A wide range of studies on the economic, political, and psychological consequences of and risk factors for terrorism can be found in the special issues of *Defence Economics* (Sandler 1992), *Journal of Monetary Economics* (King and Plosser 2004), *Journal of Conflict Resolution* (Rosendorff and Sandler 2005), *Public Choice* (Rowley 2006), *Conflict Management and Peace Science* (Lai 2007), and *Risk Analysis* (Bier and Winterfeldt 2007), and in the edited books of Silke (2004), Richardson, Gordon, and Moore (2005, 2007), Brück (2006), and Schmid, Jongman, and Price (2008).

9

Geography and Technology of Conflict*

Geography and weapons technology form an important context in which interstate, intrastate, and extra-state conflicts occur. In this chapter we explore how geography and weapons technology affect the territory controlled by armed rivals and the risk of violence between them. We begin with Boulding's (1962) spatial model of intergroup rivalry, which highlights geographical and technological dimensions of conflict such as spheres of influence, offensive and defensive technologies, and strategic depth. We then summarize O'Sullivan's (1991) three-dimensional extension of Boulding's model. We turn to the Lanchester (1916) model of war attrition to illustrate how combinations of geography and weapons technologies create incentives for nations or groups to go on the offensive, or stay on the defensive, in violent encounters. We also present Alesina and Spolaore's (2003) theory of the number and size of nations in the international system. Selected empirical studies related to the geography and technology of conflict are summarized.

9.1. Boulding's Model of Spatial Conflict

Basic Model

In his classic work *Conflict and Defense: A General Theory*, Boulding (1962) modeled conflict over territory among states or non-state groups by adapting prior economic theory on spatial competition. The basic model is

* Parts of sections 9.3 and 9.5 of this chapter are adapted from Charles H. Anderton and John R. Carter, "A Survey of Peace Economics," published in *Handbook of Defense Economics*, volume 2, edited by Todd Sandler and Keith Hartley, pp. 1211–1258, Copyright © Elsevier 2007. We gratefully acknowledge Elsevier's permission to republish material from the article.

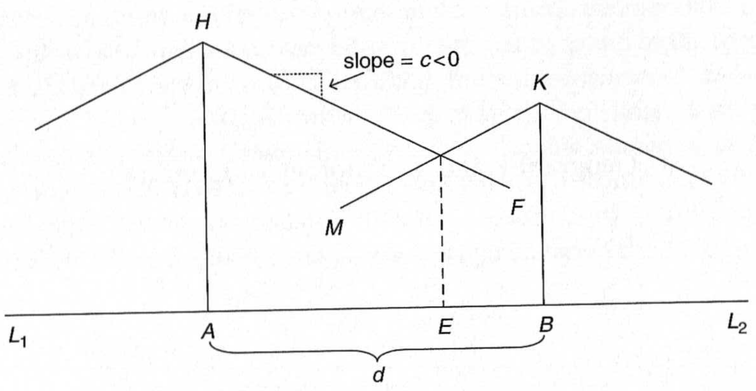

Figure 9.1. Boulding's basic model of spatial conflict (with military strength measured vertically) (adapted from Boulding 1962, p. 230).

shown in Figure 9.1, where two players *A* and *B* have home bases located at points *A* and *B* in a geographic space represented by line L_1L_2. A player's home base might be its capital if the player is a state, or a jungle or mountainous hideout if the player is a rebel or terrorist organization. In a battlefield context, the home base might be the location of a military's primary command, control, communications, computer, and information (C^4I) infrastructure, which represents the central nervous system of the military organization. The parameter *d* measures the distance between the players' home bases. Measured vertically in the figure is the military strength that a player can project when it concentrates its power at a given point in geographic space. By assumption, each player's strength is at a maximum at the player's home base, from which it falls off in either direction. The relevant portions of *A*'s and *B*'s power projection curves are labeled *HF* and *KM*, respectively, in the figure. The negative slope of a player's power projection line measures what Boulding called the loss-of-strength gradient, which is the rate at which a player's military strength decreases as the player moves away from its home base. According to Boulding (1962, p. 231), "The law of diminishing strength . . . may be phrased as *the further, the weaker*; that is, the further from home any nation has to operate, the longer will be its lines of communication, and the less strength it can put in the field." In Figure 9.1, rivals *A* and *B* are equally strong at location *E*, which is called the boundary of equal strength. At points to the left of *E*, player *A* is stronger and thus can defeat *B*, while to the right of *E*, player *B* is stronger and can defeat *A*. Thus, *A*'s sphere of influence lies to the left of *E*, and *B*'s lies to the right.

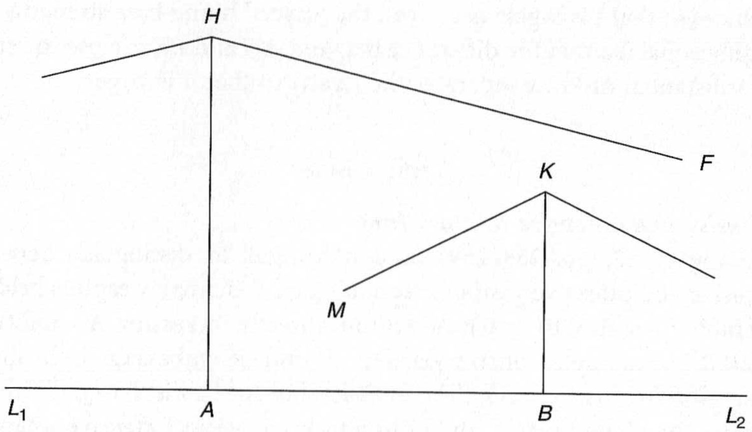

Figure 9.2. Conditional viability of player *B* (adapted from Boulding 1962, p. 232).

Boulding was particularly interested in the geographic and technological conditions under which one player can conquer another. In Figure 9.1, neither player can conquer the other because each is the stronger of the two at its own home base. Specifically, the height of *A*'s power projection line is greater than the height of *B*'s at location *A*, which implies that *B* cannot conquer *A*. Likewise, *B*'s strength is greater than *A*'s at location *B*, indicating that *A* cannot conquer *B*. Because each player is stronger at its own home base than its rival, both players are said to be unconditionally viable. This is not true in Figure 9.2, where player *B* is weaker at its home base than player *A*. In this case, *B* can be conquered by *A* and thus is said to be conditionally viable, meaning that its survival is dependent on whether *A* chooses to attack its home base.

Assume that *A*'s and *B*'s power projection curves are linear with the same common slope *c*. Then the condition for unconditional viability of both players is

$$\frac{AH - BK}{d} > c \text{ and } \frac{BK - AH}{d} > c, \tag{9.1}$$

where the first and second parts of the condition imply *A*'s and *B*'s unconditional viability, respectively (Boulding 1962, p. 232). Note that *c* is negative because it measures the loss-of-strength gradient. Hence, (9.1) implies that at least one of the two players will be unconditionally viable, because if $AH - BK$ is negative or zero, then $BK - AH$ is positive or zero, and vice versa. More important, the condition shows that both players will tend to be unconditionally viable when military strength falls steeply with distance (so that c is highly negative), the players' home-base strengths are roughly equal (so that the difference between AH and BK is close to zero), and substantial distance separates the rivals (so that d is large).

Applications

Defensive and Offensive Military Innovations

Boulding (1962, pp. 258–259) used his model to distinguish between defensive and offensive weapons technologies. Defensive weapons held by A inhibit B's ability to attack A, without directly increasing A's ability to attack B. For example, concrete barriers around US embassies diminish the ability of terrorists to attack the embassies, but the barriers do not directly increase the United States' ability to attack terrorists. Offensive weapons held by A increase A's ability to attack B, but they do not directly inhibit B's ability to attack A. For example, Hezbollah can use missiles to attack Israel, but the missiles do little to thwart Israel's ability to attack Hezbollah in southern Lebanon. The distinction between defensive and offensive weapons is not precise, however, because most weapons can be used for either defensive or offensive purposes. Moreover, weapons may be used offensively in a particular battle, whereas the battle may be part of a broader strategy designed to achieve a strong defensive posture. Despite these difficulties, Boulding maintained that the distinction between defensive and offensive weapons is important for understanding the risk and nature of intergroup violence.

An example of a defensive weapons innovation was the use of soccer stadiums by UN peacekeeping forces to defend Tutsi civilians against Hutu extremists during the 1994 Rwandan genocide. As documented in Chapter 7, the Rwandan genocide claimed some 750,000 lives as the Hutu-led government attempted to "cleanse" the country of Tutsis and moderate Hutus. Prior to the genocide, UN peacekeepers attempted to provide security to vulnerable civilians in the Rwandan capital of Kigali under the auspices of the United Nations Assistance Mission in Rwanda. The UN force had little capacity to control territory because it was significantly outnumbered by Hutu extremists.

Figure 9.3 depicts the strong position of the Hutus relative to the UN forces in Kigali. The initial Hutu and UN home strengths are AH and BK, and the respective power projection lines are HF and KM. The figure implies that the UN forces were only conditionally viable, meaning that the Hutus could carry out ethnic cleansing virtually anywhere in Kigali. If more UN peacekeepers were brought to Kigali, the strength of the UN

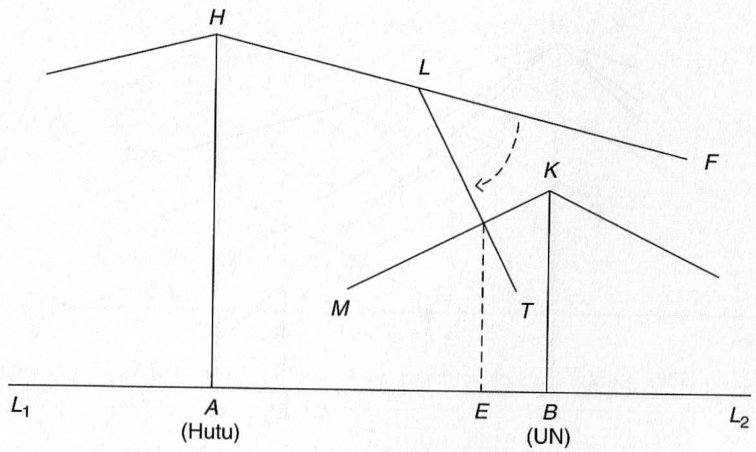

Figure 9.3. Protection of Tutsis in soccer stadiums during 1994 Rwandan genocide.

might have risen to the point where UN forces would have been unconditionally viable over a relatively large area. This could have allowed the UN to sequester a significant amount of territory to serve as a safe haven for vulnerable Tutsi, possibly moving Hutu extremists to consider a negotiated settlement. Such troops, however, were never supplied (Dallaire 2004).

Given limited forces, UN commander Roméo Dallaire developed a plan to protect civilians in soccer stadiums. At the Amahoro Stadium in Kigali, for example, Dallaire was able to defend about 10,000 civilians with just a few dozen UN troops. The stadium had high concrete walls and was surrounded by large open areas, making it highly defendable. Placement of UN troops on the walls of a soccer stadium did not enhance the UN's ability to attack the Hutus, but it did severely diminish Hutu ability to attack UN forces and Tutsis inside the stadium. In Figure 9.3, the defensive innovation is depicted by the redirection of the Hutu power projection line from HF to HLT. Near the stadium, Hutu ability to thwart UN troops and attack Tutsis was significantly diminished. In this way, the UN was able to achieve a small niche of unconditional viability using its defensive innovation.

In Boulding's model, a defensive innovation by player A causes the power projection line of B to rotate downward in some fashion. In contrast, an offensive innovation by A rotates its own power projection line upward, as shown in Figure 9.4. Assume that A and B initially have a boundary of equal strength at E based on power projection lines HF and KM. Suppose that A implements improved communications or weapons technologies, so that a given amount of military forces can be more effectively projected over

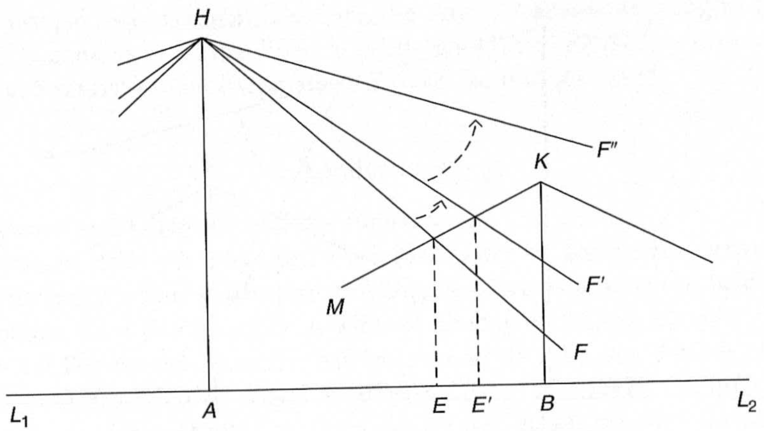

Figure 9.4. Offensive technological innovation by player *A*.

distance. *A*'s power projection line rotates upward to *HF*′, pushing the boundary of equal strength to *E*′ and increasing *A*'s sphere of influence. If *A*'s offensive innovations are large enough, *A*'s power projection line could reach *HF*″, thus jeopardizing *B*'s viability.

Figure 9.4 depicts, in a simplified way, Germany's (player *A*) deployment of blitzkrieg technologies and tactics against France (player *B*) in 1940. The German blitzkrieg encompassed improved military communications and weapons technologies such as decentralized command and maneuverable and speedy mechanized infantry, tanks, and artillery. Under the blitzkrieg, Germany was able to project power over distance with extraordinary effectiveness, thus rendering France and other European nations only conditionally viable.

Figures 9.3 and 9.4 suggest that armed rivals will be motivated to integrate new technologies into their military organizations, even if their intentions are not aggressive. Failure to do so could cause a player to lose control of territory or become vulnerable to conquest because of technological breakthroughs adopted by a rival. As Buzan (1987, p. 109) notes, "States . . . face the constant worry that their rivals will gain a military advantage by being the first to adopt a decisive technological breakthrough. Such conditions create relentless pressure on states to lead, or at least to keep up with, the pace of change by continuously modernizing their armed forces."

Military Bases

Figure 9.5 illustrates how a player can reverse its loss of strength in a particular area by utilizing a secondary center of home strength such as a

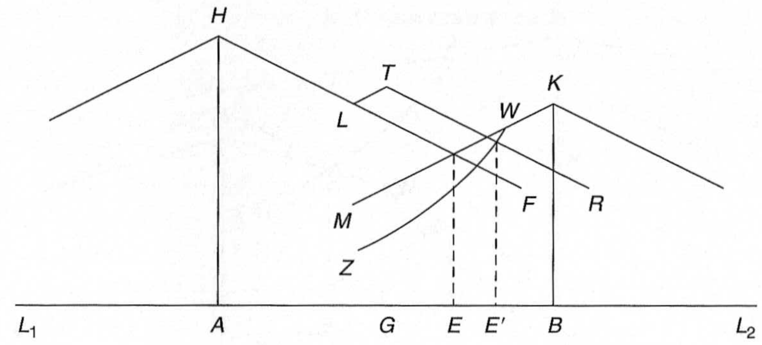

Figure 9.5. Installation of a military base (adapted from Boulding 1962, p. 262).

military base (Boulding 1962, pp. 262–263). Assume that players *A* and *B* initially have a boundary of equal strength at *E* based on power projection lines *HF* and *KM*. Suppose now that *A* establishes a military base at location *G*. The base provides additional communications and logistics support for *A*, allowing it to partially offset the loss of strength over distance. Thus, *A*'s power projection line becomes *HLTR*, which is above what it would have been had there been no military base. *A*'s base might also diminish *B*'s ability to project power over space, because *B* must exert extra effort to navigate around or through that location. Assuming *B*'s power projection line is now *KWZ*, a new boundary of equal strength emerges at *E*′, constituting an increase in *A*'s sphere of influence.

This illustrates the offensive and defensive nature of military bases (Boulding 1962, p. 263). On the one hand, *A*'s military base diminishes *B*'s power projection line, suggesting that *A* will view the base as defensive. On the other hand, the increase in *A*'s power projection line and the rightward movement of the boundary of equal strength suggest that *B* will view the base as offensive. During the 1962 Cuban Missile Crisis, for example, the United States viewed the Soviet attempt to place nuclear missiles on the island of Cuba as offensive, whereas Cuba and the Soviet Union viewed the base as defensive.

Figure 9.5 can also be used to highlight the strategic significance of high ground among armed rivals. In the 1967 Six-Day War, Israel captured the Golan Heights, a strategically important piece of geography in the border area between Israel and Syria. This action is easily translated in terms of Figure 9.5, with Israel as player *A*, Syria as player *B*, and the Golan Heights as location *G*. Control of the Golan Heights elevates Israel's power projection line from *HF* to *HLTR*, while Syria's power projection line is

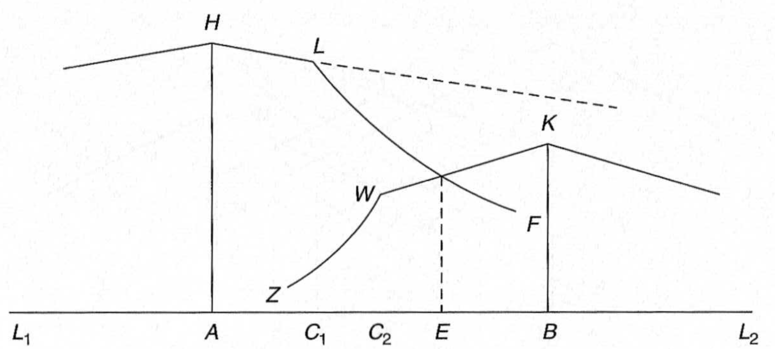

Figure 9.6. Effect of a buffer zone (adapted from Boulding 1962, p. 263).

diminished from *KM* to *KWZ*. The defensive/offensive nature of a prominent piece of geography is apparent in the Israel-Syria rivalry. Israel views control of the Golan Heights as defensive, because it diminishes the ability of Syria or other groups to launch attacks into important agricultural and industrial locations in northern Israel. Syria views Israeli control of the Golan as offensive, due in part to the short distance (about 60 km) between elevated areas of the Golan Heights and Syria's capital, Damascus.

Buffer Zones and Peacekeeping Forces

Boulding (1962, p. 263) also used his model to illustrate the theory of the buffer state. Assume in Figure 9.6 that state *C*'s territory C_1C_2 lies between the home bases of *A* and *B*, where the latter are rivals to each other but not to *C*. The presence of *C* between *A* and *B* causes the rivals' power projection lines to decline at a more rapid rate than otherwise, because the rivals must allocate extra effort to get around or through *C*'s territory. As a consequence, notice that *C*'s presence generates unconditional viability for player *B*. Without *C* as a buffer, *A*'s power projection line would decline at a constant rate, rendering *B* only conditionally viable.

Figure 9.6 provides a basic illustration of the role of peacekeeping operations (PKOs) in thwarting conflict between armed rivals. Although mandates vary widely among PKOs, many attempt to reduce the ability of rivals to project military force against each other, thus diminishing their power projection lines. For example, the United Nations Organization Mission in the Democratic Republic of the Congo (MONUC) was implemented in 1999 to diminish intrastate and interstate conflict associated with regime change and control of resources in the Democratic Republic of the Congo (DRC). MONUC used force to implement a

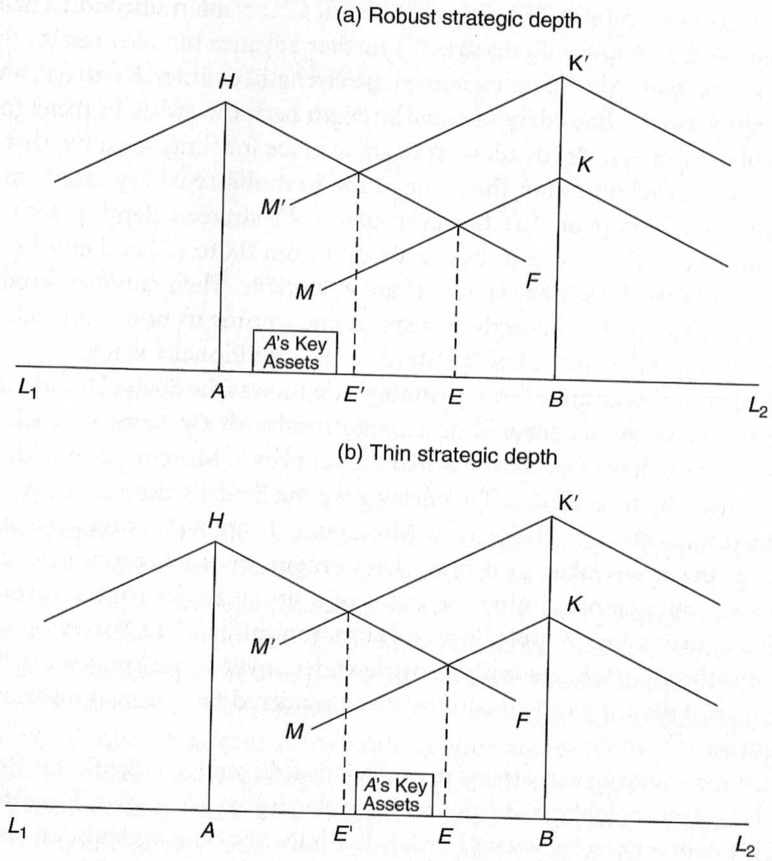

Figure 9.7. Strategic depth.

ceasefire agreement between combatants and then sought to facilitate disarmament and elections. Despite deployment of more than 16,000 personnel and an annual budget of $1.1 billion in 2007, the ability of MONUC to induce long-term peace in the DRC remains uncertain.

Strategic Depth

An oft-cited concept in the military history literature is that of strategic depth, which is a player's ability to absorb an attack while keeping its key industrial, agricultural, political, and security infrastructures unconditionally viable. Figure 9.7 illustrates the concept of strategic depth in the Boulding model. In panel (a), a boundary of equal strength initially exists at *E*. Assume that player *B* increases its home strength from *BK* to *BK'* and attacks *A*. The attack pushes the boundary of equal strength to *E'*, but *A*'s key assets (e.g., capital, industrial heartland, C^4I) remain unconditionally viable. Hence, *A* not only thwarts *B*'s further advance but also retains the assets necessary to build up its home base strength, counter *B*'s attack, and perhaps push the boundary of equal strength back toward *E*. In panel (a), *A*'s robust strategic depth allows it to trade space for time, meaning that it initially loses territory but then gains time to mobilize its key assets for a counterattack. In panel (b), however, player *A*'s strategic depth is seen to be thin. Player *B* increases its home strength from *BK* to *BK′* and invades *A*, but in this case *A*'s key assets near *E′* are vulnerable. Their conquest erodes *A*'s ability to provide strength over space, and in time its power projection line falls until *A* is ultimately rendered only conditionally viable.

A historical example of robust strategic depth was the Soviet Union's use of vast territory and forbidding climate to absorb Germany's attack in 1941. Although the Germans reached the suburbs of Moscow, it took them seven months to get there. This delay gave the Soviet's time to move key industrial assets east of the Ural Mountains. Moreover, consistent with the-further-the-weaker principle, the German troops became extended over a great distance during the onset of a brutal Soviet winter, severely compromising their supply lines and communications. The Soviet's ability to absorb an attack, resupply their defenders over a relatively short distance, and mount a robust counterattack rendered the German invasion a failure.

Contemporary examples of nations with thin strategic depth are Israel and its Arab neighbors. In the Israel-Syria rivalry, the Golan Heights is highly contentious because it borders key industrial and agricultural assets in northern Israel and is less than 60 kilometers from the Syrian capital, Damascus. To Israel's north, Beirut, Lebanon, is less than 100 kilometers away, and to the west, Amman, Jordan, is less than 40 kilometers. To the south, Israel shares borders with Jordan and Egypt. Thin strategic depth in the Arab-Israeli arena can make each state feel highly vulnerable to a quick attack from a rival, causing militaries in the region to be poised to strike quickly in the event of rising tensions. In Kemp and Harkavy's (1997, p. 165) words, "distances are very short in the core Middle Eastern zone of conflict, producing fast-moving wars with quick outcomes."

9.2. O'Sullivan's Three-Dimensional Model of Spatial Conflict

O'Sullivan (1991, pp. 80–85) provides an important three-dimensional extension of Boulding's spatial model of conflict, with applications to a rebel group's insurgency against a state. Implicit in Boulding's

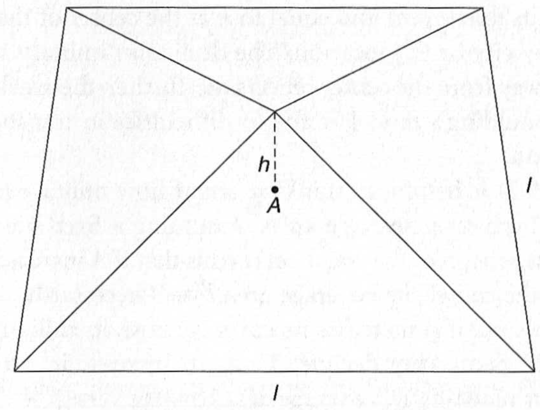

Figure 9.8. Pyramid model of spatial distribution of military power (adapted from O'Sullivan 1991, p. 81).

presentation of his basic model was the assumption that a player's power projection line depicts the maximum military strength that the player can concentrate at a particular location, effectively leaving no military strength available at other locations. O'Sullivan, however, assumes that a player can spread its military power over geographic space to control multiple areas at the same time. As a result, whether a player concentrates its military power in a small area or spreads it over a large area affects its loss-of-strength gradient, whereas in Boulding's model the gradient is exogenously fixed. O'Sullivan develops his model of spatial conflict in three dimensions based on the geometry of a square pyramid, to which we now turn.

Pyramid Model of the Distribution of Military Power

Following O'Sullivan (1991, pp. 80–81), player *A*'s total military power M_A is represented by the volume of a square pyramid, with the base of the pyramid called the coverage area. The pyramid's volume M_A, height *h*, and base length *l* are related by the equation:

$$M_A = \frac{l^2 h}{3}. \tag{9.2}$$

Figure 9.8 provides a graphical interpretation of the spatial distribution of *A*'s military power based on equation (9.2). The coverage area is shown by the square base of the pyramid with length *l* and area l^2. The vertical distance from any geographic location in the base up to the surface of the pyramid measures *A*'s military strength at that point. By assumption, this strength is at its maximum and equal to h at the center of the base, which might be a key city or C^4I location. The decline in military strength with movements away from the center reflects the-further-the-weaker principle, which as in Boulding's model is due to difficulties in transportation and communication.

Equation (9.2) is helpful in thinking about how military power can be spread over alternative coverage areas. Assuming a fixed volume of military power, inspection of the equation reveals that if A increases its military strength h at the center, its coverage area l^2 will necessarily shrink. Going the other direction, if A increases its coverage area, its military strength at the center will necessarily decline. Thus, to increase its strength at the center without reducing its coverage area (or vice versa), A must increase its total military power M_A.

Extending these insights, it can be shown that the spatial distribution of military power over a square pyramid is governed by a proportionality principle as follows:

$$\frac{\Delta M_A}{M_A} = \frac{\Delta h}{h} + \frac{\Delta area}{area}, \tag{9.3}$$

where ΔM_A is the change in A's total volume of military power, Δh is the change in the pyramid's height, and $\Delta area$ is the change in the area of the pyramid's base. Equation (9.3) implies that for a given volume of military power ($\Delta M_A/M_A = 0$), a 10 percent increase in central strength ($\Delta h/h = +0.10$) implies a 10 percent decrease in the coverage area ($\Delta area/area = -0.10$), and vice versa. More generally, a 10 percent change in the volume of military power implies a 10 percent change in strength at location A, or a 10 percent change in the coverage area, or some combination of changes adding up to 10 percent. The same proportionality principle applies to circular cones as well as to other pyramids and is independent of whether the apex of strength is directly above the center.

The logic of the proportionality principle is illustrated by the strategic difficulty faced in Iraq by coalition and Iraqi forces in 2006 and 2007. The circumstances included the extreme insecurity at the Baghdad center, the buildup of al Qaeda in Anbar Province and elsewhere, the inflow of weapons and fighters across Iraq's borders, and the relatively slow development of Iraqi military and police forces. As shown by the proportionality principle, a greater concentration of forces at the center to increase security there would worsen control in the peripheral areas, and vice versa.

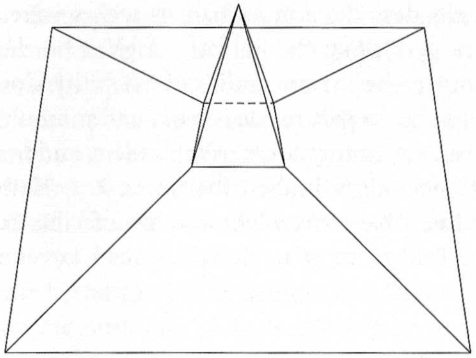

Figure 9.9. Rebel concentration of military power and conquest of the state (adapted from O'Sullivan 1991, p. 84).

Territorial Conflict

Assume that a territorial conflict arises between government forces A and a rebel group B. Following O'Sullivan (1991, pp. 81–84), their respective military powers M_A and M_B can be visualized as two square pyramids. Although the rebel group is comparatively weak, it nonetheless might be able to carve out an area in which it is unconditionally viable. Ordinarily it will do so by centering its power in the periphery of A's coverage area, where A's strength is more depleted, thus allowing B's pyramid to penetrate upward through A's. If the government spreads its military power in an attempt to increase control in the periphery, it reduces its strength at the center. B might then be tempted to try to take control of the state by concentrating its rebel forces at key location A. If the rebel group is strong enough, the result will be like that pictured in Figure 9.9, in which A's large pyramid is penetrated by B's narrow but tall pyramid. With control of key assets at the center, the rebel group might then be able to hinder the government's ability to redeploy forces back at the center. This illustrates the dilemma of government forces when facing an insurgency. If the government concentrates its forces to protect a key location, it is vulnerable to the rebel group's controlling some of the periphery of the state. If the government instead attempts to control a large area, it is vulnerable to a rebel group's concentration of forces at a key location.

O'Sullivan's three-dimensional model is applicable to the Taliban's unconditional viability in tribal areas of Pakistan. Following the September 11, 2001, terrorist attacks, the United States attacked Taliban forces in Afghanistan in retaliation for their support of al Qaeda. Although the

Taliban was initially decimated in Afghanistan, they were able to establish new command centers along the Pakistan-Afghan border. The Taliban's ability to carve out niches of unconditional viability along the Pakistan-Afghan border was due in part to the remote and mountainous terrain, to support for the Taliban among some tribal leaders, and to resistance in the Pakistani army to operations in the tribal areas. The relatively high degree of lawlessness in the tribal areas might also have facilitated the ability of a small number of Taliban to generate widespread extremism in the local population.

9.3. Schelling's Inherent Propensity toward Peace or War

According to the Nobel Prize–winning economist Thomas Schelling, certain configurations of geography, weapons technologies, and military organization can push adversaries toward either peace or war, independent of the rivals' preferences, perceptions, and goals (Schelling 1960, chs. 9 and 10, 1966, ch. 6; Schelling and Halperin 1961, chs. 1 and 2). In Schelling's (1966, p. 234) words, "There is, then, something that we might call the 'inherent propensity toward peace or war' embodied in the weaponry, the geography, and the military organization of the time." Here we develop Schelling's inherent propensity concepts using the Lanchester (1916) war model.

Basic Lanchester Model of War Attrition

Prior to war, suppose players A and B hold military stocks M_A^0 and M_B^0. The superscripts indicate that these are the players' initial, or time-zero, weapons holdings prior to the outbreak of war. Suppose now that A attacks B. The basic Lanchester model describes the attrition of the military stocks of the two sides with the following differential equations:

$$\dot{M}_A = -\beta_d M_B \tag{9.4}$$

$$\dot{M}_B = -\alpha_a M_A. \tag{9.5}$$

The $\dot{M}_A$ and $\dot{M}_B$ terms on the left side represent the rate of change of the players' military stocks during the war. For example, if time is measured in months and $\dot{M}_A = -100$ at a point during the war, A then would be losing weapons at a rate of 100 per month. The parameters α_a and β_d, called sometimes the attrition coefficients, describe the effectiveness of A's and B's weapons in destroying the other player's weapons when A is the attacker and B the defender. Consistent with Schelling, we assume that the coefficients reflect the speed and accuracy of weapons, any geographic impediments or enhancements to fighting ability, and the effectiveness of military organization and training. The M_A and M_B terms represent the military stocks of the players at a point in time during the war. Because attrition causes these stocks to change over time, M_A and M_B are functions of time.

In the basic Lanchester model, the winner in a fight-to-the-finish war is determined when the opposing player's military stock is driven to zero. Given the prewar stocks M_A^0 and M_B^0, this means that when A initiates the war, equations (9.4) and (9.5) mathematically determine the winner in accordance with the well-known Lanchester square law (Taylor 1983, v. 1, pp. 72–74):

$$\begin{aligned} \alpha_a (M_A^0)^2 > \beta_d (M_B^0)^2 &\Rightarrow A \text{ wins} \\ \alpha_a (M_A^0)^2 < \beta_d (M_B^0)^2 &\Rightarrow B \text{ wins}. \end{aligned} \tag{9.6}$$

For example, suppose A has 2,000 soldiers armed with assault rifles with effectiveness $\alpha_a = 0.01$, and B has 1,000 soldiers with machine guns with effectiveness $\beta_d = 0.05$. Substituting the data into condition (9.6) yields the inequality $40{,}000 < 50{,}000$, implying that B will win the war even though B is outnumbered two-to-one. Condition (9.6) applies when A is the attacker and B the defender, which is indicated by the subscript a (for attacker) on A's weapons effectiveness coefficient α and by the subscript d (for defender) on B's weapons effectiveness coefficient β. If, instead, B attacks A, the coefficients would be α_d and β_a in equations (9.4) and (9.5) and condition (9.6).

Lanchester Attack/Defend Model

With a little work, we can use the Lanchester square law to formalize Schelling's notion of the inherent propensity for peace or war. Assuming that A is the attacker, solving the bottom half of (9.6) for M_B^0 defines the "B can defend" condition:

$$M_B^0 > (\alpha_a/\beta_d)^{0.5} M_A^0 \Rightarrow B \text{ can defend}. \tag{9.7}$$

For given attack and defense effectiveness coefficients α_a and β_d, condition (9.7) shows the amount of military stock M_B^0 that B must have prior to war in order to successfully defend itself should A attack with military stock M_A^0. As an example, suppose $M_A^0 = 2{,}000$ weapons, $\alpha_a = 0.01$, and

$\beta_d = 0.05$. Substituting the data into condition (9.7) indicates that B needs at least $M_B^0 = 895$ weapons to thwart A's attack. When the defend condition in (9.7) is not satisfied, then A can attack and eventually defeat B. Assuming that B is the attacker, similar methods give the "A can defend" condition:

$$M_A^0 > (\beta_a/\alpha_d)^{0.5} M_B^0 \Rightarrow A \text{ can defend}. \quad (9.8)$$

When (9.8) is not satisfied, B can attack and eventually defeat A. Conditions (9.7) and (9.8) highlight two elements that affect a player's ability to defend successfully in the event of war: (1) its own and its rival's military stocks prior to the war, and (2) its weapons' effectiveness, based on technology, geography, and military organization and training.

A graph of the defense and attack potentials of A and B is shown in Figure 9.10, where M_A is plotted on the horizontal axis and M_B on the vertical axis. Possible prewar military stocks M_A^0 and M_B^0 are represented by points in the graph, such as point q in panels (a) and (b). Based on condition (9.7), B's defend condition is plotted as a straight line with slope equal to $(\alpha_a/\beta_d)^{0.5}$ and intercept equal to zero. At military stock points above and to the left of this line, B can successfully defend if A attacks; at points below and to the right, B cannot successfully defend and will eventually be defeated if A attacks. A's defend condition is plotted similarly from (9.8), with intercept equal to zero but with slope equal to $1/(\beta_a/\alpha_d)^{0.5}$.

Figure 9.10(a) is drawn under the condition that the B defends line has a smaller slope than does the A defends line, thereby creating a zone of mutual defense. The condition that determines the existence of a mutual defense zone is

$$(\alpha_a/\beta_d)^{0.5}(\beta_a/\alpha_d)^{0.5} < 1. \quad (9.9a)$$

Condition (9.9a) tends to hold when geographic, technological, and military organization factors combine to cause low attack parameters α_a and β_a and high defense parameters α_d and β_d. Given an initial weapons stocks at point q in Figure 9.10(a), both sides can successfully defend, implying a relatively low risk of war. In Schelling's terminology, Figure 9.10(a) depicts an inherent propensity toward peace.

In Figure 9.10(b), the relative magnitudes of the parameters are reversed, creating a zone of mutual attack under the condition:

$$(\alpha_a/\beta_d)^{0.5}(\beta_a/\alpha_d)^{0.5} > 1. \quad (9.9b)$$

A problem arises at point q in Figure 9.10(b) because of the common knowledge that the first mover can successfully attack and eventually win.

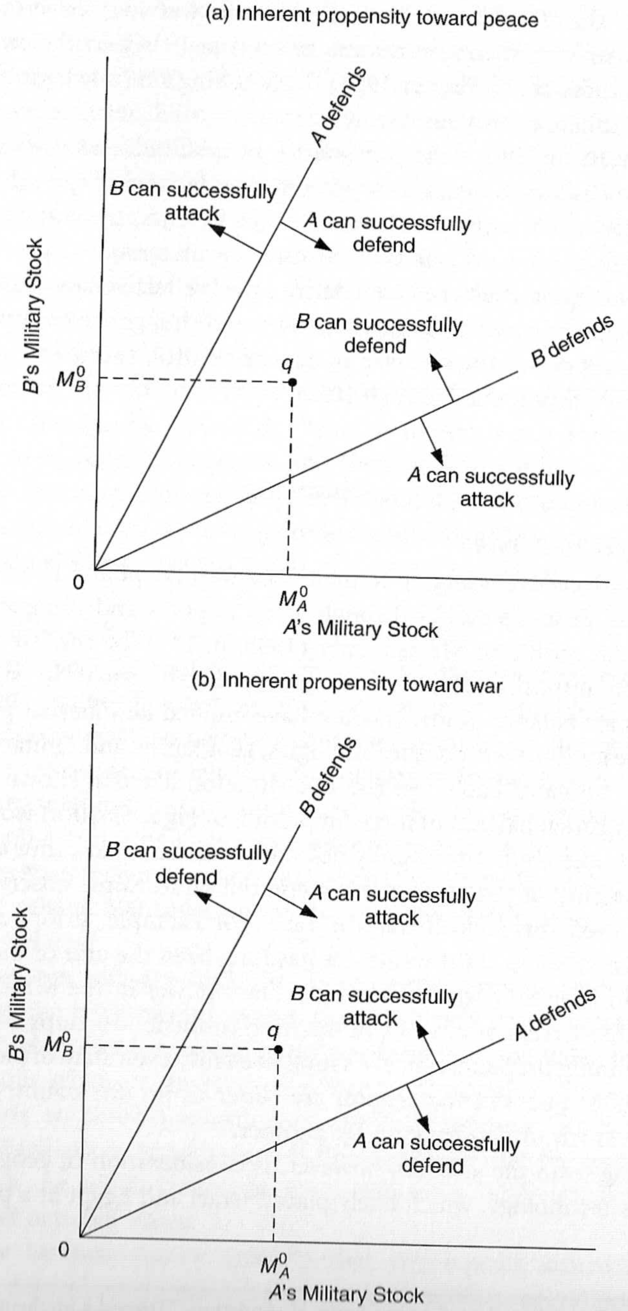

Figure 9.10. Lanchester attack/defend model.

Even rivals that fundamentally wish to avoid war may nevertheless be compelled by a first-mover advantage to attack before the rival does (Schelling 1966, ch. 6, Fischer 1984). In Schelling's terms, Figure 9.10(b) depicts an inherent propensity toward war.

Figure 9.10 highlights the importance of qualitative arms control. In Figure 9.10(b), reconfigurations of weapons technologies and military organization away from attack and toward defense, geographic repositioning of forces toward defensive postures, or placement of peacekeepers between the rivals could reduce relative attack effectiveness (lower β_a/α_d and α_a/β_d). Such qualitative arms control could change the rivalry from an inherent propensity toward war in Figure 9.10(b) to an inherent propensity toward peace in Figure 9.10(a).

Applications*

Egypt-Israel 1967 War

In the two decades leading up to their 1967 war, Egypt and Israel acquired substantial weapons stocks through arms imports and indigenous production. According to Mearsheimer (1985, p. 145), by the late spring of 1967 "the opposing forces were approximately equal in size." This approximate balance of forces could have implied an inherent propensity toward peace if the weapons technologies, geography, and military training of Egypt and Israel had given rise to a situation like that shown in Figure 9.10(a). A rough balance of forces at point q in Figure 9.10(a) would imply that both sides could successfully defend against an attack, thus enhancing the probability of peace, everything else the same. Some observers at the time believed this indeed was the case. For example, prior to the war, O'Balance (1964, p. 210) wrote, "It has long been the aim of the Western powers to keep an even balance of military power in the Middle East so that neither Israel nor any one of the Arab countries develops a dangerous overwhelming preponderance. As long as a fairly even state of parity exists, prospects of peace in that region are better as no one country becomes strong enough to quickly gulp up another."

Missing from the analysis, however, is consideration of geography and weapons technology, which likely placed Israel and Egypt at a point like q in Figure 9.10(b), where despite the balance of forces the propensity toward war was high. Consider the postwar explanation of Fischer (1984, p. 19), who wrote, "Both Israel and Egypt had vulnerable bomber fleets on open desert airfields. Each side knew that whoever initiated the first strike could easily bomb and destroy the hostile planes on the ground, thereby gaining air superiority." Fischer's analysis suggests that the attack effectiveness coefficients α_a and β_a were relatively large in the Egypt-Israel rivalry, because one plane in a surprise attack could destroy many vulnerable planes on the ground. Empirical evidence supports Fischer's contention. Epstein (1990, p. 45) reported that Israel's attack in 1967 caused Egypt to lose 20 aircraft for every Israeli aircraft lost. Also, the close proximity of the two countries enhanced the advantage of a surprise attack, further raising α_a and β_a. Prior to the outbreak of war, Aharon Yariv, head of Israeli intelligence, and General Yeshayahu Gavish, chief of the Israeli Southern Command, "believed that if Israel did not strike soon, the Egyptians might strike first, gaining the attendant benefits of delivering the first blow" (Betts 1982, p. 150).

Militarization of Space

The use of space for networked civilian communications, commercial navigation, weather forecasting, and verification of arms control treaties represents beneficial cooperation among nations. At the same time, however, space is increasingly used for military purposes. Growing reliance on military satellites and continuing research into antisatellite weapons (ASATs) raise concerns about a possible arms race in space. These concerns were magnified in January 2007 when China tested an ASAT by firing a ballistic missile 500 miles above the earth to destroy one of its aging weather satellites.

For centuries military strategists have emphasized the importance of controlling the high ground in war. Geographically, space represents the ultimate high ground, creating enormous incentives for states to control large regions of space. In the years ahead, territorial disputes in space might prove to be even more dangerous than the now-familiar earthly varieties. Particularly troublesome is the likelihood that the technologies involved in the militarization of space will carry inherent propensities toward war between states.

Suppose in some future scenario that two equally armed foes are extremely dependent on satellites to conduct military operations. These satellites are highly vulnerable. The players have launched their own satellites, so presumably they also have the capability of launching space

* This application is adapted from Charles H. Anderton, "Toward a Mathematical Theory of the Offensive/Defensive Balance," published by Blackwell Publishers in *International Studies Quarterly*, volume 36, issue 1, pp. 75–100, 1992.

vehicles to destroy their rival's military satellites. The development of laser technologies and legions of small killer satellites further increases the degree of vulnerability. Important here is the evident incentive to initiate a preemptive attack aimed at destroying a substantial portion of a rival's military satellites before the rival attempts to do the same. As Hardesty (2005, p. 49) observes, "Space-based weapons, like all space systems, are predictable and fragile, but they represent significant combat power if used before they are destroyed – leading to a strong incentive to use these weapons preemptively, to 'use them or lose them'." The scenario described might then be a point like q in Figure 9.10(b), where despite a balance of forces, the propensity toward war is high, and the need for arms control is urgent.

9.4. Number and Size of Nations

As shown in Figure 9.11, the number of nations in the international system has increased more than sevenfold since 1820. Furthermore, changes in the number of states appear to be associated at least in some instances with

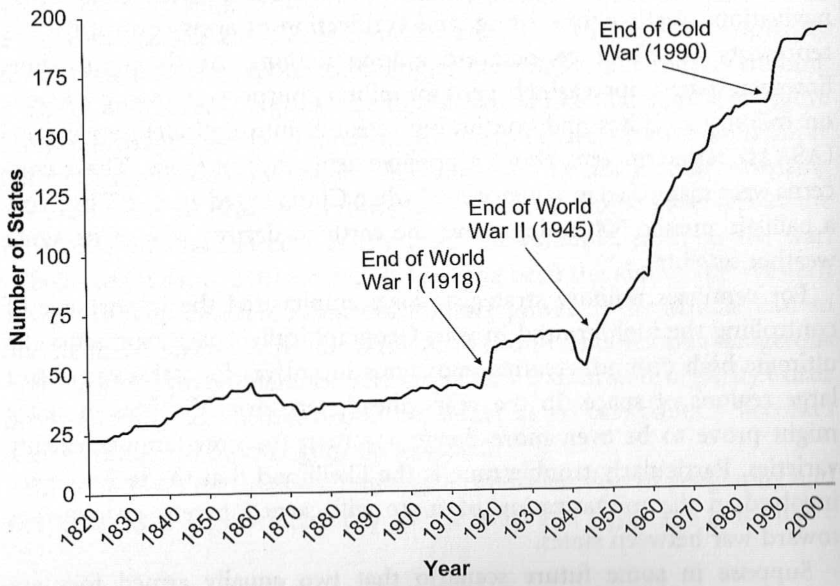

Figure 9.11. Number of states in the international system, 1820–2004.
Source: Correlates of War Project (2005), "State System Membership List, v2004.1." Online, http://correlatesofwar.org.

major events in international relations. Note, for example, the substantial increases in the number of states in the immediate years after World Wars I and II and the Cold War. Although the rise and fall of nations is not always associated with war or international tension, the threat or use of force to redraw borders is a major storyline in human history. In this section, we use the model of Alesina and Spolaore (2003) to explore determinants of the number and size of nations, with a particular emphasis on conflict and economic variables.

The Alesina-Spolaore Model

The fundamental principle of the Alesina-Spolaore model is that the number and size of states follow from a trade-off between the benefits and costs of increased size (Alesina and Spolaore 2003, pp. 3–6). On the benefit side, Alesina and Spolaore posit that per capita disposable income rises with size, because per capita taxes tend to fall as the cost of public goods is spread across a larger population. These lower costs and taxes derive from the nonrivalry property of public goods and also from likely scale economies in their provision. A prominent example is national defense, which because of its publicness can protect additional citizens at low or zero added cost. Other public goods for which per capita costs are likely to fall with increased size include monetary and judicial systems, law enforcement, and diplomatic embassies. Benefits of larger size can also arise for other reasons. To the extent that international trade is restricted, increased size generates higher per capita income owing to greater specialization and trade within a country. Also, larger states can use transfers and subsidies to provide what amounts to insurance against regional downturns and natural disasters. On the other side of the equation, Alesina and Spolaore argue that economic and political costs rise on a per capita basis as larger states encounter increased heterogeneity of preferences, languages, and cultures. Thus, as states grow larger, more individuals on average will be dissatisfied with their government's policies on matters of spending, taxation, redistribution, trade, foreign policy, language, race, religion, and so on.

In Figure 9.12 we offer a highly stylized graphical version of the Alesina-Spolaore model. In both panels of the figure, the horizontal axis measures the average size of states in terms of population. Assuming for simplicity that population and surface area are exactly correlated, the horizontal axis also measures the number of states, with the scale running from right to left. In panel (a), the vertical axis measures the total per capita benefits

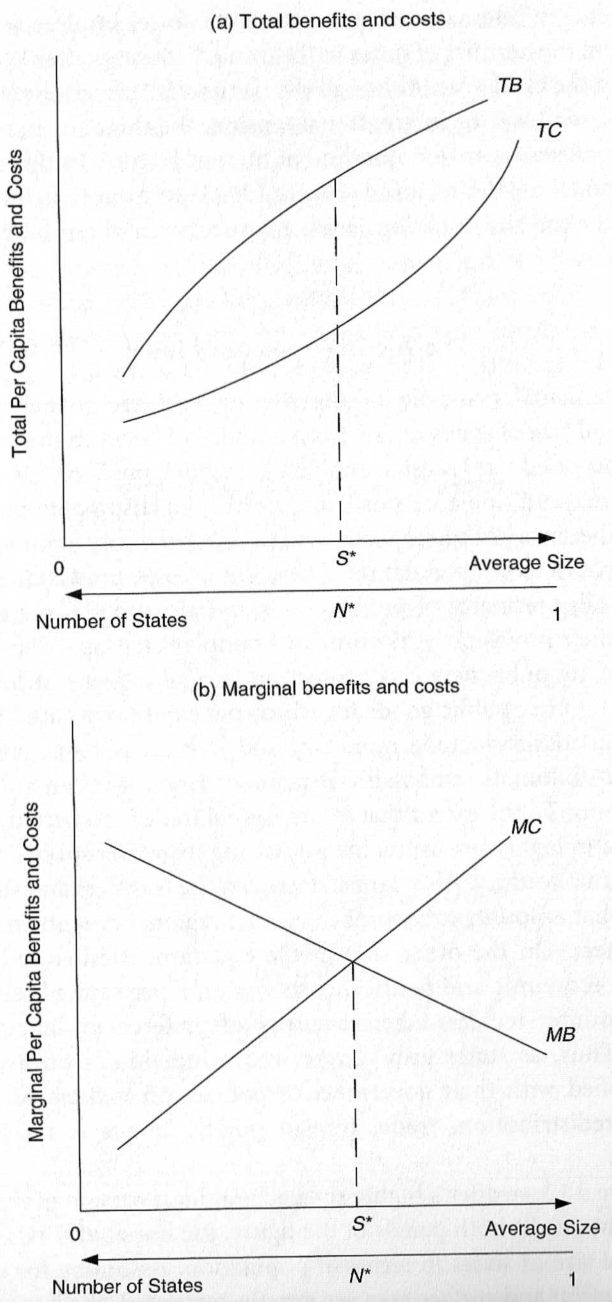

Figure 9.12. Determination of the number and average size of nations.

(*TB*) and costs (*TC*) associated with state size. As just posited, benefits increase with size owing to lower per capita taxes on public goods, wider internal specialization and trade, and more regional diversification, whereas costs increase with size owing to greater political heterogeneity. Panel (b) conveys the same information as panel (a) but does so in the more convenient form of marginal benefits (*MB*) and marginal costs (*MC*). For any given national size in panel (a), marginal benefit equals the corresponding slope of the total benefit curve; hence, marginal benefit measures the added benefit per additional unit of size. Geometrically this means that any basic change that rotates the total benefit curve upward in panel (a) will increase (i.e., shift upward) the marginal benefit curve in panel (b). Similarly, marginal cost equals the slope of the total cost curve and hence measures the added cost per added unit of size. Any change that rotates the total cost curve upward in panel (a) will increase (i.e., shift upward) the marginal cost curve in panel (b).

Net benefits in Figure 9.12 are maximized when the average state size is S^*, with a corresponding number of states N^*. The optimal or efficient size S^* is determined in panel (a), where the vertical distance between *TB* and *TC* is greatest, and it is found more conveniently in panel (b), where *MB* equals *MC*. For our purposes, it suffices to assume that the optimum also constitutes a long-run equilibrium. Thus we assume that incentives and processes exist that over the long run drive states to an average size that maximizes net benefits. This is a strong assumption about how incentives and processes actually combine to reshape national borders through both voluntary and coercive means. For more formal treatments that allow for a divergence between optimal and equilibrium size, see Alesina and Spolaore (1997, 2003).

Comparative-Static Analysis

Risk of International Conflict

When the risk of violent conflict rises in the international system, nations tend to increase their demand for military goods. Because national defense is a public good with scale economies, this means that the per capita benefits of national size will increase. In terms of Figure 9.12, increased risk of international violence will rotate the *TB* curve upward and thus cause the *MB* curve to shift upward. As a consequence, equilibrium size S^* will increase and the equilibrium number of states N^* will decrease. The opposite is predicted if the risk of violence decreases, perhaps because of reduced tensions or improved international law. As Alesina and Spolaore

(2003, pp. 95–96) explain, "In a more bellicose world, large countries have an advantage, but when the need to use military force is reduced internationally, defense becomes less important and smaller countries more safe." In this case, the *MB* curve shifts downward, leading to a decreased S^* and an increased N^*. As shown in Figure 9.11, the model's prediction of an increased number of small states is consistent with international trends following the end of the Cold War and the collapse of the Soviet Union.

Openness and Economic Integration

National size is advantageous when trade barriers exist, because specialization and trade can be extended when internal markets are larger. Thus, per capita incomes can be expected to be higher in larger countries, other things equal. Turning this reasoning around, if international trade is liberalized, the benefits of national size are reduced, as external markets are opened to smaller countries. According to Alesina and Spolaore (2003, p. 94), "As the world economy becomes more integrated, one of the benefits of large countries (the size of markets) vanishes. As a result the trade-off between size and heterogeneity shifts in favor of smaller and more homogeneous countries." In terms of Figure 9.12, trade liberalization can be expected to rotate the *TB* curve downward and thus shift the *MB* curve downward. Equilibrium size S^* will consequently decrease, and the equilibrium number of states N^* will increase. Inasmuch as the modern trend has been toward trade liberalization, the model's prediction is consistent with the rapid rise in the number of states since World War II shown in Figure 9.11.

Information Technologies and the Emergence of Trans-State Groups

The phenomenal growth of information technologies such as communication satellites, fiber optics, and microprocessors has spawned a worldwide information revolution. People around the globe can quickly and cheaply obtain information from a variety of nonprint outlets such as CNN and the internet, and they can communicate with one another in new ways via e-mail, blogs, and cell phones. This increased flow of information is likely to impact systematically the benefits and costs of national size. To the extent that the new technologies render people less dependent on state-provided information infrastructures, the benefits of national size are reduced. More important, wider information is likely to generate preferences that are more heterogeneous and hence higher costs associated with national size. If these conjectures are correct, in Figure 9.12 the increase in information shifts the *MB* curve downward and the *MC* curve

upward. As a consequence, equilibrium size S^* will decrease, and the equilibrium number of states N^* will increase.

The increase in N^* can be interpreted as a move toward increased political expression and statehood among people who learn of economic and political opportunities elsewhere and demand such opportunities for themselves. This construal is consistent with the emergence of new states in Eastern Europe at the end of the Cold War. Another interpretation might be the appearance of trans-state groups within and across nations. Trans-state groups are relatively large numbers of like-minded and connected people who view their "citizenship" as centered, not in a geographic location, but in a cause, interest, or philosophy that transcends the geographic location of a state. Transnational terrorist organizations and criminal syndicates are examples of trans-state groups that are in conflict with nations, but not all relations between trans-state groups and states are conflict prone. For example, some people serving in nongovernmental organizations or religious orders may view themselves as primarily inhabitants of their non-state organization.

9.5. Selected Empirical Studies

Determinants of Secession

Secession refers to a rearrangement of borders that is associated with a dispute between a state and an internal group and that results in the creation of a second state (see, e.g., Tir 2006, p. 310). By this definition, the dramatic rise in the number of states since World War II is largely the result of secessionist movements. In the broad terms of Alesina and Spolaore (2003), a demand for secession will arise when, owing to heterogeneity of preferences, the costs exceed the benefits of inclusion for the secessionist group. These preferences might be related to ethnic, religious, economic, or political issues. Following Boulding (1962) and O'Sullivan (1991), the secessionist demand is more likely to be manifested when the separatist group is able to carve out a region of unconditional viability against the state.

Empirical investigation of the determinants of secession generally follows one of two methodological lines. A substantial proportion of all intrastate conflicts are separatist in nature. Thus, one line of inquiry uses the country as the unit of observation and proceeds much like the study of risk factors for civil war reviewed in Chapter 7. At the same time, most separatist movements are associated with ethnic and religious identity. Hence, a second line of inquiry focuses on minority groups as the unit of observation. Representative of these respective approaches are Buhaug (2006) and Walter (2006b).

Based on the UCDP/PRIO dataset (Gleditsch et al. 2002), Buhaug (2006) reports that about one-third of all civil conflicts are aimed at securing territorial autonomy or secession, while the other two-thirds seek the more ambitious goal of governmental control. Because rebels' demands differ between these two types of civil conflict, Buhaug argues that the empirical determinants will vary systematically for secessions and revolutions. For example, drawing on both Boulding (1962) and Alesina and Spolaore (2003), he hypothesizes that larger countries, with their more distant territories and heterogeneous preferences, will be particularly likely to experience secessionist conflicts rather than revolutions, other things equal.

Buhaug tests his general thesis using a large sample of about 5,400 country-year observations spanning the period 1946–99 and including onsets of 80 secessionist conflicts and 123 governmental control conflicts. Among the various explanatory variables, he finds that country size is the single most important determinant of the likelihood of secessionist conflict, both absolutely and relative to the likelihood of governmental control conflict. Holding other factors constant, Buhaug estimates that a country in the 95th percentile for size is about 24 times more likely to experience a secessionist conflict in a given year than is a country in the 5th percentile. In contrast, country size has a much smaller and statistically insignificant effect on the likelihood of governmental control conflict. Other factors that are found to have comparatively large positive effects on the likelihood of secessionist conflict are the level of democracy and the extent of ethnic fractionalization in a country.

Shifting the focus from countries to groups, Walter (2006b) postulates that a minority group will challenge a state on issues of self-determination when the group believes that concessions can be won. To gauge the prospect of concessions, the group will look at not only current but also past and future conditions. If the state has some history of concessions to other groups, then the present group might anticipate that the state will be conciliatory to its own demands. However, this means also that if there exist other minority groups, the present group might expect the state to be less conciliatory in order to build a reputation of resoluteness. Because information is incomplete, miscalculation by a separatist group can lead to armed conflict.

Walter's sample consists of annual observations during the period 1940–2000 for 337 ethnic groups listed by the Minorities at Risk (MAR) Project. To be listed, an ethnic group must reside in a country with a population of at least one-half million, and it must be politically organized or experience discriminatory treatment. For any given group-year observation, Walter's dependent variable indicates whether the group acted violently for the first time in pursuit of "greater political autonomy, association with kin in neighboring states, and/or independence" (Walter 2006b, p. 130). Consistent with her conjectures, Walter finds that a minority group is about six times more likely to initiate violence if the government conceded autonomy or independence to one or more groups in the past; at the same time, the group is only one-third as likely to undertake violence when there are many other ethnic groups residing in the same country. Other factors showing a positive impact on the risk of violent challenge include political discrimination against the group, a loss of autonomy in the past, the absence of co-ethnics in neighboring countries that might offer a migration option, and geographic concentration of the group in a single region of the country.

Offense-Defense Theory and Evidence

Offense-defense theory (ODT) maintains that the character of international relations is influenced by the ease or difficulty of offensive relative to defensive military operations (Lynn-Jones 2004, p. xi). ODT has been applied to many aspects of international relations, including the risk of war, alliance formation, arms control, crisis behavior, size of states, and structure of the international system (Adams 2003/04, p. 46). ODT's central prediction is that war is more likely when offense has the advantage over defense in military operations (Van Evera 1999). Here we liken Schelling's concept of an inherent propensity toward peace or war with an offense-defense balance in favor of the defense and offense, respectively.

How the offense-defense balance (ODB) is defined will necessarily affect the explanatory scope claimed for ODT. Van Evera (1998) characterizes the ODB broadly to include military technology, geography, collective security systems, behavior of neutral states, and actors' perceptions. Given his broad definition, it is not surprising that he views ODT as an encompassing theory of war risk and other international relations phenomena. Indeed, Van Evera (1999, p. 190) claims that ODT should be viewed as the "master key to the causes of conflict." In contrast to Van Evera, Schelling (1966, p. 234) maintained that the elements that determine the inherent propensity toward peace or war "can hardly be considered the exclusively determining factors in international conflict." Schelling's more narrow approach suggests that the ODB is just one among other factors purported to explain war risk and that the empirical challenge is to determine the relative importance of the ODB.

An empirical test of ODT that is consistent with Schelling's more narrow approach is provided by Adams (2003/04), who defines the ODB based on military technology alone. To apply the theory, Adams distinguishes among offense, defense, and deterrence, where the latter occurs when a state prepares to use or shows an ability to use force against another state's nonmilitary assets in order to discourage that state from initiating or continuing an offensive operation (Adams 2003/04, p. 53). Based on a review of the best technologies available since 1800, Adams determines that offense was dominant during 1800–49 and 1934–45, defense was dominant during 1850–1933, and deterrence was dominant in the nuclear era beginning in 1946. Her central hypothesis is that attacks and conquests would have been most frequent in the offense-dominant eras, less frequent in the defense-dominant era, and rare in the deterrence-dominant era. To test the hypothesis, she constructs a dataset on attacks and conquests by great powers and nuclear states from 1800 to 1997. For each state and year, Adams codes three dependent variables, indicating whether the state's territory was conquered, whether the state attacked another great power, and whether it attacked a non–great power. The key independent variable is the offense-defense-deterrence balance, which is coded 0 in the deterrence-dominant era, 1 in the defense-dominant era, and 2 in the offense-dominant eras. Additional variables include relative military capability, number of years a state had been a great power or a nuclear state, and a time trend.

Adams (2003/04, p. 76) finds strong support for her central hypothesis. She estimates that attacks on other great powers were 12 times more likely each year under offensive dominance (probability 0.156) than under defensive dominance (probability 0.013) and that they were 13 times more likely each year under defensive dominance than under deterrence dominance (probability 0.001). She also finds smaller but significant effects with the predicted pattern for conquests and attacks on non–great powers. These results seem broadly supportive of the Lanchester attack/defend model summarized earlier in Figure 9.10. When the ODB favors the defense, Figure 9.10(a) pertains, and great power attacks and conquests are relatively unlikely. When the ODB favors the offense, Figure 9.10(b) obtains, and great power attacks and conquests are more likely.

In addition to the results on the ODB, Adams (2003/04, p. 77) finds that the least capable great powers (those with capability indexes in the 10th percentile) were 2.5 times less likely to attack (probability 0.006) than were the most capable great powers (those in the 90th percentile, probability 0.015), and that they were 40 times more likely to be conquered (probabilities of 0.008 vs. 0.0002). In terms of the Lanchester model, these results on relative capability pertain to the position of the initial weapons point q in Figure 9.10. When a state's relative capability is sufficiently weak, the initial weapons point falls in a zone where its rival can attack and win. This condition can hold irrespective of the ODB. Hence, the ODB is just one element that affects the risk of attack in the Lanchester model; the relative capability of the rivals also matters as Adams shows.

Note that an intermediate conception of the ODB would incorporate geographic elements of war as implied by Schelling. In the Lanchester model, the presence of mobilization advantages tilts attack/defense possibilities toward the offense. One aspect of mobilization advantage is the geographic closeness of states, measured by proximity or contiguity. Empirical research has shown that proximity and contiguity are significant risk factors for interstate war (see, e.g., Russett and Oneal 2001, Senese 2005). In our view, this lends empirical support to the Lanchester exercises explored earlier and to the value of incorporating geography in the definition of the ODB.

9.6. Bibliographic Notes

In addition to Boulding's (1962) seminal work, other early perspectives on the geography of conflict are available from Wright (1942), Richardson (1960b), and Schelling (1960, 1966) and in a special issue of *Journal of Conflict Resolution* (Singer 1960). Along with statistical investigation of risk factors for violent conflict, social scientists now study the geographic spread of violence within and beyond the territories of conflicting states (Siverson and Starr 1990, Braithwaite 2006), within and beyond the borders of states experiencing civil war (Buhaug and Gleditsch 2008), and by terrorist organizations (Enders and Sandler 2006b). The International Peace Research Institute in Oslo's (PRIO) project, "Geographic Representation of War," provides numerous references to recent scholarship on the geography of civil conflict. A number of edited volumes consider the geography of conflict from various disciplinary perspectives (e.g., Cutter, Richardson, and Wilbanks 2003, Flint 2004, Kahler and Walter 2006, and Cox, Low, and Robinson 2008). New datasets on the geography of conflict have been developed, including Starr and Thomas's (2002) geographical information systems data on the nature of interstate borders and PRIO's datasets on petroleum and diamond resources, shared river basins, and length of international boundaries.

For additional perspectives on offense-defense theory, see the edited volumes of Brown, Coté, Lynn-Jones, and Miller (2004) and Gortzak, Haftel, and Sweeney (2005). The effects of weapons technologies on intergroup violence are also assessed in the military history literature (see, e.g., Rotte and Schmidt 2003) and in the nonprovocative defense literature (see, e.g., Fischer 1984, Wiseman 2002).

During much of the twentieth century, the Lanchester model constituted the foundation of mathematical war modeling (Taylor 1983). Although Lanchester theory has been criticized by war modelers (e.g., Epstein 1985, Ancker 1995), it is still used in military service organizations to assess various dynamic aspects of war (Epstein 1985, p. 3) and in academic articles on war risk and duration (Bellany 1999, Anderton and Carter 2007). Lanchester-type models have also been used to study, among other things, terrorist recruitment (Faria and Arce 2005), guerrilla warfare (Intriligator and Brito 1988), peacekeeping (Gaver and Jacobs 1997), primitive warfare among people groups (Beckerman 1991), historical battles (e.g., Weiss 1966, Hartley and Helmbold 1995, Lucas and Turkes 2003), and war among social animals and insects (e.g., Adams and Mesterton-Gibbons 2003, Plowes and Adams 2005). For an extensive overview of quantitative methods of combat analysis, see Przemieniecki (2000).

Political economy models of the consolidation or fragmentation of states emphasize a variety of variables to explain the size and number of nations in the international system, including taxation (Buchanan and Faith 1987), wealth maximization (Wittman 2000), trade openness (Alesina, Spolaore, and Wacziarg 2000), citizens' policy preferences (Bolton and Roland 1997), states' ability to defend property (McGuire 2002), international conflict and the cost of defense (Alesina and Spolaore 2006), and civil conflict (Spolaore 2008a). Spolaore (2008b) offers a concise review of the literature. For a forum on fragmented states and trans-state groups, see Stanislawski (2008). The Federation of American Scientists provides an extensive list of para-state entities, many of which can be characterized as trans-state groups (www.fas.org/irp/world/para/index.html).

10

Arms Rivalry, Proliferation, and Arms Control*

Born in the tense early years of the Cold War, conflict economics has long been interested in arms rivalry, proliferation, and arms control. In this chapter we provide a summary of key principles and research results in this historically important branch of conflict economics. We begin with definitions followed by an empirical overview of military spending, weapons of mass destruction, and arms control treaties. We then return to the historical roots of conflict economics by sketching the seminal arms race models of Richardson and Intriligator and Brito. To these we add a rational choice model that highlights the interdependence of economics and security in issues of defense spending, arms rivalry, and arms control. Applications to historical and contemporary arms rivalries are presented, including possible proliferation of nuclear weapons to Iran, strategic implications of deployment of US antiballistic missile technology in Europe, and decay of the Soviet economy during the Cold War. We also briefly survey selected empirical studies, focusing on the structure of interstate arms rivalries, arms racing and the risk of war, and risk factors for nuclear weapons proliferation.

10.1. Definitions

An arms rivalry is a competitive increase in the weapons quantities or qualities of two or more parties. Arms rivalries are typically thought of as occurring between states, but they can also occur within states and can

* Sections 10.1, 10.3, and parts of 10.4 and 10.6 of this chapter are adapted from Charles H. Anderton and John R. Carter, "A Survey of Peace Economics," published in *Handbook of Defense Economics*, volume 2, edited by Todd Sandler and Keith Hartley, pp. 1211–1258, Copyright © Elsevier 2007. We gratefully acknowledge Elsevier's permission to republish material from the article.