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. Research using historical data suggests in contrast that warfare is actually most acute in periods of unusual cold. I examine the effects of climate change on interstate conflict subsequent to European industrialization, where the putative causes of global warming — increased consumption of carbon-based fuels — are themselves associated with changing patterns of politics, economics, and peace. Though a naïve model suggests that global warming diminishes interstate conflict, this relationship is best explained by the effects of development on both climate change and interstate conflict behavior.

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1 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 policy makers 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 Nobel Peace prize committee have highlighted the prospect that climate change will give rise to more 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 et al. 2010; Buhaug 2010).[1] In contrast, long-term macro statistical studies find that conflict increases in periods of climatic chill (Zhang et al. 2006, 2007; Tol & Wagner 2010).[2] Research on the more recent past reveals that interstate conflict has declined in the second half of the twentieth century, the very period during which global warming has begun to make itself felt (Goldstein 2002; Levy et al. 2001; Luard 1986, 1988; Hensel 2002; Sarkees, et al. 2003; Mueller 2009).[3] While talk of a "climatic peace" is premature, broader claims that global warming causes conflict must be evaluated in light of countervailing evidence and a contrasting set of causal theoretical claims.[4]

To understand why global warming can coincide with a reduction in interstate disputes, it will help 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

[1] See also, Sutton, et al. (2010) for a critique specific to Burke et al. (2009). For a replay, see Burke, et al. (2010).

[2] As early as 1974, a report from the Central Intelligence Agency was warning of the deleterious effects of a cooler climate on global agriculture, affecting in turn political stability (Office of Research and Development 1974).

[3] The intensity of conflicts in terms of battle deaths also declined (Lacina, et al. 2006; Lacina & Gleditsch 2005).

[4] "Future global warming is not likely to lead to (civil) war between (within) European countries" (Tol & Wagner 2010, page 77). Zhang and co-authors find similar results for China (2006), and for the world at large (2007). Still, these studies are routinely misrepresented in popular media as evidence that global warming *increases* violence.

greenhouse gasses which lead to global warming. These same fossil fuels propel the development of economic and political systems that are less inclined towards certain kinds of armed conflict (Gartzke and Rohner 2010a, 2010b). Industrialization contributes to economic development and democracy, each of which is associated with international peace. Prosperity and globalized politics have also produced international institutions and a stabilizing systemic hierarchy. Thus, global warming may appear to coincide with a reduction in armed conflict without actually causing peace.

This study explores the relationship between climate, liberal domestic and international processes fueled by industrialization (development, democracy, and 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 evidence reported below clearly reveals that the rise in global temperatures has not (yet) led to an increase in interstate conflict, there remains room for debate about whether global warming might have other deleterious, or even beneficial, effects. Under some circumstances climate change appears to reduce the frequency of interstate disputes, though there is no compelling rationale for why such a relationship should exist, even as these findings are 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 tradeoffs. Conversely, the consequences of global warming may well differ across countries and regions. Some states may become more violent under the pressure of a warmer planet, even as other states or regions may find greater cause for cooperation. For now, I focus on detailing global patterns of climate change and interstate conflict, a necessary first step.

2 Conceptualizing Climate and Conflict

Research on climate change has generated tremendous intellectual and policy foment. 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, and possibly most prolonged stage of the climate change debate involves decisions about what actions states and other actors should take to address consequences of global warming.

The consequences of climate change could conceivably be considered separately from its causes, provided the two are not directly related. As many have now recognized, we need not put to rest all controversy about the causes of global warming to understand something of what climate change will do to the world we all occupy. Yet, to the degree that climate change *is* attributable to processes such as industrialization, it may make sense to consider whether these processes also interact directly or indirectly with specific consequences of global warming. If the claim is that a warmer planet will be a more violent one, then we need to ascertain both that: a.) rising temperatures increase conflict globally (not just in a few possibly atypical cases),[5] and b.) the causes of climate change do not themselves have any dissipating effect on conflict that might limit, counteract, or even overwhelm the exacerbating effects said to result directly from global warming.

Research has begun to offer plausible linkages between climate change and an increase in some forms of social conflict, such as insurgency and civil war. Barnett & Adger (2007) note that "direct and indirect impacts of climate change on human security may in turn increase the risk of violent conflict" (page 639). However, the authors ignore the opposite possibility, that the causes of climate change influence conflict behavior in a generally benign direction, diminishing the tendency for nations to fight. 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,

[5]It would also be incorrect to assume general tendencies characterize phenomena in particular times or places. For example, claims about climate change and civil conflict in Africa, though under challenge today, might for the sake of argument prove valid, even while the global aggregate relationship might turn out to be quite different.

Hobson 1938[1905]). A number of scholars argue that the emergence of modern nationalism (Knorr 1966, pp. 72-74; 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 could no longer pay economically, but high costs failed to prevent a return to fighting in 1939. Early quantitative studies found little evidence that economic development reduced interstate conflict or war (Wright 1942, East & Gregg 1967, Rummel 1967), while in later research development proved marginally significant or non-robust (e.g. Bremer 1992, Reuveny & Thompson 2002). At best, development appeared to amplify the effects of dyadic democracy (Hegre 2000, Mousseau 2000). Lacking strong evidence, researchers retrenched, discounting development as a cause of peace, focusing instead on democracy.[6]

Some research has begun to unpack possible 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 rich states tend to be satisfied and secure. The most disputatious states are those at a middle level of development. Gartzke & Rohner (2010*a*) 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 2010*b*). Subsequent development reduced the utility of territorial conquest, but improved power projecting means that developed states are still willing fight over non-economic policy goals, 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, over a 500 year period from the early fifteenth

[6]The dearth of interest in, and evidence of, development and peace at the international level is perhaps best reflected by the contrast with the literature on civil wars, which has found economic development to be one of the most robust and powerful predictors of internal conflict (Fearon & Laitin 2003, Hegre & Sambanis 2006).

century, Zhang, et al. (2007) show that global *cooling* is associated with a variety of harmful social effects including population decline and war. The authors intentionally omit the period covering the fruition of western industrialization, during which the world has witnessed the most intense global warming. 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 precipitates conflict in the temperate zone, at least in the pre-modern era.

In contrast, a growing body of shorter-term studies offer a more pessimistic picture. Burke, et al. (2009), for example, provide evidence that warmer annual temperatures in sub-Saharan Africa are associated with significant increases in civil conflict. While the authors' findings are consistent with the pessimism of many concerning the effects of global warming on political violence, they again point to conflict becoming worse somewhere, but not necessarily *everywhere*. As yet, we do not know that climate change will make the world more violent on balance. Nor do we know whether the effects of climate change documented in one region necessarily translate into a general (global) tendency. I will have more to say on the literature on climate change and conflict later.

3 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 processes are in turn complex, multiple in origin and effect, poorly conceptualized and defined, even as they are critical to understanding how climate affects conflict. Still, much has been learned in recent years about the logic of war, and these insights 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; some nations have incompatible objectives, while others can coexist peacefully (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 messy, costly, apparently inefficient way of settling social tensions. Communities are much better off if members resolve their differences

non-violently. The problem, of course, is that individuals can find fighting appealing, especially when the stakes are high. Yet, even under anarchy, resolving most disagreements does not involve warfare. Leaders or their deputies haggle, compromise, negotiate, bluster or threaten their way to settlements short of military violence. War is then the result of *both* incompatible interests and whatever it is that makes some adversaries unable to arrive at bargains, when most can (and do).

Work on the theory of conflict shows that 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 it appealing for the weaker party to renege on bargains in the future.

The effects of climate change can thus propagate conflict either by making interests less compatible (while ensuring that new disputes are no more easily resolved diplomatically), or through an increase in bargaining failures. The former is the modal approach in the literature, but climate change could also increase conflict simply because it is change. This can happen in two ways. First, if changes are relatively rapid, uncertainty about the status of property rights or the disposition of resources can lead to conflict. Second, global warming could produce *predictable* long-term, secular changes in power relationships forcing declining powers into action or oblivion. If for example climate change alters agricultural growing patterns so that some nations become more fertile while others bake or dessicate, 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 advantages to carve out concessions from opponents, even acquiring 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 they are difficult to resolve, commitment problem wars tend to be large and intractable, often involving protracted military contests that sap the resources of one or both adversaries. 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

[7] Fearon discounts indivisibilities as a source of conflict since states may make side payments. Others see indivisibilities as more salient, particularly for civil contests, where at least one actor lacks sovereignty (Toft 2003, Walter 2003).

expect the "mix" of informational and commitment problem contests to be 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 war costs of participants, and when markets are available to mediate the exchange of goods and services. 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, they are probably not the major way in which climate change is likely to affect the politics of nations. 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.

4 Fighting Over the Weather

Violent conflict occurs wherever human beings inhabit the globe. Issues in dispute require some mechanism for resolution, whether this involves force or persuasion. Where the stakes are high, the temptation to resort to violence as the final arbiter must remain strong. The state monopoly on force does not refute, but instead reflects the "rightness" of might, however power is couched in law and other "legitimate" political processes. Where sovereign authority is absent or contested, the recourse to violence will prove even more tempting, if only because of the premium on initiative. The first to take arms in the event that war becomes an inevitability must naturally possess advantages over those who wait. The social consequence of this logic is captured in the prisoners' dilemma.[8]

[8] In the PD game, of course, there is no "dilemma," but a dominant strategy (to "defect" or fight). While remedies to mutual defection exist, techniques such as iterating interaction also highlight the underlying social problem, and the vulnerability of cooperation to opportunistic incentives that shorten the time horizon of actors (Axelrod 1979).

The fact that politics involves violence does not mean, of course, that all politics is violent. The possibility of physical punishment or coercion is itself available to deter or compel, and therefore can often prevent the actual exercise of violence. Common conjecture about the eventuality of force "shadows" political discourse, often making the exercise of force 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 incentives playing out, so that nominal connections between precipitants and conflict become realized. Scholars in turn must view context, motive, and information to determine whether certain situations make force more likely, or whether other factors ensure that non-violent measures dominate.

A number of researchers put forward claims about the potential of climate change to generate or exacerbate tensions in the world (c.f., 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). Elsewhere, scholars focus in contrast on local abundance of globally scarce resources as the 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 support resource scarcity arguments in the context of civil conflict, while Hendrix & Glaser (2007), for example, argue that better evidence exists in climactic variance, rather than long-term trends. Critics challenge the empirical association between resource scarcity and conflict (Raleigh & Urdal 2007, Theisen 2008). In summarizing both the theoretical and empirical literatures, Salehyan (2008) notes that there is no consensus about a simple, demonstrable connection between climate change and conflict, but that this does not preclude such a relationship from occurring in certain contexts, or indeed for the relationship to present itself in future research. With increasing recognition of climate change has come increasing interest in, and attention to, its possible correlates. New research may propose, document, or contest claims that will in turn revise our collective understanding.

One area of near consensus in the contemporary debate is the substantive focus of analytical inquiry. Resource scarcity arguments are uniformly applied to relations among groups, or between states and groups, but less often to interstate relations. To my knowledge, no study focuses in

particular on the prospect of a link between climate chance and *inter*state conflict. This is odd, since the parallels within and between nations are too strong to imagine that the resource scarcity logic itself is precluded from applying to politics at the international level. Indeed, the origins of contemporary resource scarcity arguments may be traced to the study of relations among states. Choucri and North (1975, 1989), for example, detail a theory of lateral pressure driven by population growth, but which also implies that resource scarcity could lead nations to seek to prey upon one another. One of the earliest careful discussions of a connection between resources, population and interstate conflict comes from Angell (1936). More recently, Tir & Diehl (1998) offer some evidence for a connection between population (but not population density) and interstate conflict.

Perhaps the most obvious reason for the lack of attention among studies of climate and conflict to interstate relations is the conviction that we already have the answers. Researchers generally recognize that warfare among countries has declined in roughly the same period during which climate change has begun to make itself felt (c.f., Buhaug, et al. 2010, page 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 is spurious, though they do not demonstrate that this is 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 conflictual state behavior should in turn translate into increased aggregate (i.e. systemic) conflict. Indeed, it is important to asses 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 international borders, suggesting that civil- or state-level behavior could be misleading.

Hypothesis 1 *Climate: 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 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).[9] 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 resort to war must use expensive labor in order to capture cheap inputs to production (Gartzke 2006, Gartzke & Rohner 2010*b*, Gartzke & Rohner 2010*a*).

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.

[9]Development could also have an indirect effect through creating conditions ripe for democracy (Przeworski, et al. 2000; Boix 2003; Epstein, et al. 2006, which then exhibit the "democratic peace" effect.

Initially, it is the increase in state capacity that has the most impact. As industrial economies mature, however, these forces first cancel each other out and then the declining utility of conquest prevails, leading the most advanced economies to prefer commerce to conquest. The rate at which peace prevails over power may also conform to the intensity of contests. Development should discourage larger or more lethal 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 global warming—increases.

Other liberal variables coincide with economic development and industrialization. The most prominent of these is democracy. The so-called "democratic peace" is the widely documented finding that 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 turns out that 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 et al. 2004). Intergovernmental organizations are as much a reflection of cooperation as they are a cause. Interstate trade is another process often pointed to as a cause of peace (Polachek 1980), though again there is reason to question the strength of the association (Beck et al. 1998; Morrow 1999). While all of these relationships are incorporated in the analysis, the link between economic development and conflict appears most salient for the analysis of the effects of climate change on interstate dispute behavior. I therefore focus on the following hypothesis for liberal variables.

Hypothesis 2 *Development: Systemic conflict should decrease with rising economic development.*[10]

[10]As noted, this relationship may be curvilinear (Boehmer & Sobek 2005, Gartzke 2006). Conflict may initially increase as development expands state capacity. I focus here on the "ultimate" effect of development on conflict.

5 The Effects of Climate Change on Interstate Conflict

This section tests the propositions outlined above by comparing climate variables (i.e., temperature) with other putative co-variates 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 compelling rationale for 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 begin with more fine-grained analysis. Indeed, one might well argue that 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 co-variates, but it would also raise additional questions about how these variables relate to climate change, relationships that have yet to be worked out theoretically. The specific relationships hypothesized are most likely to manifest at the systemic level. Further, the approach here provides answers—hopefully prompting new theory—without exhausting the domain for future empirical tests.

Second, a system-level analysis of basic relationships is necessary. Regardless of whether additional tests are conducted involving states or dyads, researchers will still need to know what the overall tendency of climate change on interstate conflict is, and might be. As I note of existing studies of climate and civil conflict in the literature review above, an important source of ambiguity follows from the fact that we know very little about the pervasiveness of identified tendencies. The precision of climate forecast data in particular is greatest at the global or hemispheric level. Predictions about climate change in more discrete units of ocean or territory are notoriously difficult to nail down, implying that predictions about the effects of climate change on conflict are themselves most reliable when made globally or hemispherically. Again, none of the analysis here precludes further, more fine-grained analysis. Instead, identifying relationships at the system level should help to define and propel an informed analysis of additional, more contingent and geographically varied correlates of climate change. I explore the relationship between climate and conflict as a systemic phenomenon for now, allowing for the impact of numerous other systemic processes.

5.1 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 the count dependent variable. Key independent variables, additional "control" variables, and econometric controls are all discussed below.

The Correlates of War (COW) Militarized Interstate Dispute dataset (MIDs) are the most widely referenced measure of conflict (Gochman and Maoz 1984; Ghosn, et al. 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 to create an a systemic count of conflicts.

Annual average temperature data, as well as monthly averages for the northern and southern hemispheres comes from the NASA Goddard Institute for Space Studies. Temperatures are reported as "anomalies" relative to the base time period 1951–1980 (Hansen, et al. 2006, 2010).[11]

Regime type data comes from the Polity IV project (Gurr et al. 1989, Marshall & Jaggers 2002). Polity data consist of two eleven point indexes. 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 comes from COW. Until recent years, these data report each international organization and their membership at five year intervals. I constructed a count of the international organizations per year and replace missing values with a previous year's observation.

The standard measure of economic development is Gross Domestic Product (GDP) per capita. GDP data for the bulk of the world's countries comes from Gleditsch (2002). GDP data are only generally available in recent decades. For this reason, historical research involving economic development relies on proxies. Per capita energy consumption correlates very highly with GDP per capita (c.f., Burkhart & Lewis-Beck 1994) and has the added value of actually measuring consumption of carbon emitting fuels. I use per capita energy consumption in tests reported here.

Most research on liberal peace has used trade 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

[11] Temperature anomaly data were obtained from the GISS NASA website: `http://data.giss.nasa.gov`.

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 designed to address changes that might confound the analysis. *# Countries* is a count of the number of internationally recognized nation states by year. The number of countries grows tremendously as a result of decolonization and other processes. *Population* measures the number of human beings on earth. Systemic structural changes could conceivably bias estimates of the effect of climate or other variables. I add a dummy for U.S. hegemony (1945 - present), and for the post Cold War period (1992 - present) to address the effect of system structure.

Carter & Signorino (2007) offer a simple technique to address temporal dependence involving a count for the year, plus quadratic and cubic versions of this count variable to capture non-linear dependencies. 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.

5.2 Analysis

Warfare varies over time. Figure 1 reports the annual onset of MIDs, weighted by the number of country pairs (dyads) in the international system. As the quadratic trend line indicates, the number of MIDs per annum rose throughout the nineteenth and early twentieth centuries, peaking at the time of the two world wars. Since that time, however, the trend has declined. The world has become more peaceful. This tendency is more pronounced if examine only fatal MIDs, or wars.

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.[12] Climate change appears to correlate with the decline in interstate conflict. Yet, other processes co-trend in this period. The most eligible candidates seem to involve liberal economic and political processes. Figure 3 depicts average democracy, the number of IGOs and per capita energy consumption from 1816 and 2000.[13] Values are normalized by variable means.

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

[13] While democracies increased in this period, decolonization flooded the world with new states, many autocratic.

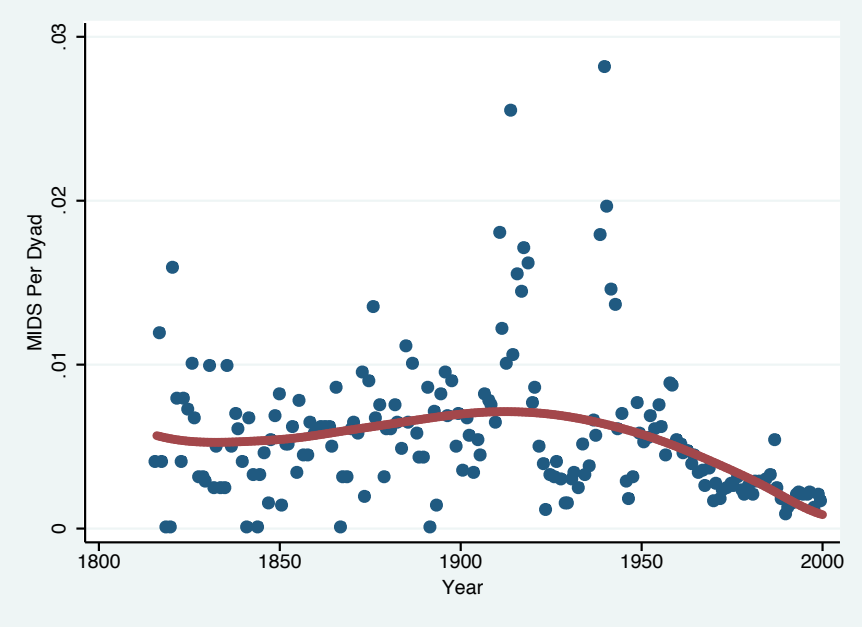

Figure 1: Frequency of MID Onsets per Year (weighted by # of dyads)

Table 1 provides eight regressions comparing the effects of climate, democracy, development and IGO membership on the number of MIDs worldwide in a given year. Model 1.1 contains only average annual temperature anomalies, world population, a count of countries in the world and the intercept. Temperature anomalies correlate positively with the count of systemic MIDs, appearing to confirm the suspicion of pundits and politicians that global warming *increases* interstate conflict.

Model 1.1 may be under specified. The negative relationship between climate and conflict could results from the non-linearity identified in Figure 1. Model 1.2 introduces the squared temperature anomaly variable. While the coefficient on the linear term remains statistically insignificant, the quadratic climate variable is negative and highly significant. Since the mean for the linear statistic is negative, while the quadratic mean is positive, and of comparable size (0.047), the combined effect is decidedly negative. Higher average annual temperatures are associated with *less* conflict.

Model 1.3 adds a variable that measures the proportion of countries in the world that can reasonably be described as democratic.[14] The level of systemic democracy actually appears to increase systemic conflict, though at the very marginal 10% level of statistical significance.

[14]In addition to the proportion of democracies, I also examined average democracy level. Results are equivalent.

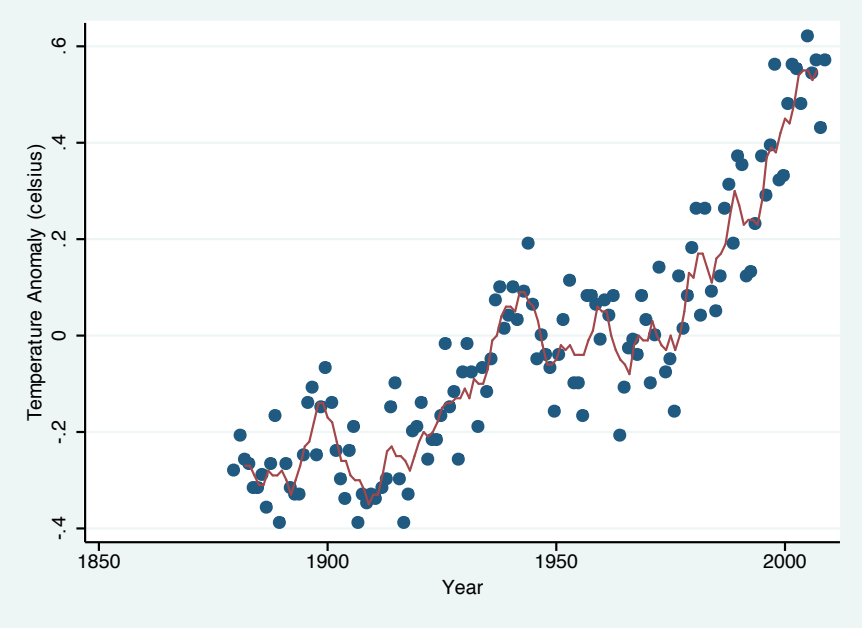

Figure 2: Global Temperatures [annual averages and five year moving average], 1880 to 2007. (Plotted values are temperature anomalies relative to the base period 1951–1980.)

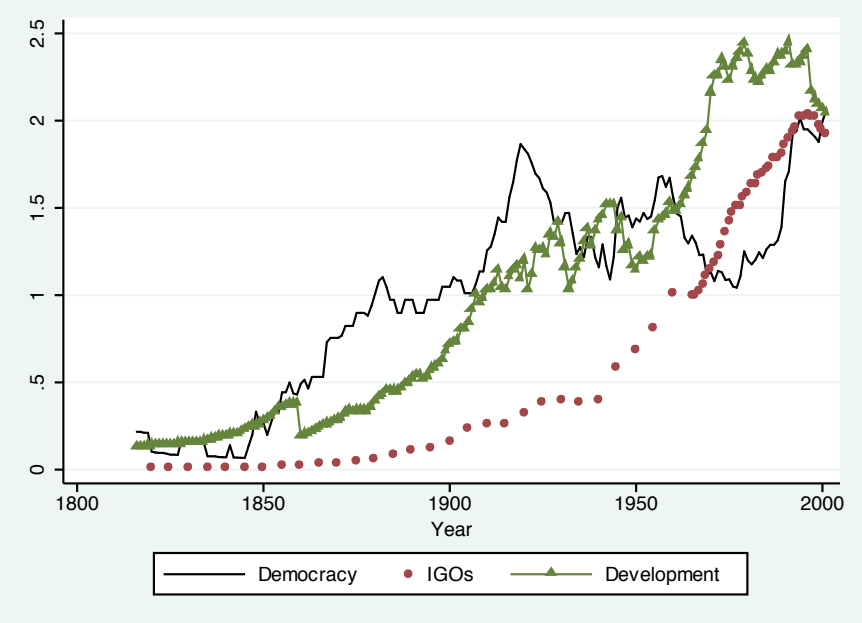

Figure 3: Global Historical Trends in Liberal Variables (values normalized)

Table 1: Predicting the Number of Systemic Militarized Interstate Disputes with Temperature Anomalies, Democracy, Development and IGOs (Negative Binomial Regression, annual MID counts 1880–2000)

Model:	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
MID Onset	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)	Coeff. (S.E.)
Temperature	0.947 †	0.461	0.361	0.369	0.231	-0.104	-0.100	-0.0577
	(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)
# Countries	0.0022	-0.0113	-0.0079	-0.0033	-0.0110	-0.0139 †	-0.0138 †	-0.0144 *
	(0.0092)	(0.0079)	(0.0083)	(0.0084)	(0.0093)	(0.0074)	(0.0073)	(0.0072)
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
$\chi^2_{(3,4,5,6,7,8,9,10)}$	121.21 ***	173.08 ***	187.46 ***	273.40 ***	340.55 ***	389.27 ***	390.30 ***	398.76 ***

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

Democracies may be less warlike toward each other, but the most disputatious dyads are heterogeneous, including one democracy and one non-democracy (Ray 1993, Gleditsch & Hegre 1997). As the number of democracies in the world increases, initially more heterogeneous dyads are created than democratic dyads, increasing apparent conflict levels. To assess this possibility, I add a quadratic term for systemic regime type to Model 1.4. The results provide some support for the curvilinear argument. Both regime type variables are highly significant and in the opposite direction. The mean for the quadratic term is slightly larger, but the respective means for the linear and squared terms (0.243 and 0.077, respectively) suggest that regime type does more to inflame than inhibit. Regime type fails to account for the apparent impact of climate on systemic conflict.

Models 1.5 and 1.6 explore the effects of economic development on interstate disputes. Model 1.5 first adds the linear development variable. Model 1.6 then introduces the quadratic term. By itself, the linear impact of development is positive and modestly statistically significant. Note also that the climate and regime type variables are 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. However, the quadratic term on the climate anomaly variable remains significant at the 1% level. While development has a much larger effect, climate still appears to diminish interstate conflict.

The final pair of regressions in Table 1 add the linear and quadratic IGO variables. Neither of the IGO variables proves statistically significant. On the other hand, introducing the IGO count variables slightly reduces the statistical significance and substantive impact of the remaining variables, including climate anomalies. Whether this is appropriate depends on one's preferred conception of world politics. On an empirical basis, the rationale is less clear, at least in Table 1.

Table 1 cannot include all correlates of climate and conflict. I address the potential for bias by adding a series of year count variables to the specification in Model 1.8. Model 2.1 in Table 2 includes a linear, quadratic, and cubic count variable for years since 1816, the initial year coded for the MIDs. These variables are all highly statistically significant. They appear to be capturing relationships across time 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

now significant. Economic development remains statistically significant. However, this approach is somewhat heavy handed, ruling out temporal relationships that may in fact be valid. While there is no a priori reason to oppose these measures, they contain limited theoretical content and should be interpreted with care. Note that both IGOs and democracy appear harmful to interstate peace.

MIDs often involve relatively minor acts of conflict that may mask relationships at higher conflict intensities. Model 2.2 examines an annual count of fatal MIDs, involving at least one battlefield death. Because of their higher intensity, the curvilinear relationship identified in Table 1 occurs prior to the beginning of the sample in 1880. Thus, a simpler model specification with no non-linear terms can be used.[15] I also introduce two additional variables: First, economic development might actually reflect the effect of trade on conflict. For this reason, I add a measure of total global trade (Oneal & Russett 2005). Second, U.S. hegemony could be responsible for the apparent effects of climate change. Model 2.2 includes a dummy variable coded one for years beginning in 1945.[16]

Climate change is again negative and statistically significant as a determinant of fatal MIDs. Development also discourages fatal MIDs, while democracy and IGOs are both statistically insignificant. Neither the *World Trade* nor the *U.S. Hegemony* variables are statistically significant.

The world became more peaceful after the Cold War, even as the effects of climate change began to make themselves 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 now marginally significant and positive, while development remains significant in the expected direction.

The impact of these additional dummy variables are best identified in a plot of these relationships. Figure 4 details the effects of climate change on fatal MIDs based on Model 2.2 in Table 2. I used the Clarify software in Stata to calculate the predicted probabilities and confidence intervals reported in the figure (Tomz, et al. 2003). Introducing *U.S. 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.

[15] All combinations of variables in Model 2.1 were examined using fatal MIDs. There are no models where democracy or IGOs are statistically significant. Development is not statistically significant if the quadratic variable is included.

[16] Colonialism/decolonization is captured indirectly by the hegemon dummy and the *# of countries* count variable.

Table 2: 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	0.0769	(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)
U.S. 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)
# Countries	-0.0236 **	(0.00773)	-0.00214	(0.0106)	-0.0102	(0.0134)
Year	-0.560 ***	(0.114)	-0.151	(0.178)	-0.177	(0.184)
Year^2	0.00515 ***	(0.00106)	0.00207 †	(0.00146)	0.00245	(0.00157)
Year^3	-0.00002 ***	(0.000003)	-0.000007	(0.000004)	-0.000009 †	(0.000005)
Intercept	21.00 ***	(4.338)	1.629	(6.815)	2.362	(7.016)
$\ln(\alpha)$	-2.347 ***	(0.293)	-16.46 ***	(0.924)	-15.97 ***	(0.739)
N	122		120		120	
Log-likelihood	-384.74		-208.95		-208.16	
$\chi^2_{(13,11,12)}$	545.06 ***		178.64 ***		179.38 ***	

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

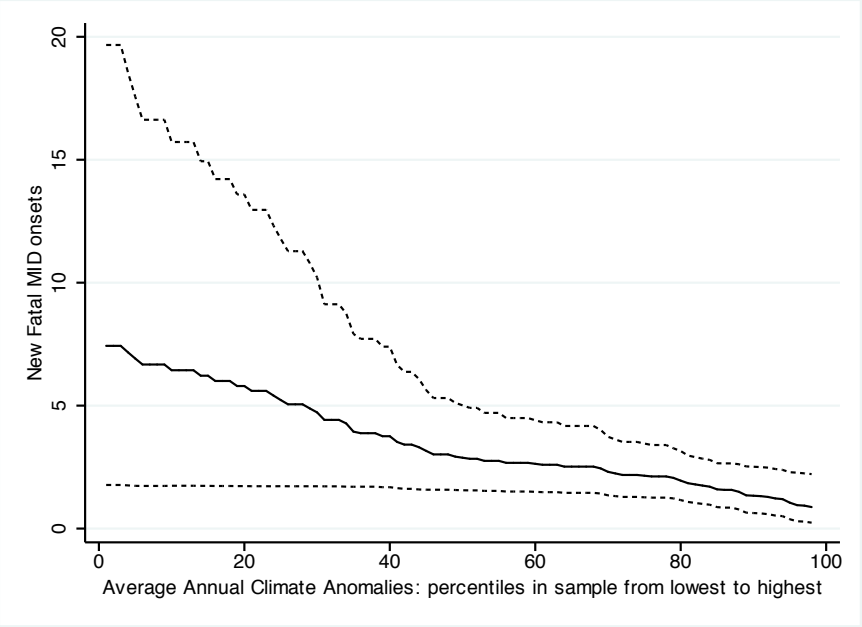

Figure 4: Global Average Annual Temperature Anomalies

The effects of energy consumption remain consistently statistically significant throughout this analysis. Figure 5 again uses Clarify. As the figure reveals, the robust effects of energy consumption result because dispersion around the estimated relationship is extremely tight across most values.

In addition to counts of MIDs and fatal MIDs, it is possible to examine the effects of climate on aggregate casualty counts. Lacina, et al. (2006) point out that casualty counts might be a better measure of trends in human conflict. While their argument is generally persuasive in terms of documenting these trends, there are at least three drawbacks to using casualty data here. First, casualties are an *effect* of warfare. As such, they are logically separable from, if not independent of, the causes of disputes. Leader choice might well be affected by concerns about casualties, but the truth is that leaders cannot accurately anticipate how many soldiers will be harmed in a contest at the outset. A relationship between climate change and casualties does not necessarily imply a relationship between climate change and the onset of disputes, or vice versa. If researchers are primarily interested in understanding the political decision by leaders to resort to arms, then casualty data could potentially be less informative than measuring the onset or number of disputes.

Second, casualty statistics are notoriously noisy and difficult to collect. Underlying relationships

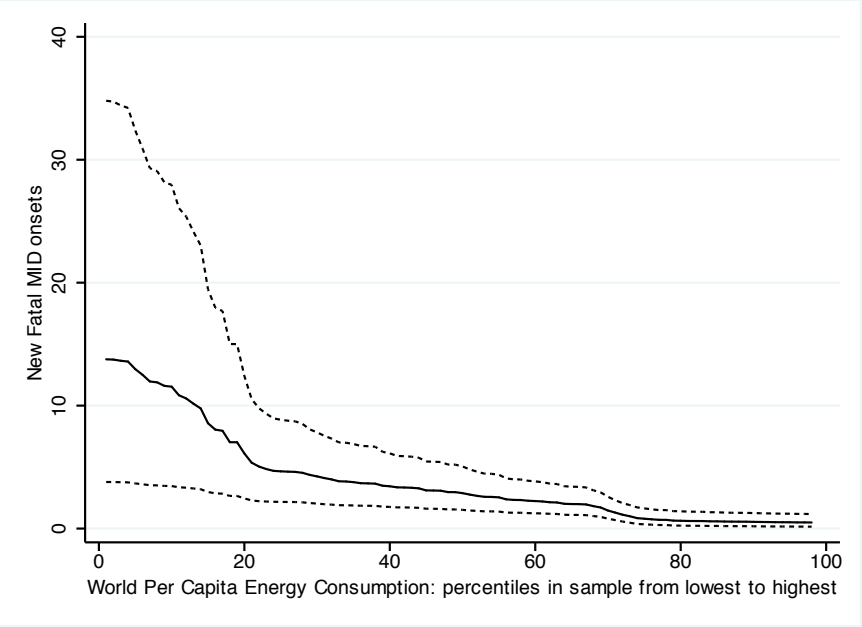

Figure 5: World Per Capita Energy Consumption

will often be missed given measurement error and reporter bias. Lacina and Gleditsch (2005) offer arguably the best available casualty data, though even these data cover only the twentieth century. Finally, casualty data at the contest level are distributed according to the power law (Cederman 2003). While most conflicts have a small number of casualties, occasionally there are extremely high casualty contests that skew the apparent intensity of disputes. In aggregating disputes at the system level, annually, the distribution is still skewed by major "outlier" wars.

To be thorough, I replicated the regressions from Tables 1 & 2, replacing the dependent variable with casualty counts or logged casualty counts. Because they provide relatively few new insights and 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.[17] 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 twentieth 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 of significance in most of the regressions analyzed.

6 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. Rich, prosperous nations are not fighting each other, even if they are also polluting the planet. Obviously, this poses important dilemmas for policy makers 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 tradeoffs lack easy solutions. Indeed, we must ask whether environmental objectives are modified by the prospect that combatting 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.

[17] Developed states appear to experience fewer casualties in ongoing research. While military lethality increases with development (in terms of maximum casualties), the motivation to participate in large contests seems to subside.

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