TREATIES: STRATEGIC CONSIDERATIONS

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This paper presents a rationalist approach to treaty formation and adherence, where nations are motivated by their self-interest in a strategic framework that accounts for other nations' responses. Key considerations include coordination games, dynamic cooperation, institutional design, and the aggregation technology of public supply. Dynamic aspects involve multilateral cooperation under a variety of game forms. Treaty design is essential in motivating nations to fulfill obligations without the need for enforcement. Some properties of public goods, such as the manner in which individual contributions determine the available consumption level, have a crucial influence over nations' incentives to adhere to treaties once ratified. The role of morality and conformity are captured in the strategic framework presented.

I. INTRODUCTION

In a provocative paper and subsequent book, Goldsmith and Posner (henceforth, "G & P") have rejected the standard "explanations of CIL [customary international law] based on *opinio juris*, legality, morality, and related concepts."[1] They have, instead, taken a positivist, rationalist viewpoint of CIL in which unitary actors, representing countries, are driven by self-interest and strategic considerations. The latter accounts for game-theoretical interactions among states, whereby an agent adjusts for how its counterparts will react to the agent's actions. G & P characterized CIL as stemming from four rationalist explanations: (i) coincidence of interests, (ii) coercion by powerful agents, (iii) cooperation motivated by a bilateral repeated Prisoner's Dilemma, and/or (iv) a bilateral

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1. Jack L. Goldsmith & Eric A. Posner, *A Theory of Customary International Law* 3 (Chicago Working Paper Series, John M. Olin L. & Econ. Working Paper No. 63, 1999), *available at* http://www.law.uchicago.edu/Lawecon/WkngPprs_51-75/63.Goldsmith-Posner.pdf [hereinafter Goldsmith & Posner, *Theory*]; *see also* JACK L. GOLDSMITH & ERIC A. POSNER, THE LIMITS OF INTERNATIONAL LAW 23–26 (2005) [hereinafter GOLDSMITH & POSNER, LIMITS].

problem of coordination.[2] In the absence of a central authority or an enforcer, G & P looked to these four factors as the foundation of CIL. Their viewpoint has evoked strong reactions from some CIL scholars who indicated that it excluded standard compliance theories,[3] where actions are motivated by a sense of legitimacy and justice.[4] Rather than rejecting the rationalist approach, van Aaken criticizes G & P's efforts at applying game-theoretical notions. In her view, their efforts do not go far enough—for example, multilateral solutions to Prisoner's Dilemmas are not addressed; law-making and law-taking actions are not adequately differentiated; and sufficient empirical support for their view is not presented.[5]

The purpose of this paper is to extend and modify G & P's interesting and useful approach in order to apply it to treaties, a second category of public international law. This exercise is partly motivated by van Aaken's critique of the G & P book. In the current paper, game-theoretical notions are applied to explain the formation and form of international treaties that are often designed to formalize multilateral solutions to transnational public goods and externality problems.[6] Strategic factors can also influence nations' adherence to treaties—a nation whose emissions result in a high portion of self-pollution is motivated to abide by a treaty, especially if the treaty also constrains some upwind neighbors. Unlike G & P, I recognize that morality and legality may also play a role in international law, and indicate how these considerations can be fitted into a rationalist framework for the study of treaties. Constituencies' concern for morality can, in part, induce nations to include such considerations in their calculus for computing net transaction benefits associated with treaty participation. The application of game theory to explain various aspects of treaty making and treaty adherence dates back to the late 1980s in economics.[7] Since the latter 1990s, economists

2. Goldsmith & Posner, *Theory*, *supra* note 1, at 2–3.

3. Compliance theory includes a regime theoretical managerial model of ABRAM CHAYES & ANTONIA HANDLER CHAYES, THE NEW SOVEREIGNTY: COMPLIANCE WITH INTERNATIONAL REGULATORY AGREEMENTS (1995), and a procedural model of THOMAS M. FRANCK, FAIRNESS IN INTERNATIONAL LAW AND INSTITUTIONS (1995).

4. *See, e.g.*, Anne van Aaken, *To Do Away with International Law? Some Limits to the 'The Limits of International Law*,' 17 EUR. J. INT'L L. 289, 291 (2006).

5. *See id.* at 295, 292, 306.

6. A transnational public good (or public bad) provides benefit (or cost) spillovers to more than one country. Some transnational public goods (e.g., limiting stratospheric ozone shield depleters) can result in global spillovers, while others (e.g., eliminating a pest) may be regional. A transnational externality is an uncompensated interdependency involving two or more countries.

7. *See, e.g.*, SCOTT BARRETT, ENVIRONMENT AND STATECRAFT: THE STRATEGY OF ENVIRONMENTAL TREATY-MAKING (2003); ECONOMIC POLICY TOWARDS THE ENVIRONMENT (Dieter Helm ed., 1991); Scott Barrett, *Self-Enforcing International Agreements*, 46 OXFORD ECON. PAPERS 878 (1994); Michael Finus & Sigve Tjøtta, *The Oslo Protocol on Sulfur Reduction: The Great Leap Forward?*, 87 J. PUB. ECON. 2031 (2003); Karl-Goran Mäler, *The Acid Rain Game*, *in* VALUATION METHODS AND POLICY MAKING IN ENVIRONMENTAL ECONOMICS: SELECTED AND INTEGRATED PAPERS FROM THE CONGRESS 'ENVIRONMENTAL POLICY IN A MARKET ECONOMY' 231

and political scientists have been devising empirical tests that capture the strategic underpinnings of these game-theoretical representations.[8] I refer to some of these tests for empirical support; at times, I provide anecdotal support.

It is my contention that treaties are ratified when the anticipated net transaction benefits are positive for *all ratifying parties* at the time of signing. Treaties are self-enforcing if countries anticipate a net gain from adhering to treaty stipulations despite changing circumstances. As shown below, the expected actions—i.e., adherence—of other ratifiers are an essential consideration when a country decides its own actions under the treaty. Anything that increases the likelihood that other countries will honor their obligations will, in turn, induce a country not only to ratify the treaty but also to abide by its provisions. For simplicity, I treat ratification and adherence as a single decision. In a more advanced analysis, these two stages can be treated separately, where a consistent subgame perfect equilibrium is displayed. Changing circumstances can be accommodated through an amendment process, so that treaties remain self-enforcing over time. This paper, however, does not investigate the amendment process per se. As provided here, a game-theoretic framework is associated with expected net gains that induce compliance. It is *not* associated with enforcement mechanisms, which are problematic, because they pose a collective action dilemma that is often ignored.

The remainder of the paper contains eight parts. In Part II, preliminaries are presented that set the stage for the ensuing analysis. The paper's overall thesis is indicated in Part III, followed by an analysis of multilateral coordination problems in Part IV that expands on G & P's coordination representation. In Part V, dynamic cooperation is investigated in a coordination framework. The facilitating nature of institution or treaty design is studied in Part VI. Part VII discusses the importance of the aggregation technology of public supply on treaty formation and compliance. In Part VIII, morality and conformity notions are integrated into the analysis. Part IX provides summary and concluding remarks.

II. PRELIMINARIES

In the realm of international law, public international law governs interactions among countries, while private international law controls transactions among citizens and/or companies (i.e., private agents) from

(H. Folmer & E. van Ierland eds., 1989); Todd Sandler & Keith Sargent, *Management of Transnational Commons: Coordination, Publicness, and Treaty Formation*, 71 LAND ECON. 145 (1995).

8. *See, e.g.*, James Murdoch, Todd Sandler & Wim P.M. Vijverberg, *The Participation Decision versus the Level of Participation in an Environmental Treaty: A Spatial Probit Analysis*, 87 J. PUB. ECON. 337 (2003); James C. Murdoch, Todd Sandler & Keith Sargent, *A Tale of Two Collectives: Sulphur versus Nitrogen Oxides Emission Reduction in Europe*, 64 ECONOMICA 281 (1997); James C. Murdoch & Todd Sandler, *The Voluntary Provision of a Pure Public Good: The Case of Reduced CFC Emissions and the Montreal Protocol*, 63 J. PUB. ECON. 331 (1997).

two or more countries.[9] Public international law can be further subdivided into CIL and treaties. In the case of CIL, states are characterized as recognizing and adhering to certain accepted practices (e.g., passage of neutral ships or treatment of prisoners of war) as an essential obligation. Treaties are written documents that bind signatories to stipulated actions. Frequently, treaties indicate responses to contingencies with an amendment process if circumstances alter. For instance, the Montreal Protocol on Substances that Deplete the Ozone Layer has, thus far, been amended four times to allow for more stringent reductions and the addition of new ozone depleters to the list of controlled substances (the London Amendment raised chlorofluorocarbons (CFCs) cuts from 50% to 85% of 1986 levels, while the Copenhagen Amendment designated hydrochlorofluorocarbons (HCFCs) and hydrobromochlorofluorocarbons as controlled depleters).[10] Treaties typically provide for a dispute resolution mechanism among signatories that may or may not deter misbehavior, depending on the ability to spot noncompliance and the costliness of the punishment. Although there are some subtle differences between the two components of public international law, G & P are right to suggest that CIL principles can also be applied to treaties.[11]

Treaties are frequently used to provide public goods or to limit public bads.[12] A public good displays two essential properties: nonrivalry and nonexcludability of benefits. Similarly, public bads possess nonrival and nonexcludable harm, control of which results in a public good. Benefits are nonrival when a unit of the good can be consumed by one agent without detracting, in the slightest, from the consumption opportunities still available for others from the same unit. A nonrival good can literally be used again and again without diminution in the consumption experience. For example, a thicker stratospheric ozone shield can be enjoyed by the residents of one nation without limiting the protection derived by residents of other nations. If benefits of a good are available to all once the good is supplied, then its benefits are nonexcludable. A thicker ozone shield is also nonexcludable to all nations. Nonexcludability results in free riding because agents will receive the benefits of the good even if they do not contribute. By free riding, these benefit recipients can use their scarce resources to purchase other goods and services for which a free ride is not possible. At the international level, actions to curb global warming or sulfur emissions will help those who limit pollut-

9. On this distinction, see Alan O. Sykes, *The Economics of Public International Law* 3–5 (Chicago Working Paper Series, John M. Olin L. & Econ. Working Paper No. 216, 2004), *available at* http://www.law.uchicago.edu/Lawecon/WkngPprs_201-25/216-aos-handbook.pdf. This paper is an excellent survey on the topic. Also see the earlier survey, Jeffrey L. Dunoff & Joel P. Trachtman, *Economic Analysis of International Law*, 24 YALE J. INT'L L. 1, 22–43 (1999).

10. TODD SANDLER, GLOBAL COLLECTIVE ACTION 216 (2004).

11. Goldsmith & Posner, *Theory*, *supra* note 1, at 5, 26.

12. TODD SANDLER, GLOBAL CHALLENGES: AN APPROACH TO ENVIRONMENTAL, POLITICAL, AND ECONOMIC PROBLEMS 15–19 (1997).

ing activities and those who do not. Treaties provide a means for nations to set contribution requirements for transnational public goods (or public bads) to ameliorate free riding. In particular, treaties have provided for common defense efforts in an alliance (the North Atlantic Treaty Organization),[13] the control of pollutants (the Helsinki Protocol on sulfur emissions),[14] and capital requirements of banks (the Basle Capital Accord among the Group-of-10 nations).[15] For global and regional commons, treaties can limit actions that degrade the shared resource. Treaties can also regulate transnational externalities.

III. OVERALL THESIS

I view nations as strategic players that sign treaties that they view as possessing positive net transaction benefits, after subtracting the transaction costs associated with treaty participation. In calculating these benefits, a nation also accounts for its constituency's interests and election concerns. At least seven considerations influence the formation and form of treaties. Four of these considerations have some overlap with G & P's drivers for CIL. First, like G & P suggested, there must be a coincidence of interests so that a treaty is incentive compatible in the sense that participants achieve a net gain.[16] I would, however, add that this coincidence must account for the strategic-based actions and reactions of others. The anticipated actions of others are an essential consideration. Second, treaty-framing nations may coerce others to join in order to augment the framers' gain. For example, framers of the Montreal Protocol gave inducements (promised financing for CFC substitution) and threatened punishments (trade boycotts) to increase participation.[17] Third, *multilateral* coordination figures prominently in treaty formation and structure, a contrast to G & P's explanation of CIL which stressed bilateral coordination.[18] Fourth, dynamic multilateral cooperation involves various game forms, not just Prisoner's Dilemma.[19] When extended to a

13. North Atlantic Treaty, Apr. 4, 1949, 63 Stat. 2241, 34 U.N.T.S. 243.

14. Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on the Reduction of Sulphur Emissions or Their Transboundary Fluxes by at Least 30 Per Cent, July 8, 1985, 1480 U.N.T.S. 217 [hereinafter Helsinki Protocol on Sulfur Emissions].

15. To attract capital inflows, nonmember nations of the Basle Accord become compelled to adopt identical requirements and practices to maintain the appearance of solvency. Such practices served as a solvency signal so that nonmembers mimicked the signatory countries' behavior. *See* DANIEL G. ARCE M. & TODD SANDLER, REGIONAL PUBLIC GOODS: TYPOLOGIES, PROVISION, FINANCING, AND DEVELOPMENT ASSISTANCE 25 (2002); WOLFGANG H. REINICKE, GLOBAL PUBLIC POLICY: GOVERNING WITHOUT GOVERNMENT? 117 (1998).

16. Goldsmith & Posner, *Theory*, *supra* note 1, at 27–28.

17. *See* RICHARD ELLIOT BENEDICK, OZONE DIPLOMACY: NEW DIRECTIONS IN SAFEGUARDING THE PLANET 54, 81 (1991); SANDLER, *supra* note 10, at 41.

18. Goldsmith & Posner, *Theory*, *supra* note 1, at 29–35.

19. In a prisoner's dilemma, two players face similar incentives to two suspects held in custody for interrogation. Each suspect has two choices, to confess or to remain quiet, but neither knows what action the other will choose. There is enough evidence to convict both suspects of lesser offenses. If both remain quiet, both will receive minimal time, three years. If one confesses, she will receive a sen-

repeated-game framework, many game forms imply a greater degree of cooperation than the Prisoner's Dilemma. Fifth, institutional design or innovation can create the right incentives and are an essential part of the treaty-making process. Even slight changes in the institutional rules can transform reluctant nations into willing participants, especially for multilateral situations. Sixth, supportive aggregation technologies of public supply, which indicate how individual contributions determine the overall level of public goods consumption, can motivate treaty participation. Seventh, morality-induced private gains can be incorporated as further incentives to sign treaties. It is not necessary to ignore these private legal motives when examining treaty participation in a strategic framework, since they merely bolster other perceived benefits.

The seven drivers above highlight the strategic factors that affect the underlying game and, thus, the incentives for treaty participation and subsequent adherence. Because coincidence of interests and coercion was carefully presented by G & P in a similar context, I shall focus on the other five influences of treaties.

IV. COORDINATION GAMES

For many, but not all, transnational treaties, a minimal degree of multilateral coordination is required if an agreement is to have an impact—e.g., eliminating terrorist safe havens, freezing terrorist funds, reducing drug trafficking, or limiting pollution. For terrorist safe havens, even a few nations that offer safe havens to terrorists can eliminate the gains from those who deny safe havens.[20] Similarly, it is apparent that even a few nations that do not freeze terrorist assets can keep risks high, particularly when one realizes that the bomb that caused $550,000 in damages to the World Trade Center on February 26, 1993 cost just $400 to build.[21] Thus, nonparticipating nations can severely compromise the gains achieved by some international agreements. To capture this strategic scenario, I use a stag-hunt game where the cooperative gains are only achieved when a sufficient number of nations adhere to the treaty or

tence of one year and testify against the other who will receive a harsher sentence of twenty-five years. If both suspects confess, they will each receive ten years. Remaining quiet can lead to the worst outcome for one suspect, if the other chooses to confess in hopes of achieving a free ride. Although cooperating to remain quiet achieves a more optimal outcome, the temptation to confess achieves either the best outcome (three years) or avoids the worst (twenty-five years). This temptation induces both prisoners to confess, thereby resulting in ten-year sentences for each. For further explanation of the Prisoner's Dilemma model, see AVINASH DIXIT & SUSAN SKEATH, GAMES OF STRATEGY 90–92 (2d ed. 2004).

20. *See* Todd Sandler, *Collective Versus Unilateral Responses to Terrorism*, 124 PUB. CHOICE 75, 85–87 (2005).

21. Bruce Hoffman, *Terrorism Trends and Prospects*, *in* COUNTERING THE NEW TERRORISM 7, 29 (Ian O. Lesser et al. eds., 1999).

agreement.[22] Bilateral stag-hunt games are generalized to a multilateral situation.

Matrix *a* of Figure 1 represents the basic two-nation stag-hunt game where each nation has two strategies: cooperate (C) and defect (D). Nation 1 is the row player, and nation 2 is the column player. In the game matrices of Figure 1, nation 1's payoff is on the left and nation 2's payoff is on the right. Mutual cooperation gives each nation a payoff of 2, while defecting alone or together provides a payoff of 1. If one nation cooperates alone, then it receives 0.[23] This game has no dominant strategy because neither player is better off playing a strategy regardless of the other player's action—i.e., 2 > 1, but $0 \not> 1$. There are two pure-strategy Nash equilibriums: mutual cooperation and mutual defection.[24] At either

FIGURE 1
ALTERNATIVE STAG-HUNT GAMES

Matrix *a*

		Nation 2 C	Nation 2 D	
Nation 1	C	**2, 2**	0, 1	p
	D	1, 0	**1, 1**	$1 - p$
		q	$1 - q$	

Matrix *b*

		Nation 2 C	Nation 2 D	
Nation 1	C	***m*, *m***	0, 1	p
	D	1, 0	**1, 1**	$1 - p$
		q	$1 - q$	

Matrix *c*

		C	D	
Nation 1	C	***U*, *U***	B, E	p
	D	E, B	***A*, *A***	$1 - p$
		q	$1 - q$	

Matrix *d*

		C	D	
Nation 1	C	***U − T*, *U − T***	$B - t, A$	p
	D	$A, B - t$	***A*, *A***	$1 - p$
		q	$1 - q$	

22. In a stag-hunt game, each player has two choices: hunt stag or hunt hare. Todd Sandler & Keith Sargent, *Management of Transnational Commons: Coordination, Publicness, and Treaty Formation*, 71 LAND ECON. 145, 146–47 (1995). Both hunters must cooperate to capture a stag, earning each two points. *Id*. If one player defects and hunts hare, she receives one point for the hare, and the other hunter receives zero points for hunting stag alone. *Id*. If both defect and hunt hare, both receive one point. *Id.*

23. In the original stag-hunt game, the players can hunt a stag, which requires multiple players to be successful, or hunt hare, which requires no cooperation. *Id.* at 146–48.

24. A Nash equilibrium exists when no alternative strategy can increase a player's payoff, given the other players' strategies. DIXIT & SKEATH, *supra* note 19, at 87. In a stag-hunt game, if one player chooses to hunt hare, the other player will achieve a pure-strategy Nash equilibrium by choosing to also hunt hare because the alternative, to hunt stag, earns zero points. Sandler & Sargent, *supra* note 22, at 145–47.

Nash equilibrium, neither player would *unilaterally* want to change its strategy. Mutual cooperation is the focus equilibrium owing to its higher payoffs. Neither nation can be sure of the other nation's action and would not want to be stuck with a payoff of 0.

A third Nash equilibrium involves mixed strategies in which each pure strategy is played in a probabilistic fashion. To uncover this mixed-strategy equilibrium, we determine the probability q of cooperation *on behalf of nation 2* that makes nation 1 indifferent between strategy C and D. That is, set

$$2q + 0(1 - q) = 1q + 1(1 - q)$$

and solve for q. Similarly, we can find the equilibrium probability p of cooperation on behalf of nation 1 that makes nation 2 indifferent between its two strategies. Once p and q are found, the mixed-strategy Nash equilibrium probabilities for defecting—$(1 - p)$ and $(1 - q)$—follow immediately. Thus, in this exercise,

$$p = q = ½ \text{ for matrix } a.$$

If, therefore, nation 1 is uncertain about nation 2's intentions, then nation 1 should cooperate, provided that it anticipates that nation 2 will also cooperate with a probability greater than ½. Lower values to these "adherence" probabilities mean that cooperation is more certain, since less certainty of cooperation by the other nation is required to induce cooperation.

In a treaty context, cooperation is abiding by the treaty's provision. For matrix b, the payoff for mutual cooperation is raised to $m > 2$ for both players. The mixed-strategy Nash equilibrium is now

$$p = q = 1/m < ½,$$

which implies that cooperation is more likely as the adherence probability falls. Similarly, it can be shown that smaller gains from defecting or greater gains from cooperating alone lower probabilities p and q and, thus, make treaty adherence more likely.

The analysis can be extended for multiple homogeneous nations. Suppose that nine nations must abide by a treaty so that each receives a payoff of 2, while any number of cooperators less than nine gains nothing from the treaty. Further suppose that independent behavior of defecting gives a payoff of 1. If nations are uncertain about the actions of others, then each nation would cooperate provided that they anticipate that *all eight* other nations in aggregate would cooperate with probability greater than ½. When nations' probabilities are *independent*, each nation must then cooperate with probability greater than 0.9170 (the eighth root of .5) for cooperation to be the desired strategy. Two lessons for treaties that require a minimal-sized coalition follow immediately. The larger the minimal number of cooperators, the harder it is to form multilateral treaties. Moreover, even a rather modest-sized group of core adherents may require near certainty of cooperation when adherence probabilities are independent. These two insights lend support for G & P's focus on bilateral CIL and treaties.

There are, however, opposing factors that attenuate this pessimism. One must remember that there are many examples of multilateral treaties, some of which (e.g., Montreal Protocol on Substances that Deplete the Ozone Layer) involve large numbers of signatories.[25] First, some treaties do not require minimal-sized coalitions for benefits to be received. In these cases, nonparticipation does not undo the gains achieved by the treaty members. For example, efforts by nations to preserve species in some endangered habitats cannot be annihilated by lack of action in other habitats. Second, coordination probabilities may not be independent as assumed. If these probabilities are correlated, then the likelihood of cooperation increases. This correlation can be achieved through the leadership of a major country, whose actions induce others to act.[26] The United States, Canada, and the Scandinavian countries served in this leadership role for the Montreal Protocol.[27] Leadership can also focus attention on the desired equilibrium for coordination games with multiple equilibriums.[28] If, in matrix *a* or *b*, nation 1 leads and cooperates, then nation 2 will follow suit since a payoff of 2 is preferred to a payoff of 1. Third, preplay communication or cheap talk can also increase the likelihood of coordination, but may not eliminate the uncertainty for some kinds of coordination games. A main purpose of treaty negotiation is to provide this preplay communication. Conventions, such as The Vienna Convention for the Protection of the Ozone Layer,[29] precede protocols that mandate action, so that a round of cheap talk takes place.

The next generalization of the stag-hunt representation of treaties in matrix *c* provides more varied payoffs by allowing the payoff A associated with mutual defection to differ from cooperating alone with payoff B or defecting alone with payoff E. Mutual cooperation provides the greatest gain of U for the two nations. Two reasonable scenarios can characterize the orderings of these payoffs:

$$U > A > E > B \text{ and } U > E > A > B.$$

The game again has two pure-strategy Nash equilibriums of mutual cooperation (i.e., the treaty solution) and mutual defection. The mixed-strategy Nash equilibrium is:

$$p = q = (A - B)/[U - B + (A - E)]. \qquad \text{(equation 1)}$$

25. Mario Molina, *The Ozone Treaty Can Do Much More for the Planet*, FIN. TIMES (Asia), Aug. 24, 2007, at 11.

26. On leadership, see C. FORD RUNGE, FREER TRADE, PROTECTED ENVIRONMENT: BALANCING TRADE LIBERATION AND ENVIRONMENTAL INTERESTS 84–108 (1994).

27. BENEDICK, *supra* note 17, at 6–7.

28. *See* Daniel G. Arce M., *Leadership and the Aggregation of International Collective Action*, 53 OXFORD ECON. PAPERS 114, 126–32 (2001).

29. *See* BENEDICK, *supra* note 17, at 40–50.

If A is greater than E, then cooperation is promoted because the adherence probabilities are smaller; if, alternatively, E is greater than A, then cooperation is hindered because the adherence probabilities are higher. The first scenario corresponds to a situation where cheating alone does not pay, while the second scenario reflects a situation where cheating alone does pay. Treaty rules that punish defectors are intended to reduce E so that signatories fulfill their obligations. This punishment can involve a loss of treaty membership benefits or explicit punishments.

A. Transaction Costs

Unlike CIL, treaties involve transaction costs for administration, communications, enforcement, monitoring, and institutional innovations, which hamper treaty formation and adherence. Transaction costs are included in matrix *d*, where mutual cooperation engenders more transaction costs, T, than partial cooperation, t, so that T is greater than t. If $U - T > A$, then the pure-strategy Nash equilibriums for this two-nation representation are again mutual cooperation and mutual defection. The mixed-strategy Nash equilibrium is:

$$p = q = (A - B + t) / [U - (T - t) - B]. \qquad \text{(equation 2)}$$

A number of different cases can be distinguished. First, suppose that t equals 0, then transaction costs raise the adherence probabilities, thereby reducing the possibility of cooperation. This follows because the gain from mutual cooperation falls. If t equals T, then transaction costs again hinder coordination by raising the adherence probabilities:

$$p = q = (A - B + T)/[U - B]. \qquad \text{(equation 3)}$$

When T is greater than t, the adherence probabilities in equation 2 are less than those in equation 3, because the same positive factor, $(T - t)$, has been subtracted from the numerator and denominator on the right-hand of equation 3. Each nation is now willing to cooperate with less certainty that the other nation will follow suit. This follows because the losses from misjudging the other player's intention to cooperate $(U - T - (B - t))$ are now smaller.

B. Transaction Costs and Group Size, n

The influence of transaction costs is illustrated for t equals T, because this simpler case captures the essential insights. A nation will coordinate provided that the collective likelihood of coordination of the other $n - 1$ nations is at least

$$(A - B + T)/(U - B)$$

for independent probabilities. This then requires each of these nations to have a likelihood of coordination greater than

$$\sqrt[n-1]{\frac{A-B+T}{U-B}}\ .$$

This stringent requirement is attenuated, because a treaty acts as a device that reduces the adherence probabilities by correlating nations' actions. In another relevant case, transaction costs rise as the minimal number, n, of coordinators increases, while coordination benefits are independent of n. In this scenario, an increase in n reduces the likelihood of coordination, but at a greater rate than previously, because n not only raises the adherence probabilities, but also the number of roots of this probability that must be found. If, instead, n increases U and T proportionally, then $U - T$ is unchanged but the payoff from failed cooperation, $B - T$, falls, so that n again works against the achievement of coordination.

An increase in transaction costs and/or the minimal-sized coalition typically works against coordination and treaty formation. There are, however, practical circumventions. For the Montreal Protocol, there were only a few major emitters—just twelve countries accounted for over seventy-eight percent of emissions—at the time of framing in 1987.[30] Thus, the minimal-sized group was small, and consequently, the mandated number of ratifiers was kept modest, provided that the main polluters were aboard.[31] Given the dire consequences in terms of health and environmental risks, the United States and other major CFC users saw net gains from using CFC substitutes even without others joining in.[32] This meant that actions would be correlated because many of these nations viewed the gains from CFC cutbacks similarly. Once the Montreal Protocol was ratified by its core supporters, these nations forced or bribed others to join.[33] Regional pollution treaties—e.g., the Helsinki Protocol on sulfur emissions—limit n through geographical identity. For the Helsinki Protocol, the main promoters were those countries with significant self-pollution or spillovers from other countries.[34]

V. DYNAMIC COOPERATION

For CIL, G & P only examined bilateral Prisoner's Dilemma as grounds for dynamic cooperation where nations adhere to an international law or custom because the short-run gains from defecting do not outweigh the long-run consequences from lost cooperative gains as the nation's counterpart punishes the defector.[35] This dynamic cooperation

30. SANDLER, *supra* note 10, at 217.
31. BENEDICK, *supra* note 17, at 89–90.
32. SANDLER, *supra* note 10, at 218–19.
33. BENEDICK, *supra* note 17, at 183–88.
34. SANDLER, *supra* note 10, at 225–32.
35. *See* Goldsmith & Posner, *Theory*, *supra* note 1, at 27.

depends on the interactions being repeated indefinitely[36] and nations valuing the future—i.e., they possess a sufficiently high discount factor, *r*. This same rationale for dynamic cooperation also applies to treaties, and holds true for many game forms in bilateral and multilateral scenarios. In fact, treaties are written documents that, among other things, give permanency to an agreement and often possess a punishment mechanism to reduce short-run gains from defecting. I take up van Aaken's challenge to display a dynamic multiplay model in the case of treaty formation.[37]

FIGURE 2
REPEATED STAG-HUNT GAME

		Nation 2			
		Grim	Tit-for-tat	Cooperate	Defect
Nation 1	Grim	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{r}{1-r},\frac{1}{1-r}$
	Tit-for-tat	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{r}{1-r},\frac{1}{1-r}$
	Cooperate	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{2}{1-r},\frac{2}{1-r}$	$\frac{2}{1-r},\frac{2}{1-r}$	$0,\frac{1}{1-r}$
	Defect	$\frac{1}{1-r},\frac{r}{1-r}$	$\frac{1}{1-r},\frac{r}{1-r}$	$\frac{1}{1-r},0$	$\frac{1}{1-r},\frac{1}{1-r}$

Grim: Cooperate in the first round, and then defect in perpetuity once the other player defects.
Tit-for-tat: Cooperate in the first round; then match the opponent's choice in the preceding round.
Cooperate: Cooperate in perpetuity.
Defect: Defect in perpetuity.

I begin with a two-nation representation of the stag-hunt game where matrix *a* in Figure 1 represents the game that is repeated indefinitely. Each nation is permitted four intertemporal strategies or pro-

36. The future also matters if the interaction has an unknown endpoint so that the number of repeated plays is unknown. *See also* George Norman & Joel P. Trachtman, *The Customary International Law Game*, 99 AM. J. INT'L L. 541 (2005). These authors show that CIL may be self-enforcing in multilateral Prisoner's Dilemmas if the future is valued and interactions are infinitely repeated. As such, their analysis is complementary to my approach.
37. *See* van Aaken, *supra* note 4, at 295–96.

grams of play: (1) Grim, (2) Tit-for-tat, (3) Cooperate in perpetuity (called Cooperate), and (4) Defect in perpetuity (called Defect). A Grim strategy has a nation begin with Cooperate in the first round. The nation continues to cooperate until its counterpart defects, from which point the nation defects henceforth as a punishment. For Tit-for-tat, a nation cooperates in the first round and then mimics the other nation's choice in the preceding round—i.e., a defection is paid back with a defection in the next round. Cooperate and Defect have a nation either cooperating or defecting in every round, respectively, regardless of its counterpart's actions in preceding rounds.

The matrix form for this game is displayed in Figure 2 where nation 1 is the row player and nation 2 is the column player. Again, nation 1's payoff is on the left and nation 2's payoff is on the right. In the sixteen payoff cells, r is the discount factor that equals $(1 + i)^{-1}$, where i is the interest rate. If, say, both nations use a Grim strategy, then each cooperates in the first round and thus in every round thereafter, since there will be no defection to trigger the punishment phase. Both nations thus get 2 in every round, with a present value of

$$2 + 2r + 2r^2 + 2r^3 + \ldots,$$

which equals $2/(1 - r)$ as indicated. If, instead, nation 1 plays Defect and nation 2 plays Grim, then nation 1 receives a payoff of 1 in every round for a present value of $1/(1 - r)$. Nation 2, however, receives 0 in the first round and 1 thereafter for a present value of

$$r/(1 - r) = r + r^2 + r^{3\cdots}.$$

The other payoffs are computed in a similar fashion. There are ten Nash equilibriums, indicated in boldfaced payoffs—nine equilibriums involve high payoffs. Perpetual defection by both nations is a nonfocal Nash equilibrium. Hence, dynamic considerations foster cooperation. The same holds for an infinitely repeated Prisoner's Dilemma; however, the number of favorable equilibriums are reduced.[38]

Next suppose that n symmetric nations play the same game, where all nations receive 2 when they cooperate in a round. Defection gives a nation a payoff of 1, while insufficient cooperation offers a cooperator a payoff of 0. Suppose that each nation has the four intertemporal strategies in Figure 2. All combinations of n nations where one or more play Grim and the rest play Tit-for-tat or Cooperate provide payoffs of $2/(1 - r)$ for all nations and are Nash equilibriums for this repeated game. However, combinations of strategies that include Defect (for any number of nations) along with Grim, Tit-for-tat, or Cooperate are *not* Nash equilibriums. There are, nevertheless, a plethora of Nash equilibriums. The nonfocal Nash equilibrium is where all n nations defect.

38. RICHARD CORNES & TODD SANDLER, THE THEORY OF EXTERNALITIES, PUBLIC GOODS, AND CLUB GOODS 316–17 (2d ed. 1996).

Clearly, repeated bilateral and multilateral games have favorable prognoses. As such, they provide an optimistic foundation to treaties that routinize these repeated cooperative interactions through a written document and institutionalized enforcement mechanism.

VI. INSTITUTIONAL DESIGN

Unlike CIL, treaties can use design principles to promote self-enforcement where adherence is engineered to be in the signatories' interests. Even the most problematic incentive structures can be set right by some simple institutional adjustments. These adjustments are not purely academic, but are used in practice.

In Figure 3, matrix *a* is a five-nation Prisoner's Dilemma where every unit of a pure public good gives each nation a benefit of 4 at a cost of 6 just to the contributor. All nations are assumed to be homogeneous. The payoffs listed are those of representative nation *i* for alternative contribution patterns of the other four nations. Each nation has two strategies: contribute nothing or contribute one unit of the public good. If nation *i* contributes nothing, then it receives 4 from every other contributor's effort—e.g., with three other contributors, *i* gains 3 × 4 = 12. When nation *i* contributes alone, it receives -2 as costs of 6 are deducted from benefits of 4. If nation *i* contributes along with two other nations, then *i* nets 6 as a cost of 6 is subtracted from its benefits of 12, derived from the three units contributed in total. In the bottom row, the other payoffs are computed in a similar fashion. The dominant strategy is for *i* to free ride and contribute nothing, because all of the payoffs in the top row are greater than the corresponding values in the bottom row. As *i* and the other four nations exercise their dominant strategy, the outcome is the Nash equilibrium where no one contributes.

FIGURE 3
PRISONER'S DILEMMA AND COST SHARING

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	**0**	4	8	12	16
i contributes	–2	2	6	10	14

a. Prisoner's Dilemma (*b = 4*, *c = 6*)

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	0	2.8	5.6	8.4	11.2
i contributes	2.8	5.6	8.4	11.2	**14**

b. Cost sharing (*b* = 4, *c* = 6/5)

In matrix *b*, cost sharing is permitted where nations agree to split the cost for each unit of the public good provided. If, therefore, nation *i* contributes alone, it only pays 6/5 in costs with the other four nations paying 6/5 each of the cost of *i*'s contribution. Nation *i* receives a net payoff of 2.8, which is the same gain as when some other nation contributes. If *i* and one other nation contributes, then *i* receives 5.6, which is the differences between 8 in benefits from the two units contributed and 2.4 in costs (2 × (6/5)). With cost sharing, the dominant strategy is to contribute and the Nash equilibrium is the social optimum with all five nations contributing for a gain of 14 for each nation. Any cost-sharing scheme will have this favorable outcome, provided that the per-unit benefit *b* exceeds per-unit shared costs of *c/n*, where *n* is group size. This result follows because cost sharing removes free-riding incentives and places each nation in the position of gaining from each unit. In essence, cost sharing works like a preference-revelation mechanism. For the Montreal Protocol on Substances that Deplete the Ozone Layer, cost sharing characterizes the Multilateral Fund, for which rich signatories jointly finance the switch from CFCs to nondepleting substances for the poor countries.[39] In the United Nations, the costs of peacekeeping missions have been covered since 1974 by cost-sharing arrangements.[40] Cost sharing characterizes the funding of the United Nations, where agreed-upon membership fees underwrite operations and the infrastructure.[41] In the International Monetary Fund (IMF), countries with higher cost shares (i.e., "quotas") cast more votes in IMF decisions as a reward.[42] This quota system provides an incentive for generosity.

The need to achieve a threshold contribution can also work in favor of public good provision or the adherence to a treaty condition—e.g., satisfying a stipulated cutback in pollution. In Figure 4, the influence of some institutional design principles is illustrated.[43] For convenience, matrix *a* displays the Prisoner's Dilemma where $b = 4$ and $c = 6$, because the modifications are made to this basic game. In matrix *b*, a minimal threshold of three contributors, or 3 units, must be met before each unit yields 4 in benefits to every nation at a cost of 6 to the contributors. If, say, country *i* and one other country contribute, then *i* pays its cost and gains nothing, since the threshold has not been obtained. Nation *i*'s net gain is then -6 after covering costs. This is the same outcome as when *i* is the sole provider. Free riding gains nothing until there are three or more contributors.

This game has no dominant strategy, but it does have a number of Nash equilibriums: no one contributes and *exactly* three players contribute. Because there are ten ways of picking three contributors from a group of five nations, there are, in total, eleven Nash equilibriums. Al-

39. BENEDICK, *supra* note 17, at 155–57.

40. TODD SANDLER & KEITH HARTLEY, THE POLITICAL ECONOMY OF NATO: PAST, PRESENT, AND INTO THE 21ST CENTURY 99 (1999); Hirofumi Shimizu & Todd Sandler, *Peacekeeping and Burden-Sharing, 1994–2000*, 39 J. PEACE RES. 651, 653 (2002).

41. *See* SANDLER & HARTLEY, *supra* note 40, at 99.

42. SANDLER, *supra* note 10, at 95.

43. The use of institutional design to achieve collective action success goes back to MANCUR OLSON, JR., THE LOGIC OF COLLECTIVE ACTION (1965). *See also* TODD SANDLER, COLLECTIVE ACTION: THEORY AND APPLICATIONS (1992).

though cooperation is more likely with a threshold, there is still the problem of having the required three contributors come forward, given that two nations are best off being free riders (gaining 12 instead of 6). In practice, the nations that assist efforts are those with the greatest gain if agents are not symmetric. Circumstances may also dictate how the threshold is reached. For the suppression of forest fires, nations may need to combine forces with others to contain a large fire, so that a threshold applies. The likely contributors will be the nearest or the downwind states that are most in harm's way. Because forest fire suppression represents an infinitely repeated game, nations have a real incentive to help one another if they value the future. When fighting diseases and pests, nations reach the threshold through action by rich countries and neighboring states.

FIGURE 4

PRISONER'S DILEMMA, THRESHOLDS, AND REFUNDABILITY

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	**0**	4	8	12	16
i contributes	–2	2	6	10	14

a. Prisoner's Dilemma ($b = 4$, $c = 6$)

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	**0**	0	0	12	16
i contributes	–6	–6	**6**	10	14

b. Minimal threshold of three contributors: no refunds

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	**0**	0	0	0	0
i contributes	–6	–6	–6	–6	**14**

c. Minimal threshold of five contributors: no refunds

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	0	0	0	12	16
i contributes	0	0	**6**	10	14

d. Minimal threshold of three contributors: refunds

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	0	0	0	8.4	11.2
i contributes	0	0	8.4	11.2	**14**

e. Minimal threshold of three contributors: refunds, cost sharing

Matrix *c* in Figure 4 extends the threshold to all five nations. Now, there is no positive payoff for free riding whatsoever. The only positive payoff derives from all nations contributing. The two Nash equilibriums are no one contributing and everyone contributing. This scenario is even more hopeful, because coordinating a subset of contributors is no longer necessary. Thus, a larger threshold may be conducive to treaty framing and adherence in some instances as nations have no incentive to vie for free riding.

In matrix *d*, refunds are permitted if the required threshold is not obtained. The payoffs for the three-contributor threshold are the same as those in matrix *b* except that the -6 payoffs are replaced with 0s owing to the refunds.[44] Now, contributing is a weakly dominant strategy until the threshold is reached, thereby focusing nations on the ten Nash equilibriums where the minimal coalition is achieved. Refundability is a conducive institutional strategy for treaty design. For UN peacekeeping, a peacekeeping force that is sufficient to maintain separation of belligerent sides is first determined.[45] Until there are enough peacekeepers pledged, the troops are not deployed and the payments are not assigned to the member states.[46] As such, the peacekeeping public good is refundable prior to the threshold.

Matrix *e* allows for a threshold, cost sharing, and refunds in which payoffs correspond to those of matrix *b* in Figure 3, except that payoffs are 0 until the threshold is reached. Now, the weakly dominant strategy for nation *i* and all others is to contribute. The sole Nash equilibrium is the social optimum where all nations contribute and receive 14 apiece.

There are many other institutional innovations that promote treaty framing and adherence. For example, correlation can be promoted by developing understandings about which nation should take the lead under various contingencies. In recent years, this leadership for peacekeeping has been offered by those nations nearest to the conflict—e.g., Australia for East Timor[47] and the United States for Haiti.[48]

VII. SUPPORTIVE TECHNOLOGIES OF AGGREGATION

The manner in which individual contributions determine the overall amount of the public good that is available for consumption[49]—the *technology of aggregation* or the aggregation technology of public supply—also influences strategic incentives to form and adhere to treaties. Public goods were initially characterized as a "summation technology," where the sum of individual contributions fixes the level of consumption. If, therefore, three nations each give four units, then twelve units of the

44. On refundability, generally, see Mark Bagnoli & Michael McKee, *Voluntary Contribution Games: Efficient Private Provision of Public Goods*, 29 ECON. INQUIRY 351 (1991).

45. SANDLER, *supra* note 10, at 93.

46. *Id.*

47. Australians and Peacekeeping, http://www.awm.gov.au/atwar/peacekeeping.htm (last visited Aug. 21, 2007).

48. *See* Ross Fetterly, *A Review of Peacekeeping Financing Methods*, DEF. & PEACE ECON., Oct. 2006, at 406.

49. Aggregation technologies of public supply was first discussed by Jack Hirshleifer, *From Weakest-Link to Best-Shot: The Voluntary Provision of Public Goods*, 41 PUB. CHOICE 371 (1983). *See also* CORNES & SANDLER, *supra* note 38, at 144; Daniel G. Arce M. & Todd Sandler, *Transnational Public Goods: Strategies and Institutions*, 17 EUR. J. POL. ECON. 493, 494, 496–501 (2001).

public good are consumed by the benefit recipients. A summation technology implies that all contributors' efforts are perfectly substitutable and that shortfalls by one nation can be made up by increased provision by others. The public good literature established that summation technology is behind some of the collective action difficulties that plague public goods (or public bads) and efforts, including treaties, to correct for their shortfall (or oversupply). For example, the so-called exploitation hypothesis, whereby the rich carry a disproportionate burden of the public good, is a direct consequence of summation technology.[50] This technology also bolsters free-riding incentives and makes income policies (i.e., tax-financed provision) ineffective at times.

An important alternative technology of aggregation is weakest link, where the overall consumption level of the public good equals the smallest provision amount of the contributors. An apt example is a dike around an island in a river, where the dike's lowest height determines the dryness of all island residents. Laziness on the part of one islander does not allow him or her to free ride on the diligence of another, who builds a high dike. In international relations, the least stringent efforts to monitor a deadly disease (e.g., bird flu) can determine the safety of all at-risk nations. Weakest link applies to efforts to eradicate a disease or to protect against a terror attack. In fact, weakest-link public goods are ubiquitous in international applications and are associated with treaties concerning financial practices, labor standards, transportation conventions (i.e., avoiding accidents at sea), health, and security.

Matrix *a* in Figure 5 illustrates some of the strategic aspects of a weakest-link public good that gives rise to an assurance game.[51] First, focus on the 2 × 2 game embedded in the upper-left corner of matrix *a* where nations 1 and 2 can provide one or no units of the public good. Because the smallest contribution level of the nations determines the amount available for consumption, both nations must contribute a unit at a cost of 4 each before receiving a benefit of 6. If, therefore, only one nation provides a unit, then it must cover the costs of 4 with no concomitant benefit for a loss of 4. The noncontributor receives no free ride. When both nations contribute, each earns 2 (6 – 4). The two pure-strategy Nash equilibriums are indicated in boldface, where there is matching behavior. For weakest-link public goods, there is no reason to contribute beyond the lowest provision level because there is no gain from this extra expense.

Next, suppose that each nation can contribute 0, 1, 2, or 3 units of the good at a cost of 4 per unit. *Each* matched unit gives net benefits of 2 to both nations. This scenario results in the payoff array displayed in matrix *a*. When, for example, each nation contributes three units, both re-

50. SANDLER, *supra* note 43, at 10–11.

51. On assurance games, see KEN BINMORE, FUN AND GAMES: A TEXT ON GAME THEORY 20 (1992), and SANDLER, *supra* note 43, at 38–48.

ceive 18 in benefits, from which they must cover their expense of 12 for a net gain of 6. Unmatched units lead to costs but no benefits. If nation 1 contributes a unit and nation 2 contributes three units, nation 1 gains 2 (6 – 4), while nation 2 loses 6 as it must pay 12 but only earns 6 in benefits from the single matched unit. The other payoffs are computed in a similar fashion. There are now four pure-strategy Nash equilibriums along the main diagonal involving matched contributions.

FIGURE 5
WEAKEST-LINK PUBLIC GOODS

		Nation 2			
		0	1	2	3
Nation 1	0	**0, 0**	0, –4	0, –8	0, –12
	1	–4, 0	**2, 2**	2, –2	2, –6
	2	–8, 0	–2, 2	**4, 4**	4, 0
	3	–12, 0	–6, 2	0, 4	**6, 6**

a. *Weakest link* (*b* = *6*, *c* = *4*)

		Nation 2			
		0	1	2	3
Nation 1	0	**0, 0**	0, –4	0, –8	0, –12
	1	–4, 0	–4, –4	–4, –8	–4, –12
	2	–8, 0	–8, –4	**4, 4**	4, 0
	3	–12, 0	–12, –4	0, 4	**6, 6**

b. Weakest link, threshold match of two units

The final equilibrium that results hinges on the financial capacity of the two nations. Suppose that nation 1 is relatively better off so that nation 2 chooses the level that it can afford and nation 1 reacts. If this level is one unit, then both nations contribute a unit unless this standard is unacceptably low for nation 1. When this is true, nation 1 must "shore up" the weakest link by either giving nation 2 an income transfer or else providing the extra units on nation 2's soil.[52] This shoring-up activity is the

52. Simon Vicary, *Transfers and the Weakest-Link: An Extension of Hirshleifer's Analysis*, 43 J. PUB. ECON. 375, 376 (1990); Simon Vicary & Todd Sandler, *Weakest-Link Public Goods: Giving In-Kind or Transferring Money*, 46 EUR. ECON. REV. 1501, 1503 (2002).

opposite of free riding. For an *n*-nation case, shoring up may involve bringing many nations up to a reasonable standard. As such, free riding becomes relevant. Consider actions to bring all airports worldwide up to an acceptable standard in terms of bomb-detection devices. Rich countries have an interest in subsidizing these efforts in poor countries or warning their citizens not to fly from these airports as terrorists will find the most opportune target. Many rich nations will sit back and wait for others to bring these airports up to an acceptable standard of security. Thus, free riding can resurface for weakest-link public goods owing to financial capacity. As group size increases, shoring up weakest links is a greater concern.

In matrix *b*, a threshold weakest-link technology is displayed with payoffs nearly identical to those of matrix *a*. The sole difference is that there must be a match of two units or more before either nation receives benefits. Only the payoff combination for a match of one unit changes when compared with matrix *a*. This match now gives costs of 4 with no benefits, because a matched unit is below the threshold at which benefits start to flow. There are three pure-strategy Nash equilibriums along the main diagonal, indicated by the boldfaced payoffs. With a relevant threshold, capacity becomes a greater concern as a certain standard of supply must be achieved. The incentives are right to act but shoring up poor countries' contributions becomes essential, especially for sizable thresholds, which is germane for problems involving health risks and security. Treaties then become a way to formalize the shoring-up process.

A. Best-Shot Technology of Aggregation

Another important aggregator for treaty-provided public goods is that of best shot where the largest contribution by a nation determines the consumption level of the entire group. Any contribution level below the maximum adds nothing and, thus, absorbs resources without gain. Even a second provision effort equal to the maximum accomplishes nothing extra. Finding a cure for a disease or identifying a new virus is a best-shot public good. Action to disarm a rogue nation or a terrorist network is a best-shot public good for all at-risk nations. Creating "best practices" is a best-shot public good, as in the institution of standards that avoid wasteful non-interoperability. With best shot, free riding is the desired outcome for all but the best shooter. The trick is to coordinate action so that there will be a single best shooter. Treaties may be used to finance the best-shot effort or to coordinate effort between countries if the role of the best shooter needs to be alternated for fairness.

Two examples of best-shot public goods are displayed in Figure 6, where each of two nations can contribute two units in one-unit increments. In matrix *a*, the first unit gives 4 in benefits to both nations, while a single added unit by the other nation gives no additional benefit. The first nation to contribute two units confers 7 in benefits to both nations.

Each unit costs the provider 2. If, say, nation 1 contributes two units and nation 2 contributes nothing, then nation 1 gets 3 after covering its cost of 4 and free-rider nation 2 receives 7. Other payoff combinations are computed similarly. Payoffs are smallest along the main diagonal owing to redundant efforts. This game has no dominant strategy even though there are two pure-strategy Nash equilibriums where one nation gives two units and the other free rides for payoffs of (3, 7) and (7, 3). These equilibriums are located at the opposite ends of the off-diagonal. Treaties can either coordinate the largest effort or else jointly finance this action. UN peacekeeping falls into the latter category where finances are pooled to underwrite the actions. In the case of nuclear proliferation, there is no effective provision for enforcement, so that either no one acts or else the most powerful country steps in. Clearly, this arrangement led to failure to stop nuclear proliferation in the case of India and Pakistan.[53] North Korea and Iran are the current concerns.[54]

FIGURE 6
BEST-SHOT PUBLIC GOODS

		Nation 2		
		0	1	2
	0	0, 0	4, 2	**7, 3**
Nation 1	1	2, 4	2, 2	5, 3
	2	**3, 7**	3, 5	3, 3

a. Best shot

		Nation 2		
		0	1	2
	0	0, 0	0, –2	**7, 3**
Nation 1	1	–2, 0	–2, –2	5, 3
	2	**3, 7**	3, 5	3, 3

b. Best shot, threshold of 2 units

In matrix *b* of Figure 6, a threshold of two units is introduced so that a maximum single contribution smaller than two units adds no benefits. Although a threshold changes a few payoff combinations, the pure-

53. *See* GEORGE PERKOVICH, INDIA'S NUCLEAR BOMB: THE IMPACT ON GLOBAL PROLIFERATION 5 (1999).

54. *See* Ashton B. Carter, *America's New Strategic Partner?*, FOREIGN AFF., July–Aug. 2006, at 33.

strategy Nash equilibriums remain, as before, at the opposite ends of the off-diagonal. This follows because best-shot public goods are consistent with one nation doing all that it can, thereby making the threshold less relevant. The threshold simply underscores that somehow the requisite capacity must be achieved.

B. Other Technologies of Aggregation

Another interesting aggregator is weaker link, where contributions above the minimum may still yield some benefits.[55] Pest control is a weaker-link public good insofar as greater efforts by some may offset less vigilance by others. Sterilization by hospitals to eliminate staph infections also abides by weaker link. Weaker-link aggregators lead to equilibriums away from the main diagonal and, thus, imply less of a need to bring all nations up to the same provision level. Consequently, capacity is less of a concern, as is the need to shore up small-contributing nations. Weaker-link public goods have a better prognosis than weakest-link public goods; thus, treaties may be more readily framed for these goods.

For better-shot public goods, contributions less than the maximum can provide some benefits. The development of vaccines and/or antibiotics is a better-shot public good where less effective outcomes may provide benefits by being tolerated by some patients, who are unable to take the best vaccine or antibiotics. This less extreme form of best shot results in equilibriums away from the opposite ends of the off-diagonal, where one nation does everything.[56] In so doing, nations can share the responsibilities, and treaties do not solely have to coalesce efforts. Collective actions become less of a concern.

C. Weighted-Sum Technology of Aggregation

Another aggregator is weighted sum, where weights are applied to countries' contributions when ascertaining each country's consumption of the pubic good. This aggregator is germane to some environmental treaties—for example, the Helsinki Protocol for sulfur emissions[57] and the Sofia Protocol for nitrogen emissions[58]—where wind direction, a country's location, and its size determine how much self and imported emissions fall on a country's soil. Once the United Nations monitored who polluted whom with sulfur, nitrogen, and volatile organic com-

55. Weaker-link public goods are analyzed by Richard Cornes, *Dyke Maintenance and Other Stories: Some Neglected Types of Public Goods*, 108 Q. J. ECON. 259 (1993), and Todd Sandler, *Global and Regional Public Goods: A Prognosis for Collective Action*, 19 FISCAL STUD. 221 (1998).

56. *See* Arce M. & Sandler, *supra* note 49, at 496; Sandler, *Global and Regional Public Goods*, *supra* note 55.

57. Helsinki Protocol on Sulfur Emissions, *supra* note 14.

58. Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes, Oct. 31, 1988, 1593 U.N.T.S. 288.

pounds in Europe, some countries had a greater rationale in joining treaties. Obviously, self-pollution and imported pollution are prime motivators for nations to frame environmental treaties to control polluters at home and abroad.[59] For the Sofia Protocol, downwind communist countries were early signatories, an unusual action by countries that typically mistrusted treaty-mandated environmental regulations.[60] Weighted-sum public goods often contain country-specific inducements for some countries to sign on. These public goods have many attributes, conducive to favorable collective action.

VIII. MORALITY AND CONFORMITY

Standard grounds for public international law can easily augment the positivist, rationalist formulation of treaties presented here.[61] Derived moral benefits from becoming a participant of a treaty translate into country-specific benefits that add to other derived benefits. For an environmental treaty, a nation gains from fewer imported emissions owing to mandated cutbacks and a country-specific gain from "doing the right thing." The latter may be bolstered if the country's constituency values the principles embodied in the treaty. Failure to respond to these constituency tastes could cost the government future elections. A country may also be drawn into a treaty over time owing to perceived gains from being part of a community of treaty adherents. The Montreal Protocol on Substances that Deplete the Ozone Layer grew from a small set of ratifiers to a group that included most nations.[62] As the number of ratifiers grows, some nonsignatories put greater value on joining and being part of the global community. This bandwagon effect only takes hold once the number of ratifiers is large. For the Chemical Weapons Convention, the United States eventually ratified, despite its verification concerns, because it worried that being an outsider to a weapons treaty would set a poor example.[63]

In terms of the various games analyzed, these moral and conformity benefits, when relevant, increase a country's payoffs, thus encouraging participation. Consider matrix *c* in Figure 1 for the stag-hunt game in light of these moral and conformity benefits. Their presence raises U and B, while it reduces A and E, all of which reduce the adherence probabilities and, thus, increase the possibility of cooperation. In addition, bandwagon influences can offset transaction costs, which also rise with greater participation. If one nation's membership is related to those of other nations, then this correlation brings down the adherence probability. For the Prisoner's Dilemma scenario (see Figure 3), these moral-

59. SANDLER, *supra* note 10, at 227–28.
60. *Id.* at 228–29.
61. *See* CHAYES & CHAYES, *supra* note 3; FRANCK, *supra* note 3; van Aaken, *supra* note 4.
62. SANDLER, *supra* note 10, at 95, 216.
63. *See* CHAYES & CHAYES, *supra* note 3, at 179–83.

based gains not only reduce the free-rider payoffs from a sense of guilt, but also increase the benefits from contributing. If the former is lowered sufficiently, the latter is raised enough, or both, then contributing may come to dominate for some nations. As such, the game is no longer a Prisoner's Dilemma.

The message here is that these benefits can influence the underlying strategic structure of the interaction. In all instances, such benefits are supportive of cooperation even though they might not change behavior. In liberal democracies, governments may put more weight on such moral obligations, because the electorate may do so. The U.S. electorate may eventually pressure the government to ratify the Kyoto Protocol on reducing greenhouse gas emissions.[64]

IX. CONCLUDING REMARKS

This paper has extended G & P's rationalist framework[65] to apply to treaties, where potential ratifiers are motivated by self-interest and strategic considerations. In so doing, I modify a couple of their four drivers of CIL and add three additional considerations. Because treaties are often framed to address public goods (or public bads) and externalities, strategic concerns are relevant as one nation's best action is dependent on that of other nations. There is no necessary pessimism that must follow from a strategic representation, because treaties can be designed where adhering to the provisions may be a dominant strategy. Moreover, some properties of public goods—e.g., a weakest-link aggregator—may eliminate free riding and other dissembling strategies as desirable actions. When dynamic considerations are investigated, multilateral interactions that involve a wide variety of game forms are germane.

Generally, treaties with fewer participants are more likely to be framed. Once framed, treaty membership can be expanded, as in the case of the Montreal Protocol for reducing stratospheric ozone shield depleters. By making for repeated interactions, treaties can circumvent underlying Prisoner's Dilemmas or coordination concerns. Treaties can promote correlated expectations that foster adherence. Moreover, clever design of treaties can align incentives for nations to ratify and later adhere to provisions without an enforcement mechanism.

I do not view strategic considerations as eliminating morality or conformity as important explanators of treaty behavior; rather, strategic aspects are more encompassing explanation that can include these legal factors. Some of my extension of G & P's analysis can also be applied to augment our understanding of CIL, where there is less infrastructure—no written set of expectations or designated signatories. For example,

64. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 10, 1997, 37 I.L.M. 22.

65. *See* GOLDSMITH & POSNER, LIMITS, *supra* note 1; Goldsmith & Posner, *Theory*, *supra* note 1.

dynamic cooperation can characterize *multilateral* CIL for a variety of game forms. Bilateral interactions are not a prerequisite, especially for repeated coordination and assurance games where the dynamic prognosis is better than that of a Prisoner's Dilemma. When correlated strategies are considered, coordination games can provide great promise for CIL. Mores and common cultures are drivers of correlated actions that can reduce adherence probabilities for CIL. However, institutional innovations that promote cooperation as a dominant strategy for successful treaties are not relevant for CIL that lack a formal structure with designated signatories.