Do Exploitive Agents Benefit from Asymmetric Power in International Politics?

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Abstract: Endowing agents that prefer cooperative outcomes with asymmetric power substantially increase the chances that both cooperative agents survive and that cooperative worlds evolve across a variety of structural settings of conflict and cooperation present in international relations; particularly when agents are endowed with the ability to selectively interact with other agents. These results are consistent with the general finding that non-compulsory play consistently helps cooperators. The question addressed in this analysis is whether or not asymmetric power also helps exploitive agents in the same structural settings; a question heretofore not analyzed. Contrary to expectations, the simulation results reported here suggest that exploitive agents do not benefit from asymmetric power. In effect there is an asymmetry in the benefits of asymmetric power.
1. Introduction

Whether and how cooperation emerges and can be maintained in social settings characterized by the presence of selfish agents engaged in repeated relations without central authority has been of considerable importance to scholars of international politics. In particular, international relations scholars have been interested in features of agents (typically nation-states), the relations among agents, and the structural environment agents are embedded in that make cooperation either possible or more likely. Nation-states, of course, are differentiated on many dimensions and it is not surprising that differentiation among agents in terms of power and capability, what I label asymmetric power, has been of particular interest to international relations scholars because such asymmetries have been an enduring feature of international systems.

In this vein, Majeski (2004) constructed a set of agent-based models based upon a group of repeated 2X2 games (Prisoners Dilemma, Chicken, Stag, Assurance, and Deadlock) and examined the effects of the introduction of asymmetric power among agents on the emergence of cooperation. The analysis demonstrated that the introduction of asymmetric power substantially increased the chances that cooperative agents survived and that cooperative worlds evolved; particularly when agents were endowed with the ability to selectively interact with other agents in their world (Majeski, 2004). Selective interaction helps agents that want to cooperate more effectively establish and maintain what could be characterized as cooperative regimes where norms of niceness, retaliation, and limited forgiveness prevail. For those cooperative regimes to be maintained agents must punish both free riders and exploiters.
It is not surprising that the introduction of selective interaction increases the likelihood that cooperative agents survive and generate high levels of cooperation in an initially hostile environment. Selective interaction is a form of non-compulsory play and, like providing agents with the option to exit, withdraw, or move away from undesirable locations, has been shown to increase the likelihood of cooperation. Selective interaction helps agents that want to cooperate because they can choose to interact only with those agents that also cooperate and avoid interacting with those agents that defect.

The reason that selective interaction helps agents that prefer cooperative outcomes also appears to apply to agents that want to exploit other agents. Exploitive agents also do well when they interact with other agents that cooperate and do poorly when they interact with other agents that defect. Exploitive agents that either only or almost exclusively interact with agents that are exploitable (those who unilaterally cooperate and/or do not punish unilateral defection) ought to do well and should be more effective at exploiting and potentially destroying cooperative regimes than exploitive agents that must interact with cooperative agents that do retaliate and punish defection and/or with other exploitive agents. Yet, the effects of providing exploitive agents with asymmetric power have not been systematically examined.

The international system contains agents that seek to exploit other agents in many contexts. Indeed, the fear that other agents will attempt to exploit them is a central concern for nation-states engaged in such phenomena as arms races and arms control arrangements. Economic embargos and sanctions often fail because some states exploit the cooperative arrangement and secretly break the embargo agreement. International agreements such as the Ottawa Treaty to Ban Landmines, Kyoto Accords on Global
Warming, and the Nuclear Non-proliferation Treaty are undermined because key states either cheat or never enter into the agreement. Finally, bargaining about trade agreements with threats of sanctions and the possibility of trade wars are designed to constrain both potential and actual exploiters. Given, the prevalence of contexts in international politics where exploitation is likely, it makes sense to determine whether or not exploitive agents also benefit from asymmetric power.

In this analysis, the impact of providing exploitive agents with asymmetric power is examined in a variety of different settings of conflict and cooperation prevalent in international relations (Chicken, Stag, Assurance, Deadlock, and Prisoners Dilemma). Before doing so, the structure of the agent-based model that agents inhabit and interact in is developed and two forms of asymmetric power are explicitly introduced.

2. Structure of the Agent-based Model

All agent-based models have two components: agents, and an environment or world the agents inhabit. In abstract terms, agents are bundles of two types of rules: those that define various internal states of the agent and those that dictate how the agent responds to various stimuli from other agents and the environment (Holland, 1995). The basic structure of the agent-based model developed here is a repeated (2X2) game. Agents have two choices: cooperate (C) and defect (D). When an agent interacts with another agent, there are four possible outcomes: both cooperate (CC), both defect (DD), one agent cooperates and the other defects (CD), or one agent defects while the other cooperates (DC).

Each agent is represented by a strategy specifying how the agent behaves when it interacts with other agents. Agent strategies are restricted to those employing the
previous interaction with other agent(s) to determine current choices. Strategies are probabilistic, defined by the conditional probabilities to cooperate \((p_1, p_2, p_3, p_4)\) given that the outcome of the previous interaction was \((\text{CC, CD, DC, or DD})\), respectively. In addition, a strategy stipulates whether the agent cooperates or defects when it interacts for the first time with another agent. For example, an agent employing the familiar “Tit for Tat” (TFT) strategy cooperates the first time it interacts with another agent. However, it cooperates with 100% probability the next time only if the other agent cooperated the last time (following a CC or DC outcome). It will defect with 100% probability the next time if the other agent defected during the prior interaction (following a CD or DD outcome). Thus, the conditional probabilities to cooperate for the TFT strategy are \([1.0, 0.0, 1.0, 0.0]\).

Several features are added to the basic repeated (2X2) game to produce the agent-based model. First, in most social contexts agents are located at or occupy some place or position in their world at any given moment in time; as a result, most interactions among social units are dictated by spatial proximity. Therefore, an explicit spatial dimension is introduced by constructing a toroidal world or environment (a 20 X 20 grid of cells) consisting initially of sixty agents randomly assigned locations on the grid. Each cell contains at most one agent. For each round of the simulation, agents interact with all agents who occupy the four non-diagonal cells that immediately surround the agent, a von Neumann neighborhood.

Second, most social agents—be they firms, tribes, individuals, or families—can and do move. Agents typically move when they find themselves in an unprofitable and undesirable situation or location. While there is usually a cost to the agent associated
with moving, the benefits from freeing itself from the negative consequences of a particular location can be sufficient to warrant relocation. The problem is that nation-states in the modern international system do not move. States may expand, collapse, or disappear; however, the state, in some sense defined as the control of a particular physical territory, does not move. Therefore, in this analysis agents cannot move. Once they are located on a cell on the spatial grid, they remain there until they run out of energy or die of old age and at that point are removed from the grid. This means that an agent with no neighbors does not interact. It cannot move, so interaction can only occur if a new agent (via replication) is located in its neighborhood.

Third, all social agents consume various resources to sustain themselves and all ecologies (environments) can support a finite number of agents. As more agents compete, the economic and environmental costs of available resources increase. Therefore, an environmental carrying capacity is incorporated into the agent-based model by introducing a cost of survival for agents. As the artificial world or environment becomes more populated, the cost of living and ultimately surviving for agents increases. The number of agents is restricted to a fixed range by applying a cost of surviving to every agent, and each iteration is dependent on population size. The formula for the cost of surviving ($\alpha$) is

$$\alpha = k + 4 \times (DC + CC) \times N / (X \times Y)$$

where $k$ is a constant, $(DC)$ and $(CC)$ are the RPD payoffs, $N$ is the number of agents in the world, and $X$ is the width and $Y$ is the height of the world grid. The cost of surviving indirectly allows the simulation to select the percentage of the population with the highest energy levels for reproduction and the lowest percentage for elimination. The
change in energy for an agent at each iteration ($\Delta E$), where $\Delta E$ equals the energy level of
the agent at iteration (t) minus the energy level at iteration (t-1), is the sum of all
interactions minus the cost of surviving

$$\Delta E = \sum_{i=1}^{4} A_i - \alpha$$

where $A_i$ is the payoff from the interaction in the $i^{th}$ direction, and $\alpha$ is the cost of surviving. An agent is eliminated from the simulation when its energy falls below zero.

Fourth, because all social units, including nation-states, eventually fall apart, disband, go bankrupt, are taken over or are overrun, agents are assumed to have a limited existence or life span. An agent has a probability ($\Gamma$) of being eliminated for all iterations of the repeated game,

$$\Gamma = (A - T) / M$$

where $A$ is the age of the agent, $T$ is a constant for the minimum life span, and $M$ is a constant where $T+M$ is the maximum life span. Once an agent reaches the minimum life span, then it has a nonzero and increasing probability of elimination until it reaches the maximum life span, and then it is eliminated with a probability of 1.0. Of course, agents can be eliminated at any time if their energy level falls below zero.

Fifth, agents reproduce in the sense that they create a replication of themselves. In effect, a successful agent “expands” by generating a “clone.” The replicated agent (“clone”) has the same strategy as its “parent” unless mutation (discussed next) occurs. Replication requires a certain level of energy (maturity, size, power, wealth) and it costs the agent a significant amount of energy. Agents must reach a fixed level of energy
(\(\rho\)) before they can replicate. Once an agent replicates, the energy of the agent and the replicated agent are both set to \((\rho/2)\). In the simulations analyzed here, \((\rho)\) is set to 1000 energy units. Following replication the agent has 500 energy units and the “clone” has 500 energy units. The replicated agents are placed in a randomly selected open cell on the grid. This approach to setting reproduction thresholds and determining the relative fitness of the members of the population has the advantage of performing the reproduction and elimination calculation at every iteration instead of making periodic sweeps through the population and more gracefully modifies the population of the simulation.

Sixth, a mechanism to vary agents’ strategies and introduce new strategies must be incorporated to give the agent-based model a dynamic component. Without the introduction of such a mechanism, the model would be static and devoid of change. In this analysis an evolutionary approach is taken and the introduction of new strategies is introduced generationally via strategy mutation. Modelski (1996) suggests that an evolutionary approach to global politics is useful when the focus of understanding, as it is in this analysis, concerns international institutions (the emergence of networks of cooperative agents in this analysis) and their transitions, where the perspective is long-term and where choice processes are a function of trial-and-error search and selection.\(^{15}\)

There are a number of other ways to vary an agent’s strategy or introduce new strategies. Agent strategies can change via imitation, learning, or innovation. While a case can certainly be made that nation-states do attempt to adapt strategies via imitation and/or learning, various features of international politics make change in strategies in this fashion problematic. Imitation is difficult for agents because it is often not in the interest of agents to reveal their strategies to other agents. Agents may observe the behavior of
other successful agents but not be able to induce and thus replicate the strategies that the successful agents employ. Learning is often difficult because the international environment is usually noisy (agents sometimes incorrectly implement their strategy choice and agents may not know or may incorrectly interpret the moves of other agents) making it hard for agents to correctly interpret the actions of other agents and thus the strategies employed by those agents that generate those actions.\textsuperscript{16}

The introduction of new strategies occurs when agents replicate. There is a fixed (20\%) chance that a strategy will mutate during the replication process. When a mutation occurs the agent’s strategy is modified by changing each of the $p_i$ in the strategy of the parent by $[-\delta, \delta]$ where $0 < \delta < 1$. Specifically, if $\delta$ is set to (.1), as is the case for the simulation results reported later, then the actual value to change the $p_i$ is randomly selected from a uniform distribution over the interval (-.1) to (.1). For example, an agent with the strategy [.5, .5, .5, .5] reaches the 1000 energy units required to replicate. When it does so, there is a 20\% chance that the strategy of the replicated agent will be mutated. Suppose that this occurs. Next, a value $\delta$ is selected randomly from the uniform distribution over the interval (-.1) to (.1) for each of the four $p_i$. Suppose that the values selected are -.08, .04, .06, and .03. Then the strategy for the new replicated agent is [.42, .54, .56, .53].

3. Asymmetric Power: Differentiation among agents in both capabilities and payoffs

Two forms of asymmetric power are introduced into the agent-based models. First, asymmetric power is introduced by giving some agents the ability to selectively interact with other agents while making interaction mandatory for all other agents. As noted earlier, selective interaction can help all agents, whether they want to cooperate or not,
because they benefit when they interact with other agents who cooperate and suffer when they interact with agents that defect. Selective interaction is introduced into the agent-based model in the following fashion. When an agent interacts with another agent, it develops a history of play with that specific agent. The agent keeps track of how many times the other agent(s) defects. If the other agent defects (n) times in (m) prior interactions, where 0<n<m, then the agent will not interact with that agent again with the following proviso: an agent can “choose” not to interact with the other agent only if it is more powerful than the other agent.

The constraint on the ability of agents to “choose” to selectively interact is designed to capture the fact that in many contexts in international relations, the choice to interact or not is often dictated by an agent’s relative capability. Weak states often lack choices that more powerful states have. In the agent-based model the power to choose to interact is measured by the agent’s energy level, a surrogate for material wealth and/or power. Reflecting the idea that more powerful agents have more choice and flexibility in international politics, only agents’ that have greater wealth and power have the ability to choose whether or not to interact with another agent.

Second, asymmetric power is introduced by differentially rewarding agents for the joint outcomes of the various games. Those agents having asymmetric power receive uniformly higher payoffs across all joint outcomes of the relevant game than the remaining agents. For example, for the Prisoners Dilemma (PD) game the payoffs for the four outcomes (CC, CD, DC, DD) are [1, -3, 3, 1], respectively, for those agents without asymmetric power and [2, -2, 4, 2] for those having asymmetric power.
4. Assessing the Benefits of Asymmetric Power for Exploitive Agents

Do exploitive agents also benefit from asymmetric power? The approach taken here is to assess whether agents having asymmetric power are more able to take over and dominate a world initially populated with cooperative agents than exploitive agents without asymmetric power. To implement this approach a design similar to that used by Axelrod (1984) is employed. Groups of agents with various types of exploitive strategies and various forms of asymmetric power are comparatively assessed to see whether they can “invade” a set of agents employing cooperative strategies. A small number of exploitive agents are said to successfully invade a larger number of cooperative agents if they can survive, replicate, and drive the cooperative agents to extinction.

In the simulations, ten exploitive Always Defect (All-D) agents and fifty cooperative agents employing three types of cooperative strategies —TFT [1, 0, 1, 0], Grim [1, 0, 0, 0], and Always Cooperate (All-C) [1, 1, 1, 1]— are randomly distributed on the grid of the agent-based model. An agent employing the All-D [0, 0, 0, 0] strategy defects whenever it plays another agent for the first time. If it interacted with an agent in the previous round, it always defects the next time regardless of the prior joint outcome. An agent employing the (All-C) [1, 1, 1, 1] strategy cooperates the first time it interacts with another agent and always cooperates the next time it interacts with that agent regardless of the prior joint outcome. As noted earlier, an agent employing the TFT [1, 0, 1, 0], strategy cooperates the first time it interacts with another agent and always cooperates the next time it interacts with that agent regardless of the prior joint outcome. However, it cooperates the next time only if the other agent cooperated the last time (following a CC or DC outcome). It will defect the next time if the other agent defected during the prior interaction (following a CD or DD outcome). An agent employing the
Grim [1, 0, 0, 0] strategy cooperates the first time it interacts with another agent. It cooperates for all subsequent interactions with that agent as long as the agent cooperates. Once the other agent defects just once, it will always defect whenever it interacts with that agent again.

To establish a benchmark and to determine whether the introduction of asymmetric power makes a difference in the ability of exploitive agents to invade a large group of cooperative agents, five simulations of each strategy mix (i.e., 50 Grim and 10 All-D) were run for each of the five different game structures without the introduction of asymmetric power. Each simulation was run for 200,000 iterations and these results are reported in Table 1. The actual payoffs the four outcomes CC, CD, DC, DD employed in the simulations are for the PD game (1, -3, 3, -1), Chicken (1, -1, 3, -3), Assurance (1, -3, -2, 0), Stag (1, -3, 0, -1), and Deadlock (−1, -3, 3, 1). These payoffs conform to the preference orderings over the outcomes for the various games. The specific payoff values were selected to make the payoffs across the five games as comparable as possible. In addition, the range of the payoffs across the games must be consistent so that the function that affects the environmental carrying capacity and the cost of survival operates consistently across the five games.

The outcome of each simulation run is placed into one of three possible categories; stable cooperation (SC), non-cooperation (NC), and punctuated equilibrium (PE). A stable cooperative outcome occurs when a high level of cooperation (the average cooperation rate among agents is over 95%) is achieved at some point in the simulation and is maintained until the end of the simulation run. A non-cooperative outcome occurs when the average cooperation rate declines and stays at less than 5% for the duration of
the simulation run. A simulation run is categorized as an instance of punctuated equilibrium if, after stable cooperation is achieved, it is followed by periodic (one or more) massive dips to near universal defection.\textsuperscript{23}

The baseline results establish where there is an opportunity to assess whether and to what extent endowing exploitive agents with asymmetric power increases the likelihood of successful invasion. Such an opportunity arises in any situation where exploitive agents \textbf{without} asymmetric power fail to invade 100\% of the time. This occurs when the non-cooperative outcome (NC) is achieved less than 100\% of the time.\textsuperscript{24}

An examination of Table 1 reveals that there is an opportunity for “improvement” for All-D exploitive agents in all the 2X2 games (PD, Chicken, Stag, and Assurance) except Deadlock. Specifically, exploitive agents can benefit from asymmetric power in the following game/cooperative agent strategy settings; Stag/All-Cooperate, Assurance/All-Cooperate and for all four games (PD, Chicken, Stag, and Assurance) where the cooperative agents “employ” TFT or Grim strategies; ten in total.

Table 1 about here

Ten simulations were run for each of these ten game/cooperative agent strategy combinations where the exploitive agents were endowed with the ability to selectively interact and another ten for each of the ten-game/cooperative agent strategy combinations where the exploitive agent benefited from differential payoffs. In total 200 simulations were run for these twenty-game/cooperative agent strategy type/asymmetric type cases. There were \textbf{only two runs (1\% of the cases)} where exploitive agents with either version of asymmetric power were able to successfully invade the cooperative agents.\textsuperscript{25} There was not a single instance where exploitive agents that benefited from selective interaction
successfully invade a world of cooperative agents. **Selective interaction is simply of no help to exploitive agents.**

Asymmetric power appears to be of essentially no use to exploitive agents. To test the robustness of this result, two additional sets of simulations were run; 1) with numerically more favorable mixes of exploitive to cooperative agents thus enhancing the chances for successful invasion by the exploitive agents, 2) with exploitive agents that employ strategies that are more manipulative and more likely to be able exploit cooperative agents than those that employ the All-Defect strategy.

Simulations were run across the twenty game/cooperative agent strategy/asymmetric type cases where the initial mix of agents was 20 All-Defect and 40 cooperative type agents. The results are identical to those reported earlier. Stacking the world initially with more exploitive agents who possess asymmetric power still does not help them successfully invade worlds initially dominated by various types of cooperative agents.

There are a number of candidates for exploitive strategies that are more “manipulative” or at least more “devious” than All-Defect. In most games, All-Defect can be an effective strategy against the “naïve” All-cooperate strategy but far less so against provicable strategies such as TFT and Grim. A potentially more effective strategy is mean tit-for-tat (MTFT). An agent employing a MTFT strategy cooperates when it first plays another agent, always defects when the other agent defected in the previous iteration, and, most importantly, defects with a probability (1-P) if the opponent cooperated on the last iteration of the game.\(^{26}\) Because agents employing such a strategy cooperate more than All-Defect strategies, they are likely to have more opportunities to
benefit from exploiting their opponent. This may put them in a position to be more likely to succeed in invading a large number of agents employing various types of cooperative strategies.

Simulations were run across the twenty game/cooperative agent strategy/asymmetric type cases (noted above) with MTFT agents replacing All-Defect agents. Exploitive MTFT agents benefiting from asymmetric power are able to successfully invade cooperative agents in only one of the twenty cases; when exploitive agents are endowed with payoff differentials and play against Grim agents in the Assurance game. Again, asymmetric power fails to help even more “sophisticated” exploitive agents.

The evidence presented to this point indicates that asymmetric power is essentially of no help to exploiting agents in their efforts to invade worlds populated with significant numbers of cooperative agents. So let us ask a different question. Does asymmetric power help exploitive agents prevent invasion by various types of cooperative agents? To answer this question simulations were run where 50 All-Defect agents defended against invasion by ten All-cooperate agents for the Assurance and Stag games, ten TFT agents for PD, Chicken, Assurance and Stag games, and ten Grim agents for PD, Chicken, Assurance and Stage games.27 The results are reported in Table 2.

Table 2 about here

For the first time asymmetric power helps exploitive agents in a significant way. All-Defect agents, who benefit from payoff differentials, defend against invasion 100% of the time in eight of the ten-game/cooperative strategy cases. Only in Chicken games do they defend successfully less than 100% of the time; 20% against invading Grim agents and
60% against invading TFT agents. Success in defending against invasion by cooperative agents is more problematic when exploitive agents are endowed with the ability to selectively interact. Nonetheless, the ability to selectively interact significantly increases the chances that exploitive agents can ward off invasion by cooperative agents in almost all cases; the lone exception being the Assurance game/TFT combination.

5. Summary

Does asymmetric power, in the form of either differences in capabilities agents are endowed with or in payoffs received from interactions, help exploitive agents to the same extent that it has been shown to benefit cooperative agents in a variety of settings of conflict and cooperation prevalent in international politics? To address this question a set of agent-based models based upon a group of repeated 2X2 games (Prisoners Dilemma, Chicken, Stag, Assurance, and Deadlock) was developed and a series of simulations were run comparing the ability of exploitive agents with and without asymmetric power to invade worlds dominated by cooperative agents. Contrary to expectations, the simulation results indicate that exploitive agents are not as fortunate as cooperative agents. Providing exploitive agents with two different forms of asymmetric power, selective interaction or payoff differentials, fails to enhance their ability to invade groups of cooperative agents. There is clearly an asymmetry to the provision of asymmetric power. Asymmetric power helps cooperative agents invade an exploitive, nasty, and conflict ridden world and build stable cooperation because it provides cooperative agents with a mechanism to initially survive in that exploitive world and build a network of cooperators that generates prosperity effectively isolating exploiters and eventually eliminating them.\textsuperscript{28}
Asymmetric power fails to help exploitive agents invade and tear down cooperative worlds because; 1) it does not enhance the ability of exploiters to survive in the early stages of the simulation because there are very few other exploiters to avoid and 2) networks of exploiters (whether they have asymmetric power or not) do not form to compete with networks of cooperators since there are no benefits derived from networks of exploiters. This is good news for cooperation theorists. However, asymmetric power does help exploitive agents defend against invasion by cooperative agents though more so when they benefit from favorable payoff differentials.

Exploitive agents, whether they are endowed with asymmetric power or not, appear to find themselves in one of two situations in most structural settings of conflict and cooperation prevalent in international politics. Either exploiters lead a lonely (few interaction opportunities with other agents) and numerically insignificant existence in a world dominated by a cooperative regime (most effectively populated by cooperative agents that do not unilaterally defect but do retaliate), or they dominate a world where there is essentially no cooperation, little to no interaction among agents, and very little prosperity (low payoffs). At best, asymmetric power helps exploitive agents maintain this bleak, low interaction Hobbesian-type world.
6. References


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<td>Chicken</td>
<td>Grim</td>
<td>60%</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>TFT</td>
<td>60% *</td>
<td>40% *</td>
<td>100%*</td>
</tr>
</tbody>
</table>

* Denotes instances of Punctuated Equilibrium and settling to .5 cooperation level
7. Endnotes

1 See Stein, 1982; Axelrod, 1984; Keohane, 1984; Snidel, 1985; and Oye, 1986.

2 As Fearon (1998) suggests, cooperation theorists have particularly tended to focus on various strategic structures that they assert fit different international issues.

3 A number of simulation and agent-based models have been developed, in part to test realist theory, that have focused on power and differences or asymmetries in power among agents (Bremer and Mihalka, 1977; Cusack and Stoll, 1990; and Cederman, 1997).

4 Agents face different incentives in each of the five 2X2 games. In some games the incentives that agents face make the decision to cooperate relatively easy and free from risk and punishment while in other games choosing to cooperate requires assuming substantial risk and cost. The ability to achieve cooperation among agents varies across these games and the meanings attributed to cooperation across the games also vary. See Oye (1986) for a description of these and other games in an international relations context as well as an assessment of the relatively difficulty of achieving cooperation across the various game structures. See Majeski (2004) for a discussion of the preference orderings over the four outcomes of each game, the Nash equilibria for the five games, and key differences in the preference orderings over outcomes that affect the likelihood of cooperation.

An exploitive strategy is one that intentionally or unprovokedly defects while the opponent cooperates. Some typical exploitive strategies are All-Defect (always defect regardless of the prior outcome), cheating tit-for-tat (defect after the opponent cooperates for n times in a row since either player last defected), and random tit-for-tat (play TFT except that following cooperation by the cooperate with probability P and defect with probability 1-P). Mean tit-for-tat, discussed and also analyzed in this analysis, is another exploitive strategy.

See Snyder and Diesing (1977) for a discussion of PD, Chicken and Deadlock games and their application to international conflicts; Axelrod and Keohane (1986) for a discussion of PD and the prevalence of Stag, Chicken and Deadlock situations in international relations; Jervis (1978) for a discussion of Stag, PD, and Chicken and their application to international conflicts; Aggarwal (1996) for a discussion of PD and Chicken and their application to international debt rescheduling; Conybeare (1987) for a discussion of PD and tariff and non-tariff barrier policies in trade; Taylor (1987) for a discussion of Chicken and Assurance games and their application to public goods and collective action; Evangelista (1990) for a discussion of PD and arms control; Downs et al (1986) and Downs and Rocke (1990) for an application of PD to arms racing; Snyder (1984) for a discussion of PD and competitive alliance formation; Martin (1992) for a discussion of PD as coadjustment games in multilateral economic sanctions; Zagare (1990) for a discussion of Chicken games and deterrence; and Stein (1990) for the application of PD, Chicken, and Deadlock to international conflict and Stag (he labels the game Assurance) to international collaboration.
An agent-based approach has been used to model a variety of political phenomena (see Epstein and Axtell, 1996; Axelrod, 1997a, 1997b; Cederman, 1997; Epstein, 1998; Lustick, 2000; Bhavnani, and Backer, 2000; Lustick and Miodownik, 2000; Cederman, 2001; Zott, 2002; Cederman, 2002; Sylvan and Majeski, 2003)

Agent strategies are based upon only the previous interaction. However, some agents will be endowed with the ability to choose whether or not to interact with other agents. This decision (not the actual probabilities of the strategy) is based on interactions with the other agent that can go back as far as six prior interactions.

See Nowak et al. (1994) for an argument about the importance of considering social dilemmas as occurring in social space and a discussion of various geometries to represent social space.

This perspective on the relevance of an environmental carrying capacity is based upon the work of Hardin (1977, 1991) and Clayton and Radcliffe (1996) who argue that human populations do have cultural carrying capacities. Note as well that the cost-of-survival mechanism is similar to Epstein’s (1998) global metabolic rate.

In the simulation results reported later, the minimum life span of an agent (T) is 2048 iterations and the maximum life span (T+M) is 6144 iterations.

In an earlier analysis (Majeski et al., 1999), simulations were run with varying life spans of agents (longer and shorter). While minor variations in the timing and likelihood of cooperation emerging occur, the model is quite robust to these minor variations. However, if agents do not die of old age eventually (they can and do still die because their energy level goes to zero), the simulation results are quite different. Cooperative
outcomes are far less likely to occur, and change in the mixtures of types of agents occurs far more slowly. Introducing a lifespan to agents gives the simulations more dynamics—changes are more likely to occur and to happen more quickly.

14 Since agents are nation-states, it makes sense to think of reproduction as asexual. The “genetic material” (here the strategy of the agent) comes from one “parent” and there is no “crossover” of genetic material. Successful nation-states “expand” by generating clones that inhabit more space in the toroidal world.

15 For the use of an evolutionary approach to explain aspects of international relations see Florini (1996) and Gilpin (1996).

16 These features of the international system also make changes in strategy due to innovation difficult. Also, when innovation is characterized as a process whereby a very small percentage of agents randomly vary their current strategy (e.g., Lomberg, 1996) as in a trial-and-error search mechanism, then it has similar properties to generational change via mutation.

17 In the simulations results reported, m=6 and n=3. Other values of m and n were examined as well with only minor alterations in the results.

18 This constraint limits the opportunities that exploitive agents have to choose not to interact with other agents. Only those more powerful than the agents they interact with have the opportunity to choose whether or not to interact.

19 The set of 10 All-D agents and 50 agents with some cooperative strategy mix (Grim, TFT, ALL-C) is used because it creates differentiation.

20 The model is used to carry out an experiment via simulation. A number of simulations are run with differing mixes of strategies where exploitive agents do not have asymmetric
power. Then the same set of simulations is run with only one change; the introduction of one type of asymmetric power and the simulation results are compared to assess the impact of this “manipulation.”

21 The Assurance game depicted here is based upon the game elaborated by Taylor (1987, 18-19, 38-39) and is consistent with its use by Franzen (1995). The structure of the Stag game presented here is consistent with what Lichbach (1996, 47) and Stein (1990) call Assurance games.

22 The agent-based model described earlier has a number of parameters that must be fixed at some value. A large number additional simulations were run to assess the robustness of the simulation results to variations in payoffs, mutation rates, mutation magnitudes, reproduction thresholds, and life span lengths. The sensitivity analysis indicated that the general results are robust to variations in these important parameters.

23 Nowak and Sigmund (1993) labeled these types of patterns punctuated equilibria and I use the term here for the sake of consistency.

24 If exploitive agents invade successfully 100% of the time without asymmetric power, then there is no way to determine whether providing asymmetric power to exploitive agents in these contexts is beneficial.

25 The two cases where exploitive agents benefited from asymmetric power occurred in Assurance games where All-Defect agents benefited from payoffs differences and were paired against Grim and TFT agents. These are quirky cases where the boost in payoffs due to the increase in payoff differences helps the All-Defect agents more when they interact with agents that retaliate than against those who do not retaliate.

26 In the simulations, agents employ the following MFTF strategy [0.3, 0.0, 0.3, 0.0].
These ten game/strategy cases were selected because these are the only situations where fifty exploitive agents without asymmetric power could not defend against invasion by various types of cooperative agents 100% of the time (see Majeski 2004).

See Majeski (2004) for a detailed discussion of how asymmetric power helps cooperative agents.