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The effect of warfare on the environment

Rafael Reuveny

School of Public and Environmental Affairs, Indiana University

Andreea S Mihalache-O'Keef

Roanoke College, Salem, VA

Quan Li

Department of Political Science, Texas A&M University

Abstract

Does warfare affect the environment? This question has received some theoretical and empirical attention, but none of the extant studies has employed large-*N* statistical models. This article theorizes the possible effects of warfare on the environment and estimates large-*N* statistical models of these effects on CO_2 emissions per capita, NO_X emissions per capita, the rate of change in forested area, and a composite indicator of environmental stress reduction. The results indicate that warfare significantly affects the environment, but the signs and sizes of these effects depend on the environmental attribute (whether the fighting is at home or abroad) and development (whether the fighting country is developed or less developed). Warfare reduces CO_2 emissions, but the effect is weaker in less developed countries (LDCs) than in developed countries (DCs). Warfare increases deforestation when fought at home and promotes forest growth when fought abroad, particularly in the LDCs. Warfare at home reduces NO_X emissions for the LDCs and increases them for the DCs; warfare abroad increases NO_X emissions for both the DCs and LDCs. Finally, warfare increases aggregated environmental stress, particularly for the LDCs when fought at home and for the DCs when fought abroad. The sizes of these effects are on par with or larger than the mandated or recommended policy goals stated by the US government for changes in CO_2 and NO_X emissions, and by the World Bank (and by implication the DCs driving its policy) for the rate of deforestation, during the coming decade.

Keywords

multidimensional, policy implications, statistical models, theory

Introduction

What is the effect of warfare on the environment of a participating country? Does warfare always harm the environment? Does the effect of warfare vary across environmental attributes or between developed countries (DCs) and less developed countries (LDCs)? Does it matter whether the fighting is at home or abroad? These questions are important because quality of life depends on the environment, while warfare, defined to include both interstate and intrastate military conflicts of at least 25 fatalities, occurs frequently throughout the world. While environmental quality is probably not a critical factor for leaders when national security is at stake, they may still consider environmental impacts when they are substantial.

Conventional wisdom suggests that warfare always damages the environment, but this is not the only possibility. Warfare may reduce environmentally harmful human activities or have no significant effect. Since these possibilities are logically plausible, the net effect is an empirical issue.

The empirical effect of warfare on the environment has received some attention through case studies. Although many studies find that warfare damages various environmental attributes, some studies find benefits. However, to our knowledge, the overall effect of warfare across warfare types and environmental attributes in a large-*N* sample of countries has not been examined. We employ a large-*N* sample of countries to determine the net effect of warfare on CO_2 emissions per capita, nitrogen oxides (NO_X) emissions per capita, forest change measured by the rate of deforestation, and an aggregate

Corresponding author:
rreuveny@indiana.edu

indicator of environmental stress reduction in countries that participate in fighting.

The next section presents theoretical considerations and summarizes the findings of previous research. Following that, we outline statistical models, address design issues, and present the empirical results. Finally, we summarize our findings, suggest future research, and discuss implications.

Theoretical arguments and extant empirical evidence

Armed forces may destroy their own environment, or the opposition's, as a strategy to win the war. For example, forests may be destroyed to deny timber or hiding places, and oil wells, freshwater, crops, land, and animals may be damaged to prevent their use by a foe. Both sides may intensify the exploitation of their own resources or the commandeered resources of the other side (e.g. Westing, 1980, 1990; Biswas, 2000). Damages may also be indirect: troop movement may degrade arable land and vegetation; fighting and arms production may increase pollution and waste; provisions for troops may intensify pressures on resources; norms in favor of environmental protection may deteriorate; and war refugees may dump waste and damage ecosystems in pursuit of food, land, and firewood (e.g. Dasgupta, 1995; McNeill, 2001).

Conversely, war may reduce ordinary activities that harm the environment. For example, industrial facilities and motor vehicles may be destroyed, reducing production and transportation and, therefore, the associated pollution and waste. Indirectly, a rise in fish stocks could occur if fewer fishing boats go to sea because fishermen are enlisted or avoid combat locations. Biodiversity may increase as the military often designates some zones as 'off limits' to people. As more fossil fuels are shipped to the front and more laborers are enlisted in the military, ordinary economic activities may decline, reducing environmental pressure, emissions, and waste (e.g. Westing, 1980; McNeely, 2000; Tucker, 2004).[1]

Empirically, most case studies find negative effects. For example, the French war in Morocco in the 1920s, the US war in Vietnam in the 1960s and 1970s, and the Soviet war in Afghanistan in the 1980s destroyed forests (Westing, 1980; McNeill, 1992, 2001). Wars in Myanmar and Cambodia (Jarvie et al., 2003) and Liberia and the Democratic Republic of Congo (Baker et al., 2003) intensified deforestation. In World War II (WWII), military forces damaged desert-crusts, which intensified sandstorms, and employed scorched-earth policies (Aarsten, 1946; Sobolev, 1947; El-Shobokshy & Al-Saedi, 1993; Clout, 1996). Data presented by Smil (1990: 427) indicate that the annual rate of release of NO_X emissions from the combustion of fossil fuels fell in the USA during the deep depression and rose after 1940, as industrial activity intensified during WWII. Dikes and dams were destroyed during the Japan–China War (1937–45), WWII, and the Korean War, flooding arable land (McNeill, 2001; Biswas, 2000; Westing, 1977). Wars in the LDCs eroded the norms and institutions focusing on environmental preservation (Deacon, 1994). The 1991 Gulf War involved oil spills and setting oil wells on fire (Hawley, 1992). Refugees degraded the environment around their camps in Afghanistan, Pakistan, Malawi, and Sudan (Allan, 1987; Jacobsen, 1997).

Positive effects are also observed. For example, during WWII fish stocks increased in the Atlantic Ocean and wild animal stocks grew in Norway and Guam, as fishing and hunting decreased (Westing, 1980). Houghton & Skole (1990: 398) indicate that the global annual release of carbon emissions from the combustion of fossil fuels (of which a large part is CO_2) declined during WW I and WWII. Smil (1990: 427) indicates that the growth rate of the global annual release of NO_X emissions from fossil fuel combustion declined during WWII compared to the 1920s/early 1930s and the 1950s. In Finland, WWII reduced natural resource extraction, waste, and polluting emissions (Laakkonen, 2004). Explosives left in the Kuwaiti desert after the 1991 Gulf War kept hunters and joy-riders away, increasing vegetation and animal stocks (Pilcher, 1993).

Finally, we need to consider three additional theoretical issues. The first concerns the location of actual fighting. There are reasons to expect that even wars fought abroad may impact a country's environment. For example, fuel and troops may be sent out of the country, rations may be imposed at home, production in some domestic sectors may decline due to labor shortages, and production of war supplies at home may grow.

Second, consider the possible intervening effect of economic development. It is reasonable to expect that effects differ between DCs and LDCs. Their economies differ in scope, composition, and dependence on the environment. For example, DCs are more industrialized and have larger transportation networks than LDCs, causing differences in producing NO_X and CO_2 emissions. In the time period for which our data are available (recent decades), the LDCs are also participating in more wars than the DCs, which further suggests the need to distinguish between the two groups.

Finally, different environmental aspects may be more or less sensitive to warfare. Some case studies support this idea, reporting that war may even benefit some environmental attributes while harming others. Table I summarizes the competing effects. Though their sizes are not known theoretically, their overall effect can be studied statistically.

[1] Peacetime military activities can also affect the environment. For example, standing armies may use resources and engage in polluting or land damaging activities, and defense spending may crowd out pro-environment expenses (Westing, 1990; Gleditsch, Cappelen & Bjerkholt, 1994; Singer & Keating, 1999). However, military spending and war preparations may curtail spending on economic activities that damage the environment; military buffer zones may provide refuge for wildlife and plants; and armies may sustain natural areas for training exercises (Westing, 1980; Tucker, 2004; Stein, Scott & Benton, 2008).

Table I. Theoretical effects of warfare on the environment

Effect	*Direct / Indirect*	*Mechanism*	*Examples*
Harmful	Direct	Destruction as a winning strategy	Destroying arable lands, forests, oil fields, mines; killing livestock
Harmful	Indirect	War-related side effects	War refugee and army movements; arms production pollution; environmental norms decline
Beneficial	Direct	Destruction of ordinary economic activity that damages the environment	Destruction of environmentally damaging industry, vehicles and transportation networks, fishing fleets
Beneficial	Indirect	War-related side effects	Less activity in unsafe/off-limits areas, fuels diverted to conflict areas – less use domestically, labor enlisted for conflict
No net effect	Direct	Small effects	Surgical air strikes, border skirmishes, low-tech conflict
No net effect	Indirect	Harmful/beneficial effects cancel out	Rising production for war balanced by destruction of environmentally damaging activity

Empirical design

Dependent variables

The previous scenarios apply to many environmental attributes, including biodiversity, pollution, and greenhouse gases.[2] In this article, we study four key contemporary issues: CO_2 emissions, NO_X emissions, forest change, and environmental stress reduction. CO_2 is the most important greenhouse gas leading to climate change. NO_X is a class of greenhouse gases and a significant cause of smog and acid rain. Deforestation is the most important cause of climate change on the absorption side, for it decreases nature's ability to sequester CO_2. Deforestation also reduces freshwater stocks, as forests hold much of the world's terrestrial rain in the ground, and is a major cause of land erosion (Harris, 2006; IPCC, 2007; EPA, 2008). Environmental stress reduction is a composite indicator that aggregates a number of environmental aspects (ESI, 2002).[3]

The indicator of CO_2 emissions is expressed in metric tons generated by a country in a year, per capita. It includes emissions generated by human activities such as fossil fuel combustion, gases released and flared in petroleum and natural gas extraction and refining, cement manufacturing and other industrial processes, and gases released from stored fuels. The CO_2 data come from the WDI (2002).

The indicator of NO_X emissions is also expressed in metric tons generated by a country in a year, per capita. It includes emissions generated by fuel combustion in motor vehicles, electricity generation, fossil fuel combustion, industrial processes, bio-fuel combustion, waste, flaring and venting in oil and natural gas production, fires, and fertilizers. The NO_X data come from GEO (2006).

The forest change indicator measures the average annual rate of change in forest area in a decade, per country. A negative rate indicates deforestation due to cutting and burning for building settlements, mining, ranching, farming, and commercial use. A positive rate indicates reforestation due to planting or natural growth of trees. The data exclude changes due to areas harvested with the intent of natural regeneration and areas degraded by gathering wood for fuel, acid rain, or natural fires. The sources of the data are the United Nations' Food and Agriculture Organization (FAO, 2001) and the World Resources Institute (1999), which also takes them from the FAO.[4]

Environmental stress reduction is an aggregate indicator measuring a country's success at reducing anthropogenic stresses in five categories: air pollution, water pollution, ecosystem stress, waste and consumption pressures, and population growth.[5] The data come from ESI (2002).

Independent variables

First, we examine fighting involving at least 25 battle-deaths per year, denoted as armed conflict.[6] It is coded in three ways. The variable *conflict at home or abroad* is a binary indicator of warfare. It is set to 1 if a country participated in at least one interstate, intrastate, or internationalized armed conflict in a year, in the time span of our sample, and set to 0 otherwise. The data are from the UCDP/PRIO Armed Conflict Dataset

[2] One may argue that since the problem of global greenhouse gases is quite new, its determinants may differ from those of ordinary environmental problems such as local pollution. This is not a concern here, as we measure greenhouse gases at the country (local) level, not at the global level.

[3] Descriptive statistics are in the Appendix. Other indicators can be studied, but given the scope and complexity of our analysis, they are better addressed in a separate study.

[4] The World Resources Institute (1999) forest data come from FAO (1995, 1997). As Rudel et al. (2005) and Ewers (2006) note, the data are criticized for their uneven quality across time and nations and inconsistency in definitions. They conclude, however, that these data provide the best available information for examining forest cover across time and nations, and use them.

[5] The environmental stress reduction indicator aggregates NO_X, SO_2, and volatile organic compound emissions; coal use; vehicles per area; water stress from fertilizers, pesticides, and industrial pollutants; acidification; forest change; radioactive waste; ecological footprint per capita; population growth from fertility; and projected population growth from fertility for 2050.

[6] In 'Additional analyses' we look at fighting involving at least 1,000 battle-deaths.

(Strand et al., 2005; Gleditsch et al., 2002). Classification by location is based on the Conflict Sites Dataset (Raleigh & Gleditsch, 2005). The variable *conflict at home* is set to 1 when armed conflict occurs at home, and to 0 otherwise. The variable *conflict abroad* is set to 1 if armed conflict occurs abroad, and to 0 otherwise.[7]

Based on literature modeling environmental degradation (e.g. Li & Reuveny, 2006; Panayotou, 2000), we also include the following independent variables: real GDP per capita (GDP/cap), GDP/cap squared, GDP/cap cubed (in some models), trade openness, level of democracy, population density, and initial forest area (in forest change models).[8]

Our democracy measure indicates the level of democracy in a country based on the POLITY IV dataset (Marshall & Jaggers, 2006). Our measure is computed as the difference between the democracy (DEMOC) and autocracy (AUTOC) indices in this dataset. The 10-point DEMOC measures the democratic attributes of the regime, and the 10-point AUTOC measures the autocratic attributes. The resulting measure ranges between –10 (most autocratic) and +10 (most democratic). This measure is widely used in the literature (e.g. Londregan & Poole, 1996; Li & Reuveny, 2003, 2006). As discussed in Li & Reuveny (2006), the effect of democracy on the environment is debated.

GDP/cap and its squared term are included to account for the Environmental Kuznets Curve (EKC). Studies hypothesize that a rise in GDP/cap increases environmental degradation until GDP/cap reaches a certain threshold. Once GDP/cap rises above this threshold, the degradation declines, since richer people demand more environmental quality. The hypothesis is intuitively appealing, but its empirical validity is debated.[9] The GDP/cap data, expressed in constant 1996 dollars adjusted for purchasing power parity differences across countries (international dollars [I$]), come from the Penn World Table 6.1 (Heston, Summers & Aten, 2002).[10]

Trade openness is a country's total trade (sum of all exports and imports) divided by its GDP. This measure captures the economic importance of trade for a country. In general, a country exporting and importing goods whose production and consumption, respectively, damage the environment will see its environmental quality decline, while its trade partner will see its environmental quality improve, *ceteris paribus*. Trade openness is also said to promote economic growth, though the effect on the environment is debated in the literature. The data come from the Penn World Table 6.1 (Heston, Summers & Aten, 2002).

Population density is the population of a country divided by its area. More densely populated countries may demand more resources and generate more pollution and waste. However, they may also be more urbanized, depend less on the environment for livelihood, and have better public transportation and shorter driving distances, leading to reduced pressures on the environment (e.g. Templeton & Scherr, 1999; Panayotou, 2000). The data come from WDI (2002).

Initial forest area indicates the forest area of a country in the first time period of our sample. This variable is included since the rate of change could be higher in countries with small forests than in countries with large forests. Countries with small forests can also experience large changes in rates of forest change, as small absolute changes can lead to relatively larger rates. One solution to this potential problem is to control for the initial forest size. The data come from the sources listed above for the rate of forest change.[11]

Design issues

In designing our analysis, we need to consider several technical issues. The first issue is whether to conduct a pooled time series cross-sectional analysis, or a cross-sectional analysis. Our choice is dictated by data availability. The CO_2 sample covers 134 countries annually from 1961 to 1997. The NO_X sample covers 128 countries with annual data for two years (1990, 1995). The forest change sample covers 134 countries with data for two decades (1980s, 1990s). The environmental stress reduction sample covers 136 countries annually for three years (2000–02). Thus, the unit of analysis is the country-year for CO_2, NO_X, and environmental stress reduction. For forest change, the unit of analysis is the country-decade. In this case, the warfare variables are coded 1 if the country experienced at least one year of warfare in the decade, and 0 otherwise, and the other right-hand side variables take on their decade-average values.[12]

To deal with the possibility of country heteroscedasticity, we estimate Huber-White robust standard errors. The inclusion of population density, GDP/cap, trade openness, democracy, and for forest change, the initial forest area also helps to control for country differences. The construction of our environmental indicators further helps to control for heterogeneity between countries by accounting for country size differences (the CO_2 and NO_X indicators are computed per capita, the

[7] Warfare incidents tabulated by location, battle-deaths, environmental indicator, and development level are in the Appendix.

[8] A few studies argue against including more than three controls. Our controls are often used in the literature, enabling us to be relatively sure our results are not vulnerable to the risk associated with the converse argument, the omitted variable bias.

[9] The EKC resembles an inverted U, where $Y = A.X + B.X2$, X is GDP/cap, Y is degradation, A and B are parameters, $A>0$, $B<0$, and $A>|B|$. Some studies include also $X3$. For examples of models including the EKC, see Panayotou (2000), Li & Reuveny (2006), Harris (2006), and studies cited in the next section.

[10] One may argue that national EKCs are of limited importance from a global view; if DCs export their environmental problems to LDCs (which is debated) it does not matter if they display EKC at home. We thank an anonymous referee for this comment. Our models work at the national, not global level. To the extent that the EKC affects degradation at home, it needs to be in our models.

[11] We thank a reviewer for suggesting adding this variable.

[12] The countries in the samples are reported in the Appendix.

forest change indicator is a rate computed as (area$_t$ – area$_{t-1}$) / area$_{t-1}$, and the stress reduction indicator controls for country size differences pertaining to its components).

Additionally, there is the concern of path dependence in the dependent variable. For environmental stress reduction, NO_X, and forest change, we have essentially cross-sectional samples, making path dependence a non-issue. For CO_2, we have pooled data that may exhibit path dependence because CO_2-generating facilities and vehicles depreciate slowly. With the prevailing technology, even when old units are replaced, new units generate emissions. Thus, a high level of CO_2 emissions in one period may be followed by a high level in the next period. If not modeled explicitly, path dependence is likely to cause serial correlation, which can bias inference. We model the path dependence by including the lagged dependent variable (LDV) in the CO_2 models.[13]

For CO_2 emissions, we need to consider the possibility that our models miss some structural variables (e.g. climate) and as such may be subject to some possible omitted variable bias. The inclusion of the LDV accounts for some of the omitted variable bias (e.g. Li & Reuveny, 2003, 2006). We further guard against this possibility by using the country-fixed effects estimator, controlling for country-specific features not included, and by using a yearly counter to account for the possible trend of CO_2 emissions since the economy is growing. While these features make it harder for us to find statistically significant effects, we prefer to err on the side of caution.[14]

Another issue is that the effects of the independent variables on our environmental indicators may not be immediate, and some of our right-hand side variables may be affected by the dependent variable (e.g. NO_X emissions may correlate with environmental laws that affect GDP/cap). Many scholars lag the right-hand variables one period, and we will do so as well for the CO_2, NO_X, and environmental stress reduction models.[15]

We also need to consider multicollinearity and, for CO_2, non-stationary dependent variable and error term. When the effects of key independent variables are insignificant and the model's R-squared value is high, the insignificance can reflect multicollinearity, which inflates the estimated standard errors. Non-stationary dependent variable and error term may cause spurious results. We employ the variance inflation factor (VIF) statistics and correlation matrices to diagnose multicollinearity, and the Levin-Lin-Chu and Im-Pesaran-Shin panel unit root tests to diagnose non-stationarity.

To diagnose the possibility that the effect of warfare on the environment may vary between DCs and LDCs, we estimate each of our models for three samples. One sample includes both the DCs and LDCs, operationalized as the Organization for Economic Cooperation and Development (OECD) and non-OECD countries, respectively. A second sample includes only the LDCs, and a third sample only the DCs.

To evaluate the robustness of our results, we conduct a relatively large number of additional analyses. These results are summarized in 'Additional Analyses' and shown in the Appendix.

Empirical results

Beginning with diagnostics, the R^2 values are larger than 0.95 for CO_2 emissions models, and in the 0.24–0.27, 0.27–0.41, and 0.31–0.64 ranges for the forest change, NO_X emissions and environmental stress reduction models, respectively, suggesting reasonably good fit.[16] The individual VIFs are below 8.5 for CO_2, and 2 for forest change, NO_X emissions, and environmental stress reduction, except for GDP/cap and its square term, for which they are larger than 10 (this cannot be helped when modeling the EKC). Thus, multicollinearity is essentially not a concern. The correlation matrices (see Appendix Tables XII-A–XV-A) support this conclusion. For the CO_2 model, the Levin-Lin-Chu and Im-Pesaran-Shin panel unit root tests indicate that non-stationarity is not a concern. With these diagnostics covered, we turn to the estimation results for armed conflict.[17]

CO_2 emissions

In Table II, the coefficient of armed conflict in Model C1 for the all-countries sample is negative and significant. Armed conflict at home or abroad reduces CO_2 emissions at home. In Model C2, the coefficients of armed conflict are both negative and significant. Armed conflict fought by a country reduces its CO_2 emissions regardless of the location of fighting. One may ask why conflict reduces emissions if GDP per capita is in the model. Recalling the second section of this article, armed conflict may affect emissions by impacting total output, factors of production, resources, norms, and their distribution in the economy. Controlling for the effect of total output on emissions, we find the net effect of armed conflict due to the other channels is negative.[18]

In Models C3 and C4 for the LDCs, the coefficients of armed conflict at home or abroad, armed conflict at home, and armed conflict abroad are not significant. Armed conflicts

[13] The inclusion of the LDV alleviates serial correlation (Beck & Katz, 1995, 1996).

[14] For NO_X, forest change, and environmental stress, we do not use country-fixed effects and yearly counters since our sample is essentially cross-sectional.

[15] For forest change, we do not lag the variables since our data are per decade, which is too long of a lag. Auxiliary estimations show lagged-variables models of forest change do not fit the data well.

[16] The R2 values for forest change, NO_X, and stress reduction are smaller than the R2 for CO_2 because the former three models are essentially cross-sectional and, therefore, exclude the country-fixed effects, year counter, and LDV. The next section shows that the high R2 for CO_2 is not due to the LDV.

[17] The VIFs are relatively larger for CO_2 due to the country-fixed effects, which cannot be helped when using a fixed-effects estimator. For NO_X, forest change, and stress reduction, we do not perform the panel unit root tests since our data are essentially cross-sectional.

[18] A sector analysis may add insight but is outside the scope of our article.

Table II. Armed conflict and CO_2, 1961–97

	All countries		*LDCs*		*DCs*	
	C1: All conflicts	*C2: Conflicts by location*	*C3: All conflicts*	*C4: Conflicts by location*	*C5: All conflicts*	*C6: Conflicts by location*
Conflict at home or abroad	−0.04		−0.02		−0.15	
	(0.02)***		(0.02)		(.08)**	
Conflict at home		−0.03		−0.02		−0.07
		(0.02)*		(0.02)		(.09)*
Conflict abroad		−0.06		0.004		−0.12
		(0.03)**		(0.02)		(.07)**
Level of democracy	−0.002	−0.002	−0.003	−0.003	0.005	0.005
	(0.001) **	(0.001)**	(0.001)***	(0.001)***	(.004)	(.004)
Real GDP per capita	8e-5	9e-5	8e-5	8e-5	8e-5	7e-5
	(2e-5)***	(1e-5)***	(3e-5)***	(3e-5)***	(4e-5)**	(4e-5)**
Real GDP per capita squared	−3e-9	−3e-9	−2e-9	−2e-9	−3e-9	−3e-9
	(6e-10)***	(6e-10)***	(1e-09)*	(1e-09)*	(9e-10)***	(9e-10)***
Trade openness	−9e-4	−9e-4	−2e-4	−2e-4	−0.009	−0.008
	(0.001)	(0.001)	(0.001)	(0.001)	(.002)***	(.002)***
Population density	7e-4	7e-4	6e-4	6e-4	0.002	0.002
	(3e-4)***	(3e-4)***	(3e-4)**	(3e-4)**	(.001)*	(.001)*
Lagged CO_2	0.87	0.87	0.85	0.85	0.88	0.88
	(0.02)***	(0.02)***	(0.04)***	(0.04)***	(.02)***	(.02)***
Year	0.001	0.001	0.001	0.001	0.01	0.01
	(0.001)	(0.001)	(0.001)	(0.001)	(.01)**	(.01)**
Constant	−1.79	−1.60	−1.47	−1.52	−19.79	−19.12
	(2.13)	(2.15)	(2.30)	(2.30)	(10.25)**	(10.56)**
Observations	3,830	3,830	3,053	3,053	777	777
R-squared	0.99	0.99	0.99	0.99	0.99	0.99

Robust standard errors in parentheses. Country-fixed effects not reported. ***$p < 1\%$; **$p < 5\%$; *$p < 10\%$.

fought by LDCs do not affect their CO_2 emissions at home. Recalling the second section of the article, the LDC results suggest that either the competing positive and negative effects of armed conflict balance each other, or the effect of armed conflict on CO_2 emissions per capita in LDCs is very small, given the generally non-industrialized nature of their economies. In Models C5 and C6 for the DCs, the coefficients of all the armed conflict variables are negative and significant. Armed conflicts fought by DCs reduce their CO_2 emissions at home regardless of the conflict's location.

Next we compute the size of the significant effects as the percent change in the predicted CO_2 emissions when armed conflict changes from 0 to 1, keeping other variables at their mean. Based on Model C2 for the all-countries sample, armed conflict at home (a change from 0 to 1) reduces the yearly CO_2 emissions per capita by 0.03 metric tons, or about 1% per year. Armed conflict abroad reduces the CO_2 emissions by 0.06 metric tons, or about 2% per year. For the DCs sample, armed conflict at home reduces emissions by about 0.8% and armed conflict abroad by about 1.4%. These numbers are of the order of magnitude of the CO_2 emission reductions called for by the Waxman-Markey bill approved by the US Congress in June 2009, which calls for a 17% cut in US CO_2 emissions by 2020 from 2005 levels (Stevenson, 2009), or an average yearly cut of 1.4% from 2009 to 2020.

While the immediate yearly effect of warfare on CO_2 emissions is considerable, it does not tell the full story because armed conflict not only directly affects emissions but also continues to do so indirectly into the future via the lagged emissions. The long-run effect of warfare on CO_2 emissions is given by the following expression: [armed conflict coefficient / (1 – lagged emissions coefficient)] * change in armed conflict.[19] In the long run, armed conflict at home reduces the estimated CO_2 emissions per capita by 6% per year and armed conflict abroad by 12% per year, both of which are larger than the immediate effect of warfare, as well as larger than the yearly effect called for by the 2009 Waxman-Markey bill.

The effects of changes in the control variables all fall within the range of possibilities discussed in the previous section. A rise in democracy in a country reduces its CO_2 emissions for the all-countries and LDCs samples. For the DCs, the effect is insignificant, as their democracy level does not change much. The coefficient of the LDV is positive and significant, indicating that CO_2 emissions exhibit inertia. Rises in trade openness show a significant effect only in DCs, where the effect is negative. The positive coefficient of the year counter is significant

[19] For details, see Londregan & Poole (1996). The change in armed conflict is 1 (from 0 to 1).

only for the DCs, indicating their emissions grow over time. A rise in population density significantly raises CO_2 emissions. The results indicate the existence of an EKC with a turning point of 12,945 real I$ for the DCs, and 20,000 real I$ for the LDCs.[20]

Forest change

The structure of Table III follows that of Table II, except there are no results for the DCs because the sample size is too small (17 observations) to produce meaningful results. In Model D1 for the all-countries sample, the effect of armed conflict at home or abroad on forest change is negative and significant, intensifying deforestation. Model D2 shows the negative effect is driven by armed conflict at home; the coefficient of conflict abroad is insignificant. Armed conflicts at home destroy forests and/or intensify logging and forest clearing. For the LDCs, Model D3 indicates the effect of armed conflict at home or abroad is negative and significant, intensifying deforestation. Model D4 shows that armed conflict fought in LDCs intensifies deforestation, as before, but armed conflict fought abroad promotes forest growth. For the LDCs, conflict abroad diverts labor and finances away from timber logging and forest clearing.

Consider next the sizes of the significant effects of warfare on deforestation. Using the approach outlined above, Model D2 for the all-countries sample suggests that armed conflict at home changes the annual rate of deforestation by 300%, from about –0.2% to –0.8% when conflict changes from 0 to 1. Model D4 for the LDCs shows that armed conflict at home changes the annual rate of deforestation by 300%, from about –0.25% to –1%, whereas armed conflict abroad changes the rate of reforestation by about 200%, from –0.25% to 0.29%. These effects are much larger than that recommended by the Global Monitoring Report (2007), which argues that the appropriate forest policy goal for most countries is a zero rate of deforestation.

Among the control variables, a rise in the level of democracy in a country promotes deforestation. Forest change does not exhibit an EKC; reforestation rises with GDP/cap, but for the all-countries sample deforestation sets in once GDP/cap is above 21,400 I$.[21] A rise in trade openness promotes reforestation. A rise in population density increases the rate of deforestation. Countries having large forest areas to begin with exhibit higher rates of deforestation than countries having smaller initial forest areas.

NO_X emissions

In Table IV, Model N1 shows that the effect of armed conflict at home or abroad on NO_X emissions per capita is negative and statistically significant, which indicates that armed conflict reduces NO_X emissions per capita. In Model N2, armed conflict at home significantly reduces NO_X emissions whereas armed conflict abroad significantly increases them. Warfare produces different effects on NO_X emissions, depending on the location of fighting.

For the LDCs, Model N3 shows the effect of armed conflict at home or abroad is significant and negative; Model N4 shows that conflict at home significantly reduces NO_X emissions but conflict abroad increases them. For the DCs, armed conflict increases NO_X emissions regardless of its location. The different effects of conflict at home between the LDCs and DCs likely reflect the disparity in the nature of their conflicts. The DCs' conflicts in the study time period are nondestructive at home and highly mechanized, likely promoting emissions, whereas the LDCs' conflicts tend to destroy plants, roads, and motor vehicles, probably reducing emissions.

Turning to the sizes of effects, Model N4 for the LDCs indicates that armed conflict at home reduces the annual NO_X emissions per capita by about 7%, from 2.78 metric tons to 2.57 when conflict changes from 0 to 1. Armed conflict abroad increases emissions by about 10% per year (2.78 to 3.06). Model N6 for the DCs shows that armed conflicts at home and abroad raise the yearly NO_X emissions by about 14% (3.61 to 4.13) and 13% (3.61 to 4.08), respectively. The US Clean Air Interstate Rule mandates that the annual NO_X emissions in the USA should decline from 1.5 million tons in 2009/2010 to 1.3 million tons in 2015, indicating an annual decrease of about 1.7% (Murray, 2005). Relative to this policy mandate, the effects of warfare on NO_X emissions are substantively much larger.

Among the control variables, a rise in democracy does not affect NO_X emissions for the all-countries and LDCs samples, and raises emissions for the DCs. A rise in trade openness raises NO_X emissions for the all-countries and LDCs samples and does not affect emissions in DCs. A rise in population density reduces NO_X emissions. For the all-countries sample, there is an EKC that peaks at 30,000 I$. For the LDCs, NO_X emissions rise with GDP/cap, and for the DCs changes in GDP/cap do not affect emissions.

Environmental stress reduction

In Table V, Model E1 suggests the effect of armed conflict at home or abroad on the aggregate indicator of environmental stress reduction is negative and significant, which indicates that conflict increases stress. Model E2 reveals that this negative effect is due to the combined effects of conflicts at home and abroad, both of which decrease the reduction of environmental stress. For the LDCs, Models E3 and E4 yield similar results, except that the effect of conflict abroad on stress reduction is insignificant; the adverse effect of conflict on stress reduction is primarily due to the influence of conflict at home. For the DCs, Models E5 and E6 indicate that the effect of conflict at home or abroad on stress reduction is also negative and significant, indicating that conflict increases stress at home.

[20] These turning points are in the range reported in the literature. For example, Cole, Rayner & Bates (1997) report $25,100 and Moomaw & Unruh (1997) find $18,333.

[21] Shafik & Bandyopadhyay (1992) and Barbier (2001) do not find an EKC, while Bhattarai & Hammig (2001) do.

Table III. Armed conflict and forest change, 1980–2000

	All countries		*LDCs*	
	D1: All conflicts	*D2: Conflicts by location*	*D3: All conflicts*	*D4: Conflicts by location*
Conflict at home or abroad	−0.42 (0.25)**		−0.51 (0.26)**	
Conflict at home		−0.60 (0.26)***		−0.76 (0.26)***
Conflict abroad		0.34 (0.30)		0.54 (0.36)*
Level of democracy	−0.06 (0.03)***	−0.07 (0.02)***	−0.05 (0.02)***	−0.06 (0.02)***
Real GDP per capita	3e-4 (8e-5)***	3e-4 (8e-5)***	2e-4 (1e-4)**	1e-4 (1e-4)*
Real GDP per capita squared	−7e-9 (3e-9)***	−8e-9 (3e-9)***	3e-9 (7e-9)	4e-9 (6e-9)
Trade openness	0.01 (0.01)*	0.01 (0.01)*	0.01 (0.01)*	0.01 (0.01)*
Population density	−0.001 (45e-5)***	−0.001 (44e-5)***	−0.001 (47e-5)***	−0.001 (44e-5)***
Initial forest area	−0.36 (0.15)***	−0.34 (0.15)**	−0.30 (0.18)**	−0.27 (0.18)*
Constant	−0.75 (0.66)	−0.75 (0.66)	−0.56 (0.69)	−0.56 (0.69)
Observations	203	203	186	186
R-squared	0.26	0.27	0.24	0.26

Forest change is the average annual rate of forest area change per country per decade. A negative value indicates deforestation and a positive value reforestation. Robust standard errors in parentheses. ***p < 1%; **p < 5%; *p < 10%.

Table IV. Armed conflict and NO_X, 1990, 1995

	All countries		*LDCs*		*DCs*	
	N1: All conflicts	*N2: Conflicts by location*	*N3: All conflicts*	*N4: Conflicts by location*	*N5: All conflicts*	*N6: Conflicts by location*
Conflict at home or abroad	−0.13 (0.10)*		−0.16 (0.10)*		0.51 (0.08)***	
Conflict at home		−0.18 (0.10)**		−0.19 (0.11)**		0.52 (0.11)***
Conflict abroad		0.32 (0.14)**		0.28 (0.16)**		0.47 (0.24)**
Level of democracy	−0.009 (0.008)	−0.006 (0.009)	−0.008 (0.008)	−0.005 (0.009)	0.29 (0.08)***	0.30 (0.08)***
Real GDP per capita	12e-5 (2e-5)***	11e-5 (2e-5)***	9e-5 (4e-5)**	9e-5 (4e-5)**	13e-5 (11e-5)	12e-5 (12e-5)
Real GDP per capita squared	−2e-9 (1e-9)**	−2e-9 (9e-10)**	4e-10 (2e-9)	8e-10 (2e-9)	−3e-9 (3e-9)	−2e-9 (3e-9)
Trade openness	0.003 (0.001)***	0.003 (0.001)***	0.004 (0.001)***	0.004 (0.001)***	8e-4 (0.002)	8e-4 (0.002)
Population density	−3e-4 (1e-4)***	−3e-4 (1e-4)***	−4e-4 (1e-4)***	−4e-4 (1e-4)***	−0.002 (0.001)***	−0.002 (0.001)***
Constant	2.18 (0.12)***	2.19 (0.12)***	2.21 (0.13)***	2.23 (0.13)***	−0.60 (1.57)	−0.64 (1.54)
Observations	236	236	194	194	42	42
R-squared	0.40	0.41	0.27	0.27	0.36	0.36

Robust standard errors in parentheses. ***p < 1%; **p < 5%; *p < 10%.

Table V. Armed conflict and environmental stress reduction, 2000–02

	All countries		*LDCs*		*DCs*	
	E1: All conflicts	*E2: Conflicts by location*	*E3: All conflicts*	*E4: Conflicts by location*	*E5: All conflicts*	*E6: Conflicts by location*
Conflict at home or abroad	−3.25 (1.22)***		−1.77 (1.11)*		−4.16 (2.49)**	
Conflict at home		−2.49 (1.21)**		−1.64 (1.13)*		−2.61 (5.23)
Conflict abroad		−2.57 (1.99)*		−0.66 (2.09)		−4.35 (2.66)*
Level of democracy	0.24 (0.10)***	0.23 (0.10)**	0.12 (0.10)*	0.12 (0.10)*	2.39 (1.92)	2.24 (1.98)
Real GDP per capita	−26e-5 (29e-5)	−26e-5 (29e-5)	69e-5 (29e-5)***	69e-5 (29e-5)***	−0.004 (0.002)***	−0.004 (0.002)***
Real GDP per capita squared	−2e-8 (1e-8)**	−2e-8 (1e-8)**	−7e-8 (1e-8)***	−7e-8 (1e-8)***	6e-8 (4e-8)*	6e-8 (4e-8)*
Trade openness	−0.03 (0.02)*	−0.02 (0.02)*	−0.01 (0.02)	−0.01 (0.02)	−0.05 (0.03)*	−0.05 (0.03)*
Population density	−0.004 (0.003)*	−0.004 (0.003)*	−4e-4 (0.002)	−4e-4 (0.002)	−0.06 (0.01)***	−0.07 (0.01)***
Constant	59.30 (1.45)***	59.14 (1.45)***	55.40 (1.42)***	55.40 (1.45)***	84.75 (32.16)***	86.39 (32.66)***
Observations	374	374	314	314	60	60
R-squared	0.39	0.39	0.31	0.31	0.64	0.64

Robust standard errors in parentheses. ***$p < 1\%$; **$p < 5\%$; *$p < 10\%$.

Model E6 shows that this effect is primarily driven by the conflicts the DCs fight abroad.

Next, we turn to the sizes of effects of warfare on environmental stress reduction. Model E2 for the all-countries sample indicates that armed conflict at home and conflict abroad decrease environmental stress reduction by about 4.8% and 4.9%, respectively (from 52.4 indicator units to 49.9, and from 52.4 to 49.8). To our knowledge, policy goals have so far not been stated in terms of environmental stress reduction, but compared to the sizes of effects obtained for our other three indicators, the warfare-induced effects on stress reduction are substantial.

Among the controls, a rise in democracy improves the reduction of environmental stress, except for the DCs sample (where democracy essentially does not change). Rises in trade openness or population density generally decrease stress reduction, that is, cause more stress. The LDCs do not exhibit an EKC, but rather the opposite pattern. Stress reduction rises until GDP/cap reaches 5,000 I$ and then falls with GDP/cap (more stress). In the DCs, stress reduction exhibits an EKC, falling until GDP/cap reaches 33,000 I$ (more stress) and then rising with GDP/cap (less stress).

Additional analyses

This section summarizes analyses that evaluate the robustness of the results presented above. Detailed results are in the Appendix.

First, we study the effect of relatively more intense warfare by recoding warfare to 1 when the fighting involves at least 1,000 battle-deaths in a year, denoted as a war, and to 0 otherwise. The data come from the UCDP/PRIO Armed Conflict Dataset (Strand et al., 2005; Gleditsch et al., 2002). In general, the results resemble those in Tables II–V but are less significant in some cases since there are considerably fewer wars than armed conflicts in our samples. In Appendix Table I-A, war generally reduces CO_2 emissions, as before. In Appendix Table II-A, war does not affect forest change. In Appendix Table III-A, war abroad raises NO_X emissions for the all-countries and LDCs samples, as before; the remaining effects are insignificant. In Appendix Table IV-A, war reduces stress reduction, as before, but now the effect of war at home is insignificant.[22]

Second, the existence of the EKC is an empirical issue, and the dependence of environmental degradation on GDP/cap may be cubic. Adding GDP/cap cubed to our models, the results for armed conflict and the controls resemble those in Tables II–V. For CO_2, there is a cubic effect for the all-countries sample, largely driven by the DCs (Appendix Table V-A); emissions rise with GDP/cap until 15,000 I$, fall until 38,000 I$, and then rise with GDP/cap. For forest change, there is a cubic effect only for the all-countries sample (Appendix Table VI-A). For NO_X, there is no cubic effect (Appendix Table VII-A). For stress reduction, there is a cubic

[22] For the DCs, the effects of war on NO_X emissions, and the effect of war at home on stress reduction cannot be estimated as the samples do not include wars.

effect, largely driven by the LDCs (Appendix Table VIII-A); stress reduction rises with GDP/cap until 5,000 I$, falls to 0 around 10,000 I$, stays 0 until 156,000 I$, and then rises with GDP/cap.[23]

Third, the CO_2 emissions models in Table II contain a lagged dependent variable (LDV) term, which may influence the estimated effects of other variables. Appendix Table IX-A reports the results excluding the LDV term. The results resemble those in Table II, except that now the negative effect of armed conflict at home for the LDCs is significant, and the negative effect for the DCs is insignificant, and the effects of the control variables are generally more significant, which is to be expected. The sizes of the effects of conflict are now considerably larger than the sizes of effects in the presence of the LDV term, which is also to be expected.

Fourth, we re-estimate the forest change model, adding an interaction term between forest area and real GDP per capita, as in Ewers (2006). The coefficient of the interaction term is negative and significant in Models D1I and D2I for the all-countries sample and insignificant in Models D3I and D4I for the LDCs samples. Ewers finds a positive and significant coefficient for the interaction term, but unlike our model, his model employs only GDP per capita, forest cover, and the interaction term, and his sample covers only 1990. For our purpose, it is important to note that the results in Appendix Table X-A resemble those in Table III.

Fifth, we find that warfare affects CO_2 emissions, forest change, NO_X emissions, and stress reduction, but one may wonder if these results reflect the reverse effect of environmental degradation on warfare. For CO_2 and NO_X emissions, there is no reason to suspect reverse causality; warfare has not been associated with conflict over CO_2 and NO_X emissions. Since Robert Malthus in the 18th century, environmental stress has been said to promote warfare. Deforestation has been particularly noted to play a causal role in warfare in some LDCs (e.g. Thomson & Kanaan, 2003). We use instrumental variables probit (IVPROBIT) to test for possible reverse effects of environmental stress reduction and deforestation on armed conflict.[24] The results in Appendix Table XI-A show that the instrumented forest change environmental stress reduction variables do not affect armed conflict. Thus, we can reject the possibility that our results are caused by reverse causality.

Finally, are there examples that support our statistical results? We can turn to our dataset, but this is of limited interest since our regressions already confirm a correlation. Instead, we revisit the literature. For example, during WWII the decreasing global rates of CO_2 and NO_X emissions (Houghton & Skole, 1990; Smil, 1990, respectively), as well as the falling rates of polluting emissions in Finland (Laakkonen, 2004) provide precedents to our findings that warfare reduces CO_2 emissions, and warfare at home reduces NO_X emissions. These examples support an interpretation that WWII destroyed normal economic activities that generated emissions and diverted effort from these activities to warfare-related activities that may have generated fewer emissions overall. Our finding that warfare abroad raises NO_X emissions at home agrees with the rise in NO_X emissions in the USA during WWII (Smil, 1990). Unlike most of the participants in WWII, the USA did not incur the same level of destruction. During the war, it became the chief producer of weapons for the free world, expanding industrial and transportation activities that generated NO_X emissions at home.

Our finding that warfare at home raises the rate of deforestation agrees with patterns described for the Vietnam War (Westing, 1980), Myanmar and Cambodia (Jarvie et al., 2003), and Liberia and DRC (Baker et al., 2003). In Vietnam, the USA destroyed forests to remove hiding places for the North Vietnamese. In Myanmar, Cambodia, Liberia, and DRC, rival forces intensified timber logging as a way to finance war. Our results that warfare raises environmental stress are consistent with effects observed during the first Gulf War (McNeill, 2001) and in DRC (Baker et al., 2003). In the Gulf War, Iraqi forces ignited oil fires, which polluted the sky, and spilled additional oil into the Persian Gulf and surrounding lands, destroying wildlife and habitats. Years of fighting in DRC destroyed environmental institutions, which intensified land degradation, deforestation, and loss of biodiversity.[25]

Conclusion

We provide the first large-*N* analysis of the net effect of warfare on different environmental dimensions, including CO_2 emissions per capita, the rate of forest area change, NO_X emissions per capita, and environmental stress reduction. Our analysis distinguishes warfare by location and intensity, differentiates countries by development level (LDCs, DCs), and conducts extensive robustness tests.

Summarizing our findings, warfare reduces CO_2 emissions in a country, but the effect is weaker in the LDCs than in the DCs. Warfare increases deforestation in a country when fought at home, and promotes forest growth when fought abroad, particularly in the LDCs. Warfare at home reduces NO_X emissions for the LDCs and increases them for the DCs; warfare abroad increases NO_X emissions for both the DCs and LDCs. Finally, warfare increases the composite indicator of environmental stress, particularly so for the LDCs when fought at home and for the DCs when fought abroad. For CO_2 and NO_X emissions, the sizes of the effects are on par,

[23] For 10,000 < GDP/cap < 156,000, the predicted stress reduction is < 0, which is interpreted as 0, as the index itself is between 0 (no stress reduction) and 100 (maximum reduction).

[24] IVPROBIT accounts for their endogeneity by using proper instruments – the variables in our warfare, and stress or forest models, respectively. The warfare variables are often used (e.g. GDP/cap, population size/growth, mountainous area share, trade openness, political instability, democracy).

[25] To our knowledge, our result that conflict abroad reduces deforestation at home is new to the literature.

or larger than, the policy goals mandated recently by the US government for the USA during approximately the next ten years. For deforestation, the sizes of the effects are much larger than the rate recommended by the World Bank (and by implication the DCs driving its policy). In this light, the effects of warfare on our environmental indicators are not trivial.

As our study represents a first attempt to statistically study the effects of warfare on environmental indicators for a large-*N* sample, we see room for future research. For example, other indicators (e.g. SO_2 emissions, fish stocks) could be used; warfare could be measured by battle-deaths or distinguished as interstate, intrastate, and internationalized. Also, the effects on the environment could be studied based on initiator vs. target countries or the impacts of different economic sectors.

Discussing the implications of our findings needs to be done cautiously, as they are based on a first study. The effects of warfare on the national economy, global economy, political development, and public health have been widely studied in the social sciences. The impact of warfare on the environment, in contrast, has received too little attention. This situation may change as environmental issues will probably acquire growing salience in the public discourse in the coming decades. Our study also contributes to the literature on the consequences of warfare by providing some generalizable statistical evidence on environmental impacts.

In considering the relevance of our research for policymaking, one may take a positive or negative perspective. Do leaders consider the environment in their decisions over the use of force? If the expected substantive effects are small, leaders will probably ignore them. If they are large, they might still be overshadowed by traditional national security-related considerations, but they may not be completely ignored. Indeed, many countries have signed treaties that impose environmental constraints on the conduct of war, and army manuals in countries like the USA instruct avoiding environmental damage, as far as military goals permit (Westing, 2000). This is consistent with our findings that the substantive effects of warfare on the environment are quite large. Thus, environmental considerations could play some, though not the most important, role in the decisions to use force.

Should leaders consider the negative environmental effects in their decisions on the use of force? Their decision likely reflects a cost–benefit analysis of expected gains (e.g. acquire resources) and expected costs (e.g. casualties). We find that warfare significantly harms some aspects of the environment. To the extent that these effects reduce human welfare, we believe they should be considered in decisions over the use of force. Doing so may tip the cost–benefit analysis in favor of attempting to resolve disputes peacefully.

However, the warfare-induced environmental benefits should be excluded from the decision to use force, for they may tip the cost–benefit analysis in favor of warfare. This would be unfortunate because the war-induced human sufferings are by far more important than the environmental benefits of war. Our finding that warfare can sometimes benefit the environment must be regarded as a statement on how the world works, not on how it should work. If environmental benefits are coveted, they can be achieved by pursuing domestic and international non-combative policies.

Data replication

The data are at http://www.prio.no/jpr/datasets. The analysis utilized Stata8.

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References

Aarsten, J P von (1946) Consequences of the war on agriculture in the Netherlands. *International Review of Agriculture* 37: 5S-34S, 49S-70S, 108S-123S.

Allan, Nigel J R (1987) Impact of Afghan refugees on the vegetation resources of Pakistan's Hindukush-Himalaya. *Mountain Research and Development* 7(3): 200–214.

Baker, Murl; Robert Clausen, Ramzy Kanaan, Michel N'Goma, Trifin Roule & Jamie Thomson (2003) Conflict timber: Dimensions of the problem in Asia and Africa, Volume III, African cases. Final report submitted to the United States Agency for International Development. Burlington, VT: ARD.

Barbier, Edward B (2001) The economics of tropical deforestation and land use: An Introduction to the Special Issue. *Land Economics* 77(2): 155–171.

Beck, Nathaniel & Jonathan N Katz (1995) What to do (and not to do) with time-series cross-section data. *American Political Science Review* 89(3): 634–647.

Beck, Nathaniel & Jonathan N. Katz (1996) Nuisance vs. substance: Specifying and estimating time-series–cross-section models. *Political Analysis* 6(1): 1–34.

Bhattarai, Madhusudan & Michael Hammig (2001) Institutions and the environmental Kuznets curve for deforestation: A crosscountry analysis for Latin America, Africa and Asia. *World Development* 29(6): 995–1010.

Biswas, Asit K (2000) Scientific assessment of the long-term environmental consequences of war. In: Jay E Austin & Carl E Bruch (eds) *The Environmental Consequences of War: Legal, Economic, and Scientific Perspectives*. Cambridge: Cambridge University Press, 303–315.

Clout, Hugh (1996) *After the Ruins: Restoring the Countryside of Northern France after the Great War*. Exeter: Exeter University Press.

Cole, Matthew A; Anthony J Rayner & John M Bates (1997) The environmental Kuznets curve: An empirical analysis. *Environment and Development Economics* 2(4): 401–416.

Dasgupta, Partha S (1995) Population, poverty and the local environment. *Scientific American* 272(2): 26–31.

Deacon, Robert T (1994) Deforestation and the rule of law in a cross-section of countries. *Land Economics* 70(4): 414–430.

El-Shobokshy, Mohammad S & Yaseen G Al-Saedi (1993) The impact of the Gulf War on the Arabian environment. *Atmospheric Environment* 27(1): 95–108.

EPA (2008) *Health and Environmental Impacts of NO_X*. Washington, DC: Environmental Protection Agency (EPA), (http://www.epa.gov/air/urbanair/nox/hlth.html).

ESI (2002) *Environmental Sustainability Index (ESI)*. Yale Center for Environmental Law and Policy, Yale University, and Center for International Earth Science Information Network, Columbia University (http://sedac.ciesin.columbia.edu/es/esi/archive.html).

Ewers, Robert (2006) Interaction effects between economic development and forest cover determine deforestation rates. *Global Environmental Change* 16(2): 161–169.

FAO (1995) *Forest Resources Assessment 1990: Global Synthesis*. Rome: Food and Agriculture Organization (FAO), United Nations.

FAO (1997) *State of the World's Forests*. Rome: Food and Agriculture Organization (FAO), United Nations.

FAO (2001) *State of the World's Forests*. Rome: Food and Agriculture Organization (FAO), United Nations.

GEO (2006) *Global Environment Outlook (GEO) Year Book*. GEO Data Portal, Nairobi: United Nations Environmental Programme (http://geodata.grid.unep.ch).

Gleditsch, Nils Petter; Ådne Cappelen & Olav Bjerkholt (1994) *The Wages of Peace: Disarmament in a Small Industrialized Economy.* London: Sage.

Gleditsch, Nils Petter; Peter Wallensteen, Mikael Eriksson, Margareta Sollenberg & Håvard Strand (2002) Armed conflict 1946–2001: A new data set. *Journal of Peace Research* 39(5): 615–637.

Global Monitoring Report (2007) *Millennium Development Goals: Confronting the Challenges of Gender Equality and Fragile States*. Washington, DC: International Bank for Reconstruction and Development, World Bank.

Harris, Jonathan M (2006) *Environmental Natural Resource Economics: A Contemporary Approach*. Boston, MA: Houghton Mifflin.

Hawley, Thomas M (1992) *Against the Fires of Hell: The Environmental Disaster of the Gulf War*. New York: Harcourt Brace Jovanovich.

Heston, Alan; Robert Summers & Bettina Aten (2002) *Penn World Table* Version 6.1. Center for International Comparisons at the University of Pennsylvania (CICUP).

Houghton, Richard A & David L Skole (1990) Carbon. In: Billie L Turner II, William C Clark, Robert W Kates, John F Richards, Jessica T Mathews & William B Meyer (eds) *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years.* Cambridge: Cambridge University Press, 393–408.

IPCC (2007) *Climate Change 2007: The Physical Science Basis, Summary for Policymakers, Intergovernmental Panel on Climate Change*. Geneva: United Nations Environment Programme and World Meteorological Organization (http://www.ipcc.ch/).

Jacobsen, Karen (1997) Refugees' environmental impact: The effect of patterns of settlement. *Journal of Refugee Studies* 10(1): 19–36.

Jarvie, James; Ramzy Kanaan, Michael Malley, Trifin Roule & Jamie Thomson (2003) *Conflict Timber: Dimensions of the Problem in Asia and Africa, Volume II, Asian Cases*. Final report submitted to the United States Agency for International Development. Burlington, VT: ARD.

Laakkonen, Simo (2004) War – an ecological alternative to peace? Indirect impacts of World War II on the Finnish environment. In: Richard P Tucker & Edmund Russell (eds) *Natural Enemy, Natural Ally: Toward an Environmental History of War*. Corvallis, OR: Oregon State University Press, 175–194.

Li, Quan & Rafael Reuveny (2003) Economic globalization and democracy: An empirical analysis. *British Journal of Political Science* 33(1): 29–54.

Li, Quan & Rafael Reuveny (2006) Democracy and environmental degradation. *International Studies Quarterly* 50(4): 935–956.

Londregan, John B & Keith T Poole (1996) Does high income promote democracy? *World Politics* 49(1): 1–30.

Marshall, Monty G & Keith Jaggers (2006) *Polity IV Project: Political Regime Characteristics and Transitions, 1800–1999*. Center for International Development and War Management, University of Maryland (http://www.systemicpeace.org/polity/polity4.htm).

McNeely, Jeffrey A (2000) War and biodiversity: An assessment of the impacts. In: Jay E Austin & Carl E Bruch (eds) *The Environmental Consequences of War: Legal, Economic, and Scientific Perspectives*. Cambridge: Cambridge University Press, 53–378.

McNeill, John R (1992) *The Mountains of the Mediterranean World: An Environmental History*. New York: Cambridge University Press.

McNeill, John R (2001) *Something New Under the Sun: An Environmental History of the Twentieth-Century World*. London: Norton.

Moomaw, William R & Gregory C Unruh (1997) Are environmental Kuznets curves misleading us? The case of CO_2 emissions. *Environment and Development Economics* 2(4): 451–463.

Murray, Beth (2005) *Clean Air Interstate Rule (CAIR): Reducing Regional Transport of Emissions and Helping States Achieve the PM2.5 and Ozone NAAQS*. Washington, DC: Clean Air Markets Division, Environmental Protection Agency.

Panayotou, Theodore (2000) Economic growth and the environment. Working paper 56. Cambridge, MA: Center for International Development and Harvard University.

Pilcher, Charles (1993) War has benefits for nature in Kuwait. *Washington Times*, 6 January.

Raleigh, Clionadh & Nils Petter Gleditsch (2005) *War Sites 1946–2003*. Oslo: Centre for the Study of Civil War, PRIO.

Rudel, Thomas K; Oliver T Coomes, Emilio Moran, Frederic Archard, Arild Angelsen, Jianchu Xu & Eric Lambin (2005) Forest transitions: Towards a global understanding of land use change. *Global Environmental Change* 15(1): 23–31.

Shafik, Nemat & Sushenjit Bandyopadhyay (1992) Economic growth and environmental quality: Time series and cross-country evidence. Background paper for the World Development Report. Washington, DC: World Bank.

Singer, J David & Jeffrey Keating (1999) Military preparedness, weapon systems and the biosphere: A preliminary impact statement. *New Political Science* 21(3): 325–334.

Smil, Vaclav (1990) Nitrogen and phosphorus. In: Billie L Turner, William C Clark, Robert W Kates, John F Richards, Jessica T Mathews & William B Meyer (eds) *The Earth as Transformed* *by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years*. Cambridge: Cambridge University Press, 423–436.

Sobolev, SS (1947) Protecting the soil of the USSR. *Journal of Soil and Water Conservation* 2: 123–132.

Stavrakou, Trissevgeni; Jean-Francois Müller, K Folkert Boersma, Isabelle De Smedt & Ronald J van der A (2008) Assessing the distribution and growth rates of NOx emission sources by inverting a 10-year record of NO_2 satellite columns. *Geophysical Research Letters* 35: 1–5.

Stein, Bruce A; Cameron Scott & Nancy Benton (2008) Federal lands and endangered species: The role of military and other federal lands in sustaining biodiversity. *BioScience* 58(4): 339–347.

Stevenson, Mark (2009) US nixes 40 percent cuts at climate change talks. *Boston Globe*, 23 June.

Strand, Håvard; Joachim Carlsen, Nils Petter Gleditsch, Håvard Hegre, Christin Ormhaug & Lars Wilhelmsen (2005) *Armed Conflict Dataset Codebook: Version 3–2005*. Oslo: PRIO.

Templeton, Scott R & Sara J Scherr (1999) Effects of demographic and related microeconomic change on land quality in hills and mountains of developing countries. *World Development* 27(6): 903–918.

Thomson, Jamie & Ramzy Kanaan (2003) *Conflict Timber: Dimensions of the Problem in Asia and Africa*. Burlington, VT: ARD.

Tucker, Robert P (2004) Impact of warfare on the natural world: A historical survey. In: Robert P Tucker & Edmund Russell (eds) *Natural Enemy, Natural Ally: Toward an Environmental History of War*. Corvallis, OR: Oregon State University Press, 15–41.

WDI (2002) *World Development Indicators (WDI)*. Washington, DC: World Bank.

Westing, Arthur H (1977) *Weapons of Mass Destruction and the Environment*. London: Taylor & Francis.

Westing, Arthur H (1980) *Warfare in a Fragile World: Military Impact on the Human Environment*. London: Taylor & Francis.

Westing, Arthur H, ed. (1990) *Environmental Hazards of War: Releasing Dangerous Forces in an Industrialized World*. Newbury Park, CA: Sage.

Westing, Arthur H (2000) In furtherance of environmental guidelines for armed forces during peace and war. In: Jay E Austin & Carl E Bruch (eds) *The Environmental Consequences of War: Legal, Economic, and Scientific Perspectives*. Cambridge: Cambridge University Press, 171–182.

World Resources Institute (1999.) *World Resources: A Guide to the Global Environment.* New York: Oxford University Press.

RAFAEL REUVENY, b. 1957, Professor, Joint PhD in Business Economics and Political Science (Indiana University, 1997); current main interests: sustainable development, militarized conflict, globalization, migration, and the Israeli–Palestinian Conflict.

ANDREEA S MIHALACHE-O'KEEF, b. 1980, ABD in Political Science (PhD expected 2010, Pennsylvania State University); Visiting Assistant Professor (Roanoke College); current main interests: interactions between cross-border capital flows and socio-political phenomena, and consequences for human welfare.

QUAN LI, b. 1966, PhD in Political Science (Florida State University, 1998); Professor and Director of Program on International Conflict and Cooperation in the Department of Political Science at Texas A&M University, College Station (2008); current main interests: political causes and consequences of globalization, political violence, environmental politics.