11

Military Alliances

Agreements wherein parties pledge various forms of military cooperation are common in the international system and are often prominent in conflict settings. In 1949, for example, the United States, Canada, and numerous Western European states formed the North Atlantic Treaty Organization (NATO) to counter the threat of attack by the Soviet Union. In turn, the Soviet Union and various Central and Eastern European nations formed the Warsaw Pact in 1955 to counter threats from NATO. Since the end of the Cold War, the Warsaw Pact has dissolved while NATO has remained in force and expanded its membership. Article 5 of the NATO Charter specifies that an attack against any member state will be considered an attack against all member states. Following al Qaeda's attack against the United States on September 11, 2001, Article 5 was invoked for the first time. The United States and its NATO allies then cooperated in an invasion of Afghanistan to overthrow the Taliban, who had supported al Qaeda. US-led forces also cooperated militarily with the "Northern Alliance," an intrastate coalition of Afghan groups fighting against the Taliban. Meanwhile, various transnational terrorist groups and criminal syndicates have been reported to cooperate with al Qaeda in ways that appear to constitute non-state alliance behavior.

The scholarly literature on alliances is vast, encompassing both theoretical and empirical research, with extensive coverage of political and economic determinants and effects. In this chapter we focus primarily on economic aspects of military alliances. In particular, we consider alliance formation as an economic choice whereby a nation or non-state group can increase its security while reducing its cost or burden of defense. We begin with definitions followed by an overview of data on interstate alliances. We then use the economic choice model from Chapter 10 to explore the seminal contributions of Olson and Zeckhauser (1966) and of Sandler and

his colleagues (Sandler and Cauley 1975, Sandler 1977, Murdoch and Sandler 1982) on the economic theory of alliances. We conclude with selected empirical studies pertaining to burden sharing within NATO and the effects of alliances on the risk of armed conflict.

11.1. Definitions

We define a military alliance as a cooperative security arrangement between two or more parties that conditions their involvement in military conflict. Such arrangements can include agreements that pertain to offensive action, defensive action, neutrality, consultation, and/or nonaggression (Leeds 2003, p. 429). Although the alliance literature focuses on cooperative security arrangements between states, the definition allows for non-state parties, such as rebel groups or transnational terrorist organizations. There is some disagreement over whether alliances must be based on formal written security arrangements. According to Walt (1987, p. 12), alliances can be formal treaties or informal arrangements. Olson and Zeckhauser (1966) suggest the possibility that "most alliances are never embodied in any formal agreement" (p. 273). Snyder (1997, p. 6) and Leeds, Ritter, Mitchell, and Long (2002, p. 239), however, distinguish between alliances and alignments, with the former based on formal written agreements and the latter regarded as tacit cooperation. Some might also question whether nonaggression pacts are alliances because they commit states to mutual nonaggression but entail no cooperation regarding conflict with third parties (Leeds 2005, p. 12).

Table 11.1 provides summary information for a selection of alliances. The top entries of the table show that the Cold War and World Wars I and II all involved rivalries between alliances. Hence, interstate alliances are a major element of actual and potential conflict in the international system. As suggested by the table's bottom entries, intrastate and non-state alliances are also significant and can be expected to grow in the decades ahead. The United States, for example, faces major security challenges from within by gang alliances and from abroad by transnational alliances of terrorist organizations and criminal syndicates. While factual details of non-interstate alliances are difficult to ascertain, some cases demonstrate formal coordination. For example, in January 2006 the two parties forming the Alliance of Revolutionary Forces of West Sudan issued the following joint statement: "The two movements have agreed to join and coordinate all political, military and social forces, their international relations and to double their combat capacity in a collective body under the name, the Alliance of Revolutionary Forces of West Sudan" (Online NewsHour 2006).

Table 11.1. *Selected military alliances.*

Name	Type	Members	Time Frame	Brief Summary
North Atlantic Treaty Organization (NATO)	Interstate	United States, Canada, various European states	1949–present	Formed to counter Soviet threat during the Cold War. Carries out peacekeeping, counterterrorism, and other security operations today.
Warsaw Pact	Interstate	Soviet Union and various Eastern European states	1955–91	Formed to counter NATO threat during the Cold War.
Triple Alliance	Interstate	Germany, Austria-Hungary, Italy	1882–1915 (periodic)	Formed to counter threat by France and other great powers.
Triple Entente	Interstate	France, Russia, United Kingdom	1907–17	Served as counterweight to Germany and the Triple Alliance.
Tripartite Axis Pact	Interstate	Germany, Italy, Japan (later other states became members)	1940–45 (Italy departs in 1943)	Opposed the Allies of WW II.
Allies of WW II	Interstate	Numerous states	1939–45	Opposed the Axis powers of WW II.
Alliance of Revolutionary Forces of West Sudan	Intrastate	Sudanese Liberation Army/ Movement (SLA/M), Justice and Equality Movement (JEM)	Formed in 2006	Fighting against the Sudanese government.
People Nation	Intrastate	Approximately two dozen US gangs operating in Chicago and other cities	Formed in the 1980s	Involved in highly organized violent criminal activities and turf wars against rival alliance known as Folk Nation.
World Islamic Front for Jihad against Jews and Crusaders	Non-state	al Qaeda and a number of other terrorist organizations	Formed in 1998	Goal is to establish a pan-Islamic Caliphate by killing Americans (military and civilian), overthrowing non-Islamic regimes in the Muslim world, and expelling non-Muslims from Muslim countries.
Golden Triangle Alliance (a.k.a. Juárez Cartel)	Non-state	Three illegal drug organizations located in Mexican states that border the United States	1990s into the mid-2000s	Goal is to conduct illegal narcotics trafficking from Mexico into the southwestern region of the United States.

Sources: Encyclopedia Britannica Online (www.britannica.com), Online NewsHour (2006), Florida Department of Corrections (2007), Federation of American Scientists (www.fas.org/irp/world/para/ladin.htm), and the US Drug Enforcement Agency (www.usdoj.gov/dea).

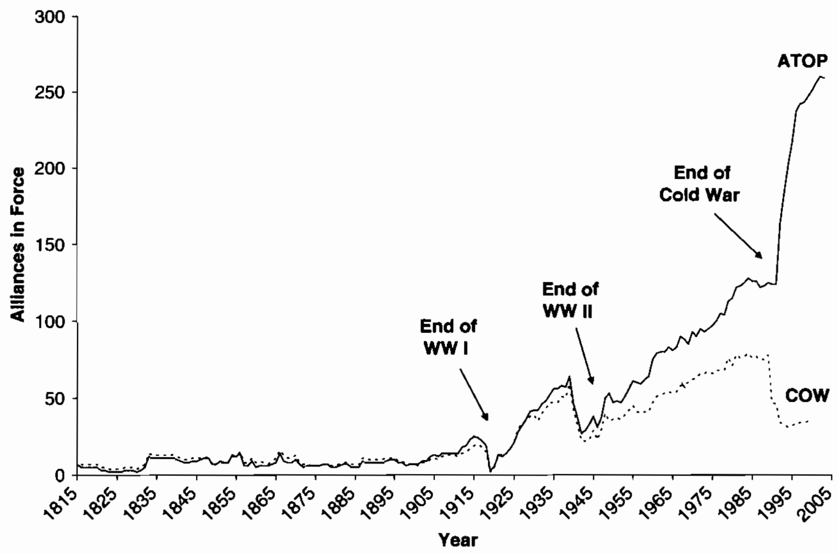

Figure 11.1. Number of interstate alliances as reported by ATOP and COW. *Sources*: Leeds et al. (2002) for ATOP and Gibler and Sarkees (2004) for COW version 3.03.

11.2. Patterns of Interstate Alliances

Figure 11.1 shows the number of interstate alliances in force by year based on data from the Alliance Treaty Obligations and Provisions (ATOP) Project and the Correlates of War (COW) Project. As indicated, many interstate alliances have existed over the past two centuries and particularly since World War I. The most striking aspect of the figure, however, is the close correspondence between ATOP and COW data on the number of alliances up to 1945, followed by a significant and growing divergence since then. Moreover, around the end of the Cold War COW shows a sudden decline in the number of alliances in force, while ATOP shows a dramatic increase. It is difficult to explain fully the divergence based on ATOP's and COW's coding rules, but part of the discrepancy apparently is due to differences in collection methods and in the classification of nonaggression pacts.

ATOP distinguishes five obligations that nations might have with an ally in the event of military conflict: to provide active military support to an attacked ally (a defense pact); to provide active military support to an ally under conditions wherein the ally is not attacked (an offense pact); to refrain from helping an ally's rival in a military conflict (a neutrality pact);

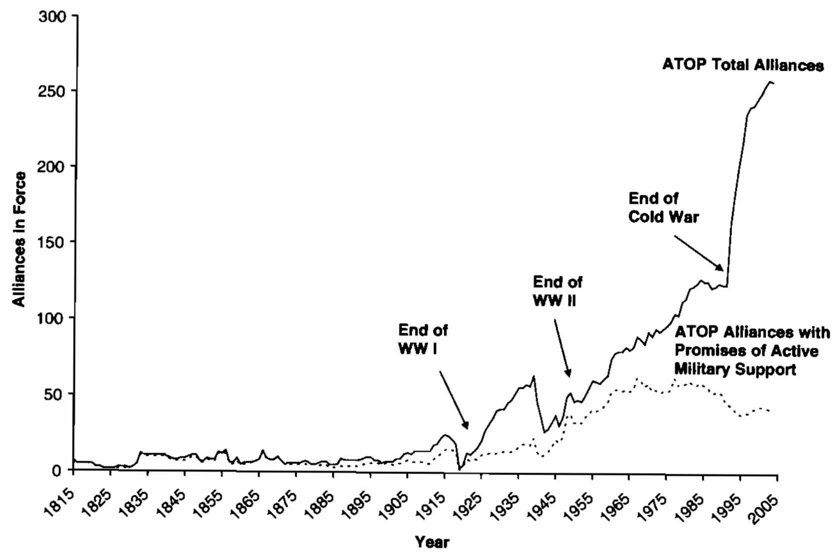

Figure 11.2. Number of interstate alliances with pledges of active military support. *Source*: Leeds et al. (2002).

to refrain from engaging in military conflict with an ally (a nonaggression pact); and to communicate with partners during crises that have the potential for military conflict (a consultation pact) (Leeds 2005). The five obligations detailed in the ATOP data are not mutually exclusive; hence, a single alliance agreement can contain more than one type of obligation.

Figures 11.2 through 11.4 provide some sense of the composition of interstate alliances over time. The first figure shows by year the number of alliances in force that contained promises of active military support. Active military alliances are those that contain defensive or offensive obligations or both, so that the allies are relying to some degree on one another's military capability. The number of active military alliances has increased since World War I but has declined as a proportion of total alliances since about 1960, thus implying that neutrality, nonaggression, and consultation pacts have become increasingly significant. Figure 11.3 reports by year the number of multilateral alliances, defined as those with three or more members. Since the end of World War II, multilateral alliances have generally increased in frequency but declined as a proportion of total alliances. Figure 11.4 shows the alliance commitments as of 2003 based on ATOP data for the seven major international powers as designated by COW. Based on these data, substantial differences are evident in the total number and composition of commitments among the major powers. For

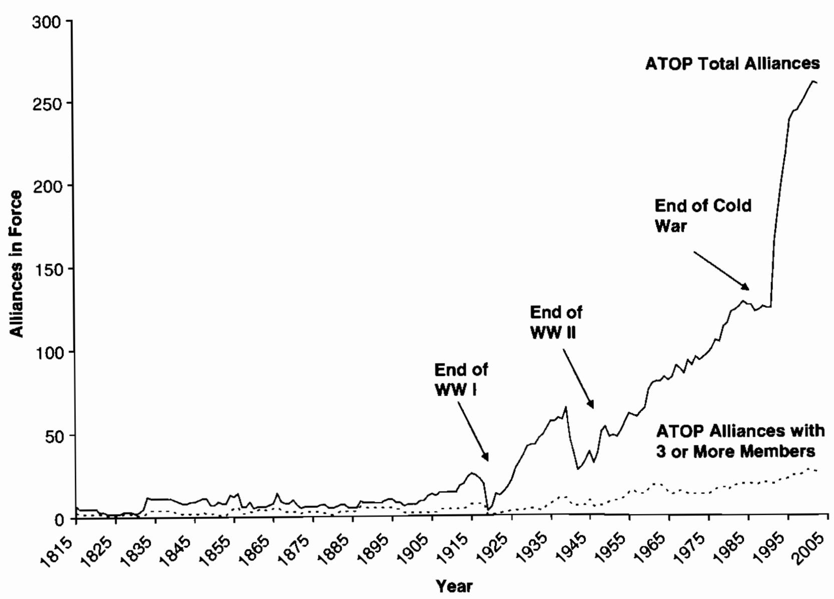

Figure 11.3. Number of multilateral alliances.
Source: Leeds et al. (2002).

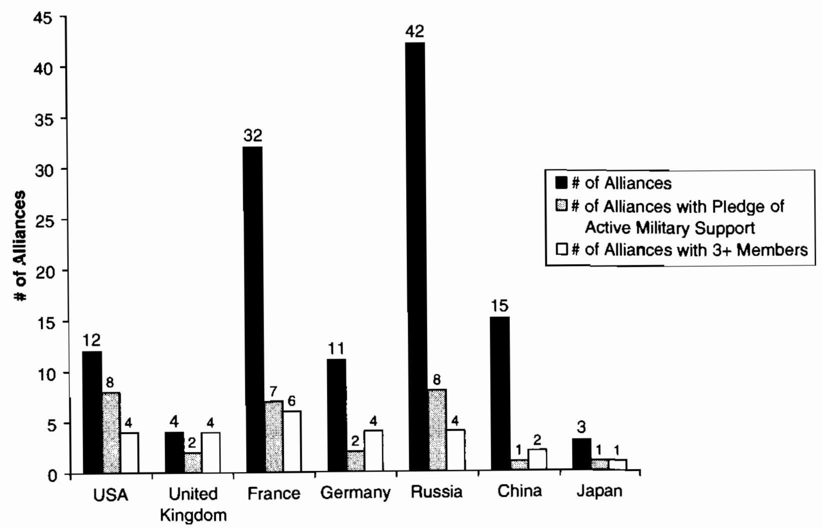

Figure 11.4. Alliance commitments of the major powers in 2003.
Source: Leeds et al. (2002).

example, Russia and France have substantially more commitments than each of the other major powers. Note also that the United States is the only major power for which more than half of its alliance commitments involve pledges of active military support.

11.3. Pure Public Good Model of Alliances

Public Goods and Alliances

Recall from Chapter 3 the distinction between private goods and public goods. A good is classified as private when its benefits are rival and excludable. For example, cereal is a private good because one person's consumption of cereal necessarily means that the same cereal cannot be consumed by others (rival); furthermore, the person possessing the cereal can withhold it from consumption by others (excludable). In contrast, the consumption benefits of a public good are nonrival and nonexcludable. For example, mosquito control is a public good for the residents of a neighborhood. One family's benefit in the form of reduced risk of disease does not preclude another family's consumption of that same benefit (nonrival); nor can the other family be denied that benefit depending on whether it contributes to the cost of the mosquito control (nonexcludable).

Olson and Zeckhauser's (1966) seminal economic model of alliances is built on the basic insight that "above all alliances produce public goods" (p. 272). The premier example of a collective benefit for alliance members is the deterrence of a common enemy. Suppose members of an alliance credibly commit to retaliate in force against any attack on one or more of its members. If the threat to retaliate successfully deters the enemy, then all members of the alliance benefit from increased security in a manner that is both nonrival and nonexcludable. Similarly, as seen in Chapter 8, offensive counterterrorism efforts can provide a public good for alliance members. To the extent that a terrorist organization is a common threat, degradation of the organization will benefit all members of the alliance, and no member can be excluded from the enhanced security.

A Diagrammatic Model

Optimization

In the model that follows, two players A and B form an alliance in the provision of a pure public good, which is a good that is perfectly nonrival and nonexcludable. For concreteness, the public good can be thought of as

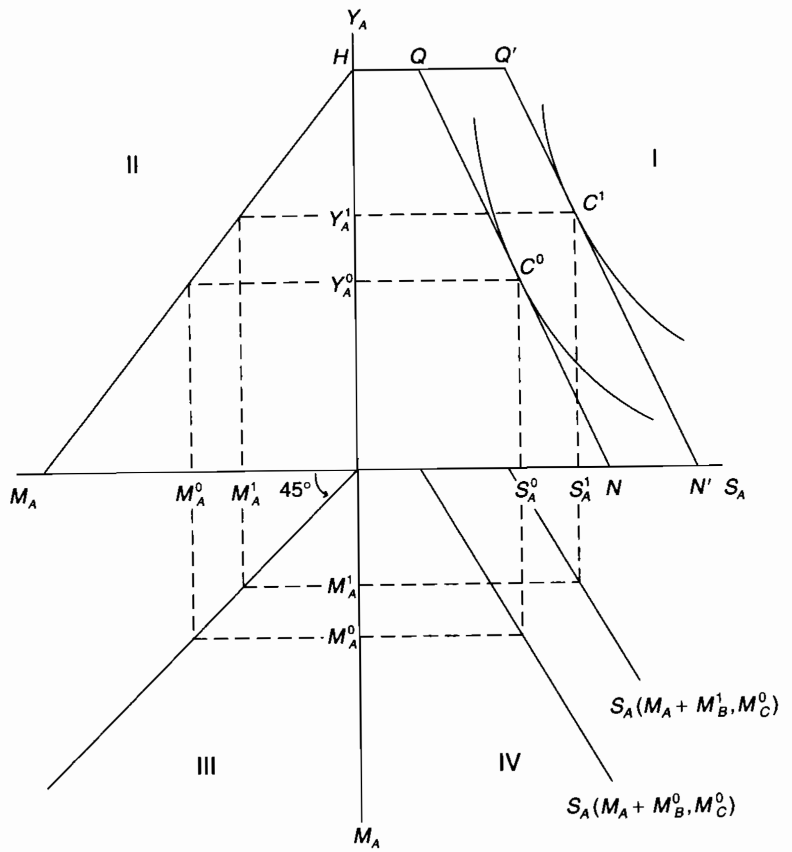

Figure 11.5. Ally *A*'s optimal allocation of resources to civilian and military goods.

military strength aimed at deterring a common enemy *C*. The allies' respective military outputs M_A and M_B are equally effective against the enemy, and the deterrence produced by one ally spills over fully to the other. Hence, the allies share a common military strength *M* equal to the sum of their military outputs, or $M = M_A + M_B$. Security for each ally *i* $(i = A,B)$ is a function of the strengths of the alliance and the enemy and can be written $S_i(M_A + M_B, M_C)$. The choice problem for each ally is to allocate resources between military output M_i and a composite civilian good Y_i so as to maximize utility, where utility $U_i(S_i, Y_i)$ is a function of security and the civilian good.

Figure 11.5 depicts the choice problem for ally *A* using a linear version of the four-quadrant diagram introduced in Chapter 10; a similar figure

would apply for ally *B*. To review, quadrant II shows *A*'s production possibilities frontier (PPF) for alternative combinations of military and civilian outputs M_A and Y_A. Quadrant III uses a 45-degree line to project *A*'s military output into quadrant IV, which shows *A*'s security function given the military outputs of ally *B* and enemy *C*. These three quadrants systematically link various civilian outputs Y_A with corresponding levels of security S_A, thus generating the civilian-security possibilities frontier (CSPF) in quadrant I. The diagram is completed by adding *A*'s indifference map to quadrant I. In geometric terms, *A*'s choice problem is to choose a combination of civilian and military outputs (and hence security) so as to reach the highest indifference curve possible along the CSPF, taking as given the military outputs of *B* and *C*.

To see how the model works, suppose that the initial military outputs of ally *B* and enemy *C* are respectively M_B^0 and M_C^0, thus generating the lower security line $S_A(M_A + M_B^0, M_C^0)$ shown in quadrant IV. Notice that the intercept of the security line is not at the graph's origin. This is because even if ally *A* were to choose a military output equal to zero, it would still enjoy some positive level of security due to the deterrence spillover from its ally's military output M_B^0. The security line and PPF in quadrant II combine in quadrant I to generate the CSPF labeled *HQN*, which is shown with an initial horizontal stretch, again due to the spillover from *B*'s military output. Given M_B^0 and M_C^0, ally *A* maximizes its utility at optimum C^0 by producing outputs Y_A^0 and M_A^0, thereby enabling ally *A* to enjoy the consumption benefit of the former and the security benefit S_A^0 of the latter.

Suppose now that ally *B*'s military output increases to M_B^1, with the enemy's output held fixed at M_C^0. Because military strength in the alliance is a pure public good, ally *A* benefits from increased security, other things equal, causing its security line to shift rightward to $S_A(M_A + M_B^1, M_C^0)$. Because of the linkages in the model, the CSPF in turn shifts rightward to *HQ'N'*. This allows ally *A* to reallocate its resources until it achieves optimum C^1 with civilian good Y_A^1, military output M_A^1, and security S_A^1. Notice carefully what has happened. Given the increased output of its ally, *A* has been able to reduce its own military output, while at the same time enjoying not only more civilian good but also more security. The result is increased utility for *A* and thus a compelling incentive to free ride off the military output of its ally. This perhaps surprising result is quite general, relying only on the publicness of the alliance's military strength and the additional but reasonable assumption that the civilian good and security are both normal goods.

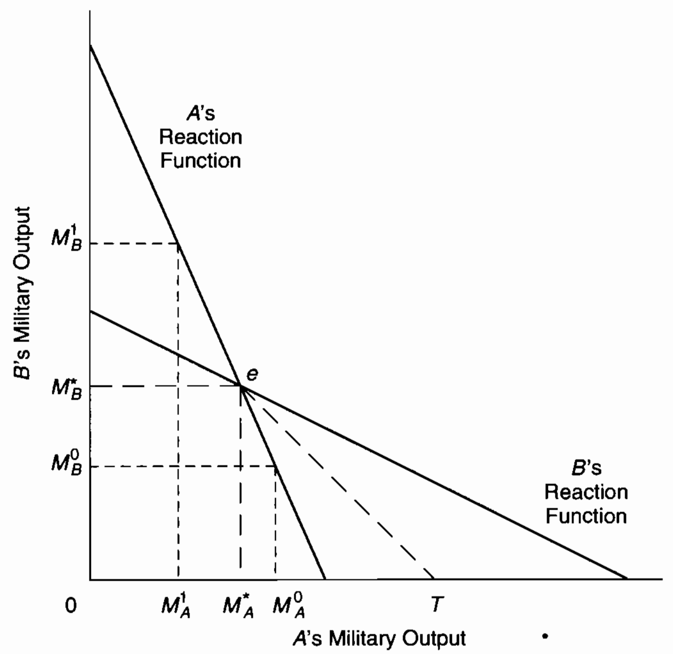

Figure 11.6. Reaction functions and alliance equilibrium.

Reaction Functions and Alliance Equilibrium

The pure public good model is completed by bringing the optimal behavior of ally *A* together with the optimal behavior of ally *B* to determine the equilibrium military outputs of the two allies. Notice that the preceding analysis already sketches how Figure 11.5 can be used to derive a reaction function for *A*. For example, if ally *B* chooses output M_B^0, *A*'s best reply in Figure 11.5 is M_A^0, and if *B* chooses M_B^1, *A*'s best reply is M_A^1. As seen in Figure 11.6, this generates two of the points along *A*'s reaction function, which shows *A*'s best reply for any given output by *B*. Similar four-quadrant analysis for ally *B* generates *B*'s reaction function. Notice that the reaction functions are negatively sloped, reflecting the incentive of each ally to free ride off the military output of the other. A Nash equilibrium exists when each ally's output is a best reply to the other's. Hence, the equilibrium for the alliance is determined in Figure 11.6 at point *e*, where the two reaction functions intersect (for a similar diagram, see Sandler and Hartley 1999, p. 33). In equilibrium, *A* chooses output M_A^*, which is a best reply to *B*'s M_B^*, while *B* chooses M_B^*, which is a best reply to *A*'s M_A^*. The total alliance strength $M^* = M_A^* + M_B^*$ equals the distance *OT*, determined

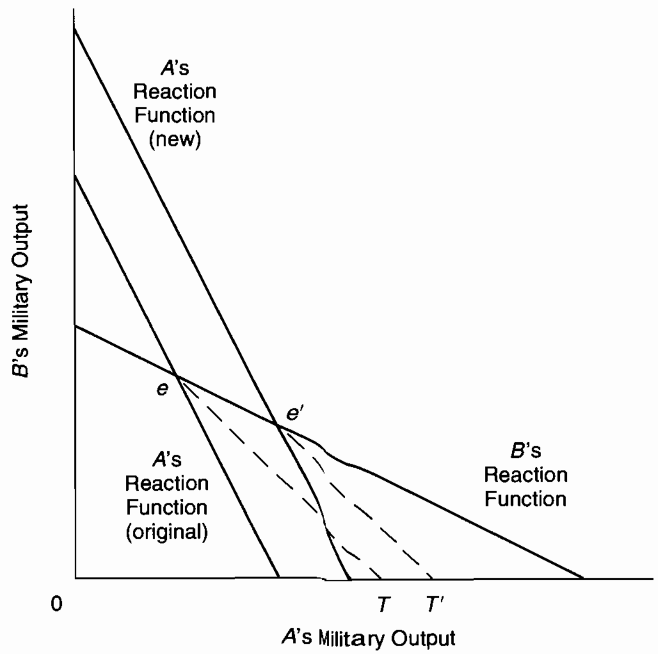

Figure 11.7. Free riding by ally *B*.

geometrically by the dashed line drawn from the equilibrium to the horizontal axis with a slope of −1 (Cornes and Sandler 1996).

Implications

Free Riding

The incentive to free ride identified earlier in the allies' reaction curves carries over to the comparative-statics of the full equilibrium model. Suppose, for example, that ally *A* perceives a new threat to its security, but ally *B* does not. *A* will tend to increase its demand for military goods, as shown by the rightward shift of its reaction function in Figure 11.7 (for a similar diagram, see Sandler and Hartley 2001, p. 874). A new alliance equilibrium emerges at point *e*′, which entails increased military output by *A* but decreased output by *B*. Note that ally *B* clearly free rides on player *A*'s increased output: despite *B*'s own decrease in military output, *B* nonetheless is able to enjoy an increase in total defense from *OT* to *OT*′ and therefore an increase in its own security.

Alliance Suboptimality

Alliance formation can improve each player's well-being relative to "going it alone" but still be inefficient in the sense that additional gains are

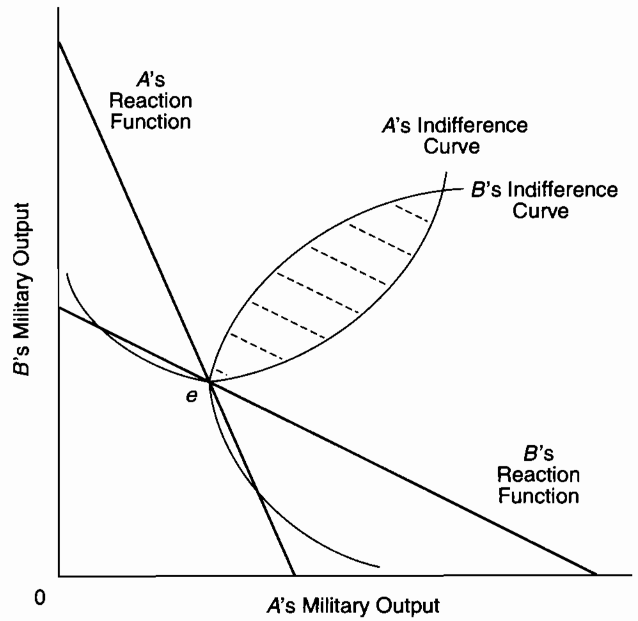

Figure 11.8. Alliance suboptimality.

available to the allies relative to the alliance equilibrium. We demonstrate this implication by supplementing the allies' reaction curves with their associated indifference curves, as shown in Figure 11.8 (for a similar diagram, see Sandler and Hartley 1995, p. 28). The logic of adding indifference curves is very similar to that used for the arms rivalry model in the preceding chapter. In brief, the PPFs and security functions are substituted into the respective allies' utility functions, resulting in translated utility functions defined in terms of both allies' military outputs M_A and M_B (along with the enemy's output M_C).

The translated utility functions are represented by indifference curves in the usual manner. Of *A*'s many indifference curves, in Figure 11.8 we have drawn just one, that being the curve passing through the equilibrium point *e*. Because *e* lies on *A*'s reaction function, we know that *A*'s military output at that point is optimal given the corresponding military output of *B*. Thus, *A* would be indifferent to a change in its own output only if the change was accompanied by a suitable change in *B*'s output as well. In particular, *A* would be content with an increase in its own output only if it was compensated for the added cost by a higher level of security emanating from an increase in *B*'s output. This means that *A*'s indifference curve must turn

upward to the right of *e*, as shown. In the other direction, *A* would be indifferent to a decrease in its own output only if it was compensated for its forgone security, once again, by higher security generated by an increase in *B*'s output. Thus, *A*'s indifference curve likewise must turn upward to the left of *e*. Repeating the same reasoning for other points along *A*'s reaction function means that *A*'s indifference curves are U-shaped around the reaction function. Also, because unilateral increases in *B*'s military output leave player *A* strictly better off, points on higher indifference curves are more preferred by *A*. For ally *B* we likewise show a single indifference curve passing through the equilibrium point *e*. Similar reasoning means that *B*'s indifference curves are U-shaped relative to the vertical axis, and points on indifference curves farther to the right are more preferred by *B*.

Notice now that the two indifference curves drawn through equilibrium point *e* form a highlighted lens-shaped area in Figure 11.8. Points within the lens lie above *A*'s indifference curve and hence are preferred to *e* by *A*; they also lie to the right of *B*'s indifference curve and hence are preferred to *e* by *B*. Thus, the lens-shaped area forms a region of mutual gain and thereby demonstrates the equilibrium *e* to be Pareto inefficient. In the absence of unspecified transaction costs, this means that both allies can benefit if they coordinate their military outputs to reach some specified point within the lens.

The source of the alliance's inefficiency is subtle but important. In the pure public good model, the players enjoy the defense benefits that spill over from their ally's military goods. Nevertheless, in their own utility functions they place no value on the defense benefits created for their ally from their own military goods. Hence, the players may form an alliance and enjoy security benefits from each other's military goods, but they make autonomous allocation choices that ignore the spillover benefits to their ally. This leads to underprovision of military goods for the alliance as a whole, a result echoed in the government counterterrorism games of Chapter 8. Elimination of the underprovision requires an alliance agreement that goes well beyond the sharing of the public good to include some form of centralized coordination of the allocation choices (see, e.g., Sandler and Hartley 1999, ch. 8).

Disproportionate Burden Sharing

Under certain assumptions, the pure public good model predicts that the wealthier ally will bear a disproportionately large defense burden, as measured by the ratio of its military goods to its aggregate output (Olson and Zeckhauser 1966, pp. 269–270; Sandler and Hartley 2001, p. 875). We

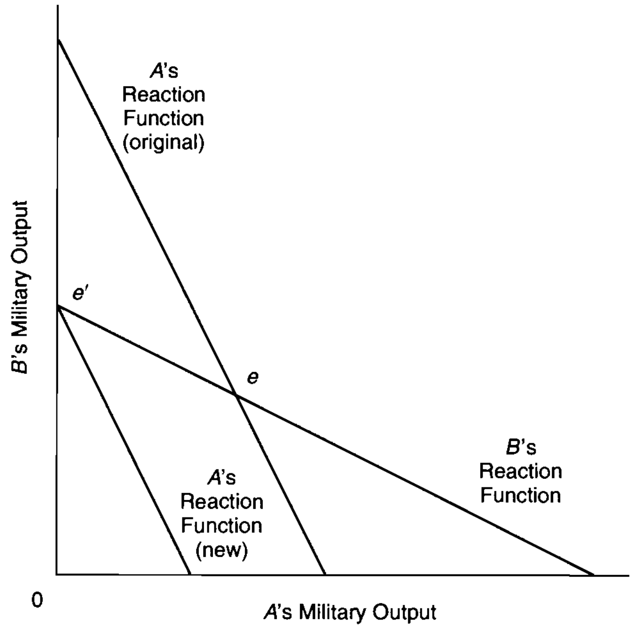

Figure 11.9. Disproportionate burden for wealthier ally *B*.

refer to this as the disproportionality hypothesis; in the alliance literature it is also known as the exploitation hypothesis. Note that the hypothesis does not say simply that the wealthier ally will produce more military goods than the poorer ally, but that the wealthier ally will allocate a greater proportion of its aggregate output to defense than the poorer ally. Figure 11.9 offers a stylized example of the disproportionality hypothesis. Assume that *A* and *B* are initially identical in every respect, including the same PPFs, security functions, and preferences, thus generating a symmetric equilibrium at point *e*. Assume now that *A*'s aggregate output, as modeled by the PPF in the four-quadrant diagram, falls until *A*'s reaction function just intersects the vertical intercept of *B*'s reaction function. In this corner solution at point *e*′, player *A* produces zero military goods, while *B* produces all of the alliance's output. This then is an extreme but clear example of the disproportionality hypothesis inasmuch as the wealthier ally *B* incurs a positive burden while *A* suffers no burden at all.

Optimal Alliance Size

Suppose an additional player joins the alliance of *A* and *B* arrayed against *C*, and the transaction costs of assimilating the new ally are zero. In the pure public good model, the military output of the new ally will be a perfect substitute for the outputs of *A* and *B*. Hence, the addition of the ally will enable *A* and *B* to reduce their respective demands for military goods, increase civilian production, and enjoy greater security, everything else the same. Similar benefits would arise if even more players enter the alliance. Consequently, there is no reason in terms of benefits and costs to limit the number of allies. In practical terms, when the security benefits generated by military goods are purely public and the transaction costs of new allies are minimal, an alliance has the incentive to bring in as many new allies as possible. A contemporary example that may approximate a purely public defense good for many players is degradation of the al Qaeda terrorist organization. If al Qaeda is weakened, all potential targets of al Qaeda benefit at the same time, and they cannot be excluded from such benefits. The pure public good model suggests that states arrayed against al Qaeda should bring in as many allies as possible if the transaction costs of operating as an alliance are sufficiently low.

11.4. Joint Product Model of Alliances

Pure Public, Impure Public, and Private Goods

The key assumption in the model just discussed is that each ally's security is based exclusively on the sharing of a pure public good. The assumption is restrictive in at least two ways. First, it requires that security be derived from a pure public good, meaning a good that is both perfectly nonrival and perfectly nonexcludable. The prototypical example is deterrence based on strategic nuclear weapons: all allies can simultaneously enjoy the security benefit of a deterred adversary, and none of the allies can be excluded from that benefit. In practice, however, the public good shared by an alliance need not be pure; rather, it can be partially rival or partially excludable or both, in which case it is called an impure public good. An example of an impure public good is territorial defense based on conventional forces. Suppose that *A* is attacked by adversary *C*, leading ally *B* to send in military forces to help counter *C*'s advance against *A*. Notice that the defense provided is partially rival: the forces committed by *B* are not available at the same time to counter an attack by *C* on *B*'s territory. Sandler and Hartley (1995, p. 31) describe this as force thinning, whereby forces are spread along a border or across an area. The defense provided by *B* is also partially excludable: ally *B* can choose to hold back some of its forces to defend its own territory. Second, the model's key assumption is restrictive in that it requires security to be based solely on a public good. In fact, however, military activity can generate security derived from goods that are wholly private to the providing ally (Olson and Zeckhauser 1966, p. 272; van Ypersele de Strihou 1967). For example, many nations use military forces to stem civil unrest, protect coastlines, or defend against domestic terrorists. All or most of the benefits of such activity do not spill over to the security of allies.

Technology of Public Supply and the Joint Product Model

In a series of formal extensions, Sandler and his colleagues relaxed the restrictive pure public good assumption and in doing so developed what is known as the joint product model of alliances (Sandler and Cauley 1975, Sandler 1977, Murdoch and Sandler 1982). In this model, allies' military goods generate a variety of defense products that range from purely public (e.g., deterrence), to impurely public (e.g., damage limitation), to private (e.g., control of domestic terrorism). The extensions represent far more than minor adjustments to the pure public good model of alliances. Rather, they culminate in a general alliance model that includes the original pure public good model as a special case. In what follows, we highlight the main elements and key results of the joint product model. More formal and complete coverage is provided by Cornes and Sandler (1984) and Sandler and Hartley (2001).

Suppose that the military outputs of allies A and B generate shared security benefits, which may be either pure or impure, and possibly also defense benefits that are strictly private. Assuming symmetry in the technology of public supply, the security functions for A and B can be written:

$$S_A = S_A(M_A + \theta M_B, \delta M_A, M_C) \tag{11.1a}$$

$$S_B = S_B(\theta M_A + M_B, \delta M_B, M_C), \tag{11.1b}$$

where $0 < \theta \leq 1$ and $\delta \geq 0$. The θ term in either equation gauges the degree to which a player benefits from a spillover from the other ally's output. When θ equals one, the alliance's shared good is purely public; when θ is less than one, the shared good is impurely public. The δ term captures the extent to which a player's military output generates private benefits. If δ is zero at the same time that θ equals one, then the security functions are identical to those in the pure public good model.

In Figure 11.10 we show reaction functions for two alternative technologies of public supply, supposing for simplicity that the allies have identical PPFs, security functions, and preferences. In both cases we stipulate

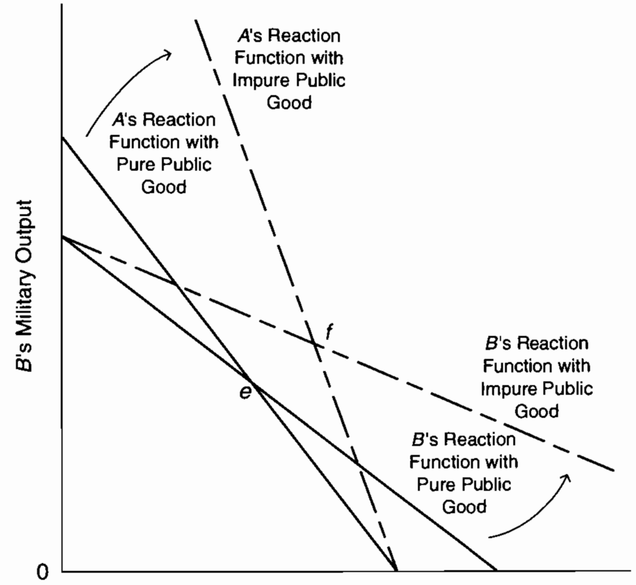

Figure 11.10. Reaction functions for a pure versus impure public good.

no private benefits, so $\delta = 0$. For the first case we assume that $\theta = 1$, meaning that the allies share a pure public good. The result is the set of solid-lined reaction functions, which are similar to those in Figure 11.6 and yield equilibrium military outputs at point e. For the second case we assume that $\theta < 1$, meaning that the spillover from each other's military output is less than complete, so that the allies share an impure public good. The result this time is the set of dashed reaction functions with equilibrium point f. Relative to the first case, notice that the reaction functions with an impure public good are rotated outward around a fixed intercept. Because the spillover is reduced, the incentive to free ride on an ally's output is reduced, causing the steepness of A's reaction curve to increase and B's to decrease. If as a third case we were to introduce private benefits with $\delta > 0$, we would expect shifts in the reaction functions (not shown), with equilibrium military outputs changing relative to cases of pure or impure public goods.

Implications

The joint product model modifies the predictions of the original pure public good model in important ways (see, e.g., Cornes and Sandler 1984, Sandler and Hartley 2001). When military goods generate partially excludable and/or partially rival defense benefits among allies, then the allies must rely more on their own military outputs to achieve security. Under such conditions, it can generally be expected that the extent of free riding, the degree of suboptimality, the disproportionality of contributions, and the optimal number of allies will all be reduced relative to what is implied in the pure public good model. Recall in Figure 11.10 that *A*'s reaction function is steeper when the alliance's public good is impure rather than when it is pure. Hence, a given increase in M_B will lead to a smaller decrease in M_A and hence less free riding. In the same way, diminished free riding is also implied by the flatter slope of *B*'s reaction function. The presence of excludable private benefits further increases the allies' reliance on their own military outputs. With decreased incentives for free riding, disproportionate burdens on wealthier allies and underprovision of alliance defense are reduced. Moreover, the impurity of the public good that arises with force thinning causes the optimal size of the alliance to be finite. In the presence of force thinning, optimality requires that allies be added only to the point where the marginal security benefits created by additional military goods just equal the marginal costs caused by additional thinning (Sandler and Hartley 1995, p. 34).

11.5. Selected Empirical Studies

Burden Sharing within NATO

A key implication of the pure public good model is that larger allies will bear a disproportionate share of the alliance burden because of free riding by smaller allies. In their seminal paper, Olson and Zeckhauser (1966) operationalized the hypothesis as follows: "In an alliance, there will be a significant positive correlation between the size of a member's national income and the percentage of its national income spent on defense" (p. 274). They tested their hypothesis in a relatively simple manner using a cross section of 14 NATO allies in 1964. The test was based on the correlation between two rank orderings – one for income (measured by GNP), and the other for defense budget as a percentage of income. These rank orderings are replicated in the left half of Table 11.2. If the disproportionality hypothesis is correct, countries that rank higher in income should also tend to rank higher in defense spending as a percentage of income. That is what the data show, although the strength of the pattern is moderate. Of the top six allies in terms of income, four of them also rank

Table 11.2. *Burden sharing in NATO, 1964 and 1971.*

Country	1964 GNP Rank	1964 Defense Budget as Percent of GNP Rank	Country	1971 GNP Rank	1971 Defense Budget as Percent of GNP Rank
US	1	1	US	1	1
Germany	2	6	Germany	2	10
UK	3	3	France	3	6
France	4	4	UK	4	3
Italy	5	10	Italy	5	9
Canada	6	8	Canada	6	13
Netherlands	7	7	Netherlands	7	7 (tie)
Belgium	8	12	Belgium	8	12
Denmark	9	13	Denmark	9	11
Turkey	10	5	Turkey	10	4 (tie)
Norway	11	11	Norway	11	7 (tie)
Greece	12	9	Greece	12	4 (tie)
Portugal	13	2	Portugal	13	2
Luxembourg	14	14	Luxembourg	14	14
Correlation		0.490			0.165
p-value (one-tailed)		0.038			0.286

Sources: Olson and Zeckhauser (1966, p. 267) and International Institute for Strategic Studies (1974, p. 78).

among the top six in defense spending as a percentage of income. As reported by Olson and Zeckhauser, across all 14 allies the correlation between the two rank orderings equals 0.490 and is statistically significant. Olson and Zeckhauser (1966, p. 265) concluded that "large nations in NATO bear a disproportionate share of the burden of the common defense," thus supporting the public good model of alliances.

Subsequent researchers, however, discovered that the rank correlation between income and defense burden diminished and ceased to be statistically significant after the mid-to-late 1960s (Sandler and Forbes 1980, Oneal and Elrod 1989, Khanna and Sandler 1996, Sandler and Murdoch 2000). As an illustration, on the right side of Table 11.2 we replicate Olson and Zeckhauser's methodology for 1971. Notice that of the top six allies in terms of income, only three also rank among the top six in spending as a percentage of income. More formally, across all 14 countries, the rank correlation falls sharply to 0.165 and is now statistically insignificant.

As might be expected, a considerable body of research has followed since the weakened rank correlations were discovered. Within this literature there exists an interesting and lively debate about NATO behavior and the applicability of the disproportionality hypothesis. We highlight some of the methodological differences and interpretive disagreements by briefly reviewing two representative studies.

Sandler and Forbes (1980) maintain that the explanatory power of the pure public good model as it pertains to NATO has been diminished by changes in weapons technologies, strategic arms control, and especially NATO strategy. In the late 1960s, NATO shifted from a doctrine of mutually assured destruction, with its objective of pure nuclear deterrence, to one of flexible response, with its increased emphasis on protection and damage limitation. As a consequence, NATO relied more on conventional and tactical nuclear weapons and hence produced more private and impure public defense goods. Based on the joint product model, Sandler and Forbes (1980, p. 426) hypothesize that as a result of the change in NATO doctrine, free riding is reduced and defense burdens are shared more in accordance with the distribution of alliance benefits. To test their hypothesis, Sandler and Forbes compute the relative defense burden of each ally as the ratio of its own expenditures to the total expenditures for NATO. Also they estimate each ally's share of the alliance's total benefits, using national income, population, and exposed borders as benefit proxies. In general, they find that while the benefit shares were quite stable, the expenditure shares shifted in the expected direction during the 1970s. For example, while the United States' share of NATO benefits remained stable at roughly 41 percent between 1960 and 1975, its share of NATO expenditures over the same period dropped from 73 percent to 67 percent. Taking on larger relative burdens were the Europeans, whose aggregate expenditure share increased from 24 percent to 31 percent. Across all 14 allies, Sandler and Forbes find that the differences between relative defense burdens and those predicted based on benefit shares diminished over the same period. The general conclusion reached by Sandler and Forbes is that changes in NATO doctrine favor the applicability of the joint product model over the pure public good model.

In a pooled cross-sectional time-series analysis, Oneal and Diehl (1994) also appeal to the joint product model, postulating that defense burdens depend on the mix of pure public, impure public, and private goods produced by NATO members. Following Olson and Zeckhauser (1966), defense burden is measured by an ally's military spending as a proportion of its national income. The key independent variables are (1) national income as a share of NATO's total income, (2) military expenditures of contiguous allies as a share of NATO's total expenditures, and (3) involvements in non–Cold War militarized disputes. These three variables allow for the effects of the pure public good of deterrence, the impure public good of territorial defense, and any private benefits that arise from non-NATO conflicts, respectively. Also included are controls for Soviet military spending and for regional interdependence among the European allies. Estimation of the model for a sample of 15 allies over the period 1950–86 shows all coefficients to be statistically significant. The effect of spending by neighboring allies is unexpectedly negative, which Oneal and Diehl interpret as an indication of free riding. Also consistent with free riding is the positive coefficient on national income as a share of NATO income. Over the sample period 1950–86, larger allies in terms of national income bore larger defense burdens, thus supporting Olson and Zeckhauser's disproportionality hypothesis. Oneal and Diehl (1994) conclude that "NATO seems primarily to have supplied a relatively pure public good throughout this period" (p. 391).

Alliances and the Risk of Armed Conflict

A seemingly natural question to ask about alliances is whether they increase or decrease the likelihood of armed conflict. As argued by Leeds (2003), however, the question is poorly posed because alliance agreements can give rise to different obligations and hence have different effects. To see this, consider three players – potential challenger A, potential target B, and ally C. In a defensive pact between B and C, if A attacks B, then C is obligated to support B. In an offensive pact between A and C, if A attacks B, then C is obligated to support A. Lastly, in a neutrality pact between A and C, if A attacks B, then C is obligated not to intervene on B's behalf. Assuming that alliances are formal agreements with credible commitments, they provide public information about the likely conduct of an armed conflict and hence about its expected outcome. Under suitable circumstances, this means that the presence of an alliance can either decrease or increase the probability of armed conflict, depending on whether the obligations favor the target or the challenger. Based on these considerations, Leeds (2003, p. 431) puts forward three hypotheses: defensive pacts decrease the likelihood of armed conflict, offensive pacts increase the likelihood, and neutrality pacts increase the likelihood.

Leeds (2003) provides a direct test of her three hypotheses based on the ATOP database, which provides sufficient information to distinguish among defensive, offensive, and neutrality obligations. Besides being an important contribution to the alliance literature, Leeds's article has the bonus benefit for our purposes of illustrating the use of directed dyads. Consider any two countries, say Iran and Israel. This single dyad provides two directed dyads. In the context of Leeds's article, one directed dyad treats Iran as the potential challenger, that is, as the country that might initiate a militarized dispute against the potential target country, in this case Israel. The second directed dyad reverses the roles, with Israel as the potential challenger and Iran as the potential target.

By drawing on all politically relevant directed dyads for each year between 1816 and 1944, Leeds constructs a sample of almost 70,000 observations, where each observation is a dyad-year. With this sample she applies advanced regression analysis to estimate the probability that for a randomly selected directed dyad-year, the challenger will initiate a militarized interstate dispute (MID) against the target. The dependent variable equals one if a dispute is initiated and zero otherwise. The key right-hand variables indicate whether the target has a defensive ally, whether the challenger has an offensive ally, and whether the challenger benefits from a relevant neutrality pact. Control variables are included for joint democracy, contiguity, common foreign policy interests, shared alliances, and comparative strength. Leeds's (2003, pp. 435–436) empirical results strongly support all three hypotheses. The estimated coefficients on the key alliance variables are statistically significant and substantively important. Assume that all control variables are fixed at their sample means. Then, compared to a no-alliance baseline, the estimated probability that a challenger will initiate a dispute is 28 percent lower if the target has a defensive ally, 47 percent higher if the challenger has an offensive ally, and 57 percent higher if the challenger has a neutral ally.

11.6. Bibliographic Notes

Since the seminal contributions of Olson and Zeckhauser (1966, 1967), Sandler and Cauley (1975), Sandler (1977), and Murdoch and Sandler (1982), numerous extensions to the economic theory of alliances have appeared. These include models that incorporate action and reaction among allies and a rival (Niou and Tan 2005), alternative technologies of public supply (McGuire 1990, Conybeare, Murdoch, and Sandler 1994), and equilibrium concepts other than Nash (Sandler and Murdoch 1990).

The theory is applied and/or tested in studies of the Warsaw Pact, Triple Alliance, and Triple Entente (Conybeare et al. 1994), peacekeeping operations (Khanna, Sandler, and Shimizu 1998, Seiglie 2007, Solomon 2007), global strategic defense (McGuire 2004), peace as an international public good (Brauer and Roux 2000), arms trade control (Sandler 2000), and protection against national emergencies (Ihori 1999). Sandler and Hartley (2001) provide a thorough review of the theoretical and empirical literature on the economic theory of alliances.

The economic analysis of alliances includes the effects of economic factors on alliance behavior and the effects of alliances on economic outcomes. The former literature includes studies of the effects of trade on alliance burden sharing (Wong 1991), while the latter considers the effects of alliances on trade (Gowa and Mansfield 2004, Long and Leeds 2006), defense industrial policy (Hartley 2006), economic growth (Macnair, Murdoch, Pi, and Sandler 1995), and exchange-rate regimes (Li 2003).

Although we emphasize the economics of alliances in this chapter, political scientists have delved into other aspects of alliance behavior, including alliance formation causes (Siverson and Starr 1994), alliance duration (Bennett 1997), and ally reliability (Leeds and Anac 2005). Special issues of *International Interactions* (Krause and Sprecher 2004) and *Journal of Peace Research* (Sprecher and Krause 2006) offer excellent summaries of quantitative research on alliances from the perspective of political science.

For studies of alliances or alignments among terrorist organizations and criminal syndicates, see Picarelli (2006) on forms of crime-terrorism interconnection, Björnehed (2004) on narcotics trafficking and terrorism, Shelley (2006) on the smuggling of nuclear materials, and the edited volume of Holmes (2007) on terrorism and corruption.