Could climate change precipitate peace?

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Abstract

Growing interest in the social consequences of climate change has fueled speculation that global warming could lead to an increase in various forms of political violence. This article examines the effects of climate change on international conflict subsequent to the onset of European industrialization. Surprisingly, analysis at the system level suggests that global warming is associated with a *reduction* in interstate conflict. This naive relationship is suspect, however, as the increased consumption of carbon-based fuels is itself associated with changing patterns of politics and prosperity. In particular, economic development has been viewed as a cause of both climate change and interstate peace. Incorporating measures of development, democracy, cross-border trade, and international institutions reveals that systemic trends toward peace are actually best accounted for by the increase in average international income. The results imply that climate change, which poses a number of critical challenges for citizens and policymakers, need not be characterized as fundamentally a security issue, though climate change may have important security implications on the periphery of world politics. The analysis here also suggests that efforts to curb climate change should pay particular attention to encouraging clean development among middle-income states, as these countries are the most conflict prone. Ironically, stagnating economic development in middle-income states caused by efforts to combat climate change could actually realize fears of climate-induced warfare.

Keywords

climate change, democracy, economic development, global warming, intergovernmental organization, international conflict, militarized interstate dispute

Introduction

An evolving consensus that the earth is becoming warmer has led to increased interest in the social consequences of climate change. Along with rising sea levels, varying patterns of precipitation, vegetation, and possible resource scarcity, perhaps the most incendiary claims have to do with conflict and political violence. A second consensus has begun to emerge among policymakers and opinion leaders that global warming may well result in increased civil and even interstate warfare, as groups and nations compete for water, soil, or oil. Authoritative bodies, leading government officials, and even the Norwegian Nobel Committee have added their voices to inchoate concerns that climate change will give rise to an increase in heated confrontations as communities compete in a warmer world.

Where the basic science of climate change preceded policy, this second consensus among politicians and pundits about climate and conflict formed in the absence of substantial scientific evidence. While anecdote and some focused statistical research suggests that civil conflict may have worsened in response to recent climate change in developing regions (c.f. Homer-Dixon, 1991, 1994; Burke et al., 2009), these claims have been severely criticized by other studies (Nordås & Gleditsch, 2007; Buhaug, Gleditsch & Theisen, 2010; Buhaug, 2010).[1]

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[1] Sutton et al. (2010) critiques Burke et al. (2009). Burke et al. (2010) offers a reply.

In contrast, the few long-term macro statistical studies actually find that conflict increases in periods of climatic chill (Zhang et al., 2006, 2007; Tol & Wagner, 2010).[2] Research on the modern era reveals that interstate conflict has declined in the second half of the 20th century, the very period during which global warming has begun to make itself felt (Goldstein, 2011; Hensel, 2002; Levy, Walker & Edwards, 2001; Luard, 1986, 1988; Mueller, 2009; Pinker, 2011; Sarkees, Wayman & Singer, 2003).[3] While talk of a 'climatic peace' is premature, assertions that global warming is injurious to world peace must be evaluated in light of countervailing evidence and contrasting causal claims.[4]

To understand why global warming can coincide with a reduction in interstate conflict, it will be useful to recall that the contemporary situation differs from earlier eras of climate change to the degree that warming is a product of human activity. Human beings burn fossil fuels that produce greenhouse gases that lead to global warming. These same fossil fuels propel economic and political systems that appear less inclined to certain forms of violent conflict (Gartzke & Rohner, 2010, 2011). Industrialization leads to economic development and democracy, each of which has been associated with peace. Prosperity also encourages international institutions and stabilizing global and regional hierarchies. Thus, global warming may coincide with peace, while not actually inhibiting warfare.

This study explores the relationship between climate change, liberal processes fueled by industrialization (development, democracy, international institutions), and interstate conflict. Previous studies of liberal peace have not paid much attention to climate change. Climatic peace may be yet another benefit purchased by all but accruing mostly to the developed world. At the same time, there might be trade-offs to consider in terms of the pace of development and the environment. The curvilinear relationship between development and interstate peace reported here and elsewhere (Boehmer & Sobek, 2005) suggests important advantages to increasing the pace of development, rapidly moving states through the 'danger zone' of partial industrialization. If efforts to combat climate change cause nations to stagnate economically, then the world may unintentionally realize the worst fears of pundits and politicians for climate-induced conflict.

While the findings reported below clearly indicate that the rise in global temperatures has not (yet) led to increased interstate conflict, there remains room for debate about whether global warming has other deleterious, or even beneficial, effects. Under some conditions climate change appears to reduce the frequency of interstate disputes, though there is no compelling rationale for why this should be the case, even as this particular relationship is not robust with respect to the broadest set of coincident explanations. It may be too soon to provide a definitive answer to whether warming increases, reduces, or has no effect on interstate conflict, though of course waiting for more data also poses trade-offs. Conversely, the consequences of global warming may well differ across countries and regions. Some states may become more violent under pressure from a warmer planet, even as other states or regions find greater cause for cooperation. For now, I focus on detailing global patterns of climate change and interstate conflict, a necessary first step.

Conceptualizing climate and conflict

Research on climate change has generated tremendous interest. Initial debate focused on whether the climate is changing. Consensus has since evolved that the earth is getting warmer. Controversy then shifted to whether human beings are responsible for climate change. The third, most prolonged stage of the climate-change debate involves deciding what actions states and other actors should take to address consequences of global warming.

These numerous and varied effects of climate change could conceivably be considered separately from their causes, provided the two are not directly related. We need not put to rest all controversy about the causes of global warming to understand a bit about what climate change will do to the world we all occupy. Yet, to the degree that climate change is attributable to industrialization, it may make sense to consider whether these processes also interact directly or indirectly with specific consequences of global warming. To determine whether a warmer planet will be a more violent one, we need to ascertain both that: (a) rising temperatures increase conflict globally (not just in a few possibly atypical cases),[5]

[2] A 1974 report from the Central Intelligence Agency warned of the dangers of a cooler climate, affecting agriculture and political stability (Central Intelligence Agency, 1974).

[3] Battle deaths in war also declined (Lacina, Gleditsch & Russett, 2006; Lacina & Gleditsch, 2005).

[4] 'Future global warming is not likely to lead to (civil) war between (within) European countries' (Tol & Wagner, 2010: 77). Zhang and co-authors find similar results for China (2006) and for the world at large (2007). These findings were widely misrepresented in popular media as evidence that global warming is associated with increased violence.

[5] General tendencies can fail to characterize phenomena in particular times or places.

and (b) the causes of climate change do not themselves dissipate conflict in a way that might limit, or even counteract, the direct (negative) effects of global warming.

Research has begun to offer plausible linkages between climate change and an increase in some forms of conflict, such as insurgency and civil war. Barnett & Adger (2007: 639) note that 'direct and indirect impacts of climate change on human security may in turn increase the risk of violent conflict'. The authors ignore the opposite possibility, that the causes of climate change are thought to have largely benign effects on interstate conflict. Looking for harmful effects of climate change does not provide an accurate picture unless global warming is only associated with harmful effects. Indeed, a rich body of research suggests that the likely cause of climate change is also capable of mitigating conflict.

Whatever its contribution to climate change, classical liberal political economists see the forces of industrialization as fundamentally pacifying (Cobden, 1903[1867]; Bastiat, 1995[1848]; Angell, 1933; Hobson, 1938[1905]). A number of scholars argue that the emergence of modern nationalism (Knorr, 1966; Gilpin, 1981), the reduction in the economic value of land (Kaysen, 1990), or changes in the nature of global production (Brooks, 1999) have decreased the benefits that can be had from conquest and hence have made war among developed nations obsolete (Mueller, 2001). Economically developed countries have increasingly become 'trading states' (Rosecrance, 1985), or even 'virtual states' (Rosecrance, 1996), substituting economic cooperation for military conquest.

Yet, the drumbeat of war has repeatedly drowned out expectations of a simple linear relationship between development and peace. Angell (1933) argued that war no longer paid economically, but high costs failed to prevent fighting in 1939. Early quantitative studies found little evidence that economic development inhibited warfare (Wright, 1942; East & Gregg, 1967; Rummel, 1967), while later research offered little more support (e.g. Bremer, 1992; Reuveny & Thompson, 2002). At best, development appeared to amplify the effects of liberal politics (Hegre, 2000; Mousseau, 2000). Lacking evidence, scholars discounted development as a cause of interstate peace, focusing instead on democracy.[6]

Some research has begun to unpack the economic determinants of conflict and peace. Boehmer & Sobek (2005) find that economic development has non-linear effects on conflict at the state level. Poor countries cannot project power, while the rich tend to be satisfied and secure. The most disputatious states are those that are partially developed. Gartzke & Rohner (2010) distinguish between conflicts over private (resources, territory) and public goods (political stability, globalization), demonstrating formally and then empirically that capital accumulation shifts conflict away from conquest and toward compellence. Initial increases in prosperity allowed states to project power and engage in conquest abroad (Gartzke & Rohner, 2011). Subsequent development reduced the utility of territorial conquest, but further improved power projection, so that developed states could still fight over foreign policy goals, when and where differences occur.

Returning to the issue of climate and conflict, scholars have sought to identify relationships over long swaths of human history. For example, Zhang et al. (2007) show that cooling is associated with a variety of harmful social effects over a 500-year period. The authors intentionally omit the period of Western industrialization. Similarly, Tol & Wagner (2010) use data on warfare in Europe over roughly half a millennium to show that the results of an earlier study by Zhang et al. (2006) are robust to different regions. Cold appears to precipitate conflict in the temperate zone, at least in the pre-modern era.

In contrast, a growing number of studies covering much more brief temporal and spatial domains offer a pessimistic picture of the effects of warming on conflict. Burke et al. (2009), for example, provide evidence that higher annual temperatures in sub-Saharan Africa are associated with significant increases in civil conflict. While these findings match existing pessimism concerning the destabilizing effects of global warming, they lack important controls and are not robust (Buhaug, 2010). Even this evidence does not demonstrate that conflict will become worse everywhere. We do not yet know whether climate change can make the world more violent *on balance*. Given past patterns of social and political inequality, it would be surprising if prosperous regions suffered to an equal extent. Indeed, the more common pattern is externality; as with pollution, resource exploitation, the brain drain, and many other processes, the developed world may benefit in security terms from climate change, while other regions experience negative effects.

Climate and conflict: Through the lens of a theory of war

If climate change influences conflict, it does so through the processes responsible for war and peace. These

[6] Poverty is linked to civil conflict (Fearon & Laitin, 2003; Hegre & Sambanis, 2006).

processes are in turn complex, multiple in origin and effect, and weakly conceptualized and defined, even as they are critical to understanding how climate affects conflict. Still, much has been learned about the logic of war that can be applied here.

Actors must typically possess substantial disagreements for fighting to occur. Some experts view national interests as inherently incompatible, as all states seek power (Mearsheimer, 2001; Schweller, 1998) or security (Waltz, 1959). Others argue that interests vary (Organski & Kugler, 1980; Bueno de Mesquita, 1981). Still others view national interests as constant, but argue that structure can change, affecting the feasibility of pursuing objectives peacefully (Snyder & Diesing, 1977; Russett & Oneal, 2001).

Whatever the origin of difference, warfare remains a costly, messy, apparently inefficient way of settling social tensions. Communities benefit if members resolve their differences nonviolently. The problem, of course, is that individuals can prefer to fight, especially when the stakes are high. Yet, even under anarchy, disagreements are typically resolved peacefully. Leaders haggle, compromise, negotiate, bluster or threaten, but do not fight. War is then the result of incompatible interests and whatever factors or forces leave some adversaries unable to arrive at compromise agreements, even as most others can (and do).

Bargains are generally available under relatively mild assumptions (war must be costly, and competitors must be able to divide up issues freely) (Hicks, 1963; Fearon, 1995).[7] States or other actors can be unable to identify or forge bargains when competitors conceal weakness or feign strength (Blainey, 1973), or when changes in the balance of power or interest make the weaker party prefer to renege on agreements in the future.

The effects of climate change can thus propagate conflict either by making interests less compatible, or through increased bargaining failures. The former is the main approach in the literature, but climate change could also increase conflict simply because it is change. This can happen in two ways. First, rapid change can lead to uncertainty about property rights or the disposition of resources, which in turn can lead to conflict. Second, global warming may produce predictable long-term, secular changes in power relationships that force declining powers into action or oblivion. If for example agricultural patterns are affected, so that some nations become more fertile while others bake or desiccate, then beneficiaries may be able to convert new resources into influence that will rise over time. A declining state may have incentives to 'use or lose' existing military advantages to carve out concessions from opponents, or acquire resources affected by climate change.

Of the two possibilities, the former appears more general than the latter. The majority of historical contests arguably derive from uncertainty (asymmetric information), rather than from power transitions (commitment problems). Precisely because commitment problems are difficult to resolve, resulting wars tend to be large and intractable, but also, for this same reason, rare. To the degree that climate change affects the causes of war in ways that parallel historical root causes of competition and conflict, we should not expect the 'mix' of informational and commitment problem contests to become much different.

If anything, it seems likely that the mix will shift away from commitment problems and toward uncertainty as a cause of (often minor) contests. The kinds of resources that will be made scarce by global warming are already scarce or unavailable in certain regions. These regions are often more peaceful than the places where such resources are abundant. Singapore cannot feed itself. Much of Asia and Europe import all or most of their fuel needs. Scarcity, in and of itself, is not a reason for warfare, especially when resources are cheap relative to the cost of fighting. Intensive producers of commodity agricultural or mineral resources may benefit or be harmed by global warming. It does not follow that they will possess the martial might to impose their will on others, especially when the consumers of such resources include powerful nations more intent on profit than plunder.

While these possibilities are intriguing, all imply some change in the macro tendency for war. I will examine the possibility that climate volatility produces uncertainty and political instability in future research. For now, it will make sense to address existing perspectives on climate change and conflict directly, as this will do more to inform the evolving debate than by simply charting additional possible correlates of climate change.

Fighting over the weather

Violent conflict occurs wherever human beings inhabit the globe. Disputes require some mechanism for resolution, whether this involves force or persuasion. When the stakes are high, the temptation to resort to violence as the final arbiter must remain strong. State monopolies on

[7] Fearon discounts indivisibilities as a cause, as states can make side payments. Others see indivisibilities as important, particularly in civil conflicts (Toft, 2003; Walter, 2003).

force do not refute, but instead reflect the logic of political competition. Of course, the fact that politics involves violence does not make all politics violent. The possibility of punishment or coercion is itself available to deter or compel, and therefore often prevents the exercise of force. Common conjecture about the eventuality of conflict 'shadows' political discourse, often making behavioral violence redundant. Political actors can anticipate when another actor is incentivized to violence and can choose to avoid provocation (Leeds & Davis, 1997). Alternately, ignorance, indifference or an inability to act can result in political violence. Scholars must thus view context, motive, and information to determine whether certain situations make force more or less likely.

Climate change could generate or exacerbate tensions in the world (cf. Homer-Dixon, 1991, 1994, 1999; Stern, 2007; Burke et al., 2009). The general argument is one of resource scarcity precipitating conflict (Percival & Homer-Dixon, 1998; Kahl, 2006).[8] Elsewhere, scholars focus on local abundance of globally scarce resources as motive for (Collier & Hoeffler, 2004), or means to finance (Le Billon, 2001), conflict.

A large accompanying literature has sought to unravel possible empirical correlates of scarcity, climate, and conflict. Hauge & Ellingsen (1998) offer one of the first systematic studies to substantiate resource scarcity arguments in the context of civil conflict, while Hendrix & Glaser (2007), for example, argue that better evidence exists in climatic variance, rather than long-term trends.[9] Critics challenge the empirical validity of the connection between resource scarcity and conflict (Raleigh & Urdal, 2007; Theisen, 2008). Salehyan (2008) notes of this literature that there is no consensus about a general connection between climate change and conflict, but that this does not preclude such a relationship from occurring in particular places, times, or indeed in future research.

Parallels within and between nations are too strong to assume that the logic of resource scarcity will not also apply to international politics. Indeed, the origins of contemporary arguments may be traced to earlier studies of scarcity among states. Choucri and North (1975, 1989), for example, argue that 'lateral pressure' driven by population growth can lead to predatory interstate behavior. More recently, Tir & Diehl (1998) offer evidence for a connection between population (but not population density) and interstate conflict. Stalley (2003) examines the effect of environmental scarcity on militarized interstate disputes (MIDs), finding that population density and soil degradation are associated with an increase in MIDs, while fish and water scarcity and resource 'vulnerability' have no significant impact on whether states fight.[10] This special issue contains some of the first studies to focuses on possible connections between climate change and interstate conflict.

One area in which intrastate and interstate conflict overlap involves water. De Stefano et al. (2012) model the evolution of competition among riparian states, citing the greatest risks in, and among, countries in North Africa and the Middle East. Feitelson, Tamimi & Rosenthal (2012) assess implications of climate change for already heavily constrained aquifers supplying Israelis and Palestinians. They find that climate change is not as critical in *altering* water tensions as it might seem. Tir & Stinnett (2012) offer a similarly optimistic interpretation of the power of interstate institutions (treaties) to manage tensions over boundary rivers.

Perhaps the most obvious reason for the lack of attention to interstate relations in studies of climate and conflict is the conviction that answers already exist. Warfare among states has declined in roughly the same period during which climate change has begun to make itself felt (cf. Buhaug et al., 2010: 14). However, the presence of an apparently counter-intuitive negative association between climate and interstate conflict cannot in itself be an argument for ignoring the subject. Buhaug et al. (2010) argue that this negative relationship must be spurious, though they do not demonstrate this to be the case.

Any relationship between climate and interstate conflict is possible, but a clear prediction can be inferred from the resource scarcity literature. This prediction should be carefully evaluated, especially since the expectations of two different bodies of theory are at odds. To the degree that climate change leads to tensions among populations over scarce resources, and populations exist within states, one should expect that states will engage in more frequent (or vigorous) conflict. An increase in

[8] Tensions could arise in other ways besides resource scarcity, such as shifting borders (rivers) or coastlines (arctic sea melt). However, these processes are still at least partially about scarcity, since it is presumably the supply of territory, or its value, that is at stake.

[9] Climate change at the poles may have larger effects on interstate conflict (Haftendorn, 2010). Yet, international resource grabs have been surprisingly peaceful (Bennett, 2010).

[10] Angell (1936) rejects claims of resource- or population-induced conflict.

conflictual interstate behavior should in turn translate into increased aggregate (i.e. systemic) conflict. Indeed, it is important to assess claims of climate-induced conflict at the system level in order to determine overall tendencies. Climate change is holistic, affecting the globe without reference to borders, suggesting that civil- or state-level behavior could be misleading.

Hypothesis 1: Systemic conflict should increase with rising average annual temperature.

Yet, whether climate change generates a ripeness for war depends not just on whether scarcity increases the opportunity for conflict, but also on whether leaders and populations are more inclined to fight. Alternatives to force are typically available, if not always exercised. Whether war or peace ensue depends on whether warfare is expensive relative to the value of goods at stake or, alternately, if other options, such as diplomatic or deliberative mechanisms, facilitate compromises that make warfare redundant. The efficacy of these political or diplomatic mechanisms is not fundamentally tied to resource allocation or climate change. Scarcity can increase the value of resources, but since it also decreases quantity, the total value of a pool of resources is ambiguous. Scarcity, in and of itself, does not motivate political violence until the total value of disputed resources or prerogatives exceeds the anticipated 'production cost' of capturing assets through military force. Localized scarcity may generate political tensions, but it can also yield technological or social innovations that manage any tendency toward conflict. Goods can be traded from regions of abundance to regions of scarcity. Governments, firms or individuals may re-allocate labor or capital. Opposing tendencies can cancel or dissipate. Whether polities resort to war given new challenges depends on how actors manage information, constraints, and opportunities, and on how actors interact.

What are these 'opposing forces'? Even if global warming causes more conflict, the precipitants of climate change have already contributed to peace in some regions. Industrial and post-industrial societies are much less inclined to use force against one another. Some argue that industrialization has led to trade that makes war more costly or less efficient (Polachek, 1980; Oneal & Russett, 1997).[11] Others focus on how economic development creates economies that are difficult to profitably coerce through force (Angell, 1933; Rosecrance, 1985). Still others claim that globalization of production networks is critical (Brooks, 2005). A final set of arguments focuses on the effect of prosperity on factor endowments; wealthy societies that fight must use expensive labor to pursue relatively cheap inputs to production (Gartzke & Rohner, 2010, 2011).

While highly developed states are arguably less prone to fight, at least with each other, the effects of development are probably non-monotonic. Economic development has at least two different effects on civilization, initially increasing state capacity and the ability to project power, but later diminishing the value of conquest to developed economies (Boehmer & Sobek, 2005; Gartzke, 2006). Increasing ability and diminishing interest form a concave function as development progresses. Initially, increased state capacity allows states to project power. As industrial economies mature, however, incentives to trade and to fight begin to cancel each other out. For developed states, it is the declining utility of conquest that prevails. The rate at which peace predominates may also conform to the intensity of contests. Development should discourage larger disputes more quickly than minor confrontations that involve relatively little expenditure of effort and more often involve policy rather than territory. Thus, while the curvature and slope of the function will vary with conflict intensity, the overall trend should be for the world to experience fewer disputes as development and, by extension, global warming increase.

Other liberal variables coincide with economic development and industrialization. The most prominent of these is democracy. Democracies seldom or never fight each other, though democracies appear no less prone to fight in general (Maoz & Russett, 1993; Oneal & Russett, 1997). Systemic democratic peace advocates attempt to broaden the liberal peace by arguing that democratization is producing a world in which even non-democracies are more peaceful (Huntley, 1996; Wendt, 1999; Mitchell, 1997, 2002). However, it is actually quite difficult to reconcile systemic claims with the dyadic finding (Gartzke & Weisiger, 2012). Liberal peace scholars also point to the role of international organizations in inhibiting conflict (Oneal & Russett, 1999). Yet, evidence for the pacific effect of international organizations is weak and subject to controversy (Boehmer, Gartzke & Nordstrom, 2004). Intergovernmental organizations are as much a reflection of cooperation as they are a cause. Trade is another process often pointed to as a cause of peace (Polachek, 1980), though again there is reason to question the strength of this association (Beck,

[11] Development could also have an indirect effect on interstate conflict through creating conditions ripe for democracy (Przeworski et al., 2000; Boix, 2003; Epstein et al., 2006).

Katz & Tucker, 1998; Morrow, 1999). While all of these relationships are incorporated in the analysis, the link between economic development and conflict appears most salient in assessing the effects of climate change on interstate conflict behavior. I therefore offer a hypothesis on development, while also measuring the impact of other liberal variables:

> *Hypothesis 2:* Systemic conflict should decrease with rising economic development.[12]

The effects of climate change on interstate conflict

This section tests the hypotheses by comparing temperature variation with other putative covariates of systemic conflict. I contrast the pessimistic view gaining traction in policy circles (Hypothesis 1) with the possibility that global warming could diminish interstate conflict. I then focus on development as a more persuasive cause of peace (Hypothesis 2).

Before forging ahead, it will be useful to explain why I explore these linkages between climate and conflict at the system-level. First, there is every reason to suspect that system-level analysis is sufficient to test the hypotheses outlined above. Without specific expectations about how the effects of climate on conflict vary from place to place, there is no *a priori* reason to favor a more fine-grained analysis. Indeed, the best place to begin an inquiry of this type is at the system level. State or dyadic analysis would allow for the inclusion of additional covariates, but the research community has yet to posit ways that these variables might relate to climate change. The relationships that have been hypothesized are most likely to manifest at the system level. The approach here thus provides answers and insights without encumbering the empirical domain for future tests.

Second, a system-level analysis of basic relationships is necessary. Regardless of whether additional tests are proposed (and conducted) involving states or dyads, researchers will still need information about the overall tendency of climate change to affect (or fail to affect) interstate conflict. An important source of ambiguity follows from the fact that we know very little about the pervasiveness of tendencies that have begun to be identified and debated in the literature. Predictions about climate change in more discrete units of ocean or territory are less reliable, suggesting claims about the effects of climate change on conflict are themselves most reliable when made where confidence about the nature and impact of temperature anomalies is least in doubt. The analysis here is meant to complement additional, more fine-grained analysis. Identifying systemic relationships should help to define and propel examination of additional, more geographically varied correlates of climate change. I investigate climate and conflict at the system level as an initial step, in the expectation that future research will fill in or possibly revise many missing details.

Research design and data

The system-level analyses conducted here involve counts of militarized disputes or fatal militarized disputes. I use negative binomial logit to evaluate a count dependent variable. Key independent variables and additional 'control' variables are all discussed below.

The Correlates of War (COW) Militarized Interstate Dispute (MID) dataset is the most widely referenced measure of interstate conflict (Gochman and Maoz, 1984; Ghosn, Palmer & Bremer, 2004). MIDs consist of militarized threats, displays, or uses of force up to and including war among internationally recognized states, 1816 to 2000. I sum MIDs annually.

Annual average temperature data are reported as 'anomalies'. First, researchers at the NASA Goddard Institute for Space Studies provide the GISS Surface Temperature Analysis (GISTEMP) time series beginning in 1880, with a base time period 1951–80 (Hansen et al., 2006, 2010).[13] Second, data from the United Kingdom Meteorological Office Hadley Centre and the Climatic Research Unit, University of East Anglia, offer annual observations from 1850, with a base period of 1961–90 (Brohan et al., 2006).[14]

Measures of regime type come from the Polity IV project (Gurr, Jaggers & Moore, 1989; Marshall & Jaggers, 2002). *Democ* measures three institutional attributes of democracy: popular suffrage, constraints on the executive, and civil liberties. *Autoc* codes restrictions on political participation. The indexes are routinely combined into an ordinal measure.

Data on IGO membership come from COW. These data report membership at five-year intervals for all but the most recent few decades. I construct a count of the

[12] As noted, this relationship may be curvilinear (Boehmer & Sobek, 2005).

[13] These data were obtained from the GISS NASA website at: http://data.giss.nasa.gov.

[14] The HadCRUT data are available at: http://www.cru.uea.ac.uk/cru/data/temperature/.

international organizations per year and replace missing values with a previous year's observation.

Gross domestic product (GDP) per capita is the standard measure of development. GDP data for the bulk of the world's countries come from Gleditsch (2002). GDP data are only available for recent decades. Historical research involving economic development must thus rely on proxies. Per capita energy consumption correlates very highly with GDP per capita (cf. Burkhart & Lewis-Beck, 1994) and has the added value of actually measuring consumption of fossil fuels. I use per capita energy consumption in tests reported here.

Most research on liberal peace has focused on trade dependence rather than economic development. Development is the more appropriate indicator here, as it is more closely linked to industrialization/pollution and climate change. I also argue that development is generally more salient than trade for mitigating conflict. It seems appropriate and practical, however, to include a measure of world trade in some regressions to confirm that the effects attributed to development are not the result of economic interdependence. Data on economic openness (monadic trade) is included in the Gleditsch data.

I add several variables to address possible confounding factors. *# Countries* is a count of the number of internationally recognized nation states by year. The number of countries grows tremendously over the period covered in the analysis. *Population* measures the number of humans on earth. Systemic structural changes could also bias estimates of the effect of climate or other variables. I add a dummy for US hegemony (1945–present), and for the post-Cold War period (1992–present) to address system structure effects.

Carter & Signorino (2010) offer a simple technique to address temporal dependence that uses a count for the year, plus quadratic and cubic versions of the count variable. This approach is well suited to the analysis conducted here. I also add a count variable for the number of countries that are members of the international system in a given year in some regressions. Additional details are discussed as they arise in reviewing the analysis.

Analysis

Figure 1 reports the annual onset of MIDs, weighted by the number of dyads in the world system. As the quadratic trend line indicates, the number of MIDs per annum rose during the 19th and early 20th centuries, peaking in two world wars. However, the post-World War II period has been more peaceful, a pattern even more pronounced for the sample of fatal MIDs or wars.

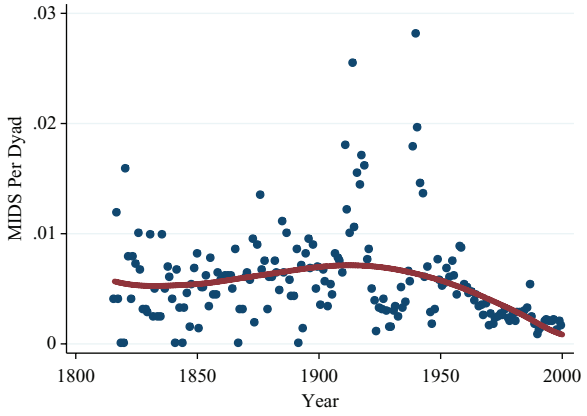

Figure 1. Frequency of MID onsets per year (weighted by number of dyads)

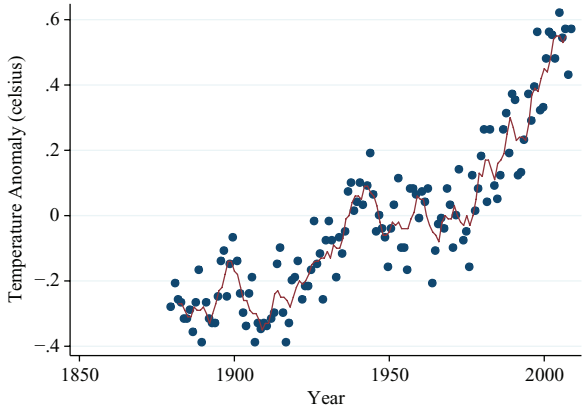

Figure 2. Global temperatures [annual averages and five-year moving average], 1880 to 2007 (plotted values are temperature anomalies relative to the base period 1951–80)

The incidence of MIDs has dropped at roughly the same time that the effects of climate change become apparent. Figure 2 details average annual global temperature anomalies and a five-year moving average.[15] Climate change appears to correlate with the decline in interstate conflict. Yet, other processes co-trend in this period. The most eligible processes are liberal economic and political variables. Figure 3 depicts average democracy, the number of IGOs, and per capita energy consumption from 1816 and 2000. Values are normalized by variable means.

Table I lists eight regressions comparing the effects of climate, democracy, development, and IGO membership on an annual count of worldwide MIDs. Model 1.1 contains only average annual temperature anomalies,

[15] See Hansen et al. (2006). These data are available at: http://data.giss.nasa.gov/gistemp/graphs/Fig.A2.txt.

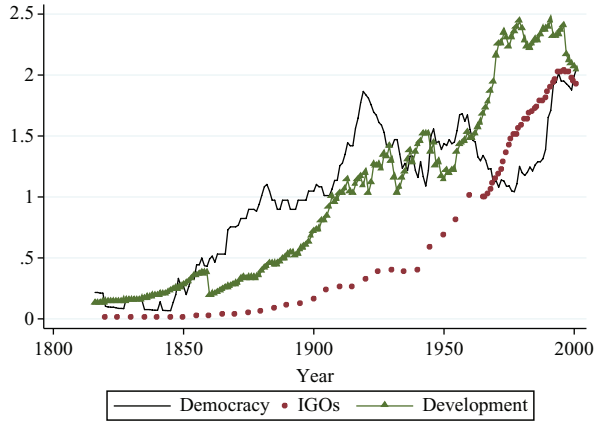

Figure 3. Global historical trends in liberal variables (values normalized)

world population, a count of countries, and the intercept. Temperature anomalies correlate positively with the count of MIDs, appearing to confirm the suspicion of many that global warming may increase interstate conflict.

Model 1.1 is almost certainly under-specified. The negative relationship between climate and conflict probably reflects the non-linear function identified in Figure 1. Model 1.2 adds the squared temperature anomaly variable. While the coefficient on the linear term remains insignificant, the quadratic variable is negative and highly significant. Given that the mean for the linear variable is negative and the quadratic mean is positive, the combined effect is negative. Higher annual temperatures still appear to reduce conflict.

Model 1.3 adds a measure of the proportion of democracies in the world.[16] Systemic democracy actually appears to increase conflict, though at the 10% significance level.

Democracies may be less warlike toward each other, but the most disputatious dyads involve one democracy and one non-democracy (Ray, 1993; Gleditsch & Hegre, 1997). As the number of democracies in the world increases, initially the bulk of dyads created are heterogeneous, theoretically increasing ecological conflict. For this reason, I add a quadratic regime type variable to Model 1.4. The results appear at first to support the curvilinear argument. Both regime type variables are highly significant in opposite directions. However, a plot of the relationship (not shown) reveals that the function trends downward, curving in the opposite direction anticipated, convex to the origin, with a minimum number of MIDs at about 85% of the maximum proportion of democracy.

Models 1.5 and 1.6 explore the effects of economic development on interstate disputes. Model 1.5 adds the linear development variable, while Model 1.6 introduces the quadratic term. By itself, the linear impact of development is positive and modestly statistically significant. The climate and regime type variables also become smaller and less statistically significant. The quadratic development variable in Model 1.6 greatly increases the significance and substantive impact of development on conflict. The democracy variables become statistically insignificant. The quadratic term on the climate anomaly variable remains significant at the 1% level. Climate still appears to diminish interstate conflict. The final pair of regressions in Table I add the linear and quadratic IGO variables. Neither of the IGO variables is statistically significant, though they slightly reduce the statistical significance and impact of the climate anomaly variables.

A pitfall inherent in the analyses in Table I is that most of the variables involved are non-stationary. Variables that trend over time will tend to correlate regardless of whether they are related causally. The results in Table I would be much more credible if it could be demonstrated that they did not result from the co-trending of key variables. Before correcting for the non-stationarity of the variables directly, I first address the time trend common to all of the variables. Model 2.1 in Table II adds linear, quadratic, and cubic count variables for years since 1816 to Model 1.8 from Table I. The time trend variables are all highly statistically significant. They appear to be capturing relationships that are not explained by the other variables. The effect of the year count variables is to make the climate variables statistically insignificant, while democracy and IGOs are significant. Economic development remains statistically significant. However, this approach is somewhat heavy-handed. While there is no *a priori* reason to oppose these measures, they contain limited theoretical content and should be interpreted with care. Note for example that both IGOs and democracy now appear to be harmful to interstate peace

A separate concern involves the coding of militarized disputes (I will return to the issue of non-stationarity in Table III). MIDs often involve relatively minor acts of conflict that could overwhelm relationships at higher conflict intensities. While potentially useful for capturing subtle effects of climate on conflict, minor MIDs may also incorporate trends that are unrelated to climate, globalization, or the rise of global democracy. Model 2.2

[16] I also examined average democracy level and found that results are equivalent.

Table I. Predicting the number of systemic militarized interstate disputes with temperature anomalies, democracy, development and IGOs (negative binomial regression, annual MID counts 1880–2000)

Model: *MID Onset*	*1.1* *Coeff.* *(S.E.)*	*1.2* *Coeff.* *(S.E.)*	*1.3* *Coeff.* *(S.E.)*	*1.4* *Coeff.* *(S.E.)*	*1.5* *Coeff.* *(S.E.)*	*1.6* *Coeff.* *(S.E.)*	*1.7* *Coeff.* *(S.E.)*	*1.8* *Coeff.* *(S.E.)*
Temperature	0.947†	0.461	0.361	0.369	0.231	–0.104	–0.100	–0.058
	(0.526)	(0.443)	(0.472)	(0.475)	(0.415)	(0.341)	(0.340)	(0.323)
Temperature^2		–4.526***	–4.821***	–3.305***	–2.810***	–2.408**	–2.433**	–2.224*
		(0.749)	(0.692)	(0.887)	(0.854)	(0.780)	(0.790)	(0.929)
Democracy			1.315†	20.65***	13.40†	–6.770	–6.231	–7.245
			(0.792)	(6.361)	(7.155)	(8.758)	(9.085)	(9.097)
Democracy^2				–27.84**	–17.37†	8.038	7.345	9.003
				(8.880)	(10.05)	(11.89)	(12.22)	(12.37)
Development					0.581*	3.298***	3.274***	3.082***
					(0.250)	(0.629)	(0.637)	(0.905)
Development^2						–1.022***	–1.006***	–0.939**
						(0.202)	(0.223)	(0.302)
Intergov. Org.							–0.788	0.712
							(4.557)	(6.162)
Intergov. Org.^{2}								–3.686
								(8.794)
Population	0.191	0.640*	0.535*	0.413	0.457†	0.694**	0.737*	0.730*
	(0.293)	(0.250)	(0.262)	(0.266)	(0.271)	(0.222)	(0.350)	(0.351)
No. Countries	0.002	–0.011	–0.008	–0.003	–0.011	–0.014†	–0.014†	–0.014*
	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)	(0.007)	(0.007)	(0.007)
Intercept	2.081***	2.447***	1.956***	–1.477	–0.441	1.484	1.371	1.611
	(0.274)	(0.255)	(0.448)	(1.231)	(1.346)	(1.369)	(1.464)	(1.499)
ln(α)	–1.412***	–1.669***	–1.682***	–1.756***	–1.799***	–2.098***	–2.096***	–2.095***
	(0.177)	(0.218)	(0.219)	(0.247)	(0.229)	(0.261)	(0.263)	(0.265)
N	122	122	122	122	122	122	122	
Log-likelihood	–422.49	–412.25	–410.76	–407.00	–404.12	–394.46	–394.45	–394.37
$\chi^2_{(8,8,8)}$	121.21***	173.08***	187.46***	273.40***	340.55***	389.27***	390.30***	398.76***

Significance levels:† 10%;* 5%;** 1%;*** 0.1%.

focuses on fatal MIDs. The higher dispute intensity moves the curvilinear relationship identified in Table I prior to the beginning of the sample in 1880. Thus, a simpler model specification with no non-linear terms is used.[17] I also introduce two additional variables. First, economic development could reflect the effect of trade on conflict. For this reason, I add a measure of total global trade (Oneal & Russett, 2005). Second, US hegemony could account for changes in conflict patterns attributed to climate change.[18] However, neither the *World trade* nor the *US hegemony* variables are statistically significant.

Interstate politics became more peaceful after the Cold War, even as climate change began to make itself felt. In Model 2.3, I add another dummy for the post-Cold War period. Climate change is just short of statistical significance at the 10% level. IGO counts are marginally significant and positive, while development remains significant.

Figure 4 details the effects of climate change on fatal MIDs based on Model 2.2 in Table II. I used the Clarify software in Stata to calculate the predicted probabilities and confidence intervals reported in the figure (Tomz, Wittenberg & King, 2003). Introducing US hegemony and post-Cold War forces the climate anomaly variable to compete for covariance over the portion of the relationship with the dependent variable where the confidence intervals are tightest. Again, statistical blunt objects must be applied to counteract the negative relationship between global warming and fatal MIDs.

Figure 5 again uses Clarify to plot the effects of development on conflict (Model 2.2). The robust relationship is reflected in tight confidence intervals around estimated values.

[17] Democracy and IGO membership are not significant in any version of Model 2.1.

[18] Colonialism is captured by the *hegemon* dummy and the *# countries* count variable.

Table II. Predicting the number of systemic MIDs with temperature anomalies, democracy, development, and IGOs (negative bin. regression, annual MID counts 1880–2000)

Model:	*2.1*		*2.2*		*2.3*	
MID Onset	*All MIDs*		*Fatal MIDs*			
	Coeff.	*(S.E.)*	Coeff.	*(S.E.)*	*Coeff.*	*(S.E.)*
Temperature	0.077	(0.360)	–2.814*	(1.403)	–2.393	(1.498)
Temperature^2	–1.398	(1.087)				
Development	6.549***	(1.219)	–1.796***	(0.547)	–1.652**	(0.547)
Development^2	–2.026***	(0.369)				
Democracy	–17.89*	(8.629)	0.457	(1.385)	–0.677	(1.945)
Democracy^2	24.85*	(11.93)				
Intergov. Org.	–25.93*	(10.27)	8.975	(5.650)	10.03 †	(5.969)
Intergov. Org.^{2}	64.53***	(20.15)				
World Trade			0.588	(2.121)	–0.0275	(2.186)
US Hegemony			–0.760	(0.538)	–0.772	(0.563)
Post Cold War					0.582	(0.548)
Population	2.168***	(0.549)	0.498	(0.909)	1.073	(1.185)
No. Countries	–0.024**	(0.008)	–0.002	(0.011)	–0.010	(0.013)
Year	–0.560***	(0.114)	–0.151	(0.178)	–0.177	(0.184)
Year^2	0.005***	(0.001)	0.002 †	(0.001)	0.002	(0.002)
Year^3	–0.000***	(0.000)	0.000	(0.000)	0.000 †	(0.000)
Intercept	21.00***	(4.338)	1.629	(6.815)	2.362	(7.016)
ln(α)	–2.347***	(0.293)	–16.46***	(0.924)	–15.97***	(0.739)
N	122		120		120	
Log-likelihood	–384.74		–208.95		–208.16	
$\chi^2_{(3,4,5,6,7,8,9,10)}$	545.06***		178.64***		179.38***	

Significance levels : † 10%;* 5%;** 1%;*** 0.1%.

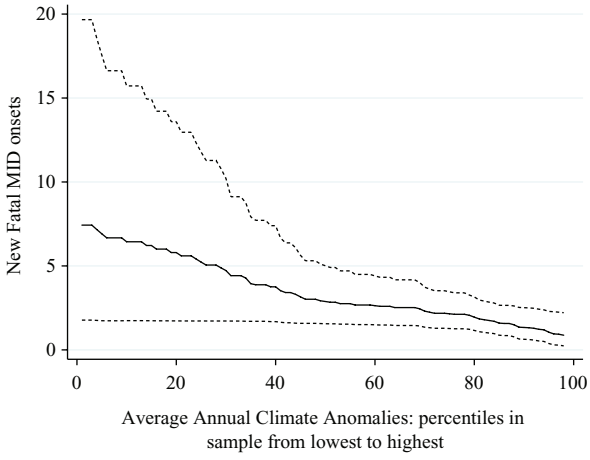

Figure 4. Global average annual temperature anomalies

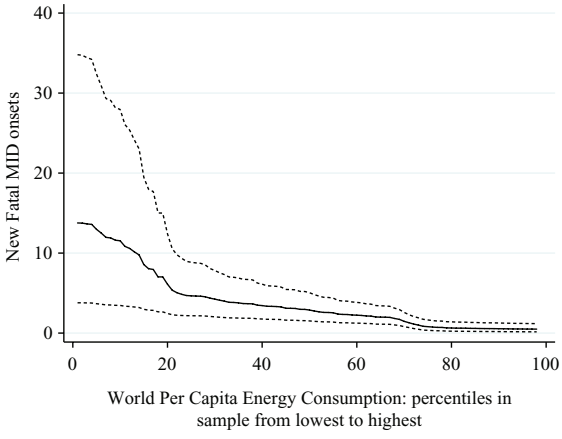

Figure 5. World per capita energy consumption

While Table II examines possible confounding temporal trends among key variables, I have still to address non-stationarity within these variables. The probability distribution of a stationary variable does not change when shifted in time or space (Hamilton, 1994). Table III offers three regressions in which the key variables have been corrected for non-stationarity. The steps involved in correcting each variable were slightly different, given differences in these data. In each case, I used plots and diagnostic tools such as the Dickey-Fuller test to identify appropriate corrections. The regime type variable serves as an example. A unit root test (Dickey-Fuller) and a plot of values of the variable

Table III. Predicting the number of systemic MIDs with stationary variables [corrected] and a second climate data source (negative binomial regression, annual MID counts 1850–2000)

Model	*3.1*		*3.2*		*3.3*	
	GISTEMP		*HadCRUT*			
MID Onset	*All MIDs*				*Fatal MIDs*	
	Coeff.	*(S.E.)*	*Coeff.*	*(S.E.)*	*Coeff.*	*(S.E.)*
Temperature $(n-1)$	0.441	(0.511)	0.540	(0.564)	0.659	(0.629)
Temperature^2 $(n-1)$	6.406*	(3.005)	3.269	(3.337)	7.671	(4.168)
Development (ln, $\bar{x}$, $n-1$)	–2.306	(1.226)	–3.639**	(1.374)	–3.686*	(1.756)
Development^2 (ln, $\bar{x}$, $n-1$)	–42.81**	(15.40)	–7.547***	(2.138)	–6.187*	(2.698)
Democracy ($\bar{x}$, $n-1$)	–3.554	(3.780)	–5.625	(4.018)	–5.963	(4.979)
Democracy^2 ($\bar{x}$, $n-1$)	172.4	(131.3)	182.1	(113.0)	129.4	(139.3)
Intergov. Org. (ln, $\bar{x}$, $n-1$)	4.357	(2.690)	3.597	(2.184)	3.693	(3.825)
Intergov. Org.^{2} (ln, $\bar{x}$, $n-1$)	–18.27*	(7.596)	–15.49**	(5.657)	–16.27	(13.16)
Intercept	2.839***	(0.116)	2.682***	(0.109)	0.868***	(0.127)
ln(α)	–0.754***	(0.125)	–0.509***	(0.101)	–0.361	(0.200)
N	121		151		151	
Log-likelihood	–454.19		–550.11		–313.06	
$\chi^2_{8,8,8}$	36.72***		62.08***		16.73***	

Significance levels : † 10%;* 5%;** 1%;*** 0.1%.

against time showed that the variable was not stationary. I first subtracted the variable mean, centering the variable about zero. I then first-differenced the variable to remove the apparent linear trend. The resulting variable exhibited no trend and had a mean of zero with constant variance. *Development* and *Intergov org* had non-linear trends. I logged each variable and then followed the steps above to produce stationary versions of the variables. First differencing was sufficient to correct the climate change variables.

Model 3.1 contains corrected versions of the eight key variables, but omits other 'control' variables. The results suggest some impact for climate and development on conflict, though only for the quadratic term. Interestingly, temperature anomalies now appear to exacerbate MID behavior, while development decreases disputes. International organizations also appear to inhibit conflict. I examined versions of the regressions in Table III that included corrected stationary versions of *Population*, *# Countries*, and other variables, but these variables were generally insignificant and tended to weaken results for key variables. Since all of the variables in these models are de-trended, the value of controls meant to capture the effect of certain trends is considerably reduced.

One of the limitations of the analysis is the limited temporal domain over which data are available on climate change. Reaching back earlier in time is useful because it places the beginning of the analysis more firmly in the pre-industrial or early-industrial period. Model 3.2 uses the HadCRUT data, which adds 30 observations to the econometric time series. These data are corrected in the same manner as the CISTEMP data used exclusively in Tables I and II. Introducing the longer time series to the stationary variables has two important effects. First, it leads the climate change variables to become statistically insignificant. Second, it strengthens the statistical significance of both *Development* variables. *Intergov org* also becomes more robustly significant.

The final model in Table III again looks exclusively at fatal disputes. The results are substantially the same as in Model 3.2, though levels of statistical significance are generally lower. The IGOs variable is no longer statistically significant, while the development variables are significant at a lower threshold level. Still, both development variables are statistically significant, despite the data contortions necessary to produce stationary variables and despite the presence of other plausible determinants of peace and conflict. What initially looked to be a product of climate is perhaps most convincingly explained by the precipitants of climate change, in particular economic development.

In addition to counts of MIDs and fatal MIDs, it is possible to examine the effects of climate on aggregate

casualty counts. Lacina, Gleditsch & Russett (2006) argue that casualty counts may be a better measure of trends in human conflict.[19] Lacina & Gleditsch (2005) offer the best available casualty data. I replicated the regressions from Tables I and II, replacing the dependent variable with casualty counts or logged casualty counts. Because they provide relatively few new insights and in order to save space, I do not report these results here. The climate anomaly variable is never statistically significant, either by itself or in conjunction with its square. Economic development is always positive and usually statistically significant, suggesting that casualty levels are increasing with modernity. While this result contrasts with the findings using MIDs and fatal MIDs, one cannot infer that developed states experience more casualties, as developed countries could be inflicting more casualties on other states. Alternately, developing countries may have higher casualties once international arms markets can supply more lethal military technologies. Finally, there is a strong curvilinear relationship between casualties and democracy or IGOs. This appears to be an accident of history more than a causal relationship. Democracy and IGOs have increased in the 20th century, while the mid-century is notable for extraordinary contests involving massive casualties. Logging casualty counts leads the IGO variable to become insignificant, while democracy remains modestly significant and negative at the 5% level in most regressions.

Conclusion

It thus appears that the processes that are widely seen by experts as responsible for global warming are themselves key contributors to the decline in global warfare. Prosperous nations are not fighting each other, even if they are polluting the planet. Obviously, this poses important dilemmas for policymakers and others. On the one hand, economic growth is inherently appealing. Prosperity solves many of the problems that plague the developing world. We must add to the advantages of economic development that it appears to make countries more peaceful. On the other hand, climate change imposes significant environmental costs. These trade-offs lack easy solutions. Indeed, we must ask whether environmental objectives are modified by the prospect that combating climate change could prolong the process of transition from warlike to peaceful polities.

Climate change may be one of the most important issues facing human civilization, or perhaps even life on earth. The effects of climate change are generally viewed as negative. Reasonable speculation also links climate to interstate conflict. However, the evidence provided here suggests reasons for cautious optimism. Interstate warfare is not generally inflamed by higher temperatures. Instead, economic development contributes to both global warming and interstate peace. Development creates nations that are no longer interested in territorial conquest, even if occasionally they continue to use force in punitive ways, or to police the growing global commons, coercing non-compliant states, groups, or leaders. In a somewhat ironic twist, the same forces that are polluting our planet and altering the climate also have beneficial effects on international conflict.

Replication data

Data and an automated do-file replicating all aspects of the empirical analysis can be found at http://www.prio.no/jpr/datasets.

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[19] Casualties are an effect of warfare. Leader choice might well be affected by concerns about casualties, but leaders may not accurately anticipate casualties early in a contest.

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