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THE LOGIC OF TERRORISM

F.E. Guerra-Pujol *

"Mr. M'Hidi, don't you think it is cowardly to use your women's baskets and handbags to carry explosive devices that kill so many innocent people?" Ben M'Hidi replies: *"Doesn't it seem to you even more cowardly to drop bombs on unarmed villages, so that there are a thousand times more innocent victims? Of course, if we had your airplanes it would be a lot easier for us. Give us your bombers, and you can have our baskets."*

–The Battle of Algiers[1]

I. INTRODUCTION

The theme of the *Barry Law Review* 2012 *Symposium* was *"Guantánamo's Legacy: Reflections on a Decade of Detention."*[2] The scholarly and learned contributions to this timely symposium explored a wide range of topics relating to this important theme, including the deplorable living conditions at the Guantánamo Bay Detention Center, United States national security policy, and the "war on terror" generally.[3] In this paper, we wish to take a step back from the detentions in Guantánamo, an important but rather small chapter in the "war on terror," in order to paint a more complete picture of the problem of terrorism. For one must always

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I would like to thank my friend and colleague David Frakt for organizing the *Barry Law Review* 2012 Symposium on "Guantánamo's Legacy: Reflections on a Decade of Detention." I also thank my former students Pamela Martini and Christopher Bailey for inviting me to present this paper in the Guantánamo symposium issue of the *Barry Law Review* and my editors Aboubakr Maaroufi and Amy E. German for their helpful comments and suggestions (although all remaining errors are mine alone). In addition, I wish to thank Daniel Nina for inviting me to present a previous draft of this paper at the Hostos Law School in Mayaguez, Puerto Rico in the spring of 2009, and I thank Ms. Bridgette Walpole for making her home "Lansdowne" in St. Ann Parish, Jamaica available to me last summer (I developed my models and wrote the final draft of my paper on the veranda of her beautiful home). Lastly, I dedicate this paper to the extraordinary men, women, and children of the Arab Spring, who have changed the world by their courageous actions and heroic example.

1. THE BATTLE OF ALGIERS (Criterion Collection 2004) (Igor Film 1966) (dialogue between a French national and an Algerian revolutionary leader. Translation provided by the author).

2. The *Barry Law Review* 2012 *Symposium* was held earlier this year at Barry Law School in Orlando, Florida on February 24, 2012.

3. We will put the phrase "war on terror" within scare quotes for the remainder of this paper as a shorthand way to refer to conflicts between terrorist or insurgent groups, such as Al Qaeda, and counter-terrorist organizations, such as the United States military. The absolute absurdity of such a phrase needs no further elaboration. Also, the author shall use the third person plural in this paper, for the creation and transmission of knowledge and ideas is a shared project between the author and his readers.

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remember that in the absence of terrorism, there would be no Guantánamo Bay Detention Center. Had there been no attacks on September 11, 2001, there would be no United States military involvement in faraway places like Iraq or Afghanistan.

To illustrate the problem of terrorism and explain the perverse logic of conflict generally, this main part of this paper will review a motion picture: *The Battle of Algiers*, a beautiful film directed by the great Italian filmmaker Gillo Pontecorvo.[4] In summary, this film teaches us three important lessons about the problem of terrorism: (1) terrorism is a reciprocal problem; that is, terrorism and counter-terrorism is a joint interaction in which it is descriptively impossible to distinguish victim from wrongdoer; (2) non-normative analysis of terrorism is a powerful tool; and (3) terrorism can be modeled as an escalating and evolutionary arms race.[5]

The remainder of this paper is thus organized as follows: following this brief introduction, Part II reviews and critiques previous approaches to the problem of terrorism.[6] Next, Part III reviews the main lessons of the classic 1966 film, *The Battle of Algiers*.[7] Building on these central lessons from the film, Parts IV and V of the paper then offer a brief sketch of our alternative approach to the problem of terrorism and present two simple models to illustrate our approach to terrorism and conflict in general.[8] In other words, in place of a normative or legal or risk-based analysis, we propose an alternative approach to the problem of terrorism, one in which terrorism is viewed as a reciprocal and evolutionary arms race between terrorists and counter-terrorists. Part VI concludes all these parts.[9]

II. PREVIOUS APPROACHES

As demonstrated by the contributions to the *Barry Law Review* 2012 Symposium, scholars have studied the problem of terrorism from a wide variety of different and illuminating perspectives, including **law**,[10] **economics and game theory**,[11] **history**,[12] **risk analysis and probability theory**,[13] **story-telling**,[14] and even **marine biology**.[15] In addition, the research papers collected in a recent

4. THE BATTLE OF ALGIERS, *supra* note 1.
5. *Id.*
6. *See infra* Part II.
7. THE BATTLE OF ALGIERS, *supra* note 1; *see infra* Part III.
8. *See infra* Parts IV–V.
9. *See infra* Part VI.
10. *See, e.g.*, STEWART A. BAKER & JOHN KAVANAGH, PATRIOTS DEBATE: EXPERTS DEBATE THE USA PATRIOT ACT (2005).
11. *See, e.g.*, Eli Berman et al., *Can Hearts and Minds Be Bought? The Economics of Counterinsurgency in Iraq*, 119 J. POL. ECON. 766 (2011) [hereinafter Berman, *Can Hearts and Minds be Bought?*]; ELI BERMAN, RADICAL, RELIGIOUS, AND VIOLENT: THE NEW ECONOMICS OF TERRORISM (2009).
12. MARK MOYAR, A QUESTION OF COMMAND: COUNTERINSURGENCY FROM THE CIVIL WAR TO IRAQ (2009).
13. *See generally* Cass R. Sunstein, *Terrorism and Probability Neglect*, 26 J. RISK & UNCERTAINTY 121 (2003).
14. *See, e.g.*, David J. R. Frakt, *Essay: Mohammed Jawad and the Military Commissions of Guantanamo*, 60 DUKE L. J. 1367 (2011).
15. *See generally* RAFE SAGARIN, LEARNING FROM THE OCTOPUS: HOW SECRETS FROM NATURE CAN HELP US FIGHT TERRORIST ATTACKS, NATURAL DISASTERS, AND DISEASE (Basic Books 2012).

volume of the leading journal *Science* illustrate this interdisciplinary and social-science perspective to the problem of terrorism and human conflict in general.[16] In place of a comprehensive review or survey of this extensive literature, we shall offer a brief critique of these previous academic approaches to the problem of terrorism before sketching our alternative approach.

First, let us consider mainstream legal scholarship. Most legal analyses of terrorism and related issues (torture, law of war, military detentions, etc.) are flimsy and unhelpful—more rhetoric than reason—for a number of reasons. In brief, legal scholars tend to place too much weight on anecdotal evidence, and are prone to normative analysis and the level of generality problem.[17] Like metaphorical sorcerers of lore, legal scholars tend to invoke vague and open-textured concepts—concepts such as "anti-subordination," "rule of law," "liberty," "national security," etc. (see, for instance, the essays in this symposium volume of the *Barry Law Review*)—as magic talismans or Delphic oracles, as though these concepts had clear or obvious meanings. But worse yet, it is not clear that the problem of terrorism is even susceptible to a legal solution,[18] rendering most legal scholarship on the "war on terror" as moot and beside the point.

By contrast, some researchers have taken a more rigorous, non-normative, risk-based approach to terrorism.[19] Although this risk-based approach is more fruitful than traditional legal scholarship—because the concept of "risk" is definable and measurable—it nevertheless suffers from a serious flaw. It does not address the root causes of terrorism. That is, it is one thing to measure the risk of terrorism, but why does this risk exist in the first place, and what can be done to reduce this risk? Also, risk analysis often neglects the reciprocal nature of terrorism risks, an issue we shall consider in greater detail below. Likewise, most of the game-theoretic literature, though mathematical and rigorous, neglects the reciprocal logic between terrorism and counter-terrorism.[20]

For example, Eli Berman and his team developed a formal economic theory of insurgency and presented an information-sharing model of conflict.[21] Specifically, they model "a three-way contest between [i] violent rebels, [ii] a government seeking to minimize violence by mixing service provision and coercion, and [iii]

16. *See generally Human Conflict: Reviews and Perspectives*, 336 SCI. 844, 844–84 (2012); Moshe Kress, *Modeling Armed Conflicts*, 336 SCI. 865, 866–69 (2012) (providing a brief history of classical "armed conflict" or AC models and surveying current and future AC models); Joan Esteban, Laura Mayoral & Debraj Ray, *Ethnicity and Conflict: Theory and Facts*, 336 SCI. 858, 860 (2012) (presenting a game-theoretic model of human conflict and distinguishing games with "public payoffs" from games with "private payoffs").

17. Since these criticisms have been made before, we will not dwell on them here. Instead, we present an alternative analysis of terrorism in Part III below as well as our own models of the arms-race logic terrorism in Parts IV and V below. *See* RICHARD A. POSNER, THE PROBLEMATICS OF MORAL AND LEGAL THEORY (Belknap Press 1999).

18. *See infra* Part IV.B.

19. *See Human Conflict*, *supra* note 16; *see also* Sunstein, *supra* note 13; WILLIAM J. BURNS, CENTER FOR RISK AND ECONOMIC ANALYSIS OF TERRORISM EVENTS (CREATE), REPORT #07–001, RISK PERCEPTION: A REVIEW (2007) (a survey of "risk perception" studies); A. Terry Bahill & Eric D. Smith, *An Industry Standard Risk Analysis Technique*, 21 ENGINEERING MGMT. J. 16 (2009) (for a brief history and summary of "risk analysis" generally).

20. This paper is designed to remedy this deficiency.

21. *See* Berman, *Can Hearts and Minds Be Bought?*, *supra* note 11.

civilians deciding whether to share information about insurgents."[22] Although this model is correct to highlight the importance of information in conflict, it does not capture the reciprocal nature of conflict. Instead, it simply assumes that rebels are "bad" and the anti-rebel government is "good." For their part, Berman and Laitin model voluntary religious organizations as private religious clubs, explain why "religious clubs can be potent terrorists"[23] and conclude that "benign tactics" are more effective in responding to religious radicals.[24] However, this approach appears to be overly optimistic and ignores the reciprocal nature of conflict—after all, one could easily argue that it is the religious radicals who should use more benign tactics to accomplish their aims. If the underlying conflict is a "Prisoner's Dilemma," dove-like strategies are never a best response to hawk-like strategies. Lastly, Bueno de Mesquita surveys the literature on terrorism.[25] A glance at the academic papers in his survey, however, shows the underlying problem with the existing literature: some researchers focus on terrorism, others on counter-terrorism, but few consider the reciprocal relation between terrorism and counter-terrorism as a whole.[26]

For his part, the marine biologist, Rafe Sagarin, offers what we consider the most promising approach to the problem of terrorism.[27] In summary, he emphasizes the concept of "adaptability" and defines this concept as "the property of being able to actively and passively alter structures, behaviors, and interactions with other organisms and the non-living world in response to selective pressures."[28] Sagarin's thesis is that successful anti-terrorism measures must incorporate "adaptability."[29] The problem with Sagarin's approach to anti-terrorism, however, is twofold: (1) the concept of "adaptability" is too vague and imprecise to be useful,[30] and (2) the focus on "adaptability" ignores the reciprocal nature of the terrorism problem.[31]

In general, these previous approaches to the problem of terrorism suffer from one or more of the following three serious flaws: (1) some research is based purely

22. *Id.* at 766–67.

23. Eli Berman & David Laitin, *Religion, Terrorism and Public Goods: Testing the Club Model*, 92 J. PUB. ECON. 1942, 1942 (2008) [hereinafter Berman & Laitin]; *see also* Lawrence R. Iannaccone & Eli Berman, *Religious Extremism: The Good, the Bad and the Deadly*, 128 PUB. CHOICE 109, 120–23 (2006).

24. Berman & Laitin, *supra* note 23. Or, in the words of the model presented in this paper, they conclude that counter-terrorism should be more dovish and less hawkish. *Id.*

25. *See* Ethan Bueno de Mesquita, *The Political Economy of Terrorism: a Selective Overview of Recent Work*, 10 POL. ECON. 1 (2008); *see also* Berman, *Can Hearts and Minds Be Bought?*, *supra* note 11, at 817–19 (surveying counterinsurgency literature).

26. *See* Bueno de Mesquita, *supra* note 25; Berman, *Can Hearts and Minds Be Bought?*, *supra* note 11, at 766, 817–19.

27. SAGARIN, *supra* note 15.

28. *Id.* Sagarin then defines "selective pressures" broadly to include "any change in the environment—climate warning, predators, limitations on available living space, competition for mates, overpopulation, failure of a food source." *Id.*

29. *Id.* at 15–16.

30. *Cf.* S. J. Gould & R. C. Lewontin, *The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme*, 205 PROC. OF THE ROYAL SOC'Y OF LONDON B, BIOLOGICAL SCIS. 581, 581–84 (1979), *available at* http://www.life.illinois.edu/ib/443/Gould%20&%20Lewontin.pdf.

31. *See infra*, Part IV.B (illustrating how terrorism can be modeled as a reciprocal "arms race" in which an adaptation on one side will be met by a counter-adaptation on the other side).

on anecdotal evidence,[32] (2) other studies are premised on (stated or unstated) normative claims that are "unfalsifiable" or untestable,[33] and (3) almost all previous work in this area neglects the "reciprocal nature" of the terrorism problem.[34] This third point is, by far, the most important one. As we shall argue in the remainder of this paper, terrorism is a "reciprocal problem,"[35] yet most studies of terrorism miss this essential point. In Part III below, we will momentarily leave behind the rarefied world of the Ivory Tower, and enter the beautiful but no-less make-believe world of the cinema. For it is a motion picture—not a book, nor a scholarly paper, nor a classified report—that best exemplifies the nuances of terrorism and illuminates the intractable, reciprocal, and arms-race nature of the "war on terror." We turn to the film *The Battle of Algiers* and review its main lessons below.[36]

III. AN ALTERNATIVE APPROACH

The film *The Battle of Algiers*—released in 1966, four years after Algeria won its independence from France in July 1962—recounts in chronological order the major events in the Algerian struggle for independence during the mid-1950s.[37] There exists an extensive secondary literature about the film as well as the historical events portrayed in the film[38] but there is no substitute for watching the film itself, for it is nothing less than a true work of art. The screenplay is just as thought provoking as one of Plato's dialogues, and the film's heroic portrayal of the Algerian insurgents (or "terrorists" in today's parlance) is simply one of the most haunting and powerful depictions of an underdog in the history of cinema. One of the details that left the greatest impact on the author was the serene and solemn faces of the young Algerian revolutionaries, some of the most haunting and beautiful faces that we have ever seen on the silver screen.[39] In addition, *The Battle of Algiers* offers a wealth of intriguing insights into the problem of terrorism and human conflict generally.[40] In this section of the paper, we summarize the three most valuable and original lessons we learned from the film: (1) the reciprocal nature of terrorism and human conflict generally,[41] (2) the need for non-normative analysis,[42] and (3) the underlying arms-race logic of terrorism and human conflict generally.[43]

32. *See, e.g.*, Erwin Chemerinsky, *Detainees*, 68 ALB. L. REV. 1119 (2004).
33. *See, e.g.*, PETER JAN HONIGSBERG, OUR NATION UNHINGED: THE HUMAN CONSEQUENCES OF THE WAR ON TERROR (2009).
34. One rare exception, however, is ROBERT A. PAPE, DYING TO WIN: THE STRATEGIC LOGIC OF SUICIDE TERRORISM (Random House 2005).
35. *Cf.* Ronald H. Coase, *The Problem of Social Cost*, 3 J. L. & ECON 1, 1–2 (1960).
36. THE BATTLE OF ALGIERS, *supra* note 1.
37. *Id.*; *see generally* MARTIN WINDROW, THE ALGERIAN WAR, 1954–1962 (1997) (for a history of the war in Algeria in English).
38. *See, e.g.*, ALISTAIR HORNE, A SAVAGE WAR OF PEACE: ALGERIA 1954–1962 183 (1977).
39. THE BATTLE OF ALGIERS, *supra* note 1.
40. *Id.*
41. *See infra* Part III.A.
42. *See infra* Part III.B.
43. *See infra* Part III.C.

A. Lesson One: Conflicts Are Reciprocal in Nature

The most important and radical lesson we learned from *The Battle of Algiers* is the idea that conflicts are "reciprocal in nature."[44] By "reciprocal in nature," we mean that both sides to a conflict are equally responsible for the conflict, since both sides can choose voluntary restraint over conflict at any time.[45] And because conflict is at the heart of all disputes in the legal system, one could argue that conflict is the driving force of almost all human interactions, including politics, family, and economic exchange. In sum, the notion that conflicts are reciprocal in nature is a fundamentally important, though counter-intuitive, idea.[46]

This idea of reciprocal conflicts is counter-intuitive—especially for persons with strong normative preferences—because, ordinarily, when one is analyzing a two-party conflict, the usual tendency is to identify one of the parties as the wrongdoer and the other party as the victim. Of course, the identity of the wrongdoer and the identity of the victim will depend crucially on one's ex ante value preferences. For example, it is tempting to see the Algerians as the victim of "French imperialism" in the Algerian conflict; after all, it was the French who annexed Algeria in the 1800's without the consent of the Algerian people.[47] Nevertheless, as the film makes clear, the French are also victims,[48] since they must expend resources to fight the brutal Algerian insurgency.[49] Of course, the insurgents would not have resorted to arms had the French met their demands, but then we are back to where we started, for why should the French government neglect its primordial duty to protect the lives and property of its own citizens in Algeria and cave in to what are in effect extortionate threats?

Before proceeding, we do not wish to imply that France has the right to annex Algeria as a colony. On the contrary, we agree that the right to self-determination is a basic right and that France must respect the wishes of the Algerian people. Nevertheless, the presence or absence of the right to self-determination does not in any way change or alter the reciprocal nature of the conflict between the French and the Algerians, or in more general terms, between the colonizer and the colonized.[50] To see why, let us substitute the more abstract terms A and B for the value-laden terms "colonizer" and "colonized"—or for such similar terms as "victim" and "wrongdoer" in the more prosaic context of a legal dispute. On one hand, A justifies its use of force against B because B has refused to meet A's conditions (e.g., that B should lay down its arms and respect A's right of self-

44. We borrow this particular phrase (as well as the underlying idea behind this phrase) from Coase. *See* Coase, *supra* note 35, at 1–2.

45. *Id.*

46. For an application of this idea to another beautiful film, the motion picture *Blade Runner*, see generally F.E. Guerra-Pujol & Orlando I. Martinez-Garcia, *Time Scarcity and the "Problem of Social Replicants:" Clones and the Coase Theorem*, 2 J. L. & SOC. DEVIANCE 43 (2011), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1991411.

47. THE BATTLE OF ALGIERS, *supra* note 1; WINDROW, *supra* note 37; HORNE, *supra* note 38.

48. THE BATTLE OF ALGIERS, *supra* note 1.

49. *Id.*

50. *Id.*

determination). On the other hand, B justifies its use of force against A because A likewise refuses to meet B's conditions (e.g., that A should lay down its arms and respect the life and property of B's citizens).

Seen this way—without the use of value-laden terms whose only effect is to prejudge the merits of each side's respective claims—the reciprocal nature of the conflict between A and B becomes abundantly clear. In other words, just as the A's of the world have the right to self-determination, by the same logic, the B's of the world have the right to life and property. At the end of the day, when we have a conflict between two competing and reciprocal rights, the question remains, which right is to prevail? The right to self-determination, or the right to life and property? More importantly, how do we decide which of these conflicting and reciprocal rights are to prevail?

Are reciprocal conflicts therefore intractable? Not necessarily. There are various solutions to the problem of reciprocal conflicts. Ideally, one could try to find a voluntary or negotiated settlement to the problem; that is, the parties to the dispute could negotiate a "Coasian" bargain and reach some form of voluntary compromise.[51] Alternatively, if negotiations or Coasian bargaining are not feasible, we could simply toss a coin or rely on some other random device for resolving the conflict. For example, we could toss a coin to arbitrarily choose A over B, or B over A.[52] In the worst-case scenario, we could settle the issue by force, the Hobbesian way.[53] Of course, this third method of resorting to the use of brute force is the least attractive method for resolving reciprocal conflicts because it is the most destructive and counter-productive way of choosing between competing and reciprocal rights. But in the absence of voluntary restraint by either A or B, or in the absence of some external power who is able to enforce the coin-toss method or the negotiation method on both A and B, what other method is there? In many ways, this is the main lesson of the film, *The Battle of Algiers,* and of today's "war on terror."

Before proceeding, it is worth noting that the reciprocal logic of conflict is not limited to the problem of terrorism. Consider the problem of surprise attack: when one ruler or city-state (such as Athens) acquires new weapons or increases its military power, the other side (Sparta) will respond by increasing its military strength to keep up with the first side, and this response, in turn, causes the first side to acquire even more weapons, and so on. This reciprocal fear of a surprise attack may not only unleash a wasteful arms race, but may also lead to a

51. *See, e.g.*, ROBERT AXELROD, THE EVOLUTION OF COOPERATION 73–87 (1984) [hereinafter, AXELROD, EVOLUTION] (describing the "live-and-let-live" system of World War I); *see generally* THOMAS C. SCHELLING, THE STRATEGY OF CONFLICT 21–52 (Harvard Univ. Press 1980). As an interesting aside, it appears that tacit or explicit Coasian bargains are occurring in some sectors of Afghanistan. According to Lt. Col. Daniel Davis, many elements of the Afghan National Security Forces have made deals or Coasian bargains with the Taliban. *See* Daniel L. Davis, *Truth, Lies, and Afghanistan: How Military Leaders Have Let Us Down*, ARMED FORCES J. (2012), *available at* http://www.armedforcesjournal.com/2012/02/8904030 ("[The Afghan security forces] won't shoot at the Taliban, and the Taliban won't shoot them").

52. *See, e.g.*, IVAR EKELAND, THE BROKEN DICE, AND OTHER MATHEMATICAL TALES OF CHANCE 3 (Carol Volk trans., 1993).

53. *See, e.g.*, THOMAS HOBBES, LEVIATHAN OR THE MATTER, FORME & POWER OF A COMMONWEALTH, ECCLESIASTICALL AND CIVIL 188–208 (A.R. Waller ed., 1904) (1651).

destructive war. For example, the ancient Greek historian, Thucydides, describes the "truest cause" of the Peloponnesian War as thus: "For I consider the truest cause [of the war] the one least openly expressed, that increasing Athenian greatness and the resulting fear among the [Spartans] made going to war inevitable."[54] Likewise, contemporary scholars have begun to use mathematical methods and the tools of game theory to model the problem of mutual fear and surprise attack.[55] But as we noted in Part II of this paper, most models of terrorism neglect this reciprocal logic.[56]

So here is the heart of the matter. Conflicts are essentially reciprocal in nature because either side could end the conflict by means of voluntary restraint, but neither side chooses to do so. Each side prefers victory over defeat and so chooses to go to war and continue the struggle, and so each has only itself to blame for the fatal consequences of its own actions. This is the first lesson of *The Battle of Algiers*, and it is an important lesson since the underlying logic of all conflicts, big and small, private and public, is ultimately reciprocal in nature.[57]

B. Lesson Two: Non-normative Analysis Is a Virtue (or, "Is" Trumps "Ought")

Another important lesson in *The Battle of Algiers*, related to the problem of reciprocal conflicts, is the virtue of "non-normative" or "Humean" analysis, in honor of one of our philosophical heroes, David Hume.[58] When we study a serious problem like terrorism, it is more productive to focus on the "is" of the conflict (i.e. understanding the source of conflict and finding the best methods for resolving it to everyone's satisfaction) and not on the "ought" of the conflict (i.e. taking sides by deciding who should prevail or by judging who is morally "right" and who is "wrong"). Instead of merely condemning terrorist tactics on both sides of a given conflict (such as the September 11 attacks or the 2003 invasion of Iraq), we need to understand what motivates the "terrorists" in the first place. Why are they willing to kill innocents, risk their own lives, and fight a quixotic battle with an imperial power?

In brief, normative analysis is problematic for at least two reasons. One is that, in reality, there are as many competing conceptions of justice and of the common good as there are individuals. Some individuals may happen to share a similar policy preference in one area of the law, but to assume that one's particular

54. THUCYDIDES, THE PELOPONNESIAN WAR 15 (Steven Lattimore trans.,1998).

55. *See* Andrew Kydd, *Game Theory and the Spiral Model*, 49 WORLD POL. 371 (1997) (presenting several simple game-theoretic models of international conflict and cooperation); *see also* Robert Jervais, *Under the Security Dilemma*, 30 WORLD POL. 167, 170–83 (1978) (presenting an incomplete information model of an arms race, specifically, uncertainty regarding a state's intentions when a state engages in an arms-buildup); SCHELLING, *supra* note 51, at 207–08.

56. *See infra* Part II.

57. THE BATTLE OF ALGIERS, *supra* note 1.

58. *Id.* For an illustration of Hume's empirical and skeptical approach to morality, see DAVID HUME, ESSAYS: MORAL, POLITICAL, AND LITERARY 479–80 (Eugene F. Miller ed., 1985). For a brief comment on the influence of Hume's approach on the author of this paper, see F.E. Guerra-Pujol, *Life, Love, and Law: An Epistolary Exchange*, 80 REV. JUR. U.P.R. 995 (2011).

preference is the correct one just because one's friends or neighbors share the same preference is neither logically compelling nor intellectually honest. The other main flaw with the normative approach to conflict is that it is totally tautological to the core because normative values are not falsifiable. Instead of engaging in falsifiable research, the researcher is merely finding reasons after the fact to justify his or her ex ante value preferences (like a judge deciding a hard case when the precedents are conflicting, unclear, or non-existent).

By contrast, the film, *The Battle of Algiers,* demonstrates the virtues of non-normative or Humean analysis.[59] It depicts in chronological order the decisive events of the armed conflict between the French military and the Algerian insurgency during the mid-1950s, but it does not take sides in that conflict.[60] The film is shot in black and white, yet its visual presentation of colonial rule and the struggle for Algerian independence is anything but black and white.[61] It does not take sides in the war.[62] In the first scene of the film, hardened French soldiers torture a poorly nourished Algerian insurgent, and later we are shown French secret agents planting a bomb in a residential neighborhood in the Casbah.[63] But we are also shown female Algerian insurgents passing through military checkpoints and planting bombs that kill and maim innocent French women and children in a well-coordinated and cold-blooded counterattack.[64] In other words, we see both sides of the conflict engage in illegal, immoral, and inhumane behavior.[65] The French military and the Algerian insurgency are both willing to engage in any means necessary to justify their respective ends.[66] There are no heroes in *The Battle of Algiers.*

Of course, one could argue that the right to self-determination is a "trump" and that, as a result, the French military occupation of Algeria was illegal or immoral.[67] However, one could just as well argue that the right to life is also a "trump" and that the insurgents, however noble or just their cause, had no right to harm innocent civilians. This is why Dworkian-style normative analysis is ultimately so hollow, empty, and intellectually dishonest to the core. When rights collide, as they so often do in real life, there is no way of mediating between competing "trumps." This lesson alone makes *The Battle of Algiers* one of the most enduring and thought-provoking works of art of our time.

The capture and killing of Osama Bin Laden in May 2011 by United States commandos provides a more recent illustration of the weakness of normative analysis (and the raid on Bin Laden's secret compound also illustrates the

59. THE BATTLE OF ALGIERS, *supra* 1.
60. *Id.*
61. *Id.*
62. *Id.*
63. *Id.*
64. *Id.*
65. THE BATTLE OF ALGIERS, *supra* 1.
66. *Id.*
67. *See* Ronald Dworkin, *Taking Rights Seriously*, *in* THEORIES OF RIGHTS 153 (Jeremy Waldron, ed., 1984) ("rights are best understood as trumps over some background justification for political decisions that states a goal for the community as a whole").

reciprocal nature of the problem of terrorism).[68] Who is the terrorist: a defenseless and unarmed Bin Laden, who was shot and killed by United States forces in his bedroom, or President Obama, who, from the safety of an underground bunker in the Situation Room, ordered Bin Laden's killing, ostensibly for purely political reasons?[69] This may sound like an obvious question, but is it? Perhaps the most profound lesson from the film *The Battle of Algiers* is that there is no clear answer to this question. Why? Because the problem of terrorism is a reciprocal one. For example, from a purely moral perspective, one could argue that the killing of Bin Laden was morally justified, that Bin Laden "deserved to die" for his instrumental role in planning and ordering the horrific and inhumane attacks of September 11, 2001.[70] Even so, one could just as well argue on purely moral grounds that the point-blank killing of Bin Laden (who was apparently unarmed when he was shot) and the secret disposal of his remains were themselves inhumane and horrific acts. Morality is of no moment because, when we talk about killing or capturing a dangerous public enemy, what is the limiting principle? What is the line between justified and unjustified homicide? To put it bluntly, what morally prevents Bin Laden's remaining supporters from trying to kill the president to "even the score," so to speak?

In sum, normative or moral analysis is unhelpful because the normative approach ignores the reciprocal nature of the problem of terrorism. The problem is that the "terrorists" believe themselves to be the real victims and thus feel justified in committing their crimes, the same way the leaders of the other side of the conflict (the counter-terrorists) feel justified in ordering violent reprisals against the first set of terrorists, thus producing a never-ending spiral of violence or global blood feud. This is why the detached, value-neutral approach to the problem of terrorism, as presented in the film *The Battle of Algiers*, is so powerful, and this is also one of the reasons why we found the film so much more compelling, intellectually enriching, and thought-provoking than most academic studies of terrorism.[71]

68. Peter Baker, Helene Cooper & Mark Mazzetti, *Obama Says Bin Laden Killed in Operation Inside Pakistan*, N.Y. TIMES, May 2, 2011, at A1, *available at* http://www.nytimes.com/2011/05/02/world/asia/osama-bin-laden-is-killed.html?pagewanted=1&ref=asia.

69. Peter Baker & Michael D. Shear, *Opponents Pounce as Obama Trumpets the Killing of Bin Laden*, N.Y. TIMES, April 28, 2012, at A13 (reporting that "President Obama is increasingly taking the unusual route of bragging about how he killed a man," and quoting Martha Joynt Kumar, a professor of political science at Towson University, stating that "'[t]he killing of Bin Laden is a natural item [sic] for President Obama to highlight'").

70. Putting indeterminate morality to one side, how can we say that a man like Bin Laden deserved to die? On what legal grounds? After all, Bin Laden did not coerce any of his men to carry out the 9/11 attacks. The truth of the matter is that his men freely and willingly volunteered to carry out the 9/11 attacks because, like Bin Laden, they rightfully (rightfully, of course, from their perspective) opposed the presence of United States military forces in their home countries. I am indebted to Ms. Sydjia Robinson for pointing this logic out to me. *See also* PAPE, *supra* note 34.

71. THE BATTLE OF ALGIERS, *supra* note 1.

C. Lesson Three: Reciprocal Conflicts Produce Evolutionary Arms Races

Having recognized the reciprocal nature of human conflict and rejected the normative approach as empty, hollow, and intellectually dishonest, how is one to understand the dynamics of human conflict situations and provide effective methods for their resolution? Once again, *The Battle of Algiers* provides great insight into the dynamics of conflict, because the film depicts the reciprocal conflict in Algeria as a kind of evolutionary arms race between the warring factions.[72] In sum, the idea that reciprocal conflicts lead to runaway processes or evolutionary arms-races, where each side is continually attempting to outmaneuver and outflank the other, is a useful way for understanding and predicting the dynamics of real-world conflict situations.

The film depicts the logic of an evolutionary arms race between the opposing forces.[73] At first, the French enjoy complete control of the capital city and possess a virtual monopoly over the use of force.[74] Given this asymmetrical situation, the insurgents consolidate their power within the Casbah by enforcing Islamic laws and rooting out petty criminals and then go on to orchestrate a series of isolated attacks against individual French police officers.[75] In response to the insurgents' increasing number of attacks against the civil police, French secret agents begin planting bombs in the residential quarters of the families of the suspected insurgents.[76] In retaliation, the insurgents up the ante by targeting the French civilian population. They devise ever-more sophisticated strategies for passing through French police checkpoints, surreptitiously planting ever-more powerful bombs in cafes and restaurants frequented by French civilians.[77] In response to this escalation of the conflict, the French authorities call up the French Foreign Legion, commanded by Colonel Mathieu (brilliantly played by Jean Martin).[78] Colonel Mathieu and his forces then carry out a large-scale offensive against the leaders of the insurgency.[79]

In summary, at each stage of the Algerian conflict, viewers see how each side carefully changes its tactics in response to the changing tactics of the other side, and viewers see a gradual but inexorable escalation of the conflict from a small-scale cat-and-mouse game all the way up to a large-scale war.[80] In short, *The Battle of Algiers* is a perfect illustration of the logic of a lethal and high-stakes evolutionary arms race between the French and the rag-tag Algerian insurgents—an arms-race that will continue to escalate indefinitely until one of the opposing

72. *Id.*
73. *Id.*
74. *Id.*
75. *Id.*
76. *Id.*
77. THE BATTLE OF ALGIERS, *supra* note 1.
78. *Id.*
79. *Id.*
80. *Id.*

forces concedes victory to the other side or until one side militarily defeats the other.[81]

This lesson is an important one beyond the events depicted in the film because almost all conflict and competitive situations can be modeled as an evolutionary arms race, such as doping in sports,[82] cheating on law school exams,[83] and host-parasite, predator-prey, and other interactions in nature,[84] or even self-deception in general.[85] The larger lesson is this—in the absence of voluntary negotiations or some other procedure for settling disputes as they arise, such as a coin toss, reciprocal conflicts will gradually spiral out of control as conflict engenders more conflict with the passage of time. No amount of normative analysis—that is, no amount of "reflective equilibrium,"[86] no amount of "rights talk,"[87] in short, no amount of wishful thinking, no matter how sincere—will change the underlying arms-race logic of a reciprocal conflict situation, as the film makes perfectly clear.

Accordingly, building on the main lessons of *The Battle of Algiers*, we present an alternative approach for understanding the problem of terrorism, and for modeling reciprocal conflicts generally, in Parts IV and V of the paper below.

IV. TERRORISM AS A RECIPROCAL ARMS-RACE

Thus far, we have reviewed previous models of terrorism as well as the classic film *The Battle of Algiers*.[88] Based on our review of this beautiful and compelling motion picture, this section will model the problem of terrorism as a reciprocal arms race: a high-stakes, life-and-death game, or a series of interactions between hawks and doves.[89] Specifically, we explain why terrorism (and conflict in general) may be regarded as an evolutionary arms race, and we treat these arms races between hawks and doves, terrorists and counter-terrorists, as a kind of "Prisoner's Dilemma" or game in which an individual or group can choose to either refrain from violence (cooperate) or resort to violence (defect).[90]

81. *Id.*

82. *See generally* Michael Shermer, *The Doping Dilemma*, 298 SCI. AM. 60, 60–67 (2008).

83. *See generally* F.E. Guerra-Pujol, *The Cheating Endemic in Law Schools*, 8 LEY Y FORO 21 (2007).

84. *Infra* Part IV.B.

85. *See generally* ROBERT TRIVERS, THE FOLLY OF FOOLS: THE LOGIC OF DECEIT AND SELF-DECEPTION IN HUMAN LIFE (2011).

86. For the idea of "reflective equilibrium," see JOHN RAWLS, A THEORY OF JUSTICE 48–51 (1971). Reflective equilibrium, however, is an especially weak method for solving intractable and incommensurate moral disputes, let alone the problem of terrorism.

87. *See, e.g.*, RONALD DWORKIN, TAKING RIGHTS SERIOUSLY xi (1978) ("Individual rights are political trumps held by individuals"); *see also* ROBERT NOZICK, ANARCHY, STATE AND UTOPIA ix (1974) ("Individuals have rights . . . .").

88. THE BATTLE OF ALGIERS, *supra* note 1.

89. *See also infra* Part V.

90. For a non-technical overview of more recent work in this area, see Martin A. Nowak & Karl Sigmund, *Cooperation versus Competition*, 56 FIN. ANALYSIS J. 13, 14–15 (2000). For a history of the "Prisoner's Dilemma" in the social sciences, see generally WILLIAM POUNDSTONE, PRISONER'S DILEMMA (1992). For an application of the Prisoner's Dilemma to doping in sports, see generally Shermer, *supra* note 82. However, before proceeding a brief but important digression about the terminology is in order. Although in this section (and in the remainder of this paper) we refer to terrorism as a "game," we do not in any way wish to belittle the horrendous human and economic costs inflicted by terrorist (and counter-terrorist) acts, nor to diminish the deadly seriousness

This section briefly discusses the utility of mathematical models generally, provides some theoretical background regarding the reciprocal arms-race logic of terrorism and counter-terrorism, and presents a simplified "dyadic" or two-player "Prisoner's Dilemma" model of terrorist and counter-terrorist interactions as well as a more realistic n-player evolutionary model.

A. A Few Words About the Utility of Models

Before proceeding, we wish to make a few general points about the utility of game-theoretic models. Much of the literature on terrorism and conflict is based on purely verbal arguments.[91] The problem with purely verbal arguments, however, is that they tend to be imprecise, fuzzy, and vague. The "looseness" of most verbal arguments leads to confusion and unproductive squabbling among scholars, who end up arguing back-and-forth for years about the meaning and implications of their verbal models.[92]

Of course, we recognize at the outset that game-theoretic models and mathematical models generally are much simpler than the real-world scenarios they are designed to depict. For example, the models in this paper are highly-stylized and based on a finite set of simplifying assumptions, such as symmetrical payoffs and a well-defined strategy set consisting of only two choices. In addition, we ignore the psychology of sunk costs, the problem of stochastic effects (such as random shocks), and the possibility of altruism or "other-regarding" behavior.[93] Nevertheless, what models give up in specificity and detail, they gain in tractability and clarity. In the words of two contemporary game theorists "models are simple maps for understanding the consequences of a small number of key assumptions."[94] In addition, formal models may help us uncover the underlying logic or unity of structure of seemingly unrelated situations. Then, and only then, after stating the operating assumptions of our models up front, do we attempt to explain the results of our model in words.

B. Theoretical Background

Since we will model the problem of terrorism as an evolutionary and reciprocal arms race, a few words about arms races are in order. In biology, an arms race refers to an evolutionary struggle or interaction between competing individuals (or, if one takes a "gene-eye" view of evolution, between competing sets of co-

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of the problem. Instead, by "game," we mean to emphasize one of the most important insights from game theory: that the outcome of any interaction or game is a function of the choices and strategies played by all the players participating in the game.

91. *See* Bueno de Mesquita, *supra* note 25; *see also* Berman, *Can Hearts and Minds Be Bought?*, *supra* note 11, at 817–19 (surveying counterinsurgency literature).

92. *See, e.g.*, Brian Leiter, *Beyond the Hart-Dworkin Debate: The Problem of Methodology in Jurisprudence*, 48 AM. J. JUR. 17 (2003).

93. *See generally* Robert Trivers, *The Evolution of Reciprocal Altruism*, 46 QUARTERLY REVIEW OF BIOLOGY 35 (1971).

94. Richard McElreath & Robert Boyd, Mathematical Model of Social Evolution: A Guide for the Perplexed 4 (2007).

evolving genes) that develop adaptations and counter-adaptations against each other.[95] Arms races occur in predator-prey interactions,[96] in host-parasite interactions,[97] and even in competitive interactions among members of the same species.[98]

Evolutionary arms races have two important (and often overlooked) features. One is the outcome of an arms race depends not on the absolute ability of each individual, but rather on each individual's ability relative to that of its competitors.[99] The other feature is that evolutionary arms races are "reciprocal" because "improved abilities in one species demand compensatory improvements by its enemies."[100] That is, "any beneficial step forward in the race by one player must cost the other and vice versa."[101] For example, in a two-player interaction, a new adaptation or strategy by one individual in the arms race leads to a new counter-adaptation or counter-strategy in the other player, and this counter-strategy, in turn, leads to a new counter-counter-strategy by the first player, and so on.[102] In the words of two biologists, "The result is a race in which both players run neck and neck, with well-matched abilities; each step forward by one player necessitates a reciprocal step by the opponent, lest the opponent fall behind."[103]

As an aside, it is worth noting that the degree of reciprocity or the "reciprocalness" of an arms race will vary with the stakes of the contest: the greater the cost of falling behind in an arms race, the more reciprocal the arms race will be.[104] For example, consider a road runner (or prey) being chased by a coyote (the

95. *See, e.g.*, R. Dawkins & J.R. Krebs, *Arms Races Between and Within Species*, 205 PROC. OF THE ROYAL SOC'Y OF LONDON B, BIOLOGICAL SCI. 489 (1979), *available at* http://www.oeb.harvard.edu/faculty/pringle/jc/Dawkins%20and%20Krebs1979.pdf (surveying literature of evolutionary biology); *see* Craig W. Benkman et al., *Reciprocal Selection Causes a Coevolutionary Arms Race Between Crossbills and Lodgepole Pine*, 162 AM. NATURALIST 182, 193–94 (2003); Gregory P. Dietl & Patricia H. Kelley, *The Fossil Record of Predator-Prey Arms Races: Coevolution and Escalation Hypothesis*, 8 PALEONTOLOGICAL SOC'Y PAPERS 353, 371–74 (2002).

96. *See generally* Benkman, *supra* note 95; *see also* Dietl & Kelley, *supra* note 95; *see also* Edmund D. Brodie III & Edmund D. Brodie Jr., *Predator-Prey Arms Races: Asymmetrical Selection on Predators and Prey May Be Reduced When Prey are Dangerous*, 49 BIOSCIENCE 7, 557 (1999).

97. *See, e.g.*, Ellen Decaestecker, et al., *Host-Parasite 'Red Queen' Dynamics Archived in Pond Sediment*, 450 NATURE 870 (2007); Vitaly V. Ganusov, Carl T. Bergstrom & Rustom Antia, *Within-Host Population Dynamics and the Evolution of Microparasites in a Heterogeneous Host Population*, 56(2) EVOLUTION 213 (2002).

98. *See generally* Benkman, *supra* note 95 (study of an arms race in the wild between red crossbills, a bird species, and Rocky Mountain lodgepole pine); Dietl & Kelley, *supra* note 95 (study of the fossil record of invertebrate predator-prey arms races—predatory crabs and their hard-shelled prey); Brodie & Brodie, *supra* note 96 (study of a predator-prey arms race between newt and garter snakes); Decaestecker, supra note 97; Vitaly, *supra* note 97; *see* Graeme P. Boswell et al., *Arms Races and the Evolution of Big Fierce Societies*, 268 PROC. OF THE ROYAL SOC'Y OF LONDON B, BIOLOGICAL SCI. 1723 (2001) (study of arms races in African ant colonies); Benkman, *supra* note 95, at 193–94 (2003) (a small sample of the vast literature on arms races); *see also* Sevan G. Ficici & Jordan B. Pollack, *Challenges in Coevolutionary Learning: Arms-Race Dynamics, Open-Endedness, and Mediocre Stable States*, *in* ARTIFICIAL LIFE VI: PROCEEDINGS OF THE SIXTH INTERNATIONAL CONFERENCE ON ARTIFICIAL LIFE (Christoph Adami, et al. eds., 1998) (presenting a fascinating "information-theoretic" model and computer simulation of an evolutionary arms race).

99. *See, e.g.*, Brodie & Brodie, *supra* note 96.

100. *Id.* at 557.

101. *Id.*

102. *Id.*

103. *Id.*

104. *Cf.* Dawkins & Krebs, *supra* note 95 ("life-dinner principle").

predator). In a terrorist conflict, the members of a small insurgent group are generally risking their entire livelihoods and fighting for their lives (like the Road Runner), while the imperial power (like the Wile E. Coyote) is merely fighting for its dinner.[105] In such contests, we would expect the process of selection to exert a stronger influence on the prey population (since the members of the prey population have more at stake) than on the predator population.[106] But in other interactions, the exploiter may actually have more to lose than the victim.[107]

Another feature of evolutionary arms races is the notion of "frequency dependence."[108] In general, each move in the arms race is met by a new counter-move, resulting in a co-evolutionary conflict. As long as neither side concedes defeat (or as long as a voluntary agreement or a Coasian bargain between them is impossible or not feasible), the two sides will remain locked into a perpetual co-evolutionary conflict or arms race, and furthermore, success in this co-evolutionary conflict is "frequency dependent." That is, a strategy fares well when rare and fares poorly when frequent, and conversely, a counter-strategy fares poorly when the strategy to be countered is rare and fares well when the strategy to be countered is frequent.[109] Because the success and failure of strategies (i.e. terrorist tactics) and counter-strategies (i.e. counter-terrorist tactics) are frequency dependent in this way, the relative frequencies of such strategies and counter-strategies will be expected to oscillate over time, but within upper and lower bounds that prevent them from disappearing altogether.[110]

This theoretical analysis thus raises an important research question: If the "war on terror" is an evolutionary and reciprocal arms race, what is to be done? If the problem of terrorism is "reciprocal" one (to borrow, once again, Coase's phrase), what is its solution? Given the lack of a legal solution to the problem of terrorism (that is, no law or legal institutions can solve the problem of terrorism),[111] how should this large legal vacuum be filled?

In summary, there are several possible solutions: commitment devices, coercion, conventions, and Coasian bargaining. But as we explain briefly below, none of these possible solutions are likely to be effective. Consider the use of binding and credible "commitments" or enforceable promises to refrain from violence.[112] The problem with this solution is that commitments are very hard to

105. The classic Road Runner and Wile E. Coyote cartoon characters were created by the animation director Chuck Jones. *See, e.g.*, Kevin McCorry, *The Road Runner Show*, GOLDENAGECARTTONS.COM, online essay *available at* http://looney.goldenagecartoons.com/tv/rrshow/ (last visited on Mar. 3, 2013).

106. *Id.*

107. Brodie & Brodie, *supra* note 96, at 561. For simplicity, in this paper we will assume that the degree of reciprocity is the same for both parties to the conflict; that is, we will assume that the stakes are more or less equal for both parties (hawk and dove, or predator and prey) and that both parties share the same level of intensity of preferences regarding the outcome of the conflict.

108. *See* TRIVERS, *supra* note 85.

109. *Id.* at 30.

110. *Id.*

111. One of my students, Ms. Sydjia Robinson, once asked the author, "What about the Hague?" in reference to the International Criminal Court (ICC) in the Netherlands and similar international legal institutions. In reply, I said, "What about the Hague?" That is, in the absence of an independent and international police force, the enforcement of international norms is sporadic and haphazard at best.

112. SCHELLING, *supra* note 51, at 24–28.

make credible and binding.[113] If the conflict is a Prisoner's Dilemma (as we believe the "war on terror" to be),[114] then all participants in the conflict (not just one player unilaterally) must commit themselves not to defect in order for the commitment to be effective, an unlikely scenario in the context of terrorism.

Another way legal vacuums are filled is through decentralized conventions or invisible-hand processes such as the Law Merchant, cyber-currencies, and caste systems.[115] Although conventions tend to arise spontaneously whenever there is a legal vacuum,[116] the problem with this solution method is that the resulting norms or conventions may not necessarily be wealth-maximizing or mutually-beneficial, and the conditions necessary for their creation and evolution may not be stable or present.[117] To be effective, there must be some mechanism for identifying and punishing defectors.

Yet another solution method is the "Leviathan" of positive law or the Hobbesian method of centralized coercion.[118] But, in the context of terrorism, a coercive solution presupposes the existence of a transnational Leviathan able to impose its will on terrorist actors, and regardless of the feasibility of creating such a Leviathan in the context of terrorism, coercive solutions are often perceived as illegitimate or unfair.[119]

Lastly, perhaps the most desirable method of filling a legal vacuum is through voluntary negotiations or Coasian bargaining among the affected parties.[120] In theory, negotiated solutions produce gains from trade in which all sides are made better off.[121] However, in practice, bargaining does not appear to be feasible in the context of terrorism, especially when both sides to the conflict are guided by diametrically opposed normative goals and believe to be acting on principle.[122]

Summing up, we have seen that the problem of terrorism appears to be insoluble because terrorism and counter-terrorism occur in a legal vacuum, and we have briefly noted the difficulties in filling this vacuum.[123] Given this legal

113. *Id.*

114. *Infra* Part IV.C.

115. *See* NOZICK, *supra* note 87, at 18–22; *see also* DAVID LEWIS, CONVENTIONS: A PHILOSOPHICAL STUDY (Harvard Univ. Press 1969).

116. *See generally* Robert Sugden, *Spontaneous Order*, 3 J. ECON. PERSPECTIVES 85 (1989).

117. *See, e.g.*, F.E. Guerra-Pujol, *On the Origins of Property* 3–7 (unpublished manuscript dated December 31, 2009, on file with the author).

118. *See, e.g.*, HOBBES, *supra* note 53, at 188–208.

119. *See, e.g.*, EDWARD ZAJAC, POLITICAL ECONOMY OF FAIRNESS 185–86 (1995).

120. We take this to be the main lesson of the economic approach to law, or "Law and Economics." *See generally* Coase, *supra* note 35.

121. *Id.*

122. Notice that, for purposes of this background section, we have identified only four methods of filling a legal vacuum: credible commitments, coercion (law), conventions (spontaneous order), and Coasian bargaining. Another possible solution method, though less frequently used in practice, is the use of a random mechanism, such as a coin toss or the drawing of lots. *See, e.g.*, Charles V. Bagli, *Flipping a Coin, Dividing an Empire*, N.Y. Times, Nov. 1, 2009, at B1; *see also* NEIL DUXBURY, RANDOM JUSTICE: ON LOTTERIES AND LEGAL DECISION-MAKING (2002) (for a more extended discussion of random mechanisms).

123. Nevertheless, on some occasions, either through tacit Coasian bargaining or "spontaneous order," a cooperative solution may emerge even among warring factions. For example, according to Lt. Col. Daniel Davis, many elements of the Afghan National Security Forces have made deals or Coasian bargains with the Taliban. Davis, *supra* note 51 ("[The Afghan security forces] won't shoot at the Taliban, and the Taliban won't shoot

vacuum, we now present a simple two-player and n-player model of terrorist and counter-terrorist interactions in which we model the behavior of terrorists and anti-terrorists in the current vacuum and predict the most likely outcome of their interactions.

C. A Two-Player Game

Our two-player game consists of a one-shot, simultaneous-move game in which the players, whom we designate as Player A and Player B, may either play a "hawk" strategy and thus *fight* or play a "dove" strategy and thus *back down*. The intuition behind this game is that both players may, in fact, prefer reciprocal conflict when they both play the hawk strategy. But at the same time, each player always has the ability to avoid reciprocal conflict by choosing the dove strategy, a point we made in our analysis of the film, *The Battle of Algiers*.[124] We begin with this simple scenario first, for ease of exposition. In the next subsection, we consider a more realistic n-player game.

First, assume that the players must simultaneously choose between one of two possible strategies at the outset of the game: *hawk* or *dove*. In addition, notice that the respective benefits and costs corresponding with each strategy are specified in abstract terms—the parameters b and c—rather than expressing them in numerical values in order to illustrate the underlying logic and structure of seemingly unrelated problems.[125] In addition, another advantage of expressing these values as abstract parameters is flexibility and generality. In other words, our abstract model permits us to derive results for any value that these parameters might actually take.[126] Since this is a game-theoretic or interactive model, the payoffs depend on the strategies simultaneously chosen by the players at the start. The game and the payoff-structure of the terrorism game can be expressed in "extended form" (see Figure 1a below) as follows:

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them."); *see also* AXELROD, EVOLUTION, *supra* note 51, at 73–87 (a similar "live and let live" dynamic or cooperative equilibrium between British and German forces occurred during the first world war).

124. THE BATTLE OF ALGIERS, *supra* note 1.

125. For simplicity, we also assume that the payoffs of each player are equal; that is, we assume that the value of the parameters b and c are fixed.

126. MCELREATH & BOYD, *supra* note 94, at 6.

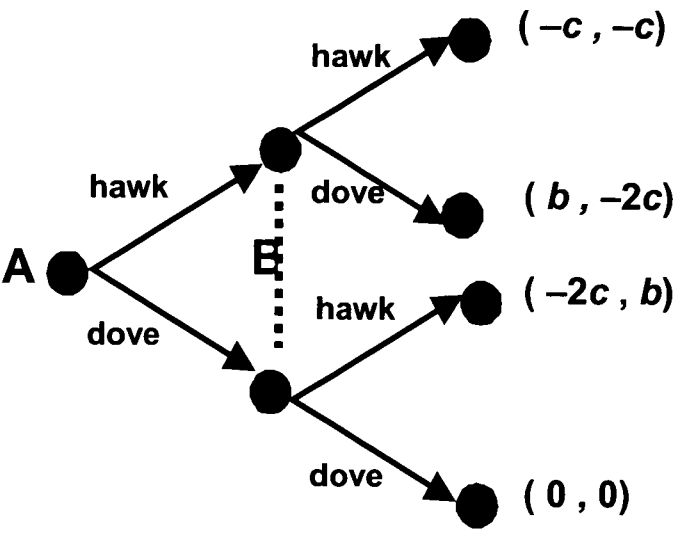

Figure 1a
Extended form game tree

Note that the dotted line between the nodes in Player B's strategy set indicates that Player B does not know what choice Player A has made. Likewise, the terrorism game is a simultaneous-movement game because the choices of the players are not observable until after both players made their respective moves. Given the importance of surprise in the "war on terror" (i.e. given that neither side knows with certainty when and where the next attack will occur), this is a realistic assumption.

In addition, aside from the game tree or extended-form depiction of the terrorism game above, the payoff structure of the game may also be expressed in "normal form" (see Figure 1b below), as in the following payoff table:

	Player B *hawk*	Player B *dove*
Player A *hawk*	$-c, -c$	$b, -2c$
Player A *dove*	$-2c, b$	$0, 0$

Figure 1b
Normal-form Payoff Table
b = benefits; c = costs

Accordingly, there are four possible interactions or scenarios in the one-shot version of our game: (1) hawk-dove, (2) dove-hawk, (3) dove-dove, and (4) hawk-hawk. These can result in four possible payoff combinations. Notice that a hawk-hawk interaction, one in which both players choose the hawk strategy, is tantamount to a reciprocal conflict, while the other three possible scenarios are not reciprocal in nature. We explain below the logic of the payoffs associated with each possible scenario as follows:

First, consider what happens if one player defects (i.e. plays hawk), while the other cooperates (i.e. plays dove). If A plays hawk, while B plays dove, then the expected value of player A's payoff in our model is b because he has, by definition, won the conflict.[127] By contrast, the expected value of player B's payoff in this scenario is $-2c$ because player B not only loses the contested resource, but by backing down, he also "loses face" by publicly demonstrating his willingness to back down and allowing himself to be bullied by player A.

Next, consider what happens when both players decide to cooperate with each other by playing dove instead of hawk. In the event of a "dove-dove" interaction, the expected value of the players' respective payoffs in our model falls to zero. Why? Because in this scenario the status quo prevails. Therefore, in effect, a

127. Note that b may be the value of a contested resource (such as land) or the increase in prestige and reputation due to winning.

stalemate or a draw occurs in which neither side loses, but neither wins. Lastly, consider what happens when both players decide to defect by playing hawk. If both players decide to fight, resulting in a "hawk-hawk" interaction, the expected value of their respective payoffs now falls to $-c$ (instead of zero) because they will each inflict a harm on the other (for simplicity, we assume the harm inflicted on each side is the same).

Given this payoff structure and these four possible interactions in our simplified one-shot, simultaneous-move model, what is the likely outcome of this game? Which of these four scenarios is most likely to occur? Stated formally, is there a stable equilibrium point?

Yes; it is the Hobbesian equilibrium of reciprocal conflict, where both sides end up playing hawk. Why? Because the "hawk" strategy is always the best response to the other player's strategy. For example, if the other player is a dove, then the first player's best response is to take advantage of the other player's weakness and play hawk, since $b > 0$. However, if the other player is a hawk, the first player's best response is still hawk because he receives a higher payoff by defecting and playing hawk than by backing down and playing dove. To be more precise, the first player minimizes his loses by playing hawk in response to another hawk, since $-c$, though bad, is still preferable to $-2c$.

Notice, then, that our model of the terrorism game bears a family resemblance with the "Prisoner's Dilemma" because the hawk and dove behaviors in our model correspond with selfish "defection" and pro-social "cooperation" in the "Prisoner's Dilemma."[128] In addition, our model resembles the "Prisoner's Dilemma" in another important respect. In the one-shot "Prisoner's Dilemma," selfish behavior is always a "dominant strategy" because defection is always a "best response" to the other players behavior, regardless whether the other player cooperates or defects.[129] Likewise, in our terrorism game, defecting (i.e. playing hawk) is always the best response to the dove strategy and to the hawk strategy.

Simply put, in the absence of coercion, conventions, credible commitments, or Coasian bargaining, or some other possible solution, such as a random device to the problem of terrorism, our simple model of the "terrorism game" is a pessimistic one, for it predicts that it is highly unlikely that the contestants will ever produce a positive-sum equilibrium in which everyone benefits from mutual cooperation. Instead, our model predicts that the players will reach negative-sum Hobbesian equilibrium, one in which everyone is worse off because of mutual defection. Instead of "reciprocal altruism," we have "reciprocal conflict."[130]

128. *See* RICHARD DAWKINS, THE SELFISH GENE 202–33 (3d ed. 2006) (overview of the "Prisoner's Dilemma"); *see generally* POUNDSTONE, *supra* note 90 (entertaining narrative history of the "Prisoner's Dilemma").

129. DAWKINS, *supra* note 128.

130. *See generally* Robert L. Trivers, *The Evolution of Reciprocal Altruism*, 46 Q. REV. BIOLOGY 35 (1971).

D. An Evolutionary *n*-Player Terrorism Game

In place of the two-player model in Part IV.C above, consider an *n*- or multi-player model of the terrorism game. Our *n*-player model operates on the following assumptions: the population of players consists of a large number of individuals; during each round of play, two individuals selected at random from the population meet and engage in a micro-interaction; and as before, there are only two possible strategies or types of individuals: *hawk* and *dove*. Lastly, we further assume that these strategies are transmitted through an asexual inheritance mechanism: the victor of each two-pair micro-interaction (i.e. the player receiving the higher payoff) not only survives, but also produces a descendant-clone who asexually inherits the victor's strategy. The loser, in contrast, is eliminated from the population. If the interaction ends in a draw or tie (i.e. a hawk-hawk or dove-dove interaction), both contestants survive but neither produces a descendant.

Given these assumptions, which strategy will be favored by natural selection? The answer to this question comes in stages. First, we restate the payoffs, V, corresponding to each possible interaction. Since the payoffs are the same as before (see Figure 1b above) and there are four possible micro-interactions in all (hawk-hawk, hawk-dove, dove-hawk, and dove-dove), the payoffs corresponding to each interaction can be written as follows:

$V(H|H)$ = [the payoff to a hawk given that he interacts with another hawk] = $-c$

$V(H|D)$ = [the payoff to a hawk given that he interacts with a dove] = b

$V(D|H)$ = [the payoff to a dove given that he interacts with a hawk] = $-2c$

$V(D|D)$ = [the payoff to a dove given that he interacts with another dove] = 0

On the far-left and far-right hand sides, we have expressed the payoffs corresponding to each interaction in mathematical form, while in the middle part we have "translated" the mathematical notation into plain English for the non-mathematical reader. Notice also that, because of the symmetrical nature of our model we have stated the payoffs of the row player only (Player A).

Since this is a population model, the fitness of a given strategy is said to be "frequency dependent" because the success, fitness, or survival rate of a strategy depends not only on the frequency of the other strategy, but also on that strategy's own frequency.[131] When fitness (rate of survival) is frequency dependent, we proceed to use evolutionary game theory to determine which strategies are

131. *See, e.g.*, MCELREATH & BOYD, *supra* note 94, at 38.

"evolutionarily stable strategies" (ESS's) and to find the long-run evolutionary equilibrium of the population—that is, the frequency of hawks and doves over many generations.[132] Specifically, we wish to answer the following two questions:

(1) Is the *hawk* or *dove* strategy able to resist an invasion by the other strategy?

(2) If neither strategy is evolutionarily stable (i.e. if neither *hawk* nor *dove* is able to resist invasion by the other strategy.) Is there an evolutionarily stable mix of strategies?

In sum, a population of hawks will always be able to resist an invasion from doves, while a population of doves will always be susceptible to invasion by a single hawk.[133] Hence, one would expect a counter-productive and wasteful arms race to develop among hawks. Each hawk attempts to minimize his losses and maximize his gains in his conflicts with other hawks by continually finding new ways of improving his fighting abilities relative to the abilities of other hawks.

V. ALTERNATIVE POPULATION MODEL OF HAWK-DOVE CONFLICT

In the previous section of the paper, we modeled the problem of terrorism as a Prisoner's Dilemma. Nevertheless, because the logic of the "Prisoner's Dilemma" has been studied so extensively by other scholars,[134] and because we wish to emphasize both the reciprocal and frequency-dependency nature of terrorist/anti-terrorist arms races, we will take a different approach in this section of the paper. We propose a logistic growth or population model to illustrate the reciprocal logic of terrorism and conflict in general.[135] That is, in place of a game-theoretic "Prisoner's Dilemma" model, here we present a simple two-equation model of interactions among a population of interacting predators and prey (such as hawks and doves) in order to illustrate the frequency-dependent nature of terrorist/anti-terrorist arms races. Our model is based on the classic Lotka-Volterra population model in biology.[136] First, we model the dynamics of the prey population.[137] Then, we model the dynamics of the predator population.[138] Last, we find the population equilibrium for our simple model.[139]

132. *See generally* JOHN MAYNARD SMITH, EVOLUTION AND THE THEORY OF GAMES 11 (1982).
133. For a formal statement of this result, see the mathematical appendix at the end of this paper.
134. *See, e.g.*, AXELROD, EVOLUTION, *supra* note 51, at 73–87; Robert Axelrod & W.D. Hamilton, *The Evolution of Cooperation*, 211 SCI. 1390, 1390–96 (1981).
135. *See* Alan A. Berryman, *The Origins and Evolution of Predator-Prey Theory*, 73 ECOLOGY 1530 (1992) (explaining the history of predator-prey population models in biology).
136. *See* Alfred J. Lotka, *Analytical Notes on Certain Rhythmic Relations in Organic Systems*, 6 PRO. OF THE NAT'L ACAD. OF SCI. OF THE U.S. 410 (1920).
137. *Infra* Part V.A.
138. *Infra* Part V.B.
139. *Infra* Part V.C.

A. The Prey Population

Since we are modeling two separate populations—predators and prey, or hawks and doves—we must first define the population dynamics of each population before we can see what equilibrium, if any, will emerge when both populations interact with each other. To keep our model as simple as possible, we first model the rate of change in the prey population (dx) over time (dt) as follows:

$$dx/dt = x(a - by)$$

Simplified, this equation becomes:

$$dx/dt = ax - bxy \qquad (1.1)$$

In other words, the rate of change in the size of the prey population over time, or dx/dt, is equal to the rate of growth of the prey population minus the rate at which the prey population is preyed upon by predators. The first term on the right-hand side of equation 1.1 is the rate of growth of the prey population: ax. The second term is the rate of predation, or bxy, which is proportional to the rate at which predators and prey interact and the rate of growth of the predator population. Lastly, notice that the term ax, the rate of growth of the prey population, is exponential in the absence of predators, i.e. when $y = 0$.

B. The Predator Population

Now that we have modeled the population dynamic among the prey population, we next model the rate of change in the predator population (dy) over time (dt) as follows:

$$dy/dt = y(bx - c)$$

Simplified:

$$dy/dt = bxy - cy \qquad (2.1)$$

Thus, the rate of change in the predator population over time, or dy/dt, is a function of two parameters: (1) the rate of predation: bxy, and (2) the rate of death or migration in the predator population: cy.

Notice that the first term on the right-hand side of equation 2.1 is identical to the second term on the right-hand side of equation of 1.1. The intuition behind this simplification is that the rate at which the predator population grows is equal to the rate at which it consumes prey. In other words, the growth rate of the predator population in equation 2.1, or bxy, is identical to the rate of predation in equation 1.1 (again, bxy). This is a simple assumption, but it is one that captures the

reciprocal nature of the predator-prey relation. In addition, the second term of the right-hand side of equation 2.1, or cy, is the "loss rate" of predators resulting from death or migration away from the predator population. Notice that this term leads to exponential decay in the absence of prey, i.e. when $x = 0$.

C. Predator-Prey Population Equilibrium

Lastly, what happens when predators and prey interact? Will predators eventually consume the entire prey population and thus end up destroying themselves as x approaches 0 (as we might expect if predator-prey interactions are modeled as a "Prisoner's Dilemma," as in Parts IV.C and IV.D above), or will both populations be able to reach a stable equilibrium and somehow co-exist side-by-side? If the latter is true, what proportion of the population will consist of predators (or hawks)? What proportion of prey (doves)? In other words, if there is a stable equilibrium will its main beneficiaries be the ruthless predators or the hapless prey?

Generally, one might expect to find an oscillating or fluctuating equilibrium.[140] At first, predators will thrive when prey are plentiful because the rate of growth of the predator population in equation 2.1 is a function of predator-prey interactions. At the same time, predators can become victims of their own success. T, the growth rate of predators will decline when predators begin to outstrip their prey-based food supply, or stated formally, when the rate of growth of the predator population exceeds the rate of growth of the prey population.

But now, the decline in predators will, in turn, lead to an increase in prey. As the predator population approaches zero, the prey population will bounce back and begin to increase again. In sum, we see a five-step dynamic or cycle in which (1) predators move in and increase in numbers; (2) this increase in the growth rate of predators causes a decline in prey; (3) the decline in prey causes a decline in predators; (4) the decline in predators causes an increase in prey; and (5) the increase in prey causes the cycle to start all over again.

This predator-prey dynamic will continue *ad infinitum*, producing a perpetual cycle of growth and decline in both populations. Notice how this cycle or "dynamic equilibrium" demonstrates the reciprocal nature of the predator-prey dynamic. On the one hand, predators are "bad" from the prey point-of-view because predators eat prey and thus cause the prey population to decline. But at the same time, prey are "bad" from predator perspective because a decline in prey likewise causes a decline in predators.[141]

Is this intuition of a perpetual, never-ending cycle correct? What does our predator-prey model predict?

140. *See* Lotka, *supra* note 136; *see* TRIVERS, *supra* note 85, at 30–36 (explaining the phenomenon of an oscillating or fluctuating equilibrium).

141. *See* Brodie & Brodie, *supra* note 96, at 558–59 (explaining the exposition of the reciprocal nature of arms races generally, or the phenomenon of "reciprocal selection").

In summary, two possible and nasty equilibriums are possible: (1) extinction and (2) perpetual conflict. Stated formally, the global population of predators and prey will reach equilibrium when the following conditions occur:

$$x(a - by) = 0$$

And when:

$$y(bx - c) = 0$$

In other words, we set each population equation equal to *zero* and solve each equation for x and y. When solved for x and y, our simple system of predator-prey equations yields two separate solutions:

Solution #1: $x = 0; y = 0$

Solution #2: $x = c/b; y = a/b$

The first solution concept represents a worse-case scenario, similar to our "Prisoner's Dilemma" model: the total extinction of both predators and prey. The mathematical logic of this solution is that if either population reaches *zero*, then they will both remain there. Consider the problem of terrorism or other high-stakes conflicts. When both sides reciprocally inflict and suffer enormous costs, one possible outcome is that, in the long run, the conflict becomes unsustainable and both sides "lose."

The second solution concept is, in essence, a "Hobbesian equilibrium" in which both predator and prey populations are able to sustain their current numbers—and in which conflict is therefore perpetual and never-ending. Stated formally, the second solution concept represents a "fixed point" at which the population equilibrium depends on the actual numerical values of the parameters a, b, and c. (Recall from our previous analysis that a is the rate of growth of the prey population, b is the rate of growth of the predator population, and c is the loss rate of the predator population). This state of affairs is perhaps preferable to complete extinction, but it implies a Hobbesian equilibrium: the existence of perpetual and reciprocal conflict.

VI. CONCLUSION

In place of normative analysis, we briefly reviewed previous models of terrorism and then presented an alternative and more realistic picture of the problem through the film, *The Battle of Algiers*.[142] Based on our review of this beautiful and compelling motion picture, we modeled the problem of terrorism as a high-stakes, life-and-death game, or a series of interactions between hawks and

142. THE BATTLE OF ALGIERS, *supra* note 1.

doves. Specifically, we presented two formal models in this paper: a simple Prisoner's Dilemma model of the "terrorism game" as well as a simple logistic or population growth model of predator-prey or hawk-dove interactions. We have shown that when the moves of the game are simultaneous and the payoffs symmetrical, hawk is a dominant and evolutionarily stable strategy. In addition, our logistic or population model has shown that, from a macro or population perspective, two possible but nefarious outcomes are likely: extinction or a Hobbesian equilibrium of perpetual conflict.[143]

Although these models, like all models of reality, are necessarily false and incomplete, they are useful because they formalize the reciprocal and arms-race nature of terrorism and counter-terrorism (two lessons which are more effectively presented in *The Battle of Algiers*).[144] Although the focus of this paper is on the problem of terrorism, the model has wide application to other forms of conflict because arms races occur and are central to all conflicts in nature and in life: parasite versus host, predator versus prey, neighbor versus neighbor, wife versus husband, parent versus offspring, and terrorist versus counter-terrorist. The difference between terrorism and other forms of (non-violent) conflict is thus one of degree. We would expect to see the same co-evolutionary and frequency-dependent dynamic occur in all types of conflict.

What normative or general lessons do these models and the film offer us? In brief, because the problem of terrorism is reciprocal in nature—like predator-prey interactions in nature—the "war on terror" is a futile endeavor. Every new attack generates a fresh counter-attack, which in turn generates a counter-counter-attack and a perpetual cycle of violence, that does not end until both sides have inflicted and suffered enormous costs or until both sides reach a stable but nefarious equilibrium (what we refer to in this paper as a "Hobbesian equilibrium"). In the absence of law, "spontaneous order," or Coasian bargaining, the use of terrorist tactics by aggrieved minorities and counter-terrorist tactics by powerful majorities may well be inevitable.

Lastly, the following areas may be ideal for future research:

(a) What happens when the payoffs are asymmetrical instead of symmetrical?

What happens when hawks have more at stake than doves, or vice versa? In this paper, we assumed for the sake of simplicity that the payoffs are perfectly symmetrical for the players. However, in reality one player may have more to gain (or more to lose) than the other player.[145] If so, what effect will asymmetrical stakes have on the outcome of the game?

(b) What happens if the values of the parameters b and c change over time?

143. Another possible conclusion is that the "war on terror" resembles a predator-prey arms race—but in place of well-defined or separate "predator" and "prey" roles, both sides of the interaction simultaneously (or successively) take on both roles of predator and prey over time.

144. *Id.*

145. *Cf.* Dawkins & Krebs, *supra* note 95.

Another interesting question for future research is to consider the possibility that the parameters b and c might change over time. Again, for simplicity, we have assumed that the values of these parameters are fixed, but in reality the payoffs might be dynamic instead of static. How do dynamic payoffs change the outcome of the game? To find out, one could build a model in which either b or c (or both) change by some constant k. This constant might itself be fixed, in which b increases by some factor k' during each round of play, or it might be probabilistic, varying from zero to one according to some random mechanism.

(c) Is there a link between the payoffs in a given round and the outcome of future rounds?

Yet another interesting idea for future work is the possibility of keeping track of the players' relative payoffs during the successive rounds of the game and determining if there is any relation between the payoff level of a player and his choice of strategy. That is, are winning players more likely to cooperate (play dove) or defect (play hawk)? The intuition here is that one's previous choices will not only have an effect on one's future choices, but will also affect the likely outcome of the future rounds of the game. Although in this paper we did not consider the accumulated payoffs (both losses and gains) from previous rounds of play (since such past payoffs are sunk costs), in the real world the outcomes of previous rounds of play may exert an enormous effect on the psychology of the players. Moreover, if the selection or implementation of a strategy is not costless, and if the resources available to the players are scarce or subject to some upper limit, then it becomes imperative to keep track of losses and gains during the rounds of play.[146]

MATHEMATICAL APPENDIX

Let p be the frequency of hawks in the population, and thus let $1 - p$ be the frequency of doves in the population. First, consider a population in which the frequency of hawks is very high ($p \approx 1$). Under this scenario, hawks rarely interact with doves because the frequency of doves is very low ($1 - p \approx 0$), and thus the average fitness of a hawk, stated formally as $W(H)$, is determined by his interactions with other hawks in the population as follows:

$$W(H) = w' + (1)[V(H|H)] + (1 - 1)[V(H|D)]$$

$$W(H) = w' + V(H|H)$$

146. For example, the payoff level of the players might be presented visually in the form of a circle. This circle, in turn, would consist of two colors, such as blue and green, with blue representing one player's level of wealth and green representing the other player's wealth level. This way, one may keep track of the changes to each player's relative payoffs during successive rounds of play.

$$W(H) = w' - c$$

Before proceeding, note that the parameter w' in our equations refers to the "baseline fitness" or baseline survival rate of all the strategies in the population—that is, the probability of survival from generation to generation—and thus reflects the strength of selection on a given population.[147] For convenience, we also assume that w' is larger than c.

Now, consider the possibility of a rare dove-like mutant. What would happen if a dove were to interact with this rare dove mutant? Put another way, will the *dove* strategy begin to spread across the population, gradually displacing the hawks, or will the *hawk* strategy be able to resist invasion? To answer this question, we must determine the average fitness of the rare dove mutants among the population of hawks. Since doves are rare $(1 - p \approx 0)$, the chance one dove will meet another dove is likewise small. As a result, the average fitness of a rare dove, or $W(D)$, is determined by his interaction with hawks as follows:

$$W(D) = w' + (1)[V(D|H)] + (1 - 1)[V(D|D)]$$

$$W(D) = w' + V(D|H)$$

$$W(D) = w' - 2c$$

Notice, then, that in a population of hawks, the hawks will on average outperform the doves because $W(H)$ is greater than $W(D)$. In other words, hawks will resist invasion from doves.

But can a population of doves likewise resist an invasion of hawks?

To answer this question, consider a population in which the frequency of doves is very high $(1 - p \approx 1)$. Since doves mostly interact with other doves and rarely with hawks, the average fitness of a dove, $W(D)$, is thus determined by his interactions with other doves as follows:

$$W(D) = w' + (1)[V(D|D)] + (1 - 1)[V(D|H)]$$

$$W(D) = w' + V(D|D)$$

$$W(D) = w' - 0 = w'$$

Next, what would happen if a rare hawk mutant were to appear on the scene? Since hawks are rare $(p \approx 0)$, the hawk mutant will interact mostly with doves and his average fitness, $W(H)$, is thus as follows:

$$W(H) = w' + (1)[V(H|D)] + (1 - 1)[V(H|H)]$$

147. MCELREATH & BOYD, *supra* note 94, at 40–41.

$$W(H) = w' + V(H|D)$$

$$W(H) = w' + b$$

Thus, hawks will invade a population of doves and eventually displace the doves because the average fitness of each hawk ($w' + b$) is on average higher than the average fitness of each dove (w'), that is, because $W(H)$ is greater than $W(D)$. A population of doves will unravel in presence of a single hawk.