPORT TAX OR SUBSIDY

	Country Alpha						Country Beta						
Initial Change in:	Amount Used	Amount Produced	Amount Exported	Value Used	Value Produced	Value Exported	Amount Used	Amount Produced	Amount Imported	Value Used	Value Produced	Value Imported	World Price
Alpha's supply (Fig. 4)	+	+	+	?	?	?	+	-	+	?	-	?	-
Alpha's export tax (Fig. 3)	+	+	+	?	?	?	+	-	+	?	-	?	-
Beta's demand (Fig. 5)	-	+	+	?	+	+	+	+	+	+	+	+	+
Beta's supply (Fig. 6)	+	-	-	?	-	-	+	+	-	?	?	-	-
Alpha's demand decreases when Alpha has export tax	-	-	?	?	?	?	?	?	?	?	?	?	?

is predicted to change in the same or opposite direction as the initial "exogenous" variable named at the left of the row. In addition to the relationships that are unambiguously predicted, others identified by "?" can go either way on the basis of the model's parameters. The first row of the table indicates, for example, that an increase (decrease) in country Alpha's supply of arms will increase (decrease) the amounts produced and used in Alpha, the amount exported, and the amount used in country Beta. The world price should fall (rise) in this case, as should the amount and value of arms produced by country Beta.

The second row of Table 1 contains the model's predictions concerning the pattern of effects from a change in the export tax or subsidy that country Alpha attaches to its arms transfers. The pattern is the same as in the first row, meaning, for example, that the imposition of diplomatic conditions on Beta's receipt of arms (one form of export tax) lowers the amount produced, used, and exported by country Alpha but raises the amount that country Beta produces domestically. The third and fourth rows of Table 1 show the model's predictions when the importing country's domestic demand and supply curves for arms shift. The last three rows depict the patterns of predicted effects from changes in country Alpha's demand for arms. These effects depend upon whether Alpha's arms exports are subject to a tax or subsidy.

Because demand and supply curves are abstractions rather than observable variables, most of the predictions summarized in Table 1 are not directly useful for policy analysis. They are made useful, however, by specifying possible influences on the four demand and supply functions and on the export tax or subsidy, in the context of actual arms production and trade. By specifying these influences, we will then be able to formulate specific predictions about real world phenomena.

In general, the *determinants of a country's demand for arms* are hypothesized to include (1) the strength and stability of the internal and external threats it perceives itself to face; (2) whether it plans to make aggresive military actions; (3) its national income; (4) its supply of foreign exchange (if importing); (5) the supply of substitutes for countering its perceived threats, e.g., the strength and reliability

of allies' commitments; and (6) the price (or cost if domestically produced) of arms. The greater the threats, the higher the country's demand curve; similarly for the second, third and fourth items on this list. The fifth and sixth items should influence demand negatively.

The relationship between demand and the sixth factor, price, is of special interest. In general, the strength of this relationship--measured by the price elasticity of demand for arms--will depend upon the other five factors. (High price elasticity implies a strong response to price changes.) We hypothesize that this elasticity will be higher:

1. The smaller the country's share in the total arms of its ally group. Countries that are less important in this sense should have more flexibility to time their arms purchases when prices are lower.
2. The longer the period of time in which the country is observed after the price change; i.e., long-run elasticities are generally greater than short-run because purchasers are less constrained by current commitments and physical stocks.

In general, the *determinants of a country's domestic supply of arms* are hypothesized to include (1) the supply of resources, measured by such indicators as the gross national product, population, or the size of the manufacturing sector; (2) the quality or technical capabilities of the economy as indicated by the education, skill, and training of the work force, value-added per capita, the share of industrial output in gross national product, or other measures of technical competence; and (3) the price at which arms can be sold. The supply of arms should respond positively to each of these factors.

As in the case of demand, the relationship of supply to the price of arms is of particular interest. The supply elasticity, which measures this relationship, depends upon producers' capabilities and incentives to change their output in response to a change in price. We hypothesize that the supply elasticity will be higher:

1. the smaller the size of the country's arms sector relative to its total manufacturing sector, in terms of output or employment.

A small arms sector makes it easier to quickly adjust the amount supplied when the price changes.

2. The smaller the country's proportion of technical resources employed in arms production.

3. The larger the country's unutilized domestic financial resources.

Finally, we hypothesize that the *determinants of the amount of export tax or subsidy* that a country imposes on its exports of arms include (1) the commonality of interests with its trading partner; (2) the nature of diplomatic transactions that can be strengthened or compensated for through ties to arms transfers; and (3) the country's domestic political climate concerning trade with a particular partner or concerning trade in arms.

By returning to the examples discussed earlier in Table 1, we can now add empirical content to the model's predictions. Looking again at the first row of the table, we predict that the greater the productive resources (a hypothesized determinant of the domestic supply of arms) a country has access to, the larger will be its production, use, and exports of arms, the larger will be the amount imported and used by its arms customer(s), and the lower will be the world price and the amount its international customer produces domestically. Similar predictions apply to the other determinants of arms supply listed above.

The third row of Table 1 in conjunction with the above list of *demand* determinants indicates another set of predictions. The second row of the table, along with the list of determinants of the amount of export tax or subsidy, gives still another set of predictions.

The appendix demonstrates that these predictions summarized in Table 1 can be further augmented by considering explicitly the determinants of elasticities of demand and supply of arms. When this is done, some of the question marks in the table can thereby be removed, yielding unambiguous predictions. Table 2 illustrates these possibilities, using the example of an increase in the exporting country's domestic supply of arms. The first row of Table 1 indicated that the

Table 2

EFFECTS OF AN INCREASE IN THE EXPORTING COUNTRY'S (ALPHA'S) DOMESTIC SUPPLY OF ARMS

		Factors Affecting Beta's Demand Elasticity		Factors Affecting Beta's Supply Elasticity		
Direction of Effect on	Predicted Effect Regardless of Factors on Right	Share of Allies' Total Arms	Time the Supply Change Has Persisted	Share of Manufacturing Sector Making Arms	Share of Engineers and Skilled Workers Making Arms	Unutilized Domestic Financial Resources
Exporting country's						
Amount used	+	+	-	+	+	-
Amount produced	+	-	+	-	-	+
Value used	?	?	?	?	?	?
Value produced	?	-	+	-	-	+
Importing country's						
Amount used	+	?	?	+	+	-
Amount produced	-	-	+	?	?	?
Value used	?	?	?	?	?	?
Value produced	-	-	+	?	?	?
World						
Amount traded	+	?	?	?	?	?
Value of trade	?	?	?	?	?	?
Price	-	-	+	-	-	+

effect on the price of arms on all the *quantity* variables of interest is unambiguously predicted by our basic model. However, all the *value* variables except one (value of arms produced by the importing country) can either rise or fall. To generate the maximum number of predictions requires further investigation of the relationships between specific elasticity determinants and particular effects. Table 2 reports these hypothesized relationships for the same example: an increase in the exporting country's domestic supply of arms. Down the left-hand column are the variables we are interested in. The next column indicates the model's ambiguous predictions for these variables, corresponding to the first row of Table 1. The remaining columns specify as examples several of the particular factors we have hypothesized to influence the demand and supply curves and the export tax. A plus sign in one of these columns indicates that the effect, whether positive or negative, is predicted to be *more* in the positive direction. A minus sign indicates the opposite, that the effect, whether positive or negative, is predicted to be *more* in the negative direction.

To take an example, the plus in the first row of the first column means that the amount of arms used in the exporting country must rise when anything shifts that country's supply curve out to the right, no matter what the value of all the variables listed along the top of the table. Moving over one column, we expect this rise to be greater in cases where the importing country has a large share of all the arms of its ally group, but smaller (next column) in a situation where the price change continues for a longer time. Moving along further to the supply side, we expect this rise in the exporting country's use of arms to be greater if most of the importing country's engineers and skilled workers are already employed in manufacturing arms.

The predicted effects of these same factors on the ten other variables listed in the left hand column of Table 2 can be read in similar fashion. Furthermore, the same kind of predictions can be derived for the other examples that form the rows of Table 1. A large number of predictions about arms production, trade, and use result.

IV. TWO EMPIRICAL APPLICATIONS

The basic model summarized in the previous section, as well as the more complex extensions outlined below, can be tested by several different empirical approaches--statistical, historical, qualitative, and case studies. We discuss these possibilities in Sec. V. Here we describe two preliminary empirical applications suggested by predictions from the basic model.[1] One application concerns a sharp change in an exporting country's domestic demand for arms. Except in the presence of an export tax (see the fifth row of Table 1) our model predicts that the country's exports should have an inverse relationship to domestic demand. The French withdrawal from Algeria was one such event.[2] Another was the rapid U.S. buildup in Vietnam and subsequent decline as American forces withdrew from that country.[3] This application concerns the American experience.

Military prime contracts (in 1972 dollars) rose from $37.3 billion in 1964, to $53.5 billion in 1967, and fell back to $36.5 billion by 1970. To analyze this period fully would require data by weapon type on production quantities, retention for own use, and export. Here, however, we use only aggregate values of military prime contracts and exports by country. We represent internal demand in two ways: prime contracts minus all exports and prime contracts minus

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[1] We emphasize again that the model developed in Sec. III is *basic*. Empirical application requires modifications based on the complex phenomena to be explained. One example of this is our consideration of foreign exchange constraints below, even though the model assumes market-clearing exchange rates. Another example is the absence of a price variable in the empirical applications, although it figures prominently in the model.

[2] Kolodziej, 1980, p. 147.

[3] As another example, Mihalka notes that after World War II and Korea, the United States sold large amounts of equipment for which it no longer had any use, considerably below cost. "If no country showed interest (or had insufficient funds), the United States effectively gave the equipment away . . . at prices one-tenth to one-hundredth the initial cost." See Michael Mihalka, *The Measurement and Modeling of Arms Accumulation: The Middle East as a Case Study*, C/75-7, Center for International Studies, Massachusetts Institute of Technology, April 1975, pp. 11-12.

exports to all countries except Vietnam and Israel. The second definition acknowledges that the defense and supply of Vietnam and Israel were in many ways equivalent to domestic U.S. demand. Exports were defined in a consistent manner--i.e., all exports, and exports less those to Vietnam and Israel.[1] Plots of these data pairs (exports and internal demand) are shown in Fig. 1 for the years 1963 to 1975.[2]

Two clusters of observations stand out, one to the right that contains the primary Vietnam buildup years of 1966-1968, and the other to the left that contains the remaining years. The predicted negative relationship between internal demand and exports is evident within each cluster. The separate clusters represent two different domestic supply curves of arms, one that shifted considerably to the right during the Vietnam buildup.[3]

Note also that the normal-years supply curve has a larger slope in the right panel of Fig. 1 than in the left panel. This indicates that U.S. arms exports are more responsive to changes in internal demand when arms for Vietnam and Israel are subtracted from the quantities. To the extent that U.S. arms transfers to these two countries are committed and fairly unresponsive to market pressures, it makes sense that our model's prediction is more strongly confirmed when these particular transfers are excluded.

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[1] In these definitions, exports were measured in the year following the contracts, because it would take at least that long for an order to mature into an export.

[2] The lines in Fig. 1 were estimated by ordinary least squares.

[3] This shift in the supply curve in response to a large shift in demand requires consideration of the short-run versus long-run features of supply--a subject ignored in the previous section's theoretical discussion. A short-run supply curve is predicated on a given number of firms, plants, and major items of capital equipment. Demand variations on the order of 10-15 percent can usually be accommodated without substantial capital investment or the entry of new firms; this kind of change in supply traces out the short-run supply curve. However, changes of 50 percent or more, as seen during the Vietnam buildup and subsequent decline, require substantial growth (or decline) in facilities, thus moving the entire short-run supply curves. The evidence is consistent with just such a movement in supply.

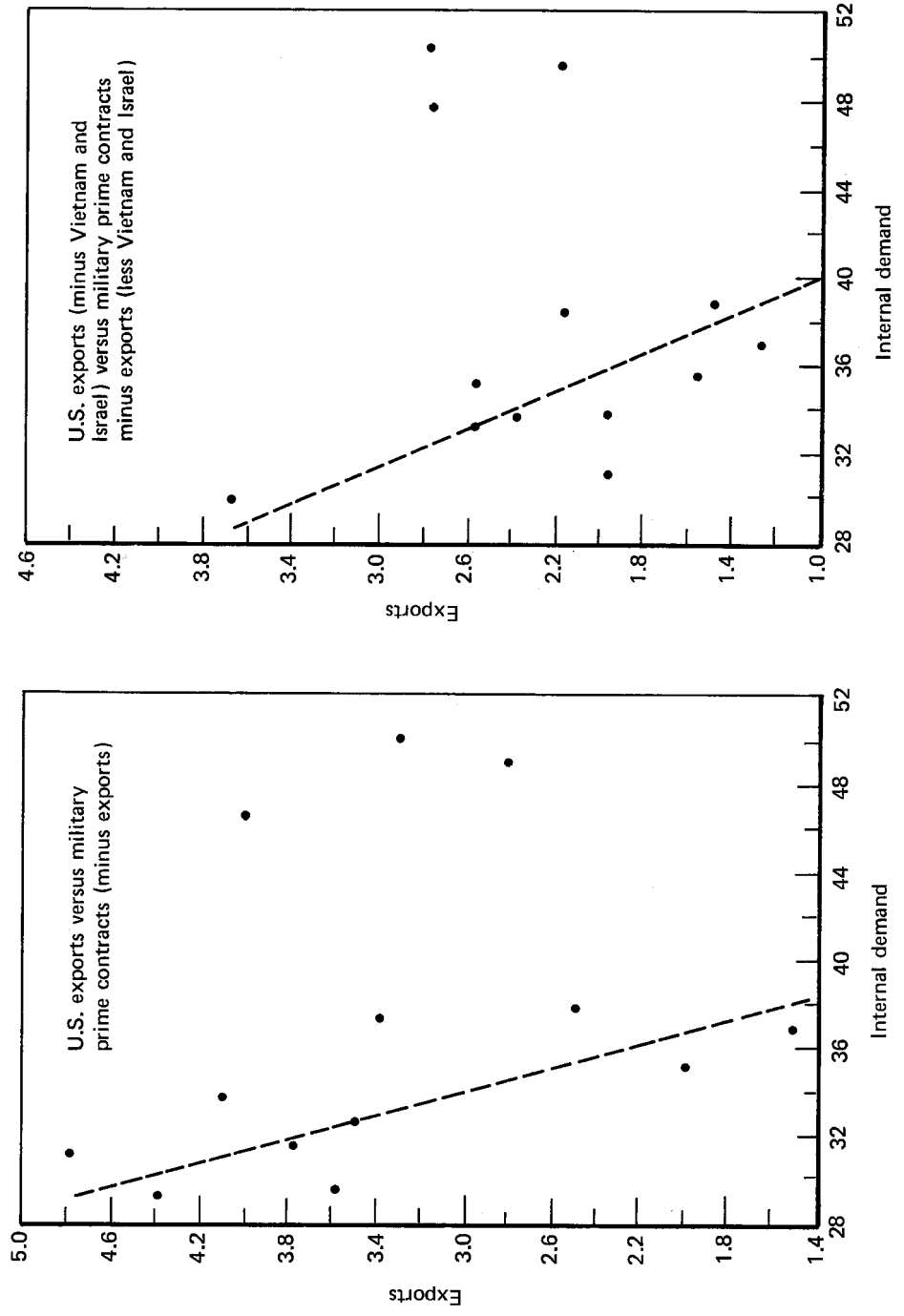

Fig. 1—Arms exports as a function of internal demand for arms (billions of 1972 dollars)

Our second preliminary analysis emphasizes the determinants of indigenous arms production, especially in countries that are not fully industrialized, and that may be as widely different as Sri Lanka and Brazil. Is such production likely to become more widespread across both weapon types and countries, and will weapons incorporating more advanced technologies than heretofore be available from more sources? Answers to these questions can vitally affect future arms control policies. For example, the effectiveness of export embargoes may be impaired by the ease with which other exporters enter the market or former importers substitute domestic production for their previous imports. It will be useful to know what characteristics of weapons and of recipient countries are most conducive to an export embargo policy.

The principal data source for this analysis is the table, "Arms Production in Developing Countries" (IISS, *Military Balance 1979-80*, pp. 101-103), which develops a scale for the capability levels of 23 countries in producing each of four types of weapons: aircraft, helicopters, armored fighting vehicles, and ships. To extend the range of capabilities and economic variables, we added the principal NATO arms producers to the sample--Belgium, France, Germany, Italy, The Netherlands, United Kingdom, and United States.

Although the published data on capability levels are not entirely appropriate for this purpose, we believe they are sufficient for an exploratory statistical analysis. For the dependent variable on arms production capability, we use the unweighted mean of the four weapons scales.[1]

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[1] We slightly modified the published scales as follows: 0 = imports only; 1 = assembly of imported components; 2 = supervised license built (some components locally built); 3 = dependent license built (some components imported); 4 = independent license built; 5 = dependent R&D (some advanced components imported or license built); 6 = independent R&D.

We then investigated whether each of the weapons production capabilities is highly correlated with the others (which would indicate that they reflect essentially similar industrial processes), or whether they are independent (suggesting separate technologies and processes). The simple correlation among the four weapons types is approximately .7 (r^2 = .5). This implies that although there is a common basis, each scale incorporates independent information that should not be

As independent variables, we sought proxies for the conceptual variables hypothesized above to influence a country's supply and demand for arms. The supply factors indicate a country's capability for arms production and are measured by two types of variables: the absolute size of the economy and the technical capabilities of the manufacturing sector. The first class of supply variables is measured in this preliminary analysis by GNP, population, and manufacturing output. Percentage of the population with second level and third level education, R&D engineers and scientists per capita, and the ratio of manufacturing output to GNP indicate the technical capabilities of the economy. Each of these factors is hypothesized to be positively related to domestic arms production capability. We also include two international finance variables in the domestic supply function: the ratio of external debt service to export earnings and the size of foreign exchange reserves as measured by the number of months of imports that can be financed by the reserves. The observed relationship between these variables could be either positive or negative, depending on whether they principally influence future activities or are the result of past behavior. The higher the export debt service the lower is a country's credit-worthiness and its ability to borrow abroad and the more expensive should be arms imports. Hence, a high export debt service would encourage domestic production. However, high debt service could also be the *result* of an inability to produce arms and other exportables, forcing the country to import and borrow, thus yielding a negative relationship between debt service and domestic production. Similarly, large reserves permit a country to buy arms abroad but may also result from the production and foreign sale of arms and other goods. On the basis of these qualitative arguments, it is not possible to determine in advance the effect of these variables. We therefore look to the statistical analysis to show the net effect of the forces.

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ignored. We therefore combine the four individual scales into an unweighted mean scale, having one value for each country. Factor analysis supported this decision as the first principal factor, accounting for almost 80 percent of the variance, was virtually an equally weighted linear combination of the separate weapons scales (f_1 = .28 aircraft + .28 helicopters + .30 armored fighting vehicles + .26 ships).

Demand factors reflect a country's motivations to possess arms. Rather than measuring the factors hypothesized in our model to influence arms use motivations, we include in this preliminary analysis a more direct measure: the level of military expenditures (absolute, per capita, and as a proportion of GNP). These variables should be positively related to arms production capability.

Table 3 reports representative regression estimates of the variables associated with arms production capabilities.[1]

In all the estimated equations, both the size and technical capabilities variables were important; however, since the variables in each class were highly correlated with the others in the same class, only one or two such variables seemed to capture the main effects. Thus in Regression (1) of Table 3, the variable actually used (ratio of industrial output to GNP) could have been replaced by GNP per capita or the proportion of the population with more than a secondary education.

The other coefficient estimates are as expected. Both supply and demand factors appear important. Based on this preliminary evidence, countries that are more industrialized and more populous can be expected to have greater capability for domestic arms production, while countries enjoying a favorable foreign exchange position can be expected to have less such capability, probably because they tend to buy arms from abroad. Of course, these findings should be interpreted as only suggestive, providing clues to guide additional research. Nevertheless, it appears that industrial capabilties are necessary--and almost sufficient--to explain arms production. If borne out in further research, one would predict arms production in growing numbers of countries in an economically developing world. This prospect would be stronger for countries whose foreign exchange positions are deteriorating, for example oil-importing countries.

This preliminary analysis could be strengthened by refining the dependent variable and adding independent variables of a political

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[1]These equations are neither pure supply nor demand functions. Rather, they are "reduced forms" that include the explanatory variables in both functions but exclude the international price of arms.

nature. The published capability scales do not differentiate among technological levels of weapons; thus, jet fighter aircraft have the same weight as simpler trainers. Adding a measure of technological complexity to the measure of capability would improve the analysis.[1] Such a multidimensional measure might be amenable to a Guttman scale analysis that ranks the possibilities according to patterns found in the data. Among the useful political variables would be measures of international conflict and cooperation as well as arms race indicators. Finally, the production capability equations reported in Table 3 could be incorporated into the broader framework of domestic production, imports, and exports of arms that is described in our theoretical model.

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[1] Improved data have recently been collected by Andrew L. Ross, "Arms Production in Developing Countries: The Continuing Proliferation of Conventional Weapons," The Rand Corporation, N-1615-AF, 1981.

Table 3

REGRESSIONS FOR ARMS PRODUCTION CAPABILITY

(Sample size = 30; estimation is by ordinary least squares; t-statistics in parentheses)

Explanatory Variables	Hypothesized Relationship	Regression (1)	Regression (2)
Industrial output (billion $)	+	.0073 (3.03)	.0062 (2.7)
Ratio of industrial output to GNP	+	11.0 (5.8)	10.0 (5.5)
Population size (millions)	+	.0060 (3.4)	.0066 (4.1)
Months of imports covered by international reserves	?	- .34 (-4.0)	- .33 (4.3)
Ratio of debt service to exports	?		- 4.00 (2.4)
Ratio of military expenditures to GNP	+		5.50 (1.9)
Intercept term		- 1.03	- 0.48
R^2		.78	.84

V. RESEARCH PLANS

The simple model outlined above and in the appendix has straightforward assumptions and many testable predictions. In future research, we plan to develop alternatives and variations on this model, use them to understand diverse empirical patterns of arms production and trade, and predict the effects of alternative arms policies. We face a number of decisions about how to use our model to study the international weapons market and related policy issues:

1. What factors and influences probably affect the demand for and supply of arms and the amounts of "tax" or "subsidy" that exporting countries impose--quantitative and qualitative influences, measurable and ethereal?[1]

2. For particular tests and application of the model, how can we approximate these factors in actual data?

3. What are the most productive ways of complicating our basic model--to allow more than two trading partners, to allow more than one trading bloc, to include more than one economic sector, to admit adaptive expectations or stock adjustment processes, or to go in still other directions?

4. What kinds of "arms" should be considered? A broad definition might consider "trade" in capital and in manpower--scientists, engineers, and technicians and in their training--as part of trade in "arms." At the other extreme, we might examine production and trade in a particular weapon, say rifles, or the M15 rifle. Regardless of how broad the study might become, it seems prudent to begin on a modest scale, with specific classes of weapons. Some weapons may be widely traded in markets for which a multicountry general equilibrium model is appropriate, others in oligopolistic markets.

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[1] Kolodziej notes, for example (*op. cit.*, p. 157), that one of the attractions of French arms, as contrasted (say) to Swedish arms is the minimum number of political strings attached to the sale.

The appropriate answers to these four questions will differ, depending upon the particular application of the model. Here are three types of applications we might pursue:

1. Select a particular historical case in which arms production in a country or group of countries has increased significantly or in which arms imports have risen. Examine what happened in this case to the other dependent variables--quantities and values of arms--on which our model focuses. Even if some data are missing, comparing these changes with the patterns predicted in Tables 1 and 2 above will generally brand some potential causes as very unlikely. Case studies of this sort can go far toward testing the predictive accuracy of the basic model, indicating the most productive directions for extending it and suggesting how it might be used to predict future patterns of arms production and trade.

2. Identify countries with consistent patterns of the variables hypothesized to influence demand, supply, and the tax--a pattern that points strongly to either arms exporting or arms importing. Check whether the countries that "should" import do, and vice versa. Since this is a *comparative* static model, it would be better to look for *changes* in the explanatory variables that strongly suggest either increasing imports or declining exports, whatever the country's initial position, then check to see if the country's trade position is changing in this predicted direction.

3. Construct a time series of cross-sectional data on as many of the dependent variables and explanatory factors as possible.[1] The types of arms and sample of countries must be decided. Then estimate the model using regression analysis. As dependent variables for each country, our basic model applied in the simplest form would include the amount produced, the amount used, the amount traded, and the price. Our second preliminary analysis discussed above is a first step in this type of research.

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[1]For example, Ross, *op. cit.*, collected indigenous arms production data for three time periods: 1960, 1970, and 1980. The time path of production determinants could be investigated with these data.

Some of the explanatory variables discussed in this report are certainly not available in numerical data series that are at all consistent across countries or over time. For example, could a panel of country or area experts agree whether the "threat" faced by a country in the sample went up or down in each calendar year since 1960? Could the panel's series be accurately replicated by an independent panel? Alternatively, one could use "objective" data such as those included in the "Conflict and Peace Data Bank" assembled by Edward Azar at the University of North Carolina. We are beginning to assemble a data base from these sources as well as from the Arms Control and Disarmament Agency, Defense Intelligence Agency, the Office of the Under Secretary of Defense for Research and Engineering, and the Defense Supply Assistance Agency. Information may also be available from sellers in the world's arms markets and from arms manufacturers, who are a potentially important, highly uncertain, and largely untapped fund of information on the state of supply and demand. How these firms plan for an uncertain future environment might prove instructive.

As we continue to gather data, extend models, and study empirical relationships, we will assess the implications of many policies that may affect international arms production and trade. The global perspective facilitates our tracing the effects in other regions of a policy aimed at one region and allows identification of long-term effects of a specific policy, such as an embargo. We should also be able to identify such forces as changes in a country's GNP or foreign exchange position that may adversely affect attempts to regulate the arms market and suggest policies to deal with them.

Although a policymaker may be interested only in a particular feature--say the amount of arms transferred--examining the rest of the arms market is often essential in understanding that one feature. The goals of such analyses are understanding the causes of observed arms proliferation; predicting regions of the world at high risk of future arms growth; and identifying U.S. policies that can slow and control the production, transfer, and use of arms in the developing world.

Appendix

AN ECONOMIC MODEL OF ARMS PRODUCTION AND TRANSFERS

We begin with the following explicit assumptions:

1. Only two countries can participate in this international arms market.
2. Each country's demand and supply curves fully summarize and reflect its perceived benefits from arms and its constraints on producing them and buying them internationally. These demand and supply curves slope down and up, respectively.
3. All arms production is used, none stockpiled, during the period of adjustment to the changed conditions.
4. All constraints on arms trade can be summarized as a proportional tax (or subsidy) imposed (or granted) by the exporting country.
5. Each country maximizes its perceived benefits from arms, subject to its domestic constraints and the world price.

For two countries, A_α and A_β are quantities of the composite good, arms (A), which is the same good and has the same effectiveness in whichever country it is produced or used.

S_α and S_β are the domestic supply curves of A.

D_α and D_β are the domestic demand curves for A.

P is the price of a unit of arms.

τ is the export tax or subsidy, measured in dollars, that country α imposes per unit of arms sold to country β. If β incurs diplomatic, economic, or political obligations to α in buying arms from α--over and above the money cost that arms users in α must pay--then τ is positive. If α wants β to have arms for less than their price in α, then τ is negative.

ES_α is the excess supply curve of arms from country α.

ED_β is the excess demand curve of country β for arms.

The supply and demand curves in Fig. A.1 are drawn so that country α, in the left panel, is able to produce arms more cheaply than country β, in the right panel, but is willing to pay less for any given quantity of arms.

Without trade, therefore, P_α is less that P_β. The two countries may be producing the same or different amounts; as drawn, A_β exceeds A_α. Assuming for now that no stockpiling occurs, each country's use of arms must equal its domestic production.

In this situation, both countries would benefit from trade in arms. We can depict trade in the center panel of Fig. A.1 by drawing α's excess supply of arms as ES_α and β's excess demand for arms as ED_β. At price P_α, ES_α is zero, since $D_\alpha = S_\alpha$ at that price, leaving no excess to be traded abroad. At higher prices, suppliers in α will produce more and demanders in α will buy less, yielding a horizontal difference, measured by ES_α, that is available for sale to β. Similarly, at price P_β, ED_β is zero, since $D_\beta = S_\beta$ at that price leaving no potential buyers in β unsatisfied. At lower prices, however, demanders in β will want to buy more while suppliers produce less, yielding a horizontal difference, measured by ED_β. Trade occurs if ES_α intersects ED_β at a positive price. (Clearly α has an excess demand curve at prices below P_α and β has an excess supply curve at prices above P_β, but no trade would occur in these price ranges.)

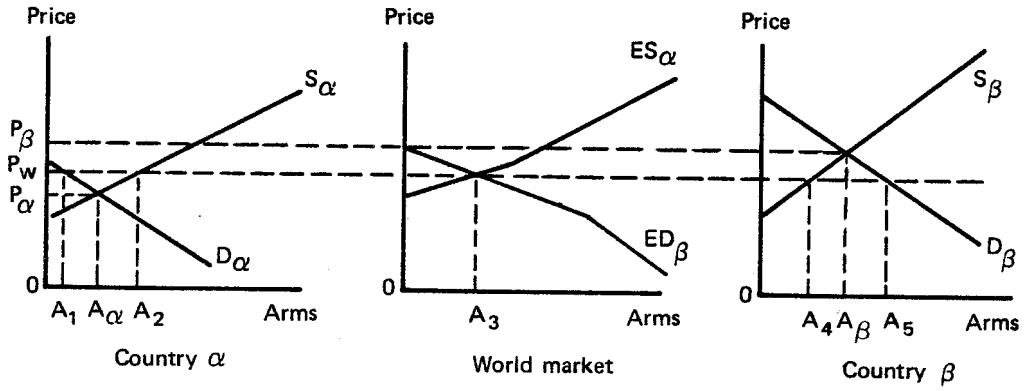

Fig. A.1—Arms trade in initial equilibrium

Equilibrium is at world price P_w with α producing A_2 arms and selling A_1A_2 in Fig. A.1. Alpha's total value of arms production is P_wA_2. In the right panel of Fig. A.2, Beta imports A_4A_5 arms (equal to A_1A_2 and to A_3) and produces A_4 itself. It pays to produce

this amount domestically because A_4 arms have total value of $P_w.A_4$ to country β but cost less than this to produce: production cost is the area under the supply curve between 0 and A_4.

It is useful to assume that α can impose costs or benefits on β, associated with β's arms purchases. We represent this in Fig. A.2 as a proportional export tax τ, which has the effect of lowering β's imports from A_4A_5 to A_8A_9 and its total use of arms from A_5 to A_9 while raising its domestic production from A_4 to A_8, all at a higher price P_x. If τ were negative, thereby reducing the effective price of arms to country β, τ's excess supply curve would shift out, yielding the opposite effects.

We now examine the effects of particular changes in the model's parameters, holding all other parameters the same. The changes to be considered are in the four demand and supply curves and in the tax (or subsidy), τ. For each change, we will look at effects on the same eleven variables: for countries α and β the amount of arms produced the amount of arms used, the value of arms produced and the value of arms used; and for the world the amount and value of arms trade and the price. Some of the predicted effects are summarized in Tables 1 and 2 in the text.

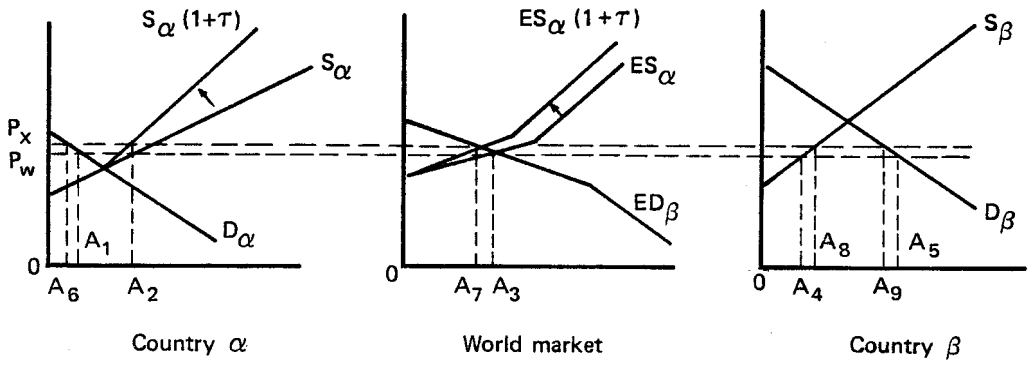

Fig. A.2—Effects of an export tax in Country α

First, consider an *increase in country α's supply curve,* depicted in Fig. A.3. This could occur because of an increase in α's physical or financial capital, or because of an increased supply of engineers or skilled workers. This change causes the world price to fall to P_x while α's production rises to A_7 and its own arms use to A_6. The amount of arms traded rises by A_3A_{10}, leading to an increase of A_5A_9 in β's use of arms in spite of a decline of A_4A_8 in its domestic production. The *value* of β's domestic supply (price times quantity) also declines. How the value of arms transfers changes cannot be predicted without further information. It depends on the elasticities of β's supply and demand curves.

Hence, an increase in α's supply curve must increase its production, domestic use, and exports and must lower the world price. It must also increase β's arms use and imports, and lower β's domestic production. The effects are the same for a decrease in the export tax τ (or increase in subsidy), since this amounts to an increase in supply at all prices above the domestic equilibrium price in α. The direction of change in the other variables of interest depends on relative elasticities of the demand and supply curves.

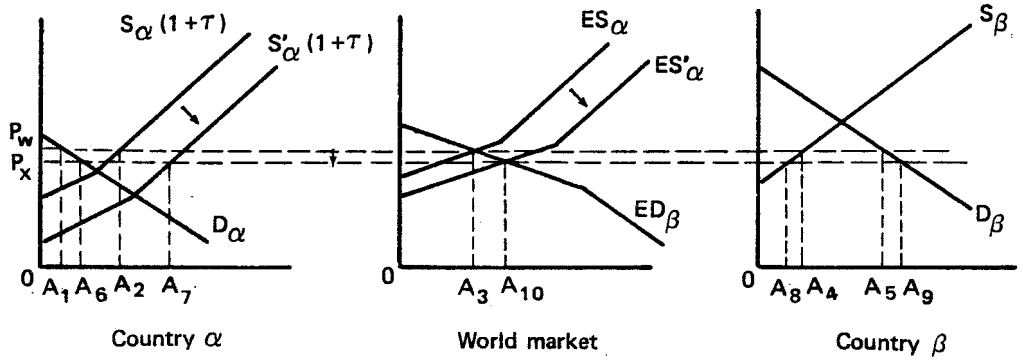

Fig. A.3 — Effects of an increase in Country α's supply

Now consider in Fig. A.4 the effects of an *increase in country* β's *demand curve for arms* from D_β to D'_β. We discuss in the text the factors that might cause such a change in demand. Beta's excess demand rises accordingly to ED'_β, eliciting a price rise and an increase in trade to A_7. Alpha provides this increase partly by increasing its production from A_2 to A_6 and partly by decreasing its own use of arms to zero as the figure is drawn. In addition to importing more, β also increases its own production from A_4 to A_8. The value of all arms used by β also increases, but the value of trade may go up or down, depending on the elasticity of α's excess supply. If either D_α or S_α is highly elastic, the value of trade is likely to increase. This result is also more likely if α offers an export subsidy rather than imposing a tax, since a subsidy has the effect of increasing the elasticity of S_α in the relevant range.

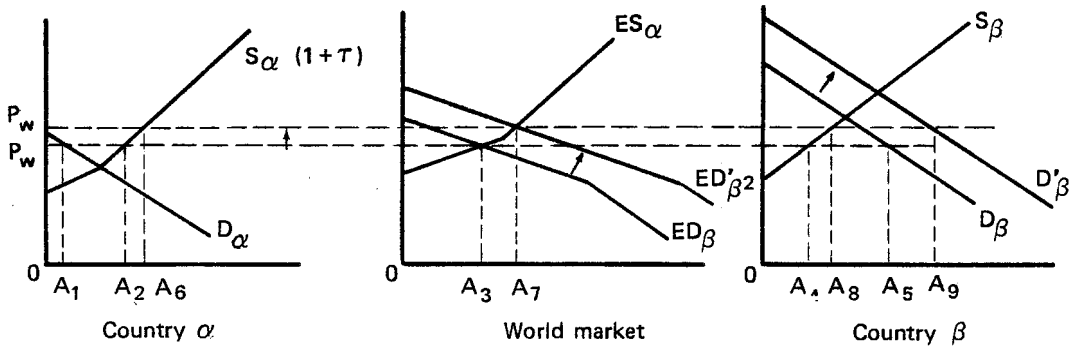

Fig. A.4 — Effects of an increase in Country β's demand

Fig. A.5 depicts the result of an increase in country β's supply of arms from S_β to S'_β. The first effect is to lower β's excess demand curve to ED'_β, thereby lowering the world price to P_x. Alpha responds by producing less and using more domestically, thereby reducing to A_8 the amount traded. Beta increases its domestic production and total use, but reduces its imports.

It is interesting to note that ED_β and ED'_β coincide below the price at which β's domestic supply ceases. If ES_α intersects ED_β in

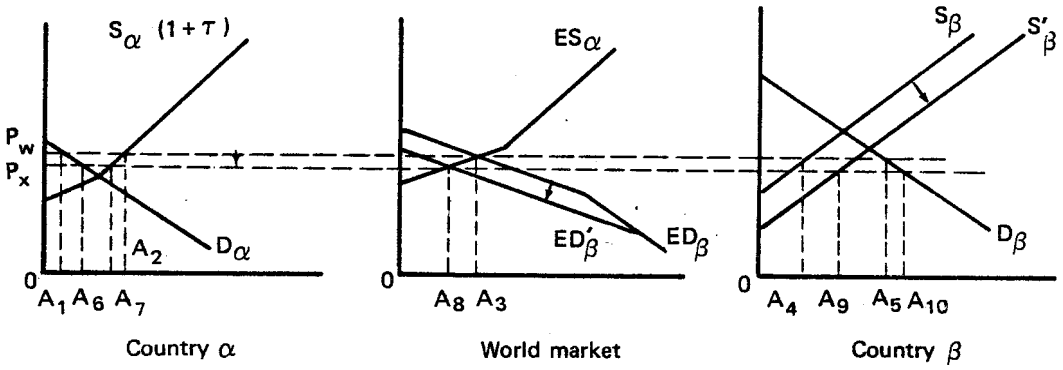

Fig. A.5 — Effects of an increase in Country β's supply

this range, changes in β's domestic supply have no effect, since it remains uneconomic for that country to begin any domestic production at all.

Finally, we consider in Fig. A.6 the effects of a decline in country α's demand for arms. These effects are more complex than in earlier cases, depending on (1) whether α imposes a tax or subsidy on exports and (2) whether β's excess demand curve is high or low relative to α's excess supply. These complications arise because the imposition of an export tax or subsidy changes S_α in its range above the new equilibrium price, thereby altering the location of the kink in ES_α. Hence a shift in the demand curve automatically causes the supply curve to shift as well. As Fig. A.6 is drawn, the decline in α's demand for arms actually lowers trade in arms from A_3 to A_7, while raising the world price, certainly a counterintuitive result. An implication is that β's domestic production increases.

If α offered an export subsidy (τ negative), A_7 would be greater than A_3, and arms trade would expand following a decline in α's demand. The same result would occur if ED_β intersected ES'_α left of its intersection with ES_α in Fig. A.6, even assuming that τ is positive.

The overall conclusion in this case is that declining demand in α must increase arms trade at a lower price if α has an export subsidy or if it has no subsidy or tax. However, if α imposes an export tax,

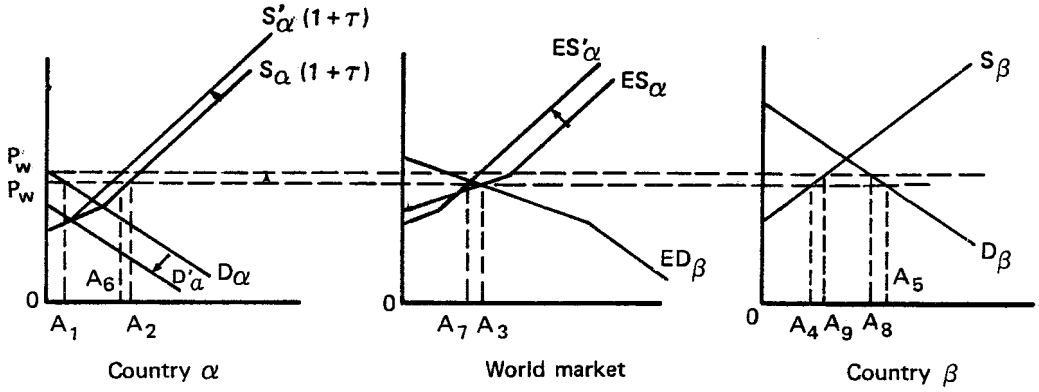

Fig. A.6 — Effects of a decline in Country α's demand

arms trade may rise or fall depending on the relative position of β's excess demand schedule. These complications do not arise when demand in α *increases*. Whether there is an export tax or subsidy, the world price rises along with production in both countries. Trade declines.

These predictions from our basic model are summarized in Table 1 of the text.