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Economics of Alliances: The Lessons for Collective Action

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1. *Introduction*

IN MARCH 1999, the North Atlantic Treaty Organization (NATO) admitted three new members—the Czech Republic, Hungary, and Poland—thus expanding the membership to nineteen allies.[2] Although NATO has taken in members in the past, this largest and latest enlargement, coming just prior to NATO's fiftieth anniversary, has implications for defense burden sharing, allocative efficiency, and alliance design and stability. An understanding of these implications can also enlighten us about scheduled enlargements of the European Union (EU), the World Trade Organization (WTO), and other international organizations. We inhabit a rapidly changing world where collective action, as directed by a growing number of transnational institutions, is becoming more relevant owing to a host of transnational externalities and public goods (Inge Kaul, Isabelle Grunberg, and Marc Stern 1999; Sandler 1997, 1998), whose increased prevalence arises from growing populations, the fragmentation of nations, enhanced monitoring abilities, and cumulative industrial pressures on the ecosphere. Transnational externalities involve an action in one country that creates a benefit or cost in another, and there is no market compensation.

Some 35 years ago, Mancur Olson and Richard Zeckhauser (1966) wrote a seminal paper on the economics of alliances that spawned a large literature. Perhaps, the greatest insights of their paper and its forerunner by Olson (1965) is the recognition that economic principles of military alliances (henceforth, alliances) apply to a wide range of transnational issues and institutions (see, e.g., Bruce Russett and John Sullivan 1971). Olson and Zeckhauser (1966) focused on burden sharing in an alliance, dependent on a pure public good of deterrence in which the large, rich ally shoulders the defense burden of the small, poor allies by providing the latter with a relatively free ride. This proposition became known as the *"exploitation hypothesis."* In 1970, for example, the United States accounted for just under 75 percent of NATO's defense spending, while the next largest allies—Germany, France, and the United Kingdom—each assumed less than 6 percent of NATO's defense

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[2] On NATO expansion, see Ronald Asmus, Richard Kugler, and F. Stephen Larrabee (1995, 1996), David Gompert and Larrabee (1997), NATO (1995), and Sandler and Hartley (1999, ch. 2).

burden. Because the United States received only 35 percent of NATO's defense benefits by one measure, an exploitation appears obvious. Other findings stemming from their and subsequent work on alliances addressed the optimal size of such collectives, the suboptimality of resource allocation, the strategic interactions among members, the nature of the collective linkage, and the form of the collective's demand for the public good. As the Olson-Zeckhauser model's predictions went wide of their mark over time for NATO and other alliances, new models stressed impurely public good aspects of the shared defense good.

In recent years, the interest in alliances and similar transnational collectives has grown in importance. Rather than the tranquility and security anticipated by the end to the Cold War, the superpower confrontation has given way to small, vicious wars driven by territorial disputes, internal power struggles, resource claims, and ethnic conflicts. In 1999, 27 wars raged throughout the globe in 26 locations (Stockholm International Peace Research Institute 1999, p. 9). During the post-Cold War era, defense collectives have increasingly turned to peacekeeping and peace enforcement in the world's trouble spots.[3] The creation of highly mobile forces, drawn from multiple allies, requires a degree of integration and cooperation heretofore never experienced in NATO (Palin 1995). Dramatic declines in defense budgets in the post-Cold War era have augmented the importance of allocative efficiency in the defense sector, as countries must maintain security with diminished resources assigned to defense.

Insights garnered from the study of alliances can be applied to a broad set of collectives concerned with curbing environmental degradation, controlling terrorism, promoting world health, eliminating trade barriers, furthering scientific research, and assisting foreign development. This essay on alliances has much to offer for understanding a wide range of international organizations such as arms-control regimes, the EU, the United Nations (UN), WTO, and pollution pacts. Although much of our specific reference will be to NATO, the economic theory of alliances has been applied to other current and historical alliances. Perhaps, the main reason why the public good theory and its offshoots have been first applied to alliances and only later to other international organizations is the relatively easy identification and measurement of costs and benefits afforded by specialist military alliances. Similarly, the readily available data on spending in NATO have made it the focus of attention in contrast to other alliances where data for so many years are not available.[4]

This essay has a number of purposes. First, it provides an up-to-date summary of the findings of the literature on the economics of alliances. Second, the essay emphasizes how the study of military alliances offers vital insights for a large number of transnational collectives. Third, the essay establishes that the manner in which alliances address

[3] NATO's new strategic doctrine of peacekeeping is presented and discussed by Erika Bruce (1995), Robert Jordan (1995), Roger Palin (1995), Steve Rearden (1995), and Sandler and Hartley (1999).

[4] By far, NATO is the most studied alliance using public good theory. Studies include Francis Beer (1972), Laurna Hansen, James Murdoch, and Sandler (1990), Hartley and Sandler (1990, 1999), Gavin Kennedy (1979, 1983), Jyoti Khanna and Sandler (1996, 1997), Klaus Knorr (1985), Martin McGuire (1990), Murdoch and Sandler (1984, 1991), Olson and Zeckhauser (1966, 1967), John Oneal (1990a, 1990b, 1992), Glenn Palmer (1990a,b, 1991), Sandler (1975, 1987), Sandler and John Forbes (1980), Sandler and Murdoch (1990), Stephen Sloan (1993), and Jacques van Ypersele de Strihou (1967).

burden sharing and allocative issues is related to strategic doctrines, weapon technology, the perceived threat, and membership composition. Fourth, the essay indicates bounds to what the economics of alliances can and cannot do, and why. Fifth, areas needing further development are identified. Throughout this essay, the reader is invited to replace NATO with the alliance or transnational institution of his or her choosing. This replacement will affect the impurity properties of the shared activity with predictable consequences to the theoretic predictions.

The remainder of this essay contains nine primary sections. Section 2 reviews the origins of the economics of alliances. In section 3, the pure public, deterrence model of alliances is presented. The more general and encompassing joint product model of alliances is then reviewed in section 4. The implications of these models on the allies' demand for defense are examined in section 5. Alternative empirical tests of burden sharing are reviewed in section 6, where the applicability of these empirical methods to the study of other collective action issues is also addressed. The implication of the economics of alliances on peacekeeping activities is the subject of section 7. In section 8, other aspects of the study of alliances are considered including dynamic concerns, alliance expansion, and alliance trade-offs (e.g., between security and autonomy). Section 9 highlights further applications to the study of other international collectives. Concluding remarks follow in section 10.

2. *The Origins of the Economics of Alliances*

Originally, the economic theory of alliances rested on the notion that allies jointly contribute to a defense activity that is a pure public good with nonrival and nonexcludable benefits. Defense benefits are nonrival when one ally's consumption of a unit of defense does not detract, in the least, from the consumption opportunities still available to the other allies from that same unit. If defense benefits cannot be withheld at an affordable costs by the provider, then these benefits are nonexcludable. The true origins of this theory of alliances is Olson's (1965, p. 36) *The Logic of Collective Action* where he used alliances, and NATO in particular, as an example of the kinds of international organizations which face allocative efficiency problems from sharing a pure public good. A formal model followed in Olson and Zeckhauser (1966) where defense was characterized as deterrence or inhibiting an enemy's attack on any ally through the threat of an annihilating retaliation.[5]

Although these authors clearly recognized possible extensions, their model rested on a number of key assumptions: (i) allies share a single purely public defense output, (ii) a unitary actor decides defense spending in each ally, (iii) defense costs per unit are identical in each ally, (iv) all decisions are made simultaneously, and (v) allied defense efforts are perfectly substitutable. Olson and Zeckhauser (1966) stressed the disproportionate sharing of burdens (i.e., the exploitation hypothesis) and the suboptimality of defense provision in a military alliance. Their approach captured the interests and imagination of economists, political scientists, and sociologists because of their explicit tests of unequal burden sharing of NATO in 1964, where the large allies were shown to carry the defense burdens of the small. This test also influenced policy

[5] On the meaning of deterrence, see Thomas Schelling (1960).

making and started a burden-sharing debate among NATO allies that carries on today (U.S. Department of Defense 1999).

In a follow-up study, Olson and Zeckhauser (1967) started the process of breaking their limiting assumptions by allowing for differences in the marginal cost of defense among allies. Once such differences are recognized, allocative efficiency favors that defense burden sharing be driven partly by comparative advantage. A low-cost, small ally may, at times, assume a greater defense burden than a larger ally if the smaller ally's cost advantage is sufficiently great (also see Kar-yiu Wong 1991). Efficiency then requires that marginal costs be equated across allies at their respective defense provision levels, and that each ally adjusts for the marginal benefits that their provision confers on itself and the other allies.

3. *Alliances: Deterrence and Pure Publicness*

In Olson and Zeckhauser (1966), defense provision within NATO was characterized as providing deterrence to forestall an enemy attack based on a pledged retaliatory response of devastating proportions.[6] Deterrence, as provided by strategic nuclear weapons (e.g., Trident Submarines, cruise missiles), is nonrival among allies insofar as these weapons' ability to deter an attack is independent of the number of allies (or citizens) on whose behalf the retaliatory threat is made, so long as the promised action is automatic and credible to would-be aggressors. There can be no time inconsistency problem where the allies pledging retaliation can reconsider the consequences of their commitment following an attack on its ally. When an ally possesses a sufficient stockpile of nuclear weapons so that it can absorb or defend against an enemy assault and still have enough surviving missiles to unleash a massive retaliation (i.e., second-strike capability), the threatened response is believable. Weapons that can be deployed to hit targets in any aggressor bolster the nonrivalry.

If the provider of strategic nuclear forces cannot fail to deliver a pledged retaliatory response against an aggressor of another ally, then the deterrence benefits are nonexcludable. Certainly, if an attack on another ally results in significant collateral damage to the deterrence provider in the form of civilian deaths, lost investments, fallout, or soldier casualties, then the promised retaliation is expected and nondiscretionary. Actions that ensure collateral damage serve to tie allies' interests together and make it difficult, if not impossible, to exclude other allies from the promised retribution to any invader of their territory. During the Cold War, the large number of U.S. troops and their dependents stationed in West Germany, the United Kingdom, and Italy served as a tripwire to the threatened U.S. strategic response if Europe were attacked.

3.1 *Baseline Pure Public Good Model*

In its most elementary representation each of n allies is assumed to allocate its national income, I, or gross domestic product (GDP) between a private numéraire good, y, and a pure public defense good, q. A decision-making oligarchy in each ally maximizes its utility:[7]

[6] On NATO's alternative military doctrines, see Gompert and Larrabee (1997), Jordan (1995), Rearden (1995), Sandler and Hartley (1999), and James Thomson (1997).

[7] The utility function is a well-behaved strictly quasi-concave function. If both goods are normal with positive income elasticity, then the Nash equilibrium exists and is unique (Richard Cornes, Roger Hartley, and Sandler 1999).

$$U^i = U^i(y^i, q^i + Q_{-i}, T), \tag{1}$$

where Q_{-i} is the sum of the other allies' deterrence spending, so that

$$Q_{-i} = \sum_{j \neq i}^{n} q^j, \tag{2}$$

and threat, T, denotes the defense expenditures of the enemy. Utility rises with increases in the private good and the overall level of deterrence spending, $Q = q^i + Q_{-i}$. At this juncture, the defense or deterrence contributions are perfectly substitutable owing to the additivity of Q.

To complete the model, we represent each ally as facing a linear budget constraint:

$$I^i = y^i + pq^i, \tag{3}$$

where the price of the private good is 1 and that of the defense activity is p. In keeping with Olson and Zeckhauser (1966), the price of defense is the same in every ally, so that there is no comparative advantage. The Nash equilibrium follows when each ally chooses its defense and private good amounts so as to maximize utility subject to its budget constraint and the best-response level of Q_{-i} of the other allies. If all allies contribute a positive amount, then the resulting first-order conditions can be written as:

$$MRS^i_{Qy} = p \tag{4}$$

for every ally i a member of the alliance. In (4), the *MRS* expression represents ally *i*'s marginal rate of substitution between defense and the private good and, as such, is a measure of the ally's marginal willingness to pay for defense or its associated marginal benefit. Thus, (4) indicates that each ally equates its marginal benefit from defense to the associated marginal cost—in this case, the relative price of defense. Suboptimality results at the overall Nash-equilibrium level of Q defined by the equation system in (4), insofar as the marginal benefits that an ally's defense provision confers on the other allies is ignored.[8] A Pareto-efficient Q level requires that each ally chooses its defense so that the *sum of MRSs* is equated to the relative price of defense. Thus, the Nash level of deterrence is less than the Pareto-efficient level (Olson and Zeckhauser 1966; Cornes and Sandler 1996).

Another crucial relationship that follows from the underlying optimization problem is the reaction function:

$$q^i = q^i(Q_{-i}, p, I^i, T), \tag{5}$$

which relates an ally's choice of q^i to the other allies' aggregate level of defense and the remaining three exogeneous variables. The Nash level of alliancewide defense spending also corresponds to the sum of the allies' defense levels that simultaneously satisfies the reaction paths in (5).

3.2 *Reaction Paths: Graphical Presentation*

These reaction paths are the allies' demands for defense, which is a function of market datum, the other allies' defense, and external threat. The second is known as defense *spillins* and gives rise to free riding as the defense efforts of the allies replace the need for the ally's own defense provision. If all goods are normal with positive income elasticities, then the reaction paths are downward sloping.

In figure 1, the two-ally case is illustrated. For the moment ignore the dashed reaction paths. Reaction path N_1N_1 is that of ally 1, while N_2N_2 is that of ally 2. The intersection of these reaction paths at point E is the Nash equilibrium where ally 1 supplies q^{1N} and ally 2 provides q^{2N}. The overall level of defense at this equilibrium is found by drawing a line (ET) with slope −1 from E to the horizontal axis, so that distance

[8] That is, $\sum_{j \neq i} MRS^j_{Qy}$ is not taken into account.

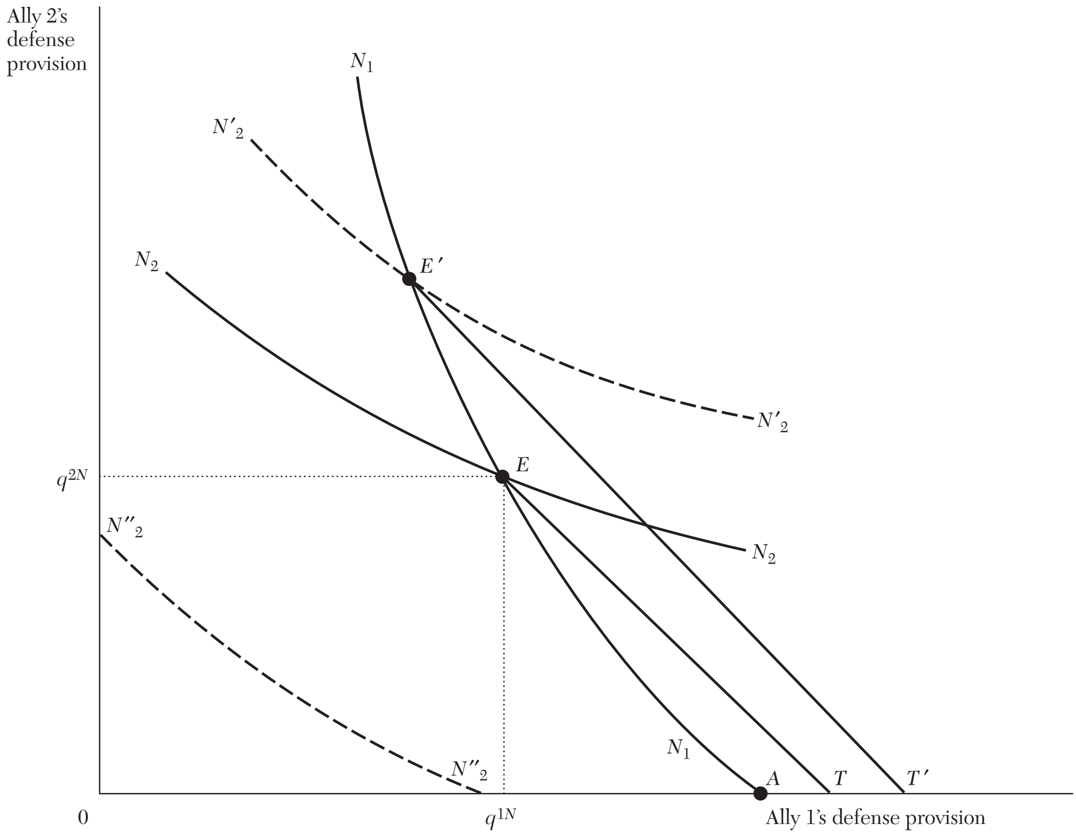

Figure 1. Allies' Reaction Paths in Deterrence Model

$0T$ equals $q^{1N} + q^{2N}$ (Cornes and Sandler 1996). The normality assumption implies that N_1N_1 (N_2N_2) is steeper (flatter) than a downward-sloping line making a 45° angle with the axes so that the equilibrium is both unique and stable.[9] Any given reaction path assumes that threat, income, and the relative price of defense are fixed; changes in any of these things will shift the respective path. If, for example, threat to just ally 2 increases, then its reaction path will shift up and to the right (see $N'_2N'_2$ in figure 1) so that ally 2 supplies a great defense level for each level of spillins. The new equilibrium at E' implies a higher alliancewide defense level (i.e., $0T' > 0T$) with ally 2 assuming a greater relative defense burden at E' as compared with E. In fact, ally 1 uses the enhanced threat to ally 2 as a means to reduce its own defense by free riding on ally 2's augmented efforts. This same kind of shift will occur if ally 2's income rises or its relative price of defense falls. The shifts are in the opposite direction if threat diminishes, income falls, or p rises. Similarly, the same kinds of shifts characterize ally 1's reaction paths. The implications of these shifts allow us to sign the coefficients of a demand curve in an empirical investigation.

[9] These implications are discussed in detail in Cornes and Sandler (1996, ch. 6), which also indicates the underlying isoutility curves for a pure public good model from which the reaction paths are derived.

The exploitation hypothesis can also be illustrated in figure 1 by supposing that ally 1 has a much greater income level than ally 2. Under these circumstances, ally 2's reaction path ($N_2''N_2''$ in figure 1) may never intersect that of ally 1, so that ally 1 would then supply $0A$ of defense, thus affording ally 2 a completely free ride. Income disparity results in the relative position of the reaction paths being such that the large ally will shoulder more, if not all, of the burden of defense. If, for example, the large ally spends \$250 billion on defense and a small ally only desires to spend \$50 billion in the absence of spillins when equating its marginal willingness to pay to marginal costs, then the small ally is unlikely to spend very much. Of course, this exploitation hypothesis rests on defense efforts being perfectly substitutable among allies.

The exploitation hypothesis is dependent on a number of implicit assumptions and does not hold in general (Sandler 1992, pp. 54–58). If, however, all allies have the same tastes, all good are income normal, and each ally faces the same constant unit cost of defense, the exploitation hypothesis follows from the standard pure public good model. The hypothesis may fail when a small ally either possesses a greater taste for defense than its larger counterparts (e.g., Israel allocates a much greater share of its GDP to defense than the United States), or has a comparative advantage in defense over the larger ally. But even with respect to the standard model, two key *implicit* assumptions are crucial for the exploitation result; namely, that Nash behavior applies and alliancewide defense is the sum of the allies' contributions. If, for example, leader–follower behavior replaces Nash behavior and the leader is the large ally, then it is possible to reverse the exploitation as the leader exercises its strategic advantage to place a greater burden on the follower (Neil Bruce 1990; Sandler 1992, p. 57). In the case of NATO and many other alliances, the requirements for the exploitation hypothesis apply to the sharing of deterrent weapons.

3.3 *Collective Action Implications*

When an alliance shares a purely public defense activity, some important collective action implications follow.[10] First, the exploitation hypothesis indicates that defense burdens are anticipated to be shared in a disproportionate fashion, leading a large, rich ally to allocate a greater portion of its GDP to defense than a small, poor ally. Second, defense spending is predicted to be allocated in a suboptimal fashion. Third, cooperation needs to address this suboptimality either through "tighter" alliance linkages to a central authority (Sandler and Forbes 1980; Sandler and Keith Hartley 1999) or else from an efficient response induced through repeated interactions. Punishment-based tit-for-tat strategies are anticipated to produce more cooperation when repeated plays among allies are allowed (John McMillan 1986; Sandler 1992, ch. 3). Fourth, the absence of rivalry in consumption for deterrence means that there is no efficiency reason to restrict alliance size as only benefits arise (e.g., cost-sharing savings) from including friendly countries. This statement hinges on the absence of transaction costs and rests on the nonrivalry notion that extending deterrence to another ally costs nothing, but would benefit the entrant. Fifth, the match between benefits received from deterrence and the actual defense burdens carried is anticipated for many allies to be weak owing to free riding. This shows up, in

[10] On collective action, see Russell Hardin (1982), Olson (1965), and Sandler (1992).

part, as a negative relationship between an ally's real defense outlays and those of its allies—i.e., a negative slope to the reaction paths. Sixth, the extent of suboptimality may be positively related to alliance size, especially if allies are of similar size (Olson 1965).

The perfect substitutability of deterrence, stemming from the additive Q relationship, imparts the purely public alliance model with the structure of a Prisoner's Dilemma provided that failing to arm does not lead to negative payoffs. If, however, an attack is eminent when adequate deterrent forces are *not* maintained, the allies can then ill-afford the dire consequences of no one arming so that a Chicken game results with some minimal deterrence being provided by a subset of allies—a scenario descriptive of NATO during 1950–66. Tit-for-tat strategies foster cooperation for repeated plays of either an underlying Prisoner's Dilemma or Chicken game. In an alliance context, a tit-for-tat response involves cutting an ally's own defense spending when other allies do not spend at "appropriate" levels.

4. *A Joint Product Model of Alliances*

The forerunner to the joint product model was presented by van Ypersele de Strihou (1967) who pointed to ally-specific benefits that are private among allies, but public within an ally.[11] For instance, defense expenditures used to maintain control over an ally's colony, such as Portugal's one-time interest in Angola, provide purely public benefits to the ally's population, but yield little or no benefits to the other allies. Similarly, defense spending on addressing a within-ally terrorist threat, not in danger of infecting other allies, gives mostly private benefits to the provider. Once private benefits are acknowledged, spending \$1 billion more on defense in ally A may no longer substitute for \$1 billion of military spending in ally B. A joint product model goes a step further by permitting the defense activity to produce a variety of outputs.

The joint product model was offered as a generalization to the purely public deterrence model by allowing a defense activity, q, to give country-specific private benefits, purely public deterrence, and impurely public damage-limitation or protection for times of conflict (Sandler and Jon Cauley 1975; Sandler 1977). Defense outputs are either partially or wholly excludable by the provider, or else partially rival among the allies. Consider conventional forces which when deployed along an alliance perimeter are subject to a spatial rivalry in the form of *force thinning* as a given amount of troops and weapons are spread over a longer exposed border. Coalescing troops in one place along the perimeter leads to vulnerabilities at other points, thus implying a rivalry in consumption. Moreover, the actual deployment decision can allow the provider to exclude some allies. Although conventional forces also serve to deter a potential aggressor, the mix of outputs and their publicness are likely to differ greatly between conventional and strategic forces. Unlike conventional forces, strategic nuclear forces cannot be used for such country-specific benefits as curbing domestic unrest, thwarting terrorism, or providing disaster relief. Conventional forces possess a larger share of ally-specific benefits and impurely public benefits than strategic forces. Essentially, the extent of publicness in the presence of joint products depends on the *ratio of excludable benefits* (i.e., ally-specific and damage-limiting benefits) *to total benefits.*

[11] Olson and Zeckhauser (1966, p. 272) clearly acknowledged these ally-specific benefits, but did not analyze their implications.

4.1 *Joint Product Model Representation*

A joint product representation allows for myriad alternative models depending on the number and mix of jointly produced outputs. Also, the manner in which the defense activity produces the various outputs can also influence the model. For illustrative purposes, we assume just two joint products—a country-specific output, x, and an alliancewide deterrence, z—which are produced under a fixed-proportion technology. Each unit of the defense activity in ally i, q^i, yields α units of x^i and β units of z^i:

$$x^i = \alpha q^i, \tag{6}$$

$$z^i = \beta q^i. \tag{7}$$

Overall deterrence, Z, is additive among allies and, thus, perfectly substitutable among allies:

$$Z = z^i + Z_{-i}, \tag{8}$$

where Z_{-i} is the sum of deterrence coming from other allies. By the joint product relationship, alliancewide deterrence can be written as:

$$Z = \beta(q^i + Q_{-i}), \tag{9}$$

where Q_{-i} denotes the sum of the defense activities in allies other than ally i. The decision-making oligarchy's utility function is now:

$$U^i = U^i(y^i, x^i, Z, T), \tag{10}$$

in which y^i is again the private numéraire and T is threat. Using equations (6) and (9), we can write the noncooperative (Nash) maximization problem confronting each ally as:

$$\max_{y^i, q^i} \{U^i[y^i, \alpha q^i, \beta(q^i + Q_{-i}), T] \mid I^i = y^i + pq^i\}. \tag{11}$$

In (11), the linear resource constraint equates the ally's income with its spending on the private good and the defense activity.

A Nash equilibrium results when each ally simultaneously satisfies its first-order conditions:[12]

$$\alpha MRS^i_{xy} + \beta MRS^i_{Zy} = p, \tag{12}$$

where the first MRS is the marginal willingness to pay for the private ally-specific defense good and the second is the marginal willingness to pay for deterrence. In (12), the weighted sum of these marginal valuations is equated to the relative price of the defense activity. This weighted sum is the marginal valuation of the defense activity (MRS^i_{qy}). A Pareto optimum requires that the first term on the left-hand side of (12) be added to the second term, *summed over the allies*; hence, optimality is not achieved unless β is zero. Deterrence benefits conferred on others are still being ignored. The weights will change with the fixed-proportion relationships. If, for example, $\alpha = 1$ and $\beta = 0$, then the defense activity is purely private among allies; if, however, $\alpha = 0$ and $\beta = 1$, then we have a purely public deterrence model. Hence, the joint product model is, indeed, a generalization of the Olson-Zeckhauser model.

An important extension, not pursued analytically here, is to allow for an impurely public damage-limiting output so that three or more outputs are produced in fixed proportions. The first-order conditions will now include the sum of three weighted terms. With this impurely public output, thinning of forces becomes germane and an optimal alliance membership must match marginal thinning costs that an entrant imposes with the savings from sharing costs over more allies (Murdoch and Sandler 1982; Sandler 1977).

[12] For a much fuller analysis of joint product models, see Cornes and Sandler (1984, 1994). The latter two works also present comparative-static results, including allowing the fixed-proportion coefficients to change.

4.2 *Collective Action Implications*

The collective action implications of the joint product model may be drastically different than those of the purely public deterrence model of alliances. First, a high ratio of excludable benefits—ally-specific and damage-limiting protection—to total benefits means that an ally must support its own defense, regardless of its size, if it is going to be protected. As this ratio nears one, the exploitation hypothesis is anticipated to lose its relevancy, so that the disproportionality between allies' GDP and their share of GDP devoted to defense is expected to dissipate. Second, as this benefit ratio nears one, the operation of markets and clubs achieves a closer equality between the relevant marginal benefits and marginal costs, so that allocations are more efficient. Contributions solicited from Kuwait, Saudi Arabia, the United Arab Emirates, and oil-dependent countries (e.g., Japan and Germany) to support the Gulf War of 1991 indicate how protection can be charged in a club-like arrangement.[13] Third, there is, consequently, less need for a tighter alliance linkage as the extent of excludable benefits increases, since cooperative gains are reduced. Fourth, alliance size restrictions depend on any thinning of forces; allies with long exposed borders cause more thinning and must contribute a greater share of the conventional forces to offset the resulting externality. Insofar as ally-specific benefits are not shared and deterrence is shared at zero costs, neither of these classes of benefits affects an alliance size determination. Fifth, joint products should result in a greater match between benefits received and burdens carried, which supports a benefit principle of taxation. Sixth, the extent of suboptimality is not related to the alliance size if there is a large share of excludable benefits.

The presence of joint product also has an implication for reaction paths, which now depict the relationship between an ally's defense *activity*, q^i, and that of the other allies, Q_{-i}. For normal goods, the marginal influence of deterrence spillins on an ally's own deterrence efforts was negative, while now the reaction of q^i to increases in Q_{-i} can be positive or negative based on the consumption relationship of the jointly produced goods. Suppose that the ally-specific defense output and alliance-wide deterrence are complementary in consumption, so that an increase in one enhances the desirability or marginal valuation of the other. The spillin of deterrence may, thus, induce an ally to spend more on defense so as to secure more ally-specific benefits which can only come from its own spending (Cornes and Sandler 1984, 1996). Consequently, a positive relationship between an ally's defense provision and that of the other allies is now possible, thus curbing free riding.

With joint products, the underlying game form may be more conducive to action than that associated with a deterrence model of alliances. Sandler and Keith Sargent (1995) demonstrated that joint products may result in a coordination game where one of the Nash equilibrium has all players contributing to the collective action. If the jointly produced private benefits are a sufficient share of the total outputs, then contributing to the defense activity may even be a dominant strategy. This has implications for alliance formation. That is,

[13] See Sandler (1992, pp. 177–80), Khanna, Sandler, and Hirofumi Shimizu (1998, p. 190), and the U.S. Department of Defense (1992) on the financing of the Gulf War. In the end, the United States assumed only $8 billion of the $61 billion costs, charging the rest to Kuwait, Saudi Arabia, and oil-dependent importers. On clubs, see James Buchanan (1965).

if alliance design allows potential allies to take advantage of ally-specific benefits as well as excludable public benefits, then the payoff pattern may be more conducive to initial formation. Thus, the mix of joint products and their publicness can influence alliance formation.

4.3 *Doctrines, Weapon Technology, and Joint Products*

By influencing the mix of joint products, the strategic doctrine of an alliance can have important allocative implications. During 1949–66, NATO ascribed to a strategic doctrine of mutual assured destruction (MAD) deterrence, for which any Soviet expansion involving NATO allies would trigger a devastating nuclear retaliation by the United States, France, and Britain. The alliance depended on strategic deterrence and, as such, shared mostly purely public benefits—this explains the successful predictions of the Olson-Zeckhauser model for 1964. During 1967–90, NATO altered its strategic doctrine to that of flexible response, where an act of aggression is met with a commensurate response: conventional or strategic challenges are countered in kind. The measured response would escalate if necessary (Erika Bruce 1995). As a consequence of this doctrine, the three kinds of forces—strategic, conventional, and tactical—became complementary as they needed to be used in conjunction, thus limiting incentives to free ride (Murdoch and Sandler 1984). Allies failing to deploy sufficient conventional forces became the weak link that would draw an attack. This doctrine's reliance on all types of forces meant that defense activities within NATO yielded joint products with varying degrees of publicness.

From 1991 on, NATO adopted a crisis-management doctrine where the alliance assumed the responsibility for ensuring Europe's security and interests from challenges both within and beyond NATO's boundaries (Gompert and Larrabee 1997, p. 37). Successful peacekeeping and crisis-management operations provide an increased measure of world stability and security that supplies nonexcludable and nonrival benefits worldwide. This new strategic doctrine also has NATO committed to limiting the proliferation of weapons of mass destruction, which also gives rise to purely public benefits. The share of purely public outputs associated with NATO's post-Cold War defense activities has increased.

Not only can the strategic doctrine influence the mix of joint products, but so can weapon technology. For example, the perfection of precision-guided munitions over the last two decades means that conventional forces do not need to penetrate a front or to be deployed along a front to hit targets with pinpoint accuracy. A cruise missile can be launched hundreds of miles away and still destroy enemy assets as demonstrated in recent NATO attacks against Serbia or U.S. strikes directed at Osama bin Laden's camps in Afghanistan. Such weapons reduce thinning and the impurity of conventional forces. An important lesson for alliances and, in fact, for any international organization dependent on joint products, is that political, technological, and other exogenous factors can alter the publicness of the shared activity.

Even the type of warfare influences the mix of joint products. Thinning considerations are more pronounced for a guerrilla warfare where large areas are defended, in contrast to a conventional war where fronts are guarded. Also the geographical location of the allies affects the mix of joint products (Sandler 1999); if allies are clustered, then publicness is enhanced.

4.4 *Aggregation of Defense Contributions*

Another dimension of publicness, brought to light in Jack Hirshleifer's (1983) seminal paper, concerns the relationship between individual contributions and the overall level of the public good. This relationship is known as the *aggregation technology*[14] and represents yet another factor that influences the mix of joint products, burden sharing, and the underlying game form (Sandler 1997, 1998). Thus far, we have only used the summation technology, where each unit of defense adds equivalently to the overall level of defense, regardless of the contributor. A second aggregation technology is *best shot* for which the level of the public good equals the largest provision level among the allies. The greatest effort may determine the overall level of protection when disarming a rogue nation or else limiting the proliferation of nuclear weapons. A best-shot technology is relevant for a "Star Wars" defense in which one or more allies possess sufficient defensive weapons to destroy an attacking nation's nuclear missiles shortly after launch. Nuclear deterrence is another instance of best shot. The U.S. nuclear arsenal was sufficient owing to its second-strike capability to deter a Soviet attack. British and French nuclear forces really did nothing to bolster this deterrence during the Cold War. Until their buildup in the 1990s, NATO's European nuclear strategic forces were more symbolic than substantive.

In contrast, a *weakest-link* technology applies when the smallest contribution fixes the effective public good level of the group. When an alliance is confronted with a conventional war, the ally deploying the least defense along its perimeter sets the security standard for the entire alliance. A fourth aggregation technology is *weighted sum* for which weights are applied to allied defense efforts prior to aggregation, and hence, limits substitutability. The marriage of these alternative aggregation technologies to a joint product model was accomplished by John Conybeare, Murdoch, and Sandler (1994) who then distinguished among alternative technologies for two World War 1 alliances. In particular, they showed that the aggressive Triple Alliance reflected a best-shot technology, while the defensive Triple Entente abided by a weakest-link technology. The geographical position of these two alliances also determined the aggregation technology characterizing these alliances. With its central cluster of allies, the Triple Alliance could rely on its strongest member, Germany, to attack the weakest link of the three geographically separated members of the Entente (i.e., Britain, France, and Russia).

[14] Hirshleifer (1983) used the alternative name of social composition function.

4.5 *Joint Products in Other Applications*

The joint product model is relevant for virtually every public good scenario. In the case of the World Health Organization (WHO), Forbes (1980, pp. 121–23) indicated that its activities provided purely public benefits (e.g., methods of disease prevention), impurely public benefits (e.g., prophylactic efforts to limit the spread of diseases), and nation-specific benefits (e.g., medical training). For rain forests, preservation gives global public benefits (e.g., biodiversity, sequestration of carbon), private benefits (e.g., timber, fruits), and local public goods (e.g., erosion control, nutrient recycling). Additionally, tied development assistance not only provides a transnational public good by alleviating a recipient's poverty or improving its health, but it also supplies donor-specific private concessions (Leonard Dudley 1979; Ravi Kanbur, Sandler, and Kevin Morrison 1999).

5. *Demand for Defense*

The economic study of alliances has included empirical applications from its outset. Some of this interest has been directed at estimating the demand for defense or the reaction path as embodied in equation (5). Empirical innovations generated in these demand studies were soon applied to other areas—e.g., agricultural research spending, charitable contributions, and environmental pollution.

5.1 *Games and Estimations*

Unlike a standard private good demand function, an ally's demand for defense includes not only relative prices and income, but also defense spillins of the other allies and a threat variable, which the theory treats as exogenous. If the allies' demands for defense are to be properly estimated, then the interdependency among the error terms of the individual ally's defense demand must be taken into account. This interdependency follows because the underlying game makes each ally's choice of defense dependent upon that of the other allies.[15] Thus, a two-stage estimation procedure must be used so that the endogeneity of spillins is taken into account. The recognition of this simultaneity later carried over to the demand estimates of other public good problems such as charitable contributions and agricultural research spending (Khanna 1993; Khanna and Sandler 2000; Bruce Kingma 1989). The threat variable can also result in a simultaneity bias if allies' *and* adversaries' demands for defense equations are being estimated.[16]

5.2 *Distinguishing between Models*

Given the two competing theoretic paradigms for the study of alliances, a crucial empirical breakthrough was to devise a procedure for distinguishing whether a joint product or a pure public good model best describes the data. Without a clever trick, one could not rely on the reaction or demand function, which when q^i is related to Q_{-i} has the same form for the two models (Sandler and Murdoch 1990). The trick involves the full-income approach where pQ_{-i} is added to both sides of the relevant budget constraint, thus transforming it to:[17]

$$I^i + pQ_{-i} = y^i + pQ, \qquad (13)$$

where Q is the Nash equilibrium choice of total alliancewide defense spending and the left-hand side sum is full income, F^i, or income plus the value of spillins.

With a full-income approach, an ally's equilibrium reaction path for *alliancewide* defense spending is:

$$Q = Q(F^i, p, T) \qquad (14)$$

for the pure public model, whereas it is:

$$Q = Q(F^i, Q_{-i}, p, T) \qquad (15)$$

for the joint product model. Because (14) nests within (15), the two models can be distinguished with the help of a simple F-test. In particular, the equation systems in (15) can be estimated for the set of allies using a two-stage least-squares procedure and then an F-test

[15] On this simultaneity bias, see Dudley and Claude Montmarquette (1981), Brian Hilton and Anh Vu (1991), McGuire (1982), Minoru Okamura (1991), and Sandler and Murdoch (1990). Also see the survey by Ron Smith (1995) on the demand for defense.

[16] On estimates involving threat see, e.g., Conybeare (1992), Conybeare and Sandler (1990), Rodolfo Gonzales and Stephen Mehay (1991), McGuire (1982), Okamura (1991), and Sandler and Murdoch (1990).

[17] The full-income approach is explained in Theodore Bergstrom, Lawrence Blume, and Hal Varian (1986), Cornes and Sandler (1996), and Sandler and Hartley (1995).

can be applied to ascertain the significance of the Q_{-i} coefficient. If this coefficient is significantly different than zero, as was the case for ten sample NATO allies during the 1956–87 period, then the joint product model is appropriate (Sandler and Murdoch 1990). The same test can be employed for any public good situation, national or international, when joint products may exist. For example, Khanna, Wallace Huffman, and Sandler (1994) employed this procedure to show that agricultural research spending in multi-state crop-growing regions in the United States adhered to the joint product model, while livestock regions (e.g., the northeast) abided by the pure public good model. For livestock regions, research findings are less geoclimatic-specific and more basic, and could be transferred among states more easily than crops research.

Other evidence for the joint product model has followed from demand estimates of NATO allies (Gonzalez and Mehay 1991; Murdoch and Sandler 1984), ANZUS allies (Murdoch and Sandler 1985), and historical alliances (Conybeare 1992; Conybeare and Sandler 1990; Conybeare, Murdoch, and Sandler 1994). By introducing a dummy variable at the time of flexible response, Murdoch and Sandler (1984) showed that following MAD the coefficient on spillins increased in value for seven of nine sample allies, indicative of a greater complementarity among allies' defense spending. Evidence of positive spillin coefficients, consistent with the joint product model, was corroborated by Smith (1989) for Britain and France during 1951–87. Thus, there is evidence that changes in strategy and even weapon technology can have a profound influence on the demand estimates. During the MAD era, NATO allies' reaction paths displayed the anticipated negative coefficient on spillins.

5.3 *Other Issues*

A host of other empirical issues surround the estimation of an ally's demand for defense. Two are briefly mentioned. First, the nature of the decision maker is a relevant concern—i.e., is it a oligarchy or a median voter? The identity of the decision maker impacts the arguments in the utility function and the form of the resource constraint—e.g., a government budget constraint or the income constraint of a median voter—and so affects the independent variables in the defense demand function.[18] Murdoch, Sandler, and Hansen (1991) devised a means for distinguishing the demand function of a government oligarchy from that of a median voter. Second, McGuire and Carl Groth (1985) raised the issue of the underlying allocative process. For example, is it a Nash noncooperative process or a cooperative Lindahl bargaining process? If applicable, the latter implies a Pareto-optimal outcome in contrast to the suboptimal Nash equilibrium. The work of McGuire and Groth (1985) and Sandler and Murdoch (1990) led to a means for discriminating between these two allocative process. For NATO, nine of ten sample allies abided by the Nash process for 1956–87, while none adhered to a Lindahl process.[19] Thus, surprisingly, there was no evidence of cooperation despite the repeated nature of the underlying game.

6. *Burden Sharing and Alliances: A Look at the Evidence*

To test the exploitation hypothesis, a measure of disproportionality was required, and Olson and Zeckhauser

[18] Median-voter models of alliances were presented by Dudley and Montmarquette (1981), Hilton and Vu (1991), McGuire (1982), and Murdoch, Sandler, and Hansen (1991).

[19] See Sandler and Murdoch (1990). Other studies on the underlying allocative process for NATO include Oneal (1990b) and Palmer (1990a,b).

(1966) defined it in terms of the share of GDP devoted to defense. By dividing military expenditures (ME) by GDP, they adjusted for the ally's ability to pay, thus giving a within-ally burden measure. According to Olson and Zeckhauser (1966), those allies that spent a greater share of their GDP on defense assumed a disproportionately large burden. The test was a simple nonparametric Spearman test where GDP ranks for the allies were computed along with their ME/GDP ranks. If a significant positive correlation between these two ranks resulted, then support for the exploitation hypothesis was uncovered. Olson and Zeckhauser (1966) found the sought-after significant positive correlation for 1964 during the MAD era. Corroborating evidence was shown by Russett (1970) for NATO annually for 1950–67 and for SEATO, CENTO, and the Warsaw Pact. Frederic Pryor (1968) also presented support for the exploitation hypothesis for NATO and the Warsaw Pact during 1956–62, while Harvey Starr (1974) indicated support in the case of the Warsaw Pact during 1967–71.

NATO burden-sharing behavior started to change around 1967 at the inception of flexible response. Even Russett's (1970) Kendall taus (a measure of correlation between defense burdens and GDP) displayed a marked decline starting in 1961 though they remained significant. Sandler and Forbes (1980) demonstrated that the significant rank correlation between defense burdens and GDP held up until 1966 and was insignificant thereafter except for 1973 during the Vietnam War. Similar evidence has been presented by Oneal and Mark Elrod (1989) and Khanna and Sandler (1996). Thus, the switch from one strategic doctrine to another had the anticipated impact on burden sharing with disproportionality ending with flexible response. In a recent study, Sandler and Murdoch (2000) showed that this correlation has been insignificant during 1988–99.

For pre-World War 2 alliances dependent on conventional armaments, Wallace Thies (1987) presented tables of burden shares that suggested the absence of exploitation and support for a joint product models. A subsequent study by Conybeare and Sandler (1990) for the Triple Entente and the Triple Alliance also uncovered little evidence of free riding on the part of the smaller allies.

This same kind of burden-sharing test can be applied to other transnational public goods and international organizations provided that some caution is exercised. When examining international organizations, the researcher must be careful to ascertain whether some institutionalized sharing arrangement is already in place so that participants cannot really exercise discretion. For example, INTELSAT, an international organization, is a consortium whose member nations share a satellite-based communication network (Sandler 1997, pp. 156–58). Its revenues are based on user fees and, as such, INTELSAT is a club arrangement with burdens based on internalizing a crowding externality with nonpayers excluded. If a large country pays more, it does so because it utilizes the network more often and gains more benefits—there is no presumption of unfair burden sharing.

Another burden-sharing measure, devised by Sandler and Forbes (1980), denotes *among-ally burdens* by relating an ally's share of NATO's total spending (ME_i/NATO ME) to its derived benefits from being defended. Benefits from defense spending arise from what is protected by the various conventional and strategic forces: the ally's industrial

TABLE 1
DEFENSE BURDENS AND AVERAGE BENEFIT SHARES IN NATO
USING POPULATION, GDP, AND EXPOSED BORDERS AS PROXIES FOR BENEFITS: SELECTED YEARS

	1970		1980		1985	
Country	Defense Burden	Average Benefit Share	Defense Burden	Average Benefit Share	Defense Burden	Average Benefit Share
Belgium	0.73	1.09	1.55	1.25	0.67	0.91
Denmark	0.35	0.93	0.64	0.99	0.35	0.85
France	5.59	6.30	10.17	7.21	5.79	5.75
Germany	5.85	7.65	10.55	8.56	5.58	6.56
Greece	0.45	2.12	0.89	2.16	0.64	2.04
Italy	2.41	5.99	3.45	6.19	2.12	5.86
Luxembourg	0.01	0.04	0.02	0.05	0.01	0.04
Netherlands	1.06	1.49	2.16	1.85	1.08	1.40
Norway	0.38	2.75	0.66	2.86	0.50	2.76
Portugal	0.42	0.97	0.34	0.98	0.18	0.78
Spain	NA	NA	NA	NA	1.10	3.26
Turkey	0.52	3.36	0.96	3.80	0.65	3.78
UK	5.58	6.96	10.48	7.44	6.51	6.30
Canada	1.98	25.82	1.79	25.64	2.01	25.53
US	74.25	34.55	56.36	31.06	72.82	34.19
NATO-Europe	23.77	39.63	41.85	43.30	25.17	40.28
NATO-North America	76.23	60.37	58.15	56.70	74.83	59.72

Source: Figures for 1970, 1980, and 1985 are from Khanna and Sandler (1996, Tables 2–3), while those for the 1990s are from Sandler and Murdoch (2000, Tables 4–5).
Notes: Figures represent percentage shares of NATO's total for each variable. For example, defense burden indicates the ally's defense spending divided by total NATO defense spending. Average benefit share denotes the arithmetic mean of each ally's share of NATO's population, NATO's GDP, and NATO's exposed borders. Germany represents West Germany up to and including 1990, and it denotes unified Germany thereafter. NA denotes not applicable. Iceland is excluded because it has no defense spending.

base, its population, and its exposed borders (i.e., borders not contiguous with another NATO ally). To calculate an overall proxy measure for these defense benefits, these authors computed each ally's share of NATO's GDP, its share of NATO's population, and its share of NATO's exposed borders. Because the ally's exact preferences are not known, these three measures are typically added together and divided by three for an "average benefit share."

In table 1, defense burdens and average benefit shares for six selected years are listed. For example, in 1970, France assumed 5.59 percent of NATO's total defense spending, while France received an average benefit share of 6.30 percent, thus implying an underpayment. In contrast, the United States assumed 74.25 percent of NATO defense spending, while it received an average benefit share of 34.55 percent, thus indicating a significant overpayment.

TABLE 1 (*Cont.*)

	1990		1995		1998	
Country	Defense Burden	Average Benefit Share	Defense Burden	Average Benefit Share	Defense Burden	Average Benefit Share
Belgium	0.92	1.03	0.94	1.06	0.82	0.96
Denmark	0.52	1.30	0.66	1.31	0.63	1.27
France	8.45	6.39	10.12	6.34	9.01	5.90
Germany	8.39	7.58	8.72	9.34	7.33	8.77
Greece	0.77	2.11	1.07	2.12	1.29	2.10
Italy	4.64	5.93	4.10	5.12	5.12	5.06
Luxembourg	0.02	0.04	0.03	0.06	0.03	0.05
Netherlands	1.47	1.54	1.70	1.60	1.50	1.50
Norway	0.67	2.81	0.72	2.81	0.71	2.78
Portugal	0.37	0.98	0.57	0.99	0.53	0.95
Spain	1.80	3.73	1.83	3.50	1.65	3.36
Turkey	1.05	4.12	1.40	4.18	1.84	4.22
UK	7.89	6.69	7.17	6.29	8.17	6.56
Canada	2.29	25.82	1.92	25.50	1.50	25.47
US	60.74	29.93	59.06	29.80	59.85	31.06
NATO-Europe	36.97	44.26	39.12	44.69	38.65	43.47
NATO-North America	63.03	55.74	60.98	55.31	61.35	56.53

When various Wilcoxon tests are employed to ascertain whether the distribution of defense burdens and the distribution of average benefit shares for the NATO allies are the same, there was no evidence of a difference except for 1985 during the Reagan buildup (Khanna and Sandler 1996). This result is further support for the joint product model where benefits and burdens are anticipated to match. By augmenting purely public benefits, the Reagan procurement buildup in 1985 lessened the applicability of the joint product model temporarily.

7. *Peacekeeping: Burden Sharing and Demands*

From 1988 to the mid-1990s, UN peacekeeping expenditures increased over a magnitude from under $300 million to over $3 billion annually (William Durch 1993; Khanna, Sandler, and

Shimizu 1998; Sandler and Hartley 1999, pp. 105–106). In the mid-1990s and thereafter, NATO has taken on large peacekeeping missions in Bosnia and Kosovo as the United Nations' ability to cope with so many missions was stretched to the limit (Khanna, Sandler, and Shimizu 1999; Congressional Budget Office 1999).[20] NATO's new crisis-management doctrine paved the way for it to assume peacekeeping missions whenever its security interests were in jeopardy. Insofar as successful peacekeeping activities provide an increased measure of world stability and security that benefits all nations, contributors and noncontributors, some benefits of peacekeeping are nonexcludable. Other peacekeeping outputs may be contributor-specific and/or partially rival. Thus, peacekeeping activities give rise to joint products whose outputs display a variety of publicness. As an example of country-specific outputs, select nations taking part in the Gulf War received lucrative contracts to rebuild Kuwait. Moreover, countries in closer proximity to a conflict or with larger trade interests may gain benefits from peacekeeping, not available to other nations (Davis Bobrow and Mark Boyer 1997). Surely, the influence of the United States in the Middle East grew in importance owing to its leadership in the Gulf War. A thinning of peacekeeping forces results as they are deployed to trouble spots worldwide.

Methods and insights gleaned from the study of alliances can be fruitfully applied to the study of peacekeeping. In the case of UN-financed peacekeeping, it became apparent at the time of the first sizable operation in the Congo during 1960–64 that UN resources would be taxed too heavily if the UN relied on regular membership fees for financing such operations. Given the publicness nature of peacekeeping, early attempts to solicit voluntary contributions yielded little funding. To create a more permanent and reliable funding source, the UN General Assembly passed a resolution that established assessment accounts beginning in 1975 for peacekeeping operations.[21] Assessments are based on Security Council membership, national income, and other factors (Mills 1990). Nations could still free ride by failing to honor assessments; many nations exercised some discretion and did not always fulfill their assessments (e.g., the United States in the 1980s and 1990s).

With the tenfold increases in crisis-management spending in the last decade, an exploitation concern exists where the large, rich nations in both the UN and NATO shoulder much of the burden of peacekeeping. Peacekeeping is anticipated to possess a smaller share of excludable benefits than defense spending and, consequently, is prone to more disproportionate burden sharing. To investigate this hypothesis, Khanna, Sandler, and Shimizu (1998) examined the Kendall rank correlation between GDP and the share of GDP devoted to UN peacekeeping for the UN and NATO. During the 1976–96 sample period, evidence of disproportionality only surfaced in the 1990s, coinciding with the era of increased peacekeeping activities. These significant rank correlations were particularly pronounced when non-UN-financed missions in Kuwait and Bosnia were included with UN missions. Non-UN-financed peace enforcement operations cost the United

[20] On UN peacekeeping, its problems, and prospects, see Durch (1993), John Heidenrich (1994), Stephen Hill and Shahin Malik (1996), and Susan Mills (1990).

[21] For institutional details, consult Sandler and Hartley (1999, ch. 4) and Durch (1993).

States well over $3 billion in both 1997 and 1998 (Congressional Budget Office 1999) and much more in 1999, so that this disproportionality is expected to grow further in the coming years as the United States, France, Britain, and Germany assume ever greater shares of peacekeeping efforts.

Yet another consideration supporting this prediction of greater disproportionality stems from investments in power projection or the ability to transport troops and matériel to conflict areas. Currently, the United States is spending nearly $20 billion during 1998–2002 to improve these projection capabilities (Congressional Budget Office 1997). Other investments are being made for rapid deployment forces with light-armored vehicles. Only the three largest NATO allies are investing heavily in troop projection and mobility. Of course, there is a strategic advantage to the smaller allies' lack of investment because when a contingency later arises, the large allies will necessarily have to transport the small allies' peacekeepers. At a time of crisis, there is no time to procure the transport vehicles.

In a follow-up study, Khanna, Sandler, and Shimizu (1999) applied the methodology, described in section 5, to estimate a system of UN peacekeeping demand equations for the primary supporters of UN peacekeeping efforts, while accounting for the endogeneity of peacekeeping spillins and country–specific trade gains. This study supported the joint product representation and identified some complementarity among different countries' efforts in providing peacekeeping.

8. *Additional Issues and Questions*

To date, the economic theory of alliances has been a static affair; there has been no successful marriage of a dynamic arms race model with the public good theory of alliances. Threat in terms of enemy spending is either treated as an exogenous variable for within–alliance choices,[22] or else as a simultaneous–choice variable among allies and adversaries (Neil Bruce 1990). In the latter situation, reaction paths of adversaries and allies are derived, but the analysis is still static. A first step at increasing the dynamics of alliance theory is to devise two- and three-stage games. For a two-stage game, the first stage can involve the alliance membership decision, while the second stage can concern the level of defense spending.[23] If a third-stage is added, it may include an interactive choice between opposing alliances, so that a within-alliance sharing decision is then followed by a noncooperative interalliance interaction in choosing defense outlays. When opposing alliances are investigated, the desirability of allied cooperative gains must be reevaluated. By augmenting defense spending, increased cooperation within an alliance may be

[22] In the international security literature, a more dynamic representation of alliance formation has been proposed (see, e.g., Paul Schroeder 1994; Randall Schweller 1994). Nations are viewed as joining an alliance to either balance a threat or to bandwagon. Bandwagoning, often for territorial gain, can heighten the threat to an opposing alliance, so that the entry decision endogenizes threat. By treating threat as exogenous, most economic theories of alliances are unable to address such dynamic choices. Cultural, political, and social considerations also influence which countries are likely to ally. Robert Axelrod and D. Scott Bennett (1993) developed a theory of alliance formation based on shared values which facilitate cooperation.

[23] In the political science literature, Morrow (1994) presented the alliance formation decision as an extensive-form game with incomplete information about the costs of war. A trade-off is made between short-run peacetime costs from allying and possible long-run costs from war resulting from not allying. Robert Powell (1993) examined interalliance decisions concerning whether or not to attack. There is again a short-run versus long-run trade-off implied by decisions to arm and/or attack.

met in kind by the enemy alliance, so that more is spent but security is not enhanced. Neil Bruce (1990) has shown that this can then result in welfare losses in a small alliance, implying that the concern over suboptimal provision within an alliance ignores interalliance interactions. This recognition that cooperation may have negative consequences in the presence of strategic responses of agents outside the group has now characterized recent analyses of other transnational public goods—e.g., pollution control (Wolfgang Buchholz, Christian Haslbeck, and Sandler 1998). Toshihiro Ihori (2000) has shown that the "Bruce effect" is less likely to hold when the number of cooperating allies increases in number—Neil Bruce (1990) had only assumed two cooperating allies.

Another means for augmenting the dynamics of alliance theory is to begin with an arms race model and introduce alliance elements of defense publicness. This, too, is a formidable task because public goods and joint products are difficult to analyze in a dynamic multiagent framework. If true dynamics are to characterize the study of alliances, then this is probably the preferable method to pursue.

A second important issue involves multiple public goods within alliances and the potential trading opportunities that they offer allies (Boyer 1989, 1990). Such multiple public goods go beyond joint products and include numerous activities, each of which can give off joint products. A good example of this is James Morrow's (1991) autonomy-security trade-off as the large allies provide the security for the small allies in return for their support on political issues. In a recent paper, Palmer and J. Sky David (1999) devised an empirical test to distinguish Morrow's diversity-of-goals model from a pure public deterrence model by examining nonnuclear and nuclear alliances, with the latter abiding by the deterrence model.

A different issue involves the design of alliances based on a transaction costs and transaction benefits approach (Oliver Williamson 1975). Such transaction-costs design analyses *depart* from the standard noncooperative model that underlies our study thus far. Design issues rely on a cooperative game theory where all participants must realize a net cooperative gain over the noncooperative status-quo equilibrium. When the ratio of excludable benefits is small, cooperative gains from improved efficiency can arise as allies form tighter linkages and sacrifice autonomy. Cooperation can take the form of increased defense spending, equipment standardization, common logistics, shared intelligence, coordinated troop deployment, common infrastructure, and collaborative weapons projects (Hartley 1991). With NATO's new crisis-management doctrine, this cooperation can also involve the development of an alliance-wide rapid deployment force. Such cooperation provides transactions benefits in terms of efficiency gains, economies of scale, and enhanced information and communication, while they also create transactions costs in the form of decision making, loss of autonomy, enforcement efforts, and monitoring. In designing an optimal alliance, transactions benefits and costs must be identified and traded off against one another (Sandler and Cauley 1977; Sandler and Forbes 1980).[24] Because alliances are

[24] David Lake (1999, pp. 35–37) presented such a theory where the form of an alliance varied from no alliance to a tightly knit hierarchy. The alliance form was determined by maximizing net transaction benefits that accounted for benefits of economies of scale and costs of hierarchical control. This exercise is analogous to a much earlier one by Sandler and Cauley (1977). Also see the net transaction benefits approach to international organizations by Kenneth Abbott and Duncan Snidal (1998).

now involved with numerous activities, transaction interactions among such activities must also be accounted for when deciding alliance structure. A looser, less integrated structure is appropriate if the ratio of excludable benefits nears one as market transactions and club arrangements can operate relatively efficiently. As strategic doctrine, technologies, and missions change with time, the proper form of alliances will need alterations—loosening some links and tightening others.

Alterations in the composition of the allies can also require structural changes to an alliance. For example, decision-making rules may need to be less inclusive when there are more allies (or members in an international organization) with greater taste diversity. Without a relaxation of an inclusive voting rule, decisions may never be reached which might destroy the viability and effectiveness of NATO as a military alliance. Of course, club membership principles can be applied to determine the optimal membership size based on thinning and transaction considerations. In a multiproduct framework where congestion can affect alliance activities differently, membership determination is more difficult. Nonetheless, the possibility of diminishing benefits and rising costs of extended membership suggests a limit to the size of the alliance; thus, the need for a comprehensive analysis of the marginal benefits and costs of NATO enlargement for existing and new members.

An optimal alliance might also be characterized by specialization based on comparative advantage with the principle applied to both armed forces and defense industries. For example, the United States might provide high-technology forces (e.g., nuclear deterrence, precision-guided weapons); Germany might supply armored forces; and the United Kingdom might contribute anti-submarine and special forces. The alliance would also need to identify and collectively fund those new weapons and forces that give rise to pure public goods (e.g., ballistic missile defenses). Weapons should be bought and sold in a NATO free-trade area.

9. *Applications to Other International Collective Action Scenarios*

9.1 *Background*

Olson (1965, pp. 35–36) focused on various interest groups (e.g., unions), most of which were national rather than international organizations, although reference was made to the UN and NATO as examples of suboptimality in large groups and the exploitation hypothesis. But Olson's (1982, p. 13) methodology towards theory and its testing always warned against accepting a theory based on one set of facts. Instead, a reader should ask, "What can this theory explain that it is not tailor-made to explain?" (Avinash Dixit 1999, p. F449). Olson insisted that "a list of instances supporting a hypothesis, no matter how lengthy, did not clinch the matter; one had to search diligently for counterarguments and counterexamples" (Dixit 1999, p. F444). This section adopts the more limited aim of considering whether the logic of international collective action can be extended to international organizations other than military alliances.

There are numerous examples of international organizations, ranging from global government organizations such as the UN; to international nongovernmental organizations (NGOs) such as Oxfam, Consumers International; international sports organizations (e.g., olympics, tennis); and food organizations such as Hungry International. Table 2 presents a four-way taxonomy

TABLE 2
A TAXONOMY OF INTERNATIONAL ORGANIZATIONS

	Small number of nations	Large number of nations
Single product (specific)	US-Russian Space Stations; US-USSR INF Treaty 1987; Anglo-French Concorde airliner; Eurofighter; US-Cuba Anti-Hijacking Treaty	WTO; European Space Agency; Environmental Treaties; International Telecommunication Union (ITU); Universal Postal Union
Multiproduct (general)	Anglo-Irish Agreement 1999; Cultural Exchange Programs	NATO; United Nations; EU; Antarctic Treaty Systems; International Maritime Organization

based on the number of nations in an international organization and the type of product provided. Small numbers involve two or three nations. Organizations providing multiple public goods or distinct activities are distinguished from those that supply a single public good. If, however, a single activity yields joint products, the parent organization is still characterized as a single-product organization owing to its single-purpose orientation. Thus, the UN and the EU are viewed as supplying multiple public goods, in contrast to the WTO, whose main purpose is to facilitate free trade, or the Universal Postal Union, which oversees the free flow of international mail.

9.2 *Transnational Pure Public Goods*

There has been a growing awareness and interest in the study of transnational public goods (e.g., actions to control malaria, to limit some pests, or to clean a transboundary river). At the global level, preservation of the stratosphere ozone layer and curbing global warming represent two pure public goods, which will be undersupplied with much of the burden falling on the richer nations. In an empirical study, Murdoch and Sandler (1997) showed that a country's income and political freedoms were the two primary determinants of cutbacks in ozone-depleting chlorofluorocarbons (CFCs) emissions. Once the ozone hole over Antarctica was discovered and its genesis understood, action by the primary CFC-producing and CFC-consuming countries was swift, culminating in the Montreal Protocol and its even stricter amendments (Richard Benedick 1991; Scott Barrett 1999). The large, rich countries not only shouldered the burdens, but also offered inducements to small, poor countries in the form of technical support and a ten-year reprieve from cutbacks. Thus, an exploitation of the large by the small is evident. The treaty served more of a long-term escape from any Prisoner's Dilemma pressures by instituting a tit-for-tat punishment on deflectors in terms of trade boycotts.

To date, the progress on global warming has not been a success story since many of the rich countries have been unwilling to shoulder the disproportionate burdens that small countries want placed on the rich. For CFCs emissions, the small countries emitted small quantities of the pollutants and were not projected in the near term to increase these emission levels. This is not the case for global warming where even poor countries can create greenhouse gases (GHGs) through their agriculture or destruction of their forests. The economic losses associated with reducing GHG emissions are much greater than those tied to limiting CFCs emissions. Thus, carrying a disproportionate burden for reducing GHGs is a much more expensive proposition for the rich. Even efforts to sequester carbon in tree plantations raise burden-sharing difficulties, not unlike those faced by defense alliances—each nation would prefer that the others finance these plantations. NATO's unintegrated structure serves as a good role model for getting a global-warming agreement off the ground, which can be subsequently tightened if warranted as we learn more about the consequences of a warmer atmosphere. If the world community initially holds out for too integrated a treaty, none may be ratified. A practical, imperfect treaty may be better than none at all.

9.3 *Transnational Joint Products*

By far the overwhelming number of transnational public goods are activities that yield outputs of varying degrees of publicness and, as such, can benefit from the joint product analysis of alliances. Take the case of sulfur emissions which remain airborne for up to seven days before falling as acid rain or dry depositions.[25] Sulfur cleanup possesses a strong country-specific share of benefits insofar as the majority of sulfur emissions in Europe land within the emitting country's own borders (Hilde Sandnes 1993). Thus, it is not surprising that European countries ratified the Helsinki Protocol mandating a 30 percent cutback in sulfur emissions from 1980 levels. For nitrogen oxides where a *much smaller share* of the emissions becomes self-pollution, an agreement was much slower and mandated smaller cutbacks than the sulfur treaty. As for military alliances, a high ratio of excludable benefits induced emission-reducing actions and allowed for treaties *without stated punishments*, unlike the Montreal Protocol for which this ratio was near to zero and punishments explicit. Consider the United Kingdom which did not sign the sulfur or nitrogen oxides protocols. A relatively small share of these pollutants from Britain land on its own soil, and, hence, it lagged other European countries in controlling emissions. Because its progress in reducing emissions was far behind treaty-mandated cutbacks, Britain opted not to ratify the treaties. Other European countries, whose self-pollution was much greater or which suffered large pollution spillins, were either already close to satisfying mandated reductions when the treaties were framed or else had much to gain from pollution constraints on others.

The UN is an example of an international organization that illustrates the importance of group size: small groups are more likely to solve the collective action problem compared with groups of many nations. As a large group, the UN is prone to fail to supply an optimal amount of public goods and to be characterized by free riding with larger members bearing disproportionate shares of the organization's burden. Such features are reflected in the habitual complaints that the UN allocates too few resources (e.g., for peacekeeping, economic development, and famine and disaster relief), that too many nations free ride (e.g., consuming peace as a public good), and that the large member states are exploited (e.g., U.S. leadership in UN-sponsored military actions). The joint product model of alliances, however, cautions that these conclusions must be attenuated if large shares of nation-specific benefits are derived from a member's UN support. In the absence of these member-specific

[25] On acid rain and sulfur emissions, see Sandler (1997, pp. 115–29) and Murdoch, Sandler, and Sargent (1997).

benefits, the large nations can retaliate against such exploitation by withholding funds for other UN activities or by using the veto in the UN Security Council (i.e., a tit-for-tat strategy). This raises interesting questions about the constitution and voting arrangements in large-number international organizations and their implications for optimal outcomes.

Further instances of joint products include supplying foreign medical assistance, alleviating poverty abroad, creating scientific discoveries, preserving tropical forests, and neutralizing a rogue nation. In all of these examples, an activity not only provides contributor-specific benefits but also groupwide pure and impure public benefits. When, for example, a country supplies foreign medical assistance, it gets contributor-specific benefits from both the experience that its medical personnel acquire and the goodwill that its efforts earn. By helping to improve the recipient country's health, people worldwide are at a reduced risk because diseases are less apt to gain or maintain a foothold there and be transmitted abroad. Medical assistance given in one country limits assistance that can be given elsewhere, so a rivalry is also present.

A number of international organizations are involved in collaboration on aerospace projects (e.g., Airbus, European Space Agency, Eurofighter). Such collaborative programs can be analyzed using the joint product model. Research and development work on collaborative programs is a public good to member states, but nonmembers are excluded from such benefits. Further public goods benefits might be reflected in contributions to promoting political unity among collaborating European nations and in enhancing NATO collective defense through weapons standardization. In addition, international collaboration yields private benefits to each member state (e.g., jobs and technology) and these are reflected in work-sharing arrangements under which each member state obtains a "fair share" of the work on the program (Sandler and Hartley 1995).

Once these joint products are recognized, incentives may be supportive of nations either acting on their own or else forming coalitions to foster collective action. The presence of private and impure public benefits means that nations do not solely need to rely on agreements and treaties for providing the public activity. As in the case of military alliances, the design of an institutional structure for promoting transnational collective action depends on the share of these excludable benefits, which can be allocated efficiently by markets and quasi-market club arrangements.

A better understanding of the design and operation of a wide range of international organizations can be learned from the study of alliances. For the EU, the determination of its optimal membership size can profit from principles guiding the expansion of NATO. NATO has embraced an ever-increasing set of activities and now includes peacekeeping, traffic control, drug interdiction, arms-treaty verification, and many others. This alliance has taken on such activities to take advantage of economies of scope, which result in a fall of average cost per linkage assigned to each activity. Common costs among linkages are behind these scope economies as the capacities of communication networks, meeting facilities, administrative offices, and bureaucratic apparatus are better utilized. These same economies of scope can explain why the UN, WHO, and other international organizations acquire additional activities over time.

10. *Concluding Remarks*

Few topics in economics can boast the impact in other disciplines that the economic theory of alliances has had. From his initial writings on collective action, Olson (1965) has used defense alliances as the quintessential example of an international collective that shares a public good. In so doing, Olson viewed alliances as being plagued by disproportionate burden sharing, suboptimality, and the need for cooperation. Principles developed in the study of alliances have brought novel perspectives in fostering understanding on how international organizations form and operate. At a time when transnational public goods and externalities are so prevalent and vital to our future well-being, this understanding is essential to addressing myriad exigencies.

As the initial predictions of the economic theory of alliances went wide of its mark, the more general joint product model provided a more flexible and better predictive theory. Because the mix of joint products depends on strategic doctrine, weapons technology, and membership considerations, researchers must be vigilant to adjust the analysis accordingly as this mix changes. Efforts to relate the mix of joint products to the design of alliances have much to tell us about other international collectives. For instance, the greater is the ratio of excludable benefits in terms of overall benefits within an international collective, the less suboptimal will be the outcome of members' independent behavior, and, thus, the smaller is the need for corrective action. Club arrangements can be used to allocate impurely public benefits, while markets can serve to allocate member-specific benefits. With joint products, there is a better prognosis for successful action than when just a pure public good is being shared. In developing techniques to test the theory of alliances, economists now have empirical methods with wide applicability to public good scenarios within and among nations. These methods have been applied in both economics and political science. A rich agenda for both theoretical and empirical research remains, particularly in developing a better dynamic representation of alliance behavior, in analyzing arms races among opposing alliances. On the empirical side, advances in time series methods need to be applied to the study of allies' demand for defense.

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