The Theory of Public Choice - II
James M. Buchanan and Robert D. Tollison, Editors
http://www.press.umich.edu/titleDetailDesc.do?id=7229
The University of Michigan Press, 2009.

Burden Sharing, Strategy, and the Design of NATO

Todd Sandler and John F. Forbes

War is a matter not so much of arms
as of expenditure, through which
arms may be made of service.
—*Thucydides,* History I

The theory of public goods played a fundamental role in the economic studies that predicted burden-sharing and suboptimality problems for military alliances.[1] The "purely public" deterrence model showed that disproportionate burdens were shouldered by large rich allies, and defense expenditures were suboptimal owing to noncooperative behavior (Olson and Zeckhauser 1966, 268–71). Later analyses considered both the deterrent and protective (i.e., damage-limiting) aspects of defense and, in so doing, stressed the impure public good properties.[2] The joint product model (Sandler 1977) is the most comprehensive model of alliance behavior, because it includes private, impure public, and pure public outputs of defense expenditures. Moreover, this model degenerates to the deterrence or the impure public models as special cases.

Changes in the seventies no longer allow for the straightforward application of the pure public good model to alliance behavior. The change in NATO's military strategy, the development of new weapon systems, and the increase of disputes exogenous to the East-West split favor the application of the joint product model, since rivalry in consumption, multiple outputs, benefit exclusion, *and* private benefits are increasingly characterizing modern alliances. These strategic developments concern the doctrine of flexible response, the deployment of tactical nuclear weapons (TNW), and the Strategic Arms Limitation Talks (SALT).[3] New weapon technologies involve multipurpose "Precision-guided munitions" (PGM) which blur the traditional distinctions between conventional, theater nuclear, and strategic weapons (Burt 1976, 23).

This article utilizes the joint product model to examine defense burden sharing and NATO's structure with respect to current strategic, diplomatic, and technological developments. In particular, we show that the unintegrated ("loose") structure of NATO, where allies act with little loss of autonomy, is justifiable from an economic viewpoint due to these developments, because

First published in *Economic Inquiry* 18 (July 1980): 524–44, Journal of the Western Economic Association.

the proportion of excludable benefits *and* the recognition of common interests are increasing in NATO. Even though allies use their discretion to purchase most weapons across markets, *defense burdens are* hypothesized to be approximately *shared according* to private and public *benefits* received. Any discrepancy is attributable to either the provision of strategic nuclear weapons or the pursuit of private benefits yielding jointly produced public benefits; hence, burden sharing is *independent* of the ally's industrial size. Empirical evidence supports our theoretical predictions and discriminates between the joint product and the deterrence models.

Five reasons make this study of general interest. First, the study casts doubt on the classic case for a nonmarket allocative structure (i.e., defense expenditures). Second, ability-to-pay *and* benefit measures are used to analyze burden-sharing behavior within an international organization. Third, the joint product methodology can be profitably employed to examine other international and national organizations. Fourth, this study presents an up-to-date view of American and Western European defense policy. Finally, the analysis *alters conventional wisdom* regarding alliance behavior by enriching and extending the theory and empirical support.

The paper contains six additional sections. The joint product model and its implications are reviewed in section 1, while current developments in strategy and technology are discussed in the next section. Section 3 analyzes NATO's structure. Benefit proxies for burden sharing, the statistical results, and the conclusions are presented in the remaining sections.

1. The Joint Product Model

Deterrence, Protection, and Publicness

By relying on the *threat of punishment,* deterrence *forestalls* hostility through an interalliance information flow of threats and counterthreats.[4] If the *sole* purpose of a weapon is to convey a credible retaliatory threat on behalf of an alliance (e.g., assured destruction), then the weapon is purely deterrent (*DW*) (e.g., Trident submarines, B-1 bombers). The other major component of defense involves an arsenal's damage-limiting abilities used when deterrence fails and war begins. Purely protective or damage-limiting weapons (*PW*) are deployed to deny an enemy its military objective. Antiballistic missiles, antitank guided weapons, and aircraft shelters represent *PW*. Since many weapons (e.g., multipurpose aircraft, cruise missiles) can satisfy both deterrent and damage-limiting purposes, these weapons are classified as mixed defense weapons (*MW*). The mixture of protective and deterrent components can be used to distinguish *MW* along a continuum with *PW* and *DW* located at the poles. While strategic nuclear weapons are best characterized as *DW*, conventional and tactical nuclear weapons are either *PW* or *MW* depending upon the weapon's design and purpose.

How well a weapon fulfills the publicness requirements of nonrivalry and nonexcludability depends in large p ırt on the weapon's classification. When-

ever an alliance's commitment to retaliate against aggressive acts directed at any ally is *credible*, then the punishment threat of *DW* provides nonrival benefits to the entire alliance. That is, additional nations can join the alliance without diminishing the deterrence provided to the existing allies. Furthermore, if an attack upon any ally inflicts unacceptable damage on the other allies in terms of fallout, or the loss of foreign investment interests and/or military personnel, then deterrence is nonexcludable, and *DW can* satisfy both characteristics of publicness. Nevertheless, it is doubtful whether deterrence as provided by strategic nuclear weapons is fully nonexcludable, because control of these weapons remains essentially in U.S. hands and the resulting damage to American interests from an attack on European allies may be within acceptable limits.

Many of the benefits derived from *PW* are impurely public owing to elements of rivalry *and* exclusion. When an arsenal of *PW* is required to protect a larger front or boundary as a new ally joins, a *thinning of forces* results from a spatial rivalry which detracts from the protection of the existing allies. This thinning effect depends on the allies' relative locations, the enemy's position, and the topographical characteristics of the front. Insofar as damage-limiting forces can be withdrawn and deployed elsewhere, many benefits of *PW* are subject to exclusion at the will of the provider. When a strong protective force reduces the probability that an opposing army will win, *PW* also provide some purely public benefits to the other allies in the form of deterrence. *MW* embody both deterrent and protective capabilities. Consequently, these weapons exhibit different properties of publicness (especially rivalry) in accordance with their utilization. A formal analysis must treat *MW* and *PW* as producing joint outputs which may be private, pure public, or impure public in nature.

The thinning phenomenon of *PW* and *MW* has important implications for sharing arrangements that determine alliance size, user fees or tolls, and defense provision. If an alliance depends on an arsenal of *PW* (e.g., a conventional war alliance), size restrictions must be based on thinning considerations. A potential ally should be permitted to join whenever its total benefits from membership equal or exceed the thinning costs imposed on the other allies. The price or user charge for a *unit* of defense is determined at the margin by the sum of thinning costs inflicted on the allies. Total charges should differ between allies depending upon their defense utilization rates as determined by their *exposed border* length. Exposed border consists of a country's perimeter less shared perimeter or border with a friendly country. For optimal provision, the sum of the allies' incremental benefits from force concentration (thickening) resulting from an expansion of the arsenal must equal the incremental costs of the new weapons. When utlilization and thinning are measured in an agreed way, the proposed toll scheme can finance optimal provision.[5] In the absence of a sharing arrangement, allies would purchase their weapons and deploy them as they see fit along their borders. Efficiency incentives would induce allies to negotiate subsequent sharing and

standardization schemes so that weapons are optimally distributed and interoperable. Hence, rivalry and exclusion aspects of *PW* can *partially circumvent* free rider problems, since markets and sharing arrangements provide some means to share burdens and to approach efficiency based on utilization. Markets will not, however, work perfectly unless the common-interest aspects associated with the pure public outputs of *PW* and *DW* are recognized by the allies.

Alliances are classifiable along a spectrum where placement is determined by the ratio of *PW* to the sum of *PW* and *DW* in the arsenal (see fig. 1). *MW* must be separated into their deterrent and protective components when making the placement. By utilizing the ratio of protective to deterrent elements, *MW* can be transformed in value terms into *PW* and *DW*.

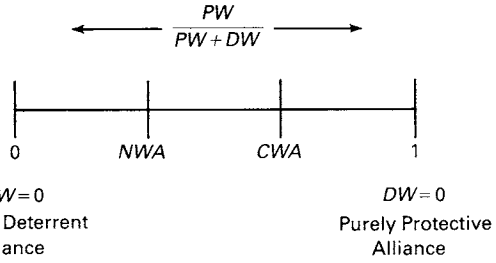

Fig. 1

Diverse alliance types occupy different locations along the continuum; e.g., conventional war alliances (*CWA*) are nearer to the right pole than nuclear war alliances (*NWA*). The right pole corresponds to a purely protective alliance, whereas the left indicates a purely deterrent one. The further an alliance lies on the right, the stronger is the thinning effect *and* the greater is the proportion of excludable benefits.

Defense and Joint Products

In addition to deterrence and damage-limiting protection, alliance-wide expenditures yield benefits that are private between allies, but public within an ally. For example, armed forces can maintain domestic order (e.g., Britain in Northern Ireland), provide foreign exchange to a host nation (e.g., Germany), or facilitate the development of an arms industry (e.g., United States). Expenditures on *DW* and *PW* yield private benefits such as augmented national prestige (for *DW*) and protection of coastal waters (*PW*); however, *PW* probably provide relatively more private benefits, since they can be used for intracountry purposes (e.g., national guard). Modern *DW* primarily include strategic weapons which do not readily serve intracountry threats and purposes. Thus, the right side of the spectrum is hypothesized to include a larger proportion of private benefits.

We assume that a general defense good (or an arsenal) produces deter-

rence, protection, and one or more private goods in fixed proportions.[6] If the general defense good is optimally provided, the incremental benefits of *all* of the joint outputs must be summed together and equated to the incremental cost of production. Moreover, the incremental benefits from deterrence and damage limitation must be summed over all allies, while those of the private good do not require summing; i.e., only one ally receives each unit. Size considerations for the alliance are solely based on the thinning costs arising from collective utilization of the damage-limitation joint product. This follows because the private goods are not shared and deterrence can be shared at zero costs. Thus, the previously given size requirements still hold. Pricing of the general defense good is related to the marginal value of the private benefits, the marginal thinning costs of protection, and the marginal value of the excludable benefits of deterrence.

The joint product model's implications for NWA are significantly at odds with those of the deterrence model. For the joint product model, *alliance size restrictions* should be determined by thinning. Secondly, defense preferences will be partially revealed and, consequently, efficient provision can be market financed *whenever* private and excludable public outputs are a *substantial* proportion of the jointly produced outputs. Thirdly, the ratio of excludable outputs *to* the sum of excludable and nonexcludable outputs indicates the extent of suboptimality; as the ratio approaches 1, suboptimality is reduced, because free riding declines. An unequal burden will fall on those allies, *regardless of income levels,* who are either providers of *DW* (e.g., Britain, France, United States) *or else* significant purchasers of private and/or excludable public outputs yielding alliance-wide deterrence (e.g., Britain, Germany, United States). In contrast, a deterrent alliance requires *no size restrictions*. Furthermore, allies reveal *false preferences* in the market, and disproportionate burdens are imposed *on the large rich allies*. Finally, the relative economic sizes of the allies determine suboptimality (Olson and Zeckhauser 1966).

2. Strategy, Technology, and the Alliance Spectrum

During the 1950s and early 1960s, NATO was near the left pole of the spectrum, because it relied upon strategic weapons due to the USSR's unbeatable conventional forces in Europe (Iklé 1973; Quester 1970). Current changes in strategy, diplomacy, and technology are significantly shifting NATO's position toward the protection end. For example, the current strategy of limited nuclear response increases the need for conventional forces, especially during the initial "testing" stages of an escalation (Davis 1975; Iklé 1973). This strategy introduces flexibility into NATO's nuclear employment plans by providing for a sequence of measured responses toward aggression so that general nuclear war can be avoided and deterrence restored when provocation requires a military response. With this strategy, strong conventional and tactical nuclear forces are essential if aggression in Europe is to be thwarted immediately by a show of intention.

Recent technological improvements in TNW and PGM allow NATO to overcome partially the pact's conventional superiority[7] owing to NATO's technical advantage in these weapon systems (Burt 1976; Canby 1974; Heisenberg 1973). Ultraaccurate guided munitions can be effective in counteracting the 3 to 1 tank disparity between the two sides. Development of these weapons adds credibility to the doctrine of flexible response, because NATO can defend itself without resort to an assured destruction response. By placing limits on strategic weapons, SALT also increased the importance of conventional forces and TNW. Current strategic and technological developments augment the importance and need for *PW*.[8] Therefore, thinning considerations are becoming more prevalent, and benefit exclusion more feasible; hence, *allies can rely on markets* to supply defense more effectively than previously supposed.

These changes in the international situation are not only increasing the importance of thinning and excludability, but they also are augmenting the perceived common interests of the European allies. Flexible response brings the initial stages of a war onto European soil. Until the seventies, there was little reason for the European allies to build up conventional forces, since *any* war would be fought in minutes with an exchange of nuclear warheads. Additionally, the technological advantage of NATO in precision weaponry augments common interests by giving the Europeans an alternative to nuclear exchange by the superpowers. SALT and détente are bringing the European allies closer together also, because they are apprehensive about arms agreements between the U.S. and Russia which they are not consulted about. As common interests are recognized, the positive externalities of defense will become internalized. Thus, the increased perception of common interests and the increased privateness of defense should make the European allies more willing to contribute toward NATO's defense.

The trend in NATO toward a larger proportion of *PW* is difficult to show empirically, primarily because detailed weapon expenditure information is classified; however, this trend is indicated by computing the ratio of non-U.S. defense expenditures in NATO *to* total NATO defense expenditures. If this ratio increases, the proportion of conventional forces is hypothesized to have increased, since the major contributor of strategic forces is the U.S. Moreover, there is no evidence that France and/or Britain have significantly increased their strategic forces expenditures. The average annual ratios for non-U.S. expenditures in NATO were .25 for 1949–1960; .26 for 1961–1970; and .34 for 1971–1977.[9] This upward movement in the 1970s is indicative of a larger share of *PW*, especially since the U.S. strategic forces budget showed no upward trend during the 1970s and actually declined by 5.5 percent a year in real terms (Department of Defense 1976, 41–43).

3. The Design of NATO

NATO operates as a "loose" or unintegrated structure in which sovereign nations maintain both policy independence and discretionary power over mili-

tary expenditures.[10] Any action of the decision-making body of NATO (i.e., the North Atlantic Council) must be unanimous. Articles 4 and 5 of the treaty mandate consultation in the event that one of the allies or its property is attacked, but the commitment of the allies is left unspecified. The unintegrated nature of NATO is reflected in the expenditures on commonly funded projects reported in table 1. The three major areas of common funding include the civil budget financing NATO headquarters, its staff, and committees; the military budget supporting NATO's military structure, its staff, and committees; and NATO infrastructure (e.g., pipelines, communication networks, airfields). The figures for the civil and military budgets are unclassified, but have been buried in classified documents and have heretofore been unavailable. In table 1, all years indicate that less than *1 percent* of NATO's defense expenditures *is jointly financed;* hence, *over 99 percent of NATO expenditures is at the discretion of the allies and is transacted across markets.*

Should NATO be more tightly integrated? This question can only be answered by computing the net benefits from increased integration. Benefits in terms of efficiency gains, scale economies, and political and military consultation must be matched against communication, planning, interdependen-

TABLE 1. NATO Common Funding Expenditures 1968–78 (in millions of dollars)

Year (1)	Civil Budget[a] (2)	Military Budget[c] (3)	Infrastructure[d] (4)	Total Common Funding (5)	NATO Expenditures[e] (6)	Common Funding Percentage of NATO Expenditures (7)
78[a]	233.956[b]	850.328	283.333	1367.6		
77[a]	202.240[b]	717.152	300.000	1219.4	165,352	0.7
76	173.728	598.871	381.493[f]	1154.1	146,562	0.8[f]
75	174.436	611.213	180.539	966.2	145,955	0.7
74	132.900	480.422	281.819	895.1	132,919	0.7
73	113.608	457.360	232.828	803.8	119,933	0.7
72	97.376	391.436	137.766	626.6	112,212	0.6
71	74.168	382.672	175.178	632.0	103,862	0.6
70	68.884	308.052	61.336	438.3	103,279	0.4
69	63.472	259.343	134.255	457.1	105,171	0.4
68	55.148	241.957	92.600	389.7	103,914	0.4

[a]The classified sources for each year are as follows: BC-D(71)54 for 1968; BC-D(71)62 for 1969; BC-D(71)72 for 1970; BC-D(72)27 for 1971; BC-D(73)16 for 1972; BC-D(74)11 for 1973; BC-D(75)11 for 1974; BC-D(76)11 for 1975; and BC-D(77)7 for 1976.

[b]These figures are projected estimates and are extracted from the report on the 1978 civil budget, C-M(77)95.

[c]The source for 1975–78 is the files of the Military Budget Section of the U.S. Mission to NATO. The figures for 1968–74 come from the NATO Sub-Registry Financial Statements.

[d]These data are converted from that given in *NATO Infrastructure Program,* U.S. Mission to NATO, February 1977. To derive NATO's infrastructure expenditures from U.S. obligations, we used the following U.S. shares of the total: 1968–70, 33%; 1971–73, 32%; 1974–75, 31%; 1976–77, 30%; and 1978–79, 28%.

[e]All the figures for these years are projected estimates.

[f]The figures for 1976 are for the period from July 1975 to 30 September 1976, because the start of the U.S. fiscal year was moved from July to October.

[g]See the source in note 10.

cy, and decision-making costs that increased cooperation entails (Sandler and Cauley 1977). If the presence of common-interest awareness and private benefits induce preference revelation, as argued here, minimal gains in allocative efficiency can be achieved by further integration. Moreover, scale economies in weapons production are, essentially, being exploited through the market when large-scale producers sell weapons to allies and nonallies (Stanley and Pearton 1972; Facer 1975). Some additional scale economies may arise as European allies form consortia for the purpose of common weapon procurement (e.g., Roland Missiles, Alpha Jets). Facer (1975, 36–48) has shown that most common weapon procurement programs involved only two or a few of the NATO allies and that a cost premium resulted due to international cooperation. These premiums must be weighed against the benefits from common procurement, which include savings in research and development costs, scale economies, and the elimination of duplicate efforts; however, as yet there is little concrete evidence specifying the net benefits from common procurement.

Without this evidence, the major offset to the costs of increased integration must come from the benefits of *political and military consultation* (e.g., increased deterrence from a unified stand against an opposing alliance, increased force efficiency from an integration and interoperability of armies, better intelligence from shared information). In a recent report, the Department of Defense (1977*b*) indicated that significant efficiency gains are expected from standardization of weaponry, logistics, training, and doctrine, but the report also stated (p. 2) that only modest progress has been made regarding standardization due to political, economic, and military obstacles. One major obstacle concerns the unwillingness of allies to sacrifice autonomy over their military forces. Unless the political and military benefits outweigh the costs of increased cooperation, NATO's unintegrated structure probably will be maintained.

Positions along the alliance spectrum can be related partially to the desired degree of integration in NATO. Deterrent alliances can achieve significant efficiency gains by integrating, because the publicness of *DW* leads to nonrevelation of preferences and free rider behavior. These efficiency gains may offset costs of increased integration. In contrast, protective alliances can better utilize markets to allocate defense expenditures between allies and, consequently, less integrated alliances are desirable, because significant efficiency gains cannot be matched against integration costs.

The desired degree of NATO integration depends upon the awareness of common interests and the ratio of excludable to nonexcludable outputs as determined by the spectrum position. If this awareness and ratio increased in the seventies, then integration becomes less essential as preferences are revealed via markets.

4. Benefits and Burden Sharing in NATO

Previous NATO burden-sharing studies have invariably employed an ability-to-pay measure, usually that of GNP or per capita GNP. For example, van

Ypersele de Strihou (1967*b;* 1968) computed burden-sharing assessments using the British tax rates applied to per capita GNP and found that the large rich nations overcontributed and the small European countries undercontributed. Even though different ability-to-pay measures and/or tax rates were applied, similar results were shown by others.[11]

Table 1 raises doubts about some NATO burden-sharing studies (e.g., Price 1967) which, by only examining NATO's civil budget (accounting for less than 0.2 percent of NATO's total defense expenditures), could indicate little about overall burden sharing. Moreover, studies (Beer 1972, 24–25; Olson and Zeckhauser 1966, 276–79; Väyrynen 1976, 301–3) arguing that small countries' overpayment to infrastructure could compensate for large countries' overpayment to defense ignored the relative magnitude of NATO's infrastructure expenditures (i.e., less than 0.3 percent of NATO's annual defense expenditures).

By utilizing the ability-to-pay approach, all previous NATO burden-sharing studies have focused on the revenue side and have left the expenditure side dangling. We propose an improved approach including both benefits proxies and an ability-to-pay measure. Proxies for individual countries' share of total defense benefits are employed and compared with their actual share of NATO's total defense expenditures. According to the theory, the difference between actual and predicted burdens (i.e., those based on benefit proxies) should decrease in recent years due to strategic and technological changes.

What benefits do allies gain from deterrence and damage limitation? In the worst scenario, conflict could escalate into an assured destruction exchange in which both sides are annihilated. Defense benefits consist of what would be saved; *lives* and *industry*. Population size and gross domestic product (GDP) can serve as proxies for the excludable benefits derived from defense.

Since the benefits from *PW* depend crucially on thinning, which is determined by the length of perimeter needing protection, exposed border is included as an additional benefit proxy. This proxy also serves as a user fee measure.

5. Statistical Results

Investigating the empirical relationship between NATO defense expenditures and benefits-received or ability-to-pay indices raises problems of definition, measurement, and methodology. Although international comparisons of defense expenditures are often ambiguous due to variation in national definitions of defense expenditure, inconsistency between NATO allies is largely eradicated owing to the adoption of a common definition of defense expenditure.[12] Furthermore, the usual problems associated with comparing real product levels in different countries are inherent, but often intractable or ignored, in the existing valuation and comparison of ally defense expenditure.[13]

The choice of statistical methods in testing the hypotheses of the joint

product and deterrence alliance models is constrained by the composition and characteristics of NATO data. Several studies (Beer 1972; van Ypersele de Strihou 1967*b;* 1968) exploited parametric methods using Pearson product moment correlations and ordinary least squares regression. Path analysis and generalized least squares regression were used by Shaffer (1975) in a time series study of the interrelationship between individual ally defense effort, aspects of the internal alliance setting, and external influences such as alliance threats. However, given our interest in examining the distribution of defense burdens and benefits between allies at specific points in time, parametric procedures are inappropriate due to the nature and limitations of NATO data.[14] Therefore, following Olson and Zeckhauser (1966), we utilize distribution-free inferential methods in our statistical analysis.

Traditionally, the ratio of defense expenditures to GNP at factor cost valued in national currencies has been used to measure each ally's defense burden. This approach, while lending itself readily to applications of the ability-to-pay principle, does not facilitate a comparison of relative defense expenditures and benefits received. Defense expenditures expressed as a percentage of GNP measure the burden of defense *within* an ally as opposed to the burden shared *between* allies. Thus, in addition to the conventional empirical measure of ability to pay, this study uses a relative burden measure derived by calculating each ally's share of total NATO defense expenditure (see columns 6 and 10 in table 3).

An empirical test, which discriminates between the "purely public" or deterrence model and our joint product model, emerges from examining the relationship between the size of a nation's GDP and the percentage of GDP spent on defense. The deterrence model suggests that there should be a systematic and significant positive relationship between the size of GDP and the "defense effort" within an ally, measured by the percentage of GDP spent on defense, since, *ceteris paribus,* "the larger a nation is, the higher its valuation of the output of an alliance" (Olson and Zeckhauser 1966, 274). Our joint product model predicts that as an alliance moves toward the protective pole, there will be less of a systematic relationship between the size of GDP and "defense effort." An ally's "defense effort" should be unrelated to its size, since an increase in the incidence of private and/or excludable public benefits should stimulate preference revelation and generate, as well as maintain, an increase in "defense effort" irrespective of the industrial size.

To test the implications of both models the following hypotheses are used:

H_1: Within NATO, there is a significant positive correlation between the absolute size of an ally's GDP and its ratio of defense expenditure to GDP.

H_0: There is no significant correlation between the variables in H_1.

The hypotheses are tested for individual years over a sixteen-year period (1960–75) using Kendall's rank correlation coefficient (τ), a measure of

association between random variables from any bivariate population. A generalized Kendall partial rank coefficient is also used to measure the linear dependence of GDP and the ratio of defense expenditure to GDP, holding selected variables (viz., per capita GDP and exposed border) constant.[15] Results of the correlations are presented in table 2.[16]

Generally, between 1960 and 1966, the correlation results do not support H_0 and, thus, suggest the positive relationship between ally size and "defense effort" predicted in the deterrence model. However, beginning in 1967, the strength of the correlations tends to decline, and the null hypothesis of independence is rejected only once thereafter. The declining trend in the correlations suggests a gradual shift in NATO away from a purely deterrent alliance in the early 1960s toward a more conventional or protective alliance structure.

If, as argued here, ally defense expenditures are related to benefits received, we should expect an association between defense burdens and benefit proxies. More specifically, the residuals between actual defense burdens and predicted defense burdens based on benefits should decrease over time as common-interest awareness *and* the ratio of excludable outputs to the sum of excludable and nonexcludable outputs increases.

TABLE 2. Kendall Rank Correlation Results for Hypothesis 1

Year	τ_{12}	$\tau_{12,3}$	$\tau_{12,34}$
1960	.3186 (1.587)	.3761* (1.874)	.2589 (1.290)
1961	.2747 (1.368)	.3315* (1.651)	.2317 (1.154)
1962	.3406* (1.697)	.3880* (1.933)	.3039 (1.514)
1963	.3626* (1.806)	.4094* (2.040)	.3340* (1.664)
1964	.3406* (1.697)	.3934* (1.960)	.3094* (1.541)
1965	.3186 (1.587)	.4086* (2.036)	.3442* (1.715)
1966	.3186 (1.587)	.4086* (2.036)	.3538* (1.763)
1967	.2307 (1.149)	.3220 (1.604)	.2449 (1.220)
1968	.1428 (0.711)	.2600 (1.295)	.1823 (0.908)
1969	.0769 (0.383)	.1792 (0.893)	.0763 (0.380)
1970	.0989 (0.493)	.2130 (1.061)	.1057 (0.527)
1971	.1648 (0.821)	.3047 (1.518)	.2153 (1.073)
1972	.1868 (0.931)	.3180 (1.584)	.2249 (1.120)
1973	.2088 (1.040)	.3332* (1.660)	.2428 (1.210)
1974	.1868 (0.931)	.3180 (1.584)	.2318 (1.155)
1975	.0989 (0.493)	.2516 (1.253)	.1398 (0.696)

Sources: See table 3.

Note: τ_{12} = Zero order Kendall τ of GDP and ratio of defense expenditure to GDP.

$\tau_{12.3}$ = First-order Kendall partial τ of GDP and ratio of defense expenditure to GDP with per capita GDP held constant.

$\tau_{12.34}$ = Second-order Kendall partial τ of GDP and ratio of defense expenditure to GDP with per capita GDP and exposed border held constant. Numbers in parentheses are z-values (see n. 16). * indicates significantly different from zero at the 95 percent confidence level. Critical values for the one-tailed z test are 1.645 (95 percent confidence level) and 2.326 (99 percent confidence level).

Table 3 presents ally percentage shares of NATO's defense expenditure for 1960 and 1975, in columns 2 and 7 respectively.[17] In addition, the allies' shares of the overall population, GDP, and exposed border of NATO are depicted for 1960 and 1975.[18] Given an aggregate measure of ally benefits, actual defense shares can be compared with those based upon the three benefit proxies. Myriad weighting methods conceivably could be used to aggregate the various benefit measures. However, given our lack of knowledge regarding the appropriate specification of the allies' utility functions, we weight the individual indices equally in the absence of an alternative weighting formula of unquestionable superiority. Columns 6 and 10 of table 3 are arithmetic means of the population, GDP, and exposed border shares for the respective years, and represent composite benefit measures for predicted ally defense burdens which can be juxtaposed against actual defense burdens.

An examination of table 3 reveals that the United States overcontributed in 1960 relative to average benefits, whereas the remaining allies undercontributed. The ordering of allies, based on a comparison of relative defense burdens and benefits, corresponds to earlier studies using ability-to-pay assessments (e.g., van Ypersele de Strihou 1967*b*, 301).

Table 3 also indicates that the period between 1960 and 1975 resulted in notable changes in NATO burden sharing. While average relative benefits remained largely unchanged, relative defense contributions appear to have shifted in the seventies. Although the United States still overcontributed, approximately 6 percent of the total NATO defense expenditure was shifted onto the European allies, an increased European defense burden which represents approximately 27 percent of the European relative defense contribution in 1960. The shift is small in absolute magnitude, but it is still noteworthy, since no other period in NATO showed *any* measurable change in burden sharing. With the exception of Canada, the absolute value of the residuals between predicted and actual defense shares declined for *all* allies.[19] As the joint product model suggests, the providers of *DW*s and the recipients of private benefits (e.g., Britain, France, Germany, and the United States) either overcontributed or contributed roughly in accordance with relative benefits. The overcontribution of the United States (+26.3 percent) is closely predicted by our model; i.e., the U.S. expenditure on deterrent strategic weapons was approximately 30 percent of its defense budget (Department of Defense 1977*a*, 85), which translates into 20.1 percent of the total 1975 NATO defense expenditures. Canada emerged as the greatest undercontributor, which is to be expected, since the United States would have great difficulty in excluding Canada from its deterrent umbrella. The negative residual between Canada's assessed share and actual defense contribution (−7.56 percent) is more than compensated by the excess contribution of the United States. Thus, the redistribution of the NATO defense burden between the North American and European allies generally is consistent with our model's prediction that as the alliance shifts toward the protective pole, allies are more apt to reveal preferences and share defense burdens voluntarily.

TABLE 3. Relative Defense Burdens and Benefits in NATO Using Population, GDP, and Exposed Borders as Proxies: 1960, 1975

Country (1)	1960 Defense Burden[a] (2)	1960 POP[b] (3)	1960 GDP[c] (4)	Exposed Border[d] (5)	1960 Average Benefit Share[e] (6)	1975 Defense Burden[a] (7)	1975 POP[b] (8)	1975 GDP[c] (9)	1975 Average Benefit Share[e] (10)
Belgium	0.64	1.92	1.40	0.14	1.15	0.98	1.77	1.58	1.16
Canada	2.64	3.76	4.39	20.02	9.39	2.26	4.12	5.33	9.82
Denmark	0.33	0.96	0.86	2.23	1.35	0.46	0.91	0.89	1.34
France	6.34	9.59	7.18	4.44	7.07	7.01	9.52	8.70	7.55
Germany	5.38	11.64	10.29	2.75	8.23	8.09	11.16	10.56	8.16
Greece	0.26	1.75	0.42	5.84	2.67	0.85	1.63	0.66	2.71
Italy	2.06	10.54	4.75	9.09	8.13	2.90	10.07	5.29	8.15
Luxembourg	0.01	0.07	0.07	0.00	0.05	0.01	0.06	0.06	0.04
Netherlands	0.88	2.41	1.67	0.92	1.67	1.39	2.46	1.90	1.76
Norway	0.28	0.75	0.61	5.67	2.34	0.45	0.72	0.71	2.37
Portugal	0.20	1.86	0.30	1.50	1.22	0.48	1.70	0.40	1.20
Turkey	0.49	5.78	0.65	10.72	5.72	1.26	7.23	0.96	6.30
United Kingdom	7.25	11.04	8.15	9.27	9.49	6.86	10.11	6.89	8.76
United States	73.24	37.93	59.26	27.42	41.54	66.98	38.53	56.08	40.68
NATO–Europe	24.12	58.31	36.35	52.56	49.07	30.76	57.35	38.59	49.50
NATO–North America	75.88	41.69	63.65	47.44	50.93	69.24	42.65	61.41	50.50

Source: [a]*World Armaments and Disarmaments: Stockholm International Peace Research Institute Yearbook 1976* (London: MIT Press, 1976). Defense expenditures are valued in U.S. dollars at 1970 prices and 1970 exchange rates.
[b]*National Accounts of OECD Countries*, Vol. I "Main Aggregates" (Paris: OECD/OCDE, 1975). Population figures are midyear estimates.
[c]*Ibid.* GDP = Gross Domestic Product in purchaser's values in U.S. dollars, 1970 prices and 1970 exchange rates.
[d]*The Times Atlas of the World: Comprehensive Edition* (London: Times News-Limited, 1972). Exposed borders are derived from chartodometer estimates.
[e]See text.

Note: Figures represent percentage shares.

Area protected could be included as an additional benefit proxy reflecting resource wealth and option value. Moreover, area serves as a user fee measure for some defense benefits (e.g., national guard, monitoring purposes). When area is included as a proxy (see table 4), the results for 1960–1975 are almost the same as those reported previously; i.e., no shift in burdens occur until the seventies. The closeness of fit between actual and expected burdens *is,* however, *better* owing to the additional proxy. Furthermore, the North American allies only overcontributed by half of that shown in table 3 for 1975: some 9.5 percent. The fit for any set of proxies will not be perfect, because the publicness elements of defense can never be eliminated fully. Nevertheless, our proxies are an improvement over previous investigations, since ability-to-pay, benefit, and user fee measures are used here.

6. Summary and Policy Implications

By increasing both the relative proportion of PW and the common-interest awareness of allies, current strategic and technological developments in NATO are allowing markets to distribute defense burdens more efficiently than previously supposed. These developments favor the application of the joint product model over the deterrence model, because NATO's current arsenal jointly provides deterrence, damage limitation, and private benefits.

TABLE 4. Relative Defense Burdens and Benefits in NATO Using Area, Population, GDP, and Exposed Borders as Proxies: 1960, 1970, 1975

Country	Area[d]	1960 Defense Burden[a]	1960 Average Benefit Share[e]	1970 Defense Burden[a]	1970 Average Benefit Share[e]	1975 Defense Burden[a]	1975 Average Benefit Share[e]
Belgium	0.14	0.64	0.90	0.72	0.90	0.98	0.90
Canada	45.09	2.64	18.32	1.95	18.48	2.26	18.64
Denmark	0.19	0.33	1.33	0.35	1.06	0.46	1.06
France	2.47	6.34	5.92	5.67	6.17	7.01	6.28
Germany	1.12	5.38	6.45	5.92	6.56	8.09	6.40
Greece	0.60	0.26	2.15	0.45	2.17	0.85	2.18
Italy	1.36	2.06	6.44	2.40	6.48	2.90	6.45
Luxembourg	0.01	0.01	0.04	0.01	0.03	0.01	0.03
Netherlands	0.18	0.88	1.30	1.06	1.35	1.39	1.37
Norway	1.47	0.28	2.13	0.37	2.13	0.45	2.14
Portugal	0.42	0.20	1.02	0.42	0.98	0.48	1.00
Turkey	3.53	0.49	5.17	0.55	5.41	1.26	5.61
United Kingdom	1.10	7.25	7.39	5.60	6.97	6.86	6.84
United States	42.32	73.24	41.73	74.52	41.32	66.98	41.09
NATO–Europe	12.59	24.12	39.95	23.53	40.20	30.76	40.27
NATO–North America	87.41	75.88	60.05	76.47	59.80	69.24	59.73

Sources: a, d, e: see table 3.
Note: Figures represent percentage shares.

A rank correlation test supports the joint product model and discriminates between it and the deterrence model. If the deterrence model is applicable, then a significant relationship between industrial size and defense effort should be present; however, after 1966 the relationship is not statistically significant. This result is in agreement with the joint product model which predicts that defense efforts should be related to the distribution of excludable benefits *rather than* size, as the alliance shifts toward the protective pole in the late sixties and the seventies. Our statistical analysis indicates that defense shares are related to the benefit proxies chosen. The theoretical model accurately predicts the overcontributors: those allies providing DW and those receiving large private benefits.

The burden-sharing results suggest that the group of European nations is beginning to pay more of their share (especially when area is also a proxy). Hence, the European Defense Improvement Program (EDIP) appears to be achieving its objectives of increasing European defense expenditures. *However,* we would argue that the change in the alliance's orientation toward PW and *not* the EDIP (started in 1971) caused the desired result. If current strategic and technological developments continue to increase common-interest recognition among allies and the proportion of excludable benefits, then this burden-shifting trend should continue into the eighties. Nevertheless, a program to increase Canadian defense expenditures seems appropriate.

Our model and findings support NATO's unintegrated structure whereby sovereign nations decide their defense expenditures via market transactions. Arguments for a more integrated alliance *must rest on political and military benefits,* because many scale economies are exploited and efficiency gains are small due to the large portion of excludable benefits. Nonetheless, standardization agreements may warrant some increase in NATO's degree of integration. As strategy and technology change in the future, the structure of NATO must be reexamined in order to determine whether integration should be altered.

NOTES

The paper was written when Sandler was on leave at the Department of Economics and Related Studies at the University of York, U.K. He gratefully acknowledges the support of a NATO Postdoctoral Fellowship in Science. We thank T. J. Loveland from the U.S. Mission to NATO who provided data on NATO's civil and military budgets. Comments by Jon Cauley, Ann Chamberlain, Shelby Gerking, Donna Lake, James R. Marsden, Mancur Olson, Kate Ranta, William Schulze, V. Kerry Smith, and an anonymous referee significantly improved the paper. All views expressed and any remaining shortcomings are solely those of the authors.

1. The relevant literature consists of Beer (1972), Frohlich (1974), Loehr (1973), Olson (1965), Olson and Zeckhauser (1967), Russett (1970), Russett and Sullivan (1971), Sandler (1975, 1977), Sandler and Cauley (1977), van Ypersele de Strihou (1967*a*, 1967*b*, 1968), Väyrynen (1976), and Wagner (1975).

2. A pure public good (e.g., a cleaner environment) is totally nonrival in consumption, since its consumption by one individual does not detract in the slightest from the consumption possibilities available to other persons. Moreover, the benefits of a pure public good are nonexcludable, i.e., once it is provided, the good is available to everyone. In contrast, a private good (e.g., a piece of food) is totally rival and its benefits are excludable. Impure public goods exhibit varying degrees of rivalry and/or excludability.
3. These strategic developments are discussed by Burt (1976), Canby (1974), Davis (1975), Grey (1975), Heisenberg (1973), Iklé (1973), Nerlich (1975), and Rosecrance (1975). Flexible response permits an alliance to react to an enemy's challenge in multiple ways (e.g., limited nuclear war) so that a full nuclear exchange is but one option.
4. On the distinction between deterrence and protection, see Canby (1974), Heisenberg (1973), Iklé (1973), McGuire (1967), Rosecrance (1975), Sandler (1977), Schelling (1966), van Ypersele de Strihou (1967*a*, 1967*b*, 1968), and Väyrynen (1976).
5. Self-financing fails whenever increasing returns (i.e., falling average costs) occur. In this case, tolls must be based on average rather than marginal costs or else subsidies must be arranged.
6. Fixed proportions indicate that the units of each of the jointly produced outputs are in a fixed relationship with respect to the units of the general defense good. Any fixed proportion relationship can be accommodated by judicious choice of the units of the jointly produced outputs (Samuelson 1969, 28–30).
7. Fischer (1976) calculated the following Warsaw Pact/NATO ratios to show the pact's conventional superiority: active combat units 2.1/1, groundforce manpower 1.09/1, and combat aircraft in Central Europe 2.1/1.
8. The current switch from *DW* to *PW* is in line with the policy of assured destruction and damage limitation first put forth by McNamara (House Committee on Appropriations 1965, 32–35. Once the objectives of assured destruction are reached, McNamara indicated that defense expenditures should be increasingly redirected toward damage limitation. The stockpile of *DW* is enabling NATO to follow McNamara's advice.
9. The ratios for 1949–1973 were computed from data given by NATO (1976, 296–97), while the ratios for 1974–1977 were computed from data listed in NATO (1977).
10. For an institutional description of NATO, see NATO 1976.
11. See Beer (1972), Olson and Zeckhauser (1966), Peacock (1972), Price (1967), and van Ypersele de Strihou (1967*b;* 1968). Important articles on burden sharing in international organizations include Kravis and Davenport (1963), and Pincus (1965).
12. The standard NATO definition of defense expenditure is outlined in Jordan 1967, 217–8.
13. International comparisons of defense expenditures are invariably based on converting the money value of defense expenditure to U.S. dollars via official or prevailing exchange rates. Although errors are introduced into comparisons based on this method due to the inequality of official exchange rates and purchasing power parities, defense expenditure comparisons using more accurate repricing or adjusted exchange rate methods are generally not feasible. Binary repricing schemes between pairs of countries, for example, are constrained by the problem of repricing unique defense goods (e.g., U.S. intercontinental ballistic missiles)

and variation in empty good categories or zero expenditure on specific categories of defense goods across countries. For a cogent summary of the problem of international defense expenditure comparisons, see Stockholm International Peace Research Institute 1976, 285–87.

14. Insufficient knowledge regarding the specific distribution function of the population from which NATO data is drawn is the primary justification for using distribution-free procedures. A preliminary investigation using the Shapiro-Wilk test, an omnibus test which detects deviation from normality due either to skewness or kurtosis (Shapiro and Wilk 1965; Shapiro, Wilk, and Chen 1968) revealed that the assumption of normally distributed NATO data is violated for GDP, defense expenditures, and defense expenditures/GDP ratio in the original data metric and in a logarithmic transformation. Moreover, the number of NATO allies dictates a cross section sample size of n = 14 (since Iceland does not contribute) which may jeopardize the asymptotic properties of regression techniques.
15. See Somers (1959) for a theoretical exposition and discussion of the generalized Kendall partial rank correlation coefficient.
16. It is well known that the zero order Kendall rank correlation coefficient is asymptotically normally distributed under the null hypothesis of independence as the sample size $n \rightarrow \infty$ and that for $n > 10$ the normal distribution provides an accurate approximation (Kendall 1970; Jirina 1976). Although to the best of our knowledge, the exact distribution of the Kendall partial rank correlation coefficient remains untabulated, it has been shown, using a Monte Carlo simulation, that the normal distribution provides a satisfactory approximation for the Kendall partial rank coefficient frequency distribution (Hoflund 1963).
17. The tables for 1965 and 1970 are virtually identical to that of 1960 and have been deleted. They are available from the authors.
18. The data of these tables can be easily arranged so that each ally is ranked with respect to relative defense burdens and benefits. With the data suitably transformed, Kendall's coefficient of concordance (W), a nonparametric analysis of variance technique, is used to test the null hypothesis that the defense burden and benefit rankings for NATO allies are independent. The value of W for 1960, 1965, 1970, and 1975 is .7951, .7978, .7967, and .8000, respectively. As all values are significant at the 99 percent confidence level, we reject the null hypothesis of independence and conclude that relative defense burdens in NATO are significantly related to relative benefits. The values of W are virtually identical when area rather than exposed border is used as a land proxy.
19. The coefficient of inequality (U) suggested by Theil (1966) is used to measure the magnitude of the overall residual error between predicted and actual defense burdens. As the value of U is bounded by 0 and ∞, smaller values of U indicate a closer correspondence between predicted and actual burdens; hence if $U = 0$, predicted and actual burdens are equivalent for all allies. The value of U based on the estimated residuals declines from .4556 in 1960 to .4177 in 1975, thus suggesting that a shift in burden sharing has occurred, reducing the residual error between predicted and actual defense burdens.

REFERENCES

Beer, Francis. "The Political Economy of Alliances: Benefits, Costs, and Institutions in NATO." *Sage Professional Papers in International Studies*. Beverly Hills, Calif.: Sage Publications, 1972.

Burt, Richard. *New Weapons Technologies: Debate and Directions. Adelphi Papers.* no. 126. London: International Institute for Strategic Studies (IISS), 1976.

Canby, Steven. *The Alliance and Europe: Part IV Military Doctrine and Technology. Adelphi Papers.* no. 109. London: IISS, 1974.

Davis, Lynn. *Limited Nuclear Options: Deterrence and the New American Doctrine. Adelphi Papers.* no. 121. London: IISS, 1975.

Department of Defense. *Annual Defense Department Report FY 1977.* Washington, D.C.: Department of Defense, 1976.

Department of Defense. *Annual Defense Department Report FY 1978.* Washington, D.C.: Department of Defense, 1977*a*.

Department of Defense. *Rationalization/Standardization Within NATO, Third Report.* Washington, D.C.: Department of Defense, 1977*b*.

Facer, Roger. *The Alliance and Europe: Part III Weapons Procurement in Europe—Capabilities and Choices. Adelphi Papers,* no. 108. London: IISS, 1975.

Fischer, Robert. *Defending the Central Front: The Balance of Forces. Adelphi Papers.* no. 127. London: IISS, 1976.

Frohlich, Norman. "Self-Interest or Altruism, What Difference." *Journal of Conflict Resolution 18* (1974):55–73.

Gibbons, J. D. *Nonparametric Statistical Inference.* New York: McGraw-Hill, 1971.

Grey, Colin. "Deterrence and Defense in Europe: Revising NATO's Theater Nuclear Posture." *Strategic Review,* 1975, pp. 1–9.

Heisenberg, Wolfgang. *The Alliance and Europe: Part I Crisis Stability in Europe and Theater Nuclear Weapons. Adelphi Papers,* no. 96. London: IISS, 1973.

Hoflund, Olle. "Simulated Distribution for Small n of Kendall's Partial Rank Correlation Coefficient." *Biometrika 50* (1963): 520–22.

House Committee on Appropriations. *Department of Defense Appropriations for 1966, Hearings, Part 3.* Washington, D.C.: U.S. Government Printing Office, 1965.

Iklé, Fred. "Can Nuclear Deterrence Last Out the Century?" *Foreign Affairs 51* (1973): 267–85.

Jirina, Miloslav, "On the Asymptotic Normality of Kendall's Rank Correlation Statistic." *Annals of Statistics 4* (1976): 214–15.

Jordan, Robert. *The NATO International Staff/Secretariat 1952–1957: A Study in International Administration.* London: Oxford University Press, 1967.

Kendall, M. G. *Rank Correlation Methods.* London: Griffin, 1970.

Kravis, Irving, and Davenport, Michael. "The Political Arithmetic of International Burden-Sharing." *Journal of Political Economy 71* (1963): 309–30.

Loehr, William. "Collective Goods and International Cooperation: Comments." *International Organization 27* (1973): 421–30.

McGuire, Martin. "The Structure of Choice Between Deterrence and Defense." in *Issues in Defense Economics,* edited by Roland McKean, 129–49. New York: National Bureau of Economic Research, 1967.

NATO Information Service. *NATO Facts and Figures.* Brussels: NATO Publications, 1976.

NATO Press Service. *Financial and Economic Data Relating to NATO Defense.* M-DPC-3(77)18. Brussels: NATO Press Service, 1977.

Nerlich, Uwe. *The Alliance and Europe: Part V Nuclear Weapons and East-West Negotiations. Adelphi Papers,* no. 120. London: IISS, 1975.

Olson, Mancur. *The Logic of Collective Action.* Cambridge, Mass.: Harvard University Press, 1965.

Olson, Mancur, and Zeckhauser, Richard. "An Economic Theory of Alliances." *Review of Economics and Statistics 48* (1966): 266–79.

Olson, Mancur, and Zeckhauser, Richard. "Collective Goods, Comparative Advantage, and Alliance Efficiency." *Issues in Defense Economics*, edited by Roland McKean, 25–48. New York: National Bureau of Economic Research, 1967.

Peacock, Alan. "The Public Finance of Inter-Allied-Defense Provision." in *Essays in Honour of Antonio de Vito de Marco*, edited by Cacucci, 371–84. (*Bari, Italy: 1972*).

Pincus, John. *Economic Aid and International Cost Sharing*. Baltimore, Md.: John Hopkins Press, 1965.

Price, James. "The 'Tax' Burden of International Organizations." *Public Finance 22* (1967): 496–513.

Quester, George. *Nuclear Diplomacy*. New York: Dunellen Co., 1970.

Rosecrance, Richard. *Strategic Deterrence Reconsidered. Adelphi Papers*, no. 116. London: IISS, 1975.

Russett, Bruce. *What Price Vigilance? The Burden of National Defense*. New Haven, Conn.: Yale University Press, 1970.

Russett, Bruce, and Sullivan, John. "Collective Goods and International Organizations." *International Organization 25* (1971): 845–65.

Samuelson, Paul. "Contrast Between Welfare Conditions for Joint Supply and for Public Goods." *Review of Economics and Statistics 51* (1969): 26–30.

Sandler, Todd. "The Economic Theory of Alliances: Realigned." in *Comparative Public Policy: Issues, Theories and Methods*, edited by C. Liske et al., 223–39. New York: John Wiley and Sons, 1975.

Sandler, Todd. "Impurity of Defense: An Application to the Economics of Alliances." *Kyklos 30* (1977): 443–60.

Sandler, Todd, and Cauley, John. "The Design of Supranational Structures: An Economic Perspective." *International Studies Quarterly 21* (1977): 251–76.

Schelling, Thomas, *Arms and Influence*. New Haven, Conn.: Yale University Press, 1966.

Shaffer, S. M. "The Influence of Threat and Alliance Setting on National Defense Expenditures: NATO, 1950–1969." Ph.D. diss., University of Michigan, 1975.

Shapiro, S. S., and Wilk, M. B. "An Analysis of Variance Test of Normality (Complete Samples)." *Biometrika 52* (1965): 591–611.

Shapiro, S. S.; Wilk, M. B.; and Chen, H. J. "A Comparative Study of Various Tests for Normality." *Journal of the American Statistical Association 63* (1968): 1343–72.

Somers, Robert. "The Rank Analogue of Product-Moment Partial Correlation and Regression, with Application to Manifold, Ordered Contingency Tables." *Biometrika 46* (1959): 241–46.

Stanley, John, and Pearton, Maurice. *The International Trade in Arms*. London: Chatto and Windus, 1972.

Stockholm International Peace Research Institute. *World Armaments and Disarmaments: Stockholm International Peace Research Institute Yearbook 1976*. London: MIT Press, 1976.

Theil, Henri. *Applied Economic Forecasting*. Amsterdam: North-Holland Publishing Company, 1966.

van Ypersele de Strihou, Jacques. "Comments." in *Issues in Defense Economics*, edited by Roland McKean, 58–63. New York: National Bureau of Economic Research, 1967*a*.

———. "Sharing the Defense Burden Among Western Allies." *Review of Economics and Statistics 49* (1967*b*): 527–36.

———. "Sharing the Defense Burden Among Western Allies." *Yale Economic Essays 8* (1968): 261–320.

Väyrynen, Raimo. "The Theory of Collective Goods, Military Alliances and International Security." *International Social Science Journal 38* (1976): 288–305.

Wagner, R. Harrison. "National Defense as a Collective Good." in *Comparative Public Policy: Issues, Theories and Methods*, edited by C. Liske et al., 199–221. New York: John Wiley and Sons, 1975.