Ecological Economics 70 (2011) 698–712

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

# On conflict over natural resources

Rafael Reuveny [a,*], John W. Maxwell [b], Jefferson Davis [c]

[a] School of Public and Environmental Affairs, Indiana University, Bloomington, IN 47405, United States
[b] Kelley School of Business, Indiana University, United States
[c] Stat-Math, Indiana University, United States

ARTICLE INFO

*Article history:*
Received 27 November 2008
Received in revised form 22 September 2010
Accepted 9 November 2010
Available online 11 January 2011

*Keywords:*
Game theoretic model
Dynamics
Simulations
Policy

ABSTRACT

This paper considers a game theoretic framework of repeated conflict over natural resource extraction, in which the victory in each engagement is probabilistic and the winner takes all the extracted resource. Every period, each contesting group allocates its capabilities, or power, between resource extraction and fighting over the extracted amount. The probability of victory rises with fighting effort, but a weaker group can still win an encounter. The victorious group wins all of the extracted resources and converts them to power, and the game repeats. In one model, groups openly access the resource. In a variant of the model, the stronger group can access a larger part of the resource than its rival, while in a second variant of the model the advantage of the dominant group is made more decisive than in the first two models. Our models generate outcomes that mimic several aspects of real-world conflict, including full military mobilization, defeats in one or repeated battles, victories following defeats, changes in relative dominance, and surrender. We examine comparative dynamics with respect to changes in the resource attributes, resource extraction, initial power allocation, fighting capabilities, and power accumulation. The policy implications are evaluated, and future research avenues are discussed.



## 1. Introduction

Conflicts over natural resource extraction may go on for many years against a background of resource dependence, a weak state, and underdeveloped property rights. This generalization is not in dispute, but some studies argue that actors fight over resources when they are scarce, while others argue they fight over resources when they are abundant. We develop models of conflict that apply for both situations.

Our models build on the game theoretic approach developed by Hirshleifer (1988, 1991). The rival actors allocate their effort to production and fighting and seek to maximize their gain by taking over the output of their rival. The fighting takes place against a background of anarchy, defined as a situation lacking an accepted authority, social norms, and property rights.

The Hirshleifer approach is useful for our purpose, as fighting implies that actors decide to take matters into their own hands, rejecting existing systems of law, order, and norms of peace. However, it has a limitation in that the actors clash only once and the game ends. The one-shot game cannot address questions involving repeated fighting over resources. For example, does a rise in the resource stock over time lessen the conflict? How does the conflict affect, or how is the conflict affected by, changes in the allocated efforts over time? How are these dynamic issues affected by resource and group features?

We model repeated conflict over resource extraction among two groups of agents: two states, rebels and state forces, or two communities. Every period, each group allocates its power, defined as a composite indicator of available capabilities or efforts, to resource extraction and fighting in order to take over the resource extracted by their rival.[1] Victories are stochastic, though not entirely random. The probability of victory rises with the fighting effort, but a weaker group can still win. The victor's conflict spoils amount to all of the extracted resource in the given period. The groups see a decline in their power due to depreciation and fighting damage, but the winner converts the conflict spoils into power, which the loser cannot do. Having more power, the victor is in a better position at the start of the next engagement since it can allocate more effort to fighting.

We apply this framework in three contexts. In the first, the groups are assumed to have open access to the resource. In the second, a more powerful group has access to a larger part of the resource. In the third model, the stronger group's relative power is more decisive, though the victory is still stochastic.

Given their mathematical complexity, our models can only be solved or simulated numerically. Summarizing our simulation results, a larger resource stock intensifies the conflict since it raises the extraction, or the spoils. A group with greater fighting efficiency

* Corresponding author. Tel.: +1 812 855 6112; fax: +1 812 855 7802.
*E-mail address:* rreuveny@indiana.edu (R. Reuveny).

[1] The terms capability, effort, and power are used interchangeably.

0921-8009/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2010.11.004

allocates less effort to conflict and is less likely to surrender since it has a larger marginal return to fighting. A group more efficient at extraction allocates more effort to extraction since it has a larger marginal return to extraction, but as a result it is more likely to surrender. Groups worse at converting spoils to power and groups having less power initially surrender more often. These results hold across our models, but power-based access reduces the spoils, which dampens the fighting, and a more decisive conflict increases the marginal return to conflict, intensifying the fighting.

Real-world resource conflict is obviously more complex and multifaceted than in our models, but features of our models are often observed in reality. Our approach may apply to cases in which groups fight repeatedly and the situation is quite anarchic. Our assumed all-or-nothing victory may not fit all cases, though we believe it captures the reality of many conflicts in which the winner clearly takes the vast majority of the conflict spoils. This assumption seems to better match many conflicts than the popular alternative assumption in which the combatants share the spoils according to their fighting efforts. We can thus think about our models as providing an upper limit for a continuum of resource extraction splitting ratios.

Our models' outcomes tend to mimic aspects of real-world resource conflict, including concurrent extraction and fighting, a decline in the resource stock, full mobilization to fighting, defeat in one or repeated battles, victory following defeat, changes in relative dominance, and surrender. It may therefore be useful to cautiously examine the policy implications of our finding.

The remainder of the paper proceeds as follows. Section 2 provides background. Sections 3–5 present models and simulations. Section 6 applies the models to real world resource conflicts and examines policy implications, and Section 7 summarizes and suggests future research.

## 2. Background

Our paper brings together elements from the literature on conflict over resource extraction, the predator–prey literature in ecology, the economic literature on conflict, and the ecological economic literature on conflict over resources. These literatures are too large to fully review here. We discuss a number of studies that provide the background for our models.

In the social sciences, the idea that actors fight over scarce resources dates back to Malthus (1798). Elaborating on this logic, contemporary studies expect conflict when demand exceeds supply, and when actors block access to scarce resources based on factors such as race, ethnicity, or religion.[2] For example, fish scarcity leads to piracy and violence among fishermen (UN, 1998), and clashes between Britain–Iceland (Jóhannesson, 2004), Canada–Spain, Malaysia–Thailand, and Japan–Russia (Renner, 1996; Reuveny, 2002). Arable land scarcity plays a role in the El Salvador–Honduras 1969 War (Durham, 1979), the Somalia–Ethiopia 1977–78 War (Myers, 1993), and the ongoing Darfur War (Jeffrey, 2005).[3] Water scarcity contributes to the ongoing Arab-Israeli conflict and other cases.[4] Food scarcity fuels long conflicts in Peru (McClintock, 1984) and Sub-Saharan Africa (Holst, 1989).

Applying this approach to major countries, Hobson (1902) and Lenin (1916) argue the business class pushes states to seize foreign resources, leading to imperialism. The German geopoliticians justify the German expansionism before 1945 as a drive for resources and Lebensraum (Heske, 1987). Choucri and North (1975, 1989) argue more generally that economic development and population growth generate "lateral pressure," an expansionist drive to seize foreign resources that may cause wars. Demonstrating this logic, studies argue that lateral pressure plays a role in World War I (Choucri and North, 1975), the pre-1945 Japanese expansionism (Choucri et al., 1992), the US foreign policy since the 19th century (Pollins and Schweller, 1999), and the current Iranian aggressiveness (Wickboldt and Choucri, 2006).

Observers predict that resource scarcity will lead to more conflicts in the future as supply falls short of demand due to development and population growth, and climate change intensifies pressures on water, arable land, and agriculture, assuming a business as usual climate change policy. The less developed countries (LDCs) may exhibit more conflict since they depend more on resources, are less able to adapt, and have larger populations, but the violence may spread to the developed countries (DCs).[5]

Other studies argue that groups tend to fight over abundant resources, not scarce, since the resource revenue can finance their arming and activities. Resource plenty can lead to a prolonged "Dutch Disease," a decline in export, investments, and economic growth due to currency appreciation, and can be a "curse," eliciting corruption and rent seeking, increasing grievances, and ultimately leading to violence over resource extraction. The domestic problems may tempt other countries to attack, or promote leaders to rally the people behind the flag by attacking other countries.[6]

Westing (1986) finds that access to abundant resources fueled 12 major wars in 1914–1982, including the two World Wars. Yergin (1992) describes the role of oil in World Wars I and II. Oil is a factor in the 1991 and 2003 Iraq Wars, and fuel tensions in the South China Sea and the Caspian Sea Basin (Klare, 2001; Follath, 2006; Mayr, 2006; Judis, 2007). Abundant arable land fuels a long conflict in Borneo; oil in Angola; copper in the Bougainville Island; timber in Liberia, Cambodia, Burma and other states (Klare, 2002; Thomson and Kanaan, 2003; Global Witness, 2002, 2010); minerals, metals and oil in the Congo; diamonds in Sierra Leone and Angola; oil and drugs in Colombia; wood and minerals in Indonesia; and cocoa in Côte d'Ivoire (Renner, 2002; PBS, 2008; Gettleman, 2009; Global Witness, 2002, 2010).[7]

Arising from the work of Lotka (1924) and Volterra (1931), the predator–prey literature in ecology models the dynamics of competition between animal species that feed on each other and consume resources by using a system of differential equations that codifies the behavior of each element (e.g., Slobodkin, 1980; Clark, 2010). Economists studied analogies between this approach and economic competition over time (e.g., Hirshleifer, 1977; Jacquemin, 1987). Political scientists have used somewhat different systems of differential equations to examine the conflict and arms races dynamics (e.g., Richardson, 1960; Zinnes and Gillespie, 1976; Luterbacher and Ward, 1985; Hess, 1995). Unlike animal species and resources, however, people may not necessarily follow codified rules of deterministic behaviors, but rather choose an action they deem to be optimal, taking account of the constraints they face.

2 On resource conflict within states, see, e.g., Myers (1993), Dasgupta (1995), Lietzmann and Vest (1999), Homer-Dixon (1999), Baechler (1999), Kahl (2006), and Reuveny (2002, 2007, 2008).

3 Other examples include conflicts in the Philippines (Hawes, 1990), Haiti (Homer-Dixon, 1999), Sudan (UNEP, 2007), South Africa (Percival and Homer-Dixon, 2001), New Guinea (Hirshleifer, 1995), Rwanda (Renner, 1996; Lietzmann and Vest, 1999), Mexico (Homer-Dixon, 1999; Brown, et al., 1999), Bangladesh, India (Swain, 1996), and Nigeria (The Economist, 2001).

4 Examples include disputes between Brazil–Paraguay; Ethiopia–Somalia; Egypt–Sudan–Ethiopia–Tanzania; Syria–Turkey–Iraq; South Africa–Lesotho; India–Bangladesh; Senegal–Mauritania; and internal conflicts in Yemen, Darfur, China, Ethiopia, and Somalia (e.g., Myers, 1993; Renner, 1996; Pomfret, 1998; Libiszewski, 1999; Beach et al., 2000; Klare 2002; Reuters, 2006; Gleick, 2008; Jeffrey, 2005; Kasinof, 2009; Zahran, 2010).

5 On increased resource conflict see, e.g., World Bank (1995), Klare (2002, 2005), Forney (2004), Reuters (2006), and Follath (2006). On resource conflicts precipitated by climate change see, e.g., Reuveny (2002, 2007), Schwartz and Randall (2003), Gore (2007), CNA (2007), Parthemore and Rogers (2010), and Parsons (2010).

6 For example, see Krebs and Levy (2001), Sachs and Warner (2001), Klare (2002), Renner (2002), Le Billon (2001), and World Bank (2004).

7 Le Billon (2001) lists other examples, including Liberia (iron, rubber); Nicaragua, El Salvador, and Guatemala (coffee); Indonesia (oil, copper, gold); Senegal (land); Mauritania (land); Afghanistan (opium); and the Philippines (wood).