Economic Interdependence and International Conflict

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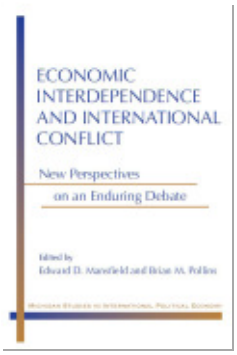

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Temporal Dynamics and Heterogeneity in the Quantitative Study of International Conflict

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and Christopher J. Zorn

Our discussion focuses on the importance of temporal dynamics in the study of international conflict and more specifically on the nature of those dynamics as they relate to interdependence. Our goal is to point out some areas in which the substantial achievements of international politics scholars may be further improved. In part because of the unique challenges posed by data on international relations, students of international politics have been among those at the forefront of developing innovative approaches to the study of political phenomena. For example, scholars studying international conflict have, in recent years, begun to go beyond the mere incidence of international disputes to study the *process* by which conflicts occur, including the stages through which nations typically pass as crises escalate to war (e.g., Reed 2000b; Reed and Clark 2000; Reed and Lemke 2001; Schultz 2000, 2001; Signorino 1999; Smith 1996, 1999) or fail to escalate to war (Gartzke this volume; Mansfield this volume). Such studies highlight a central characteristic of international conflict: the importance of time and temporal dynamics in the development of such disputes. These studies have been accompanied by ever more sophisticated analyses of the causes of conflict, many of which explicitly model the influence of those causes over time (e.g., Beck, Katz, and Tucker 1998; Beck 1999; Bennett and Stam 2000; Maoz and Russett 1993; Oneal and Russett 1999a, 1999b).

We emphasize the importance of paying greater attention to the connection between a number of general theoretical expectations regarding time and

conflict and the kinds of statistical tools used to model and test those expectations. Neither model assumptions (e.g., that of temporal parameter stability) nor basic political facts about the phenomenon of study (e.g., the repeated nature of conflict in the international arena) are innocuous. Different methodological treatments of repeated disputes, for example, imply fundamentally different understandings of the effects of those disputes on current conflicts. We concentrate on three main areas ripe for development: investigating temporal variation in the influence of covariates on conflict, evaluating the importance of repeated conflicts between nations over time, and incorporating corrections for unobserved heterogeneity (both temporal and otherwise) in international-conflict data.

Temporal Change in the Causes of Conflict

Scholarship on the connection between interdependence and conflict has in recent years become more sophisticated. Earlier interdependence-conflict studies essentially ignored temporal dimensions, including research that assumed normally distributed (Polachek 1980; Gasiorowski 1986; Mansfield 1994) and categorical dependent variables (Maoz and Russett 1993; Barbieri 1996; Oneal and Russett 1997). In the late 1990s, studies of the interdependence-conflict connection and international relations more generally began to apply more sophisticated models that accounted for temporal dynamics. Notably, nearly all have adopted duration models as the primary tools of analysis. The most common of these is the Weibull model (e.g., Bennett 1997, 1998; Werner 1999), though both Cox models (e.g., Raknerud and Hegre 1997) and discrete-time approaches (e.g., Beck, Katz, and Tucker 1998; Crescenzi and Enterline 2001) have also been considered. Most of the recent interdependence-conflict scholarship has used the discrete-time approach (Beck, Katz, and Tucker 1998; Crescenzi and Enterline 2001; Gartzke, Li, and Boehmer 2001; Bennett and Stam 2000; Mansfield and Pevehouse 2000), though other methods accounting for temporal effects have been employed, including generalized estimating equations (GEEs) (Oneal and Russett 1999a, 1999b), Cox models (Hegre 2000), Granger causality models (Reuveny and Kang 1996), and fixed-effects models (Green, Kim, and Yoon 2001).

A signature characteristic of most of these studies is the assumption that the impact of causal factors on the occurrence of a dispute remains constant over time. In the context of nearly all widely used duration models, this is referred to as the assumption of *proportional hazards,* so-called because the effect of a unit change in a covariate is to shift the hazard rate by a factor of proportion-

ality. The result is that the marginal effect of a covariate remains constant across time: a one-unit shift in, say, the balance of power between two nations affects the hazard of a dispute between them by the same (proportional) amount, irrespective of whether that change occurs in the first or the fortieth (or four hundredth) year of peace between them.

For some influences on international disputes, the assumption of proportional hazards is likely to be a reasonable one. For others, however, international relations theories suggest a need to relax this requirement and allow the influence of factors known to affect the onset of international crises to vary over time. This is the case, for example, when the influence of some factor on the likelihood of conflict is theorized to wax or wane over time. Here, we briefly describe how theories about interdependence and conflict suggest that the relationship between them may vary across time and outline some methodological innovations to allow and test for that proposition.

The idea that higher levels of trade and economic interdependence between states reduce the likelihood of conflict between them is one of the oldest in the study of international conflict. This eighteenth-century Enlightenment proposition has very recently received substantial empirical attention from international relations scholars. Oneal and Russett (1997, 1999a, 1999b; see also Gartzke, Li, and Boehmer 2001; Mansfield and Pevehouse 2000) exemplify this position, finding a statistically significant negative relationship between higher levels of trade and the likelihood of conflict. Critics have argued, on theoretical and methodological grounds, that there is no such relationship (Barbieri 1996; Beck, Katz, and Tucker 1998; Green, Kim, and Yoon 2001). The logic of the trade-conflict argument is that higher levels of economic interaction between two states provide subnational groups a stake in continued trade between the two countries; conversely, war is expected to substantially disrupt or even sever trade relations. As a result, these groups have a strong incentive to pressure the national government to maintain peace with trading partners (Papayoanou 1999; see also Gowa 1999).

A logical extension emerges from the mitigating effects of economic ties on international conflict: that these effects should become more substantial as time passes. The passage of time permits the deepening and institutionalization of economic ties, as nations take a variety of actions to strengthen the interdependence between them; nations establish economic consulates, increase cultural and educational exchanges, and expand the scope of contact to new parts of the two economies, among other things (e.g., Mansfield this volume). Moreover, by lowering information costs and reducing the incentive to renege on contracts, longer-term relationships permit more efficient transfers of goods

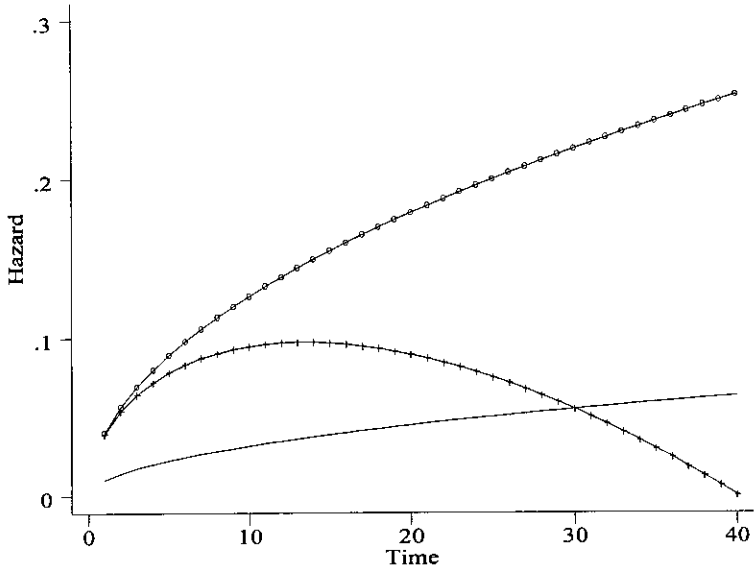

Fig. 1. An illustration of proportional and nonproportional hazards. The smooth line plots a baseline hazard; the circled line represents a proportional covariate effect; and the crossed line shows a variable with a nonproportional effect.

and services, a situation beneficial to both sides. Thus, as time passes, increasing interdependence provides more groups in a society with greater incentives to maintain peace (Keohane and Nye 1989). It is not simply higher *levels* of economic interdependence between states that mitigate conflict but also longer *histories* of economic interdependence. Put differently, the theory suggests that equal levels of trade will have a greater pacifying impact later in the relationship between two nations than earlier.[1]

The example outlined here is but one of many potential examples where theories of international politics predict significant temporal variability in the effects of those factors important in international disputes (see also Box-Steffensmeier, Reiter, and Zorn 2002). Testing such a theory, however, requires a model that allows the influence of economic interdependence on conflict to vary over the history of the dyad. Such considerations are important for two reasons. First, as has been widely shown in the statistics literature, estimation of proportional-hazards models when the covariate effects are nonproportional may result in biased estimates, incorrect standard errors, and faulty inferences about the substantive impact of independent variables (e.g., Kalbfleisch and

Prentice 1980; Schemper 1992; Klein and Moeschberger 1997). Thus, it is important that researchers examine the extent to which the assumption of temporally constant covariate effects applies. Second, only models that permit covariate effects to change over time will allow for appropriate tests of these theories; nearly all such models in current use are not capable, without modification, of evaluating whether and how the factors influencing conflict vary over time.

There is a wide range of methods for investigating nonproportional covariate effects in hazard-rate models (see, generally, Box-Steffensmeier and Zorn 2001). Statisticians have developed an array of both graphical and statistical tests for assessing the presence and nature of nonproportionality (e.g., Schemper 1992; Grambsch and Therneau 1994; Ng'andu 1997), nearly all of which are easily implemented in commonly used software for estimating duration models (such as Stata™). As a result, the potential for wide adoption of such methods is great, provided that scholars are aware of the possible gains from such approaches and the risks of ignoring temporal dynamics.

Not Like Last Time: The Dynamics of Repeated Conflict

Do conflicts beget future conflicts? Existing work on international conflict largely neglects the issue of past conflicts; such studies implicitly treat the first and the tenth disputes between two countries as exactly the same. These approaches thus run counter to much of what we know about international politics: that repeated conflicts often occur due to enduring rivalries (e.g., Bennett 1998; Diehl 1998; Goertz and Diehl 2000), that nations learn from previous conflicts (e.g., Reiter 1996), and that the information so gained is incorporated into future security decisions (e.g., Waltz 1979). Moreover, a number of competing theoretical perspectives on the nature of international conflict have real and potentially important implications for our expectations about repeated conflicts.

On one hand, studies of the "security dilemma" (e.g., Jervis 1978) point out that a state's planning for war (e.g., by building up its military capabilities) can be interpreted as a sign of hostility by other nations, which in turn endeavor to cultivate their own capabilities. A related view holds that nations often go to war when the opposing state is perceived as hostile (e.g., Jervis 1976; Lebow 1981; Larson 1997); these hostile images of the opponent are exacerbated by conflicts, which serve to reinforce those images. Taken together, these perspectives suggest that, by feeding fears over security and fostering negative views of the enemy, the occurrence of an international conflict makes future conflicts

that much more likely. On the other hand, rationalist perspectives on international conflict argue that "war is in the error term" (Gartzke 1999): that two states go to war when their perceptions about their relative capabilities diverge (Fearon 1995). To the extent that war itself reveals information about capabilities, then, it should have the effect of making future conflicts less likely. Thus, under this view, conflicts are self-restraining phenomena: because of what it reveals about the two states' power relationship, the occurrence of a dispute makes immediate future disputes less likely.

Accounting for repeated events is likely to be especially important in the study of the interdependence-conflict relationship. The principal internal logic of the claim is that higher levels of trade make war less likely because of the expectation that war will diminish trade levels. If two nations fight and experience a corresponding disruption of trade, then the lesson that war prevents trade will be driven home, making the reoccurrence of war even less likely. If, however, war does not interrupt trade (Barbieri and Levy 1999), then states will reduce their estimates of the costs of war and fighting wars may make future wars more (or at least no less) likely. Additionally, if uncertainty is relatively low between trading states (Reed 2000a), then when trading states do fight it will likely be for reasons other than uncertainty, such as the indivisibility of issues or the inability of the two sides to commit to a settlement (Fearon 1995). Under these conditions, war is not caused by uncertainty, and therefore the reduction of uncertainty produced by war does not make future war less likely.

While these competing views offer divergent predictions about the influence of previous disputes on future conflicts, the vast majority of extant analyses pay little attention to such considerations.[2] By adopting approaches that ignore the influence of past events, these studies fail to address researchers' substantive interests in the effects of multiple disputes; moreover, and as a result, they likely also provide incorrect inferences about the estimated effects of covariates on those disputes. This omission is surprising, given both the centrality of concerns about enduring rivalries in theoretical discussions and the fact that the general issue of multiple events is one that has come to occupy center stage in statistical duration analysis research.

Researchers have derived a host of methods, generally referred to as *variance-corrected* approaches, for making valid inferences about repeated events when those events are dependent and for assessing the impact of previous events on future ones (e.g., Andersen and Gill 1982; Prentice, Williams, and Peterson 1981; Wei, Lin, and Weissfeld 1989; for recent reviews, see Box-Steffensmeier and Zorn 2002; Kelly and Lim 2000). These approaches vary widely

in their foundations: for example, some impose a sequential ordering on events, such that a subject is only "at risk" for a second event after a first event has occurred. Others impose no such restriction, allowing events to develop in "parallel" fashion. The choice of which such model is appropriate for the subject at hand depends critically on the data-generating process in question. Similarly, some such methods (including all those used thus far in studies of international conflict) restrict the baseline hazard of the event in question to be constant over repeated events; in such instances, the conditional odds of a conflict are forced to be constant across disputes, whether that dispute is the first or the tenth between the states. By contrast, other methods allow for a relaxation of this restriction, thus permitting the researcher to *estimate* whether and to what extent the conditional odds of a dispute change over time. Such approaches are invaluable, for they provide a clear, easily interpretable way of assessing the various hypotheses outlined earlier: spirals of conflict imply steadily rising baseline hazards, while if disputes are self-regulating, those hazards should decline. More generally, we suggest that, at a minimum, the assumption that all sequential disputes are exactly the same, regardless of their order, needs to be tested.

One of These Dyads Is Not Like the Others: Unobserved Heterogeneity in International Relations Research

The consideration of repeated events is very closely related to the issue of *heterogeneity* among pairs of nations. Implicit in all existing quantitative studies of international conflict is the assertion that observations are exchangeable; that is, conditional on the covariates considered in the model, the probability of any two nations engaging in a dispute is the same (King 2001). Such an assumption is, we believe, not supportable on either theoretical or empirical grounds: unmeasured and unmeasureable factors such as history, culture, and exogenous shocks clearly impact the probability of conflict.[3] In addition, heterogeneity may also arise more directly from repeated events, since the correlation between repeated conflicts can be viewed as a specific form of heterogeneity. Because such heterogeneity amounts to a specific form of model misspecification, these influences make the conclusions drawn using standard statistical approaches problematic at best and simply incorrect at worst. Accordingly, in addition to the aforementioned variance-corrected approaches for addressing repeated events, we suggest the use of *mixture* models, including "cure" and "frailty" models, as a means of addressing unmeasured heterogene-

ity and discuss how such models both conform closely to our understanding of international disputes and provide superior assessments of the causes of those disputes.

Previous work on international conflict has, on occasion, recognized the importance of such unmeasured factors in studying the onset of war. One significant example is the debate surrounding the definition and use of "politically relevant dyads": pairs of nation-states that, because of geography or international status, have more than a trivial chance of coming into conflict (e.g., Maoz and Russett 1993; Bennett and Stam 2000; Lemke and Reed 2001; Barbieri this volume). The argument for examining only politically relevant dyads lies in the hundreds of thousands of dyads for which conflict is essentially impossible (e.g., Surinam-Malaysia); because such dyads offer little information about the roots of international conflict, scholars argue, they can and should be omitted from quantitative analyses of international disputes. Others question the politically relevant approach, arguing that focusing on pairs of states we know are seriously thinking about fighting each other because of a clash over a serious political issue is the correct approach (e.g., Huth 1996).[4] This approach, however, leads directly to the problem of determining what dyads are seriously thinking about war over time. And still others advocate the analysis of all dyads in such studies, on the belief that their exclusion represents a potentially more serious threat to inference than any ill effects from their inclusion.

The issue of heterogeneity is especially salient in studying the interdependence-conflict connection. For building large data sets covering the entire international system, trade data between states is available only for aggregate levels of exports and imports. However, within these aggregate measures, trade in different kinds of goods is likely to vary in impact. Trade in goods that are strategic is likely to have a greater pacifying effect, as a state may be less willing to accept an interruption in oil imports, for example, than in children's toys. Similarly, some domestic industries may be more politically powerful, meaning that they will be more effective in preserving peace if export-reducing conflict threatens. Busch and Reinhardt (1999), for example, found that geographically concentrated but politically dispersed industries are more effective in affecting foreign-trade policy. In short, among dyads that have apparently equal levels of trade the pacifying effect of trade is likely to vary in ways that are practicably unobservable.

The central issue with politically relevant dyads is the possibility of a dispute—that is, whether the nations in question are *ever* likely to experience a conflict. Cure (or "split-population") models allow for the possibility that

some observations in the data will never experience the event of interest (e.g., Maller and Zhou 1996; Schmidt and Witte 1989).[5] Most often, this is accomplished by setting the hazard of the event equal to a mixture of a standard distribution and a point mass at zero; in this way, some observations are allowed to be "immune" from ever experiencing the event of interest. These models are thus an improvement on more standard approaches, for two critical reasons. First, in contrast to cure models, all other duration models assume that every observation in the data will eventually experience the event being studied. In the context of international conflict, this is equivalent to stating that *all* dyads will someday have a militarized dispute. Second, cure models allow the researcher to empirically assess the likelihood that an observation is "cured." Thus, rather than relying on necessarily arbitrary ex ante distinctions about which dyads may or may not clash, cure models offer a means of determining both *whether* and *when* a conflict may or may not occur and of assessing the influence of covariates on both of those processes. Importantly, the covariates may have different effects for different parts of the model, that is, for whether versus when the event may occur.

The effects of ignoring unobserved heterogeneity of any sort are as widely understood as they are pernicious: biased estimates of variable effects, incorrect standard errors, and a lack of consistency in parameter estimates. Heterogeneity thus represents a serious threat to our understanding of international conflict, a fact scholars are only now beginning to appreciate (e.g., Clark and Regan 2001; Beck and Katz 2001; Bennett and Stam 2000; Green, Kim, and Yoon 2001; King 2001; Zorn 2000; but see Bennett 1997 for an earlier exception).

One prominent means for making valid inferences in the presence of such heterogeneity has been the use of *frailty* models (e.g., Manton, Stallard, and Vaupel 1981; Omori and Johnson 1993; Sastry 1997).[6] Frailty models, also known as "random-effects" models in econometrics, allow for individual heterogeneity in the form of a subject-specific term that captures that particular observation's unobserved propensity toward the event of interest. A general form of such models is

$$Y_i = f(X_i\beta + \alpha_i + \varepsilon),$$

where the α_i represents individual- (here, dyad-) level heterogeneity. The most common approach is to assume that the αs are random draws from some known distribution, the parameters of which are then estimated along with the model coefficients. Such models provide a direct means of both assessing the

extent of individual-level heterogeneity in the data and of making valid inferences about covariate effects in the presence of such heterogeneity. Because of these characteristics, frailty models have been highlighted as particularly promising models for event-history research.

We argue here that a frailty approach to the study of international conflict offers significant improvements over conventional methods. By adopting frailty approaches, researchers can estimate the unobserved tendency toward conflict in a dyad, even after controlling for those factors we know contribute to the likelihood of such conflict. The importance of this fact is clear: such a flexible empirical approach is generally to be preferred over necessarily arbitrary distinctions about "political relevance" and methods requiring one to omit large amounts of data (such as fixed-effects models; e.g., Green, Kim, and Yoon 2001).[7] In addition, frailty models offer an attractive solution to the problem of obtaining consistent estimates of variable effects in the face of such heterogeneity. These models are also straightforward to estimate and interpret and are easily implemented using standard software, making their potential for widespread adoption by substantively oriented political scientists high. Finally, frailty models may help with concerns over the dyadic focus in international relations, since one of the advantages of frailty models is their ability to allow for *multilevel* inferences, for example, to assess the influence of dyadic, nation-, alliance-, and regional-level variables (Jones and Steenbergen 1999; Sastry 1997). In the introduction to this volume Edward D. Mansfield and Brian M. Pollins highlight the theoretical importance of identifying relevant actors at various levels. Multilevel duration models offer a promising methodological match for this problem.

The underlying logic of frailty models is that some observations (or groups of observations) are intrinsically more or less prone to experiencing the event of interest than are others. We submit that it is important in all empirical endeavors to assess the potential biases that may result from unobserved heterogeneity in one's data and to employ methods appropriate for correcting those biases; the models offered here provide an attractive means of doing so.

Quantitative Methods and the Future of International-Conflict Research

Advances in the quantitative study of interdependence and international conflict need to be melded with the increasing theoretical and data-gathering sophistication of this work. Our goal here has been to outline a number of promising directions for the continuing evolution of these methods. In partic-

ular, we focus on the issue of temporal dynamics and heterogeneity in international conflict and draw upon techniques developed in biostatistics, epidemiology, and demography to address those issues. While scholars have long recognized the importance of temporal dynamics in the study of international relations, there has not been enough attention to, let alone agreement about, the best way to address these dynamics empirically. We argue that allowing time-varying effects of covariates, statistical incorporation of facts such as repeated conflicts, and recognition of and accounting for heterogeneity will help align the theory and quantitative analysis.

The solutions we offer here, while general, nonetheless require a good deal of hard substantive thinking on the part of scholars. Issues of case selection, measurement, and model specification are critical to the success of these or any other empirical endeavors. Our proposals must thus be considered a starting point, rather than the last word, about the directions scholars should take in further empirical analyses of international disputes. Nonetheless, we hope that they will inspire researchers to continue with ever more rigorous and informative work on this subject of critical importance.

NOTES

We would like to thank the participants of the Interdependence and Conflict Conference, the editors of the volume, Bridget Coggins, and Andy Farrell for comments.

1. One study that accounts for nonproportionality found that trade was not significantly correlated with conflict (Box-Steffensmeier and Zorn 2001a).

2. Recent exceptions include Beck, Katz, and Tucker 1998; Jackman 2001; and Crescenzi and Enterline 2001.

3. More generally, Blossfeld and Rohwer (1995, 243) point out that, as social scientists, "we can usually be sure that we were not able to include all important covariates" in our models.

4. Alternatively, Lemke (1995) suggests "military reachability" as a more viable means for assessing which dyads have at least the potential for conflict.

5. Applications of cure models in political science include Box-Steffensmeier and Radcliffe 1996; Hettinger and Zorn 2002; and Clark and Regan 2001.

6. The term *frailty* comes from biostatistics and refers to the notion that some observations are more "frail" than others (due to unmeasured factors) and thus will experience the event of interest (often the recurrence of a disease) earlier.

7. In fixed-effects models, each of the individual αs are estimated along with the model's structural parameters. The literature on fixed effects points out a number of problems with these models (e.g., Andersen, Klein, and Zhang 1999). Among these is the

"incidental parameters problem": absent a truly "fixed" number of fixed effects, fixed-effects ML estimators are inconsistent (Lancaster 2000). Moreover, fixed effects prevent researchers from estimating the impact of variables that do not vary within units/dyads (e.g., contiguity), a significant disadvantage in studies of international conflict.

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