Parametric Models, Duration Dependence, and Time-Varying Data Revisited

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Box-Steffensmeier and Jones (1997) provide a good overview of the class of models known as "event history" or "duration" models, but omit some important points about the relationship between duration dependence and time-varying data in parametric models of duration. The key reason to use duration analysis methods is to allow for the possibility of duration dependence in one's data. However, while assumptions about the form of duration dependence appear to be purely methodological, duration dependence can have important substantive implications for theories of politics. There is often an interaction in estimation between duration dependence and covariates. In particular, duration dependence can be revealed or eliminated when particular time-varying variables are included in or removed from a model. This point is especially important because time-varying covariates are more central and common to important research questions than is sometimes realized. Overall, these points lead to the conclusion that findings about duration dependence go hand-in-hand with proper specification and that model specification both in terms of functional form and included variables must be carefully considered before duration methods are applied.

1. Introduction

Box-Steffensmeier and Jones (1997) provide an excellent introduction to event history models (also referred to as duration and hazard models). They deal with important elements of duration analysis that users of these methods should be familiar with, particularly in the setting of parametric models of duration. In particular, two fundamental elements of duration analysis that they address are choosing whether or not to construct a data set with time-varying covariates and specifying the functional form of the hazard rate to model duration dependence. Choices about how to collect data, build a data set, and then associate a model with that data may have important implications for the results of analysis, and Box-Steffensmeier and Jones familiarize readers with the available options. They do not, however, emphasize that important interactions exist between the selection of functional form and the inclusion of covariates (independent variables), especially those which are time-varying, a point which is important for users of duration analysis methods to understand. Here I deal with the sometimes quite sizable interactions between substantive variables and functional form and present examples to illustrate their importance.

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I make three points. First, although assumptions about the form of duration dependence sometimes appear to be purely methodological, duration dependence can be interpreted as having important substantive implications for theories of politics. Duration dependence is more than simply a nuisance in estimation. Second, there is often an interaction in estimation between duration dependence and covariates. This potential interaction implies that assessment of functional form and apparent duration dependence must be made in conjunction with assessment of the hypotheses and variables under consideration. In particular, duration dependence can be revealed or eliminated if particular variables are included in a model. Third, time-varying covariates are more central and common to important research questions than given credit for in Box-Steffensmeier and Jones (1997).

2. Terminology

Before exploring interactions among functional form, data, and specification, I identify a few key event history terms. As Box-Steffensmeier and Jones point out, event history analysis is concerned with patterns and causes of change (1997,1414; citing Yamaguchi 1991). In particular, we want to understand why *units* under consideration remain for some period of time in one *state* and then change to another. So, for instance, a country (the unit) may be at peace (one state) for some period of time and then become involved in a war (change to a different state). Each interval in a given state is a *spell* or *episode*; so the country in question has a spell of peace followed by a spell of war. In some data sets, each unit will have only one spell. For instance, if a study is of the time until an individual's first election to a government office, there will be, by definition, only one spell for each individual (unit) in the data. In other studies, units may have multiple spells (for instance if a country experiences a spell of peace from 1871 to 1914 and another from 1918 to 1939). The duration of each spell is analyzed by focusing on the *hazard rate*, which is the rate (roughly, the probability) at which the spell or episode ends at a particular duration, given that it reached that duration. We are interested in understanding the hazard rate because it can tell us how long units are expected to remain in a given state before experiencing a transition to a different state. Usually we are also interested in understanding how exogenous variables affect the hazard rate. If independent variables are expected to have an effect on duration, then the hazard is specified as

$$h(t) = h_0(t)\, e^{\beta X} \qquad (1)$$

where $h_0(t)$ is known as the baseline hazard and βX is a vector of estimated coefficients and actual data. Exogenous variables affect the rate of transition through the $e^{\beta X}$ term, while the basic rate of transition is captured in $h_0(t)$. In the nonparametric Cox model of duration, the baseline hazard $h_0(t)$ is not estimated; in parametric models of duration, a particular functional form for the hazard is specified to model *duration dependence* (discussed below).

To set up a data set for duration analysis, each spell must have at minimum one line of data. This line contains the *duration* of the spell (the time from start to finish, such as 43 years) and any relevant variables or covariates (e.g., type of government or level of unemployment during the spell). If each spell has only one line of data and thus one observation per spell, the data are *time-invariant*. In this case, by construction, there are no differences in the values of the variables in individual years, months, or days within a spell. Alternatively, if variables are measured at multiple times within a spell when the values of the variables change, the variables and data are *time-varying*. In this case each individual spell has multiple observations (lines of data) within the data set, one for each interval.[1] As an example, in time-varying data studying the spell of international peace from 1919 to 1939, Germany would be coded as a democracy from 1919 to 1933 but a nondemocracy from 1934 to 1939, leading to two rows in a data matrix.

3. The Key Feature of Event History Models: Duration Dependence

An important aspect of using event history methods to study political phenomena is that they allow analysts to explore the duration dependence of a process. Duration dependence occurs when the hazard rate of a process is not constant over time. That is, if the expected future duration of a spell from any given point forward is partially dependent on the amount of time that the spell has already lasted, the process is duration dependent. Several types of duration dependence may be observed; the simplest and most frequently modeled form is monotonic negative or monotonic positive duration dependence. Monotonic negative duration dependence has been observed in labor strikes, where studies have found that strikes tend to become entrenched as they continue (e.g., Vuchinich and Teachman 1993; Rubin and Smith 1991). As time passes during a strike, the positions taken by negotiators and workers tend to harden, the strike becomes harder to settle, and the future duration of the strike increases. Since the hazard rate falls over time, data on strikes are said to exhibit negative duration dependence. In contrast, positive duration dependence has been observed in enduring rivalries between coun-

[1]Time-varying data is distinct from time-dependent data, which denotes variables that are explicitly modeled as a function of time. Job experience, for instance, is a time-dependent variable for as long as an individual remains in a particular position. The distinction between these two types of data, both of which change over time, is not made clear in all references. Moreover, the terminology is reversed in some sources.

tries (Cioffi-Revilla 1998; Bennett 1998). Enduring rivalries are pairs of countries with a long history of conflictual relations. As these dyads age, the hazard rate increases, and rivalry settlement becomes increasingly likely.[2] Essentially, rivals appear to wear themselves out and become more willing to settle their disputes over time.[3]

The possibility of explicitly modeling duration dependence sets parametric duration models (using the Weibull or other nonexponential distributions) apart from simpler techniques. For instance, logit is often used as a discrete-time event history method on a set of pooled binary time-series cross-sectional data, where the dependent variable is coded in each time period as a "1" if an event occurred and a "0" if it did not. The estimation in this case is of the probability that an event will occur in each discrete time interval. Unfortunately, while this technique allows us to explore the effects of independent variables on the transition from one state to another, it *assumes* that no duration dependence exists. The exponential function in logit simply does not allow duration dependence to be examined.

Luckily, as Beck, Katz, and Tucker (1998) note, such binary time-series cross-sectional data are actually identical to grouped duration data, and it is straightforward to begin considering those data within a duration analysis framework. The information contained in such a data set is precisely the length of time that each unit was in a particular state—for example, the state of peace—before experiencing an event or change. But by considering the duration between events instead of the isolated occurrence of events, consideration can be given to the underlying hazard rate as the dependent variable. Once this shift is made, techniques are readily available to examine duration dependence without even substantially modifying the data set. Instead, modifications are made in the assumed functional form of the hazard.

In the simplest extension from the exponential logit function, a Weibull function is often chosen to model monotonic duration dependence. In such an analysis the baseline hazard $h_0(t)$ from Equation 1 is specified as

$$h_0(t) = pt^{p-1}. \tag{2}$$

[2]Cioffi-Revilla also finds that a broader set of rivals show negative duration dependence during early years, followed by a fairly flat hazard rate for some period, and then show an increasing hazard rate. In this regard, rivals show a form parallel to the human life cycle. In humans, the hazard rate initially falls after birth as children survive various childhood diseases and dangers and then rises as people reach old age. Modeling this entire sequence as one process would require the use of a nonmonotonic parametric hazard model.

[3]Note that the "negative" or "positive" in identifying patterns of duration dependence refers to changes in the *hazard rate* over time, *not* changes in *expected duration* over time. Thus positive duration dependence refers to a hazard rate that increases over time, leading to shorter durations, while negative duration dependence is associated with a decreasing hazard rate and longer durations.

In this Weibull specification, the tendency of the hazard rate to increase or decrease monotonically over time is captured by adding a single parameter p.[4] More generally, the functional form of $h_0(t)$ determines what form of duration dependence is modeled. For instance, if an exponential hazard function is specified, $h_0(t)$ is set equal to 1; since this is constant over time, the specification assumes that no duration dependence is present. As another alternative, if a logistic hazard function is specified as

$$h_0(t) = pt^{p-1}/(1 + t^p), \tag{3}$$

then the specification is for a nonmonotonic hazard (the logistic allows a hazard which initially falls but then rises over time). If particular patterns of duration dependence are suspected, other distributions (e.g., the gamma, log-normal, or others discussed by Box-Steffensmeier and Jones, 1997) can be specified. The Weibull is probably the most widely-used form in political science, as it is the simplest parametric form that allows duration dependence to be directly estimated.

Estimates of the values of parameters such as p are produced when duration data are analyzed, along with standard errors. Conventional significance tests may be used to assess whether these "shape parameters" contribute to a model's fit, and likelihood ratio tests can be used to assess whether allowing more sophisticated patterns of duration dependence improves the fit of the model over some baseline model. The exponential model is nested within the Weibull, for instance, which is in turn nested within a model that incorporates possible heterogeneity (see Greene 1993,724). At each stage, it is possible to assess whether and by how much the log-likelihood improves.

Again, a major advantage of duration analysis or event history methods is that they allow duration dependence to be modeled and explicitly examined. Duration dependence is not identical to autocorrelation but is similar in that it is a relationship over time in the data that we do not want to ignore. Unlike autocorrelation in a binary time-series cross-sectional setting, however, duration dependence can be easily analyzed, as methods have been developed in other disciplines to analyze duration data with time dependence in mind. It is partly for this reason that event history methods are being used more frequently in political science.

4. Duration Dependence Has Substantive Implications

Duration dependence is actually much more than an elaboration or relaxation of a logit model, though. Findings from models allowing duration dependence have important substantive interpretations, as duration depen-

[4]Note that the mathematical notation for designating coefficient normalizations, hazard functions, and the p shape parameter often differs between sources.

dence in data reveals important features of political processes. Generally, duration dependence can suggest whether processes are likely to die out on their own, and so are self-damping, or whether they will show a tendency to continue. In the self-damping case, when the data under examination exhibit positive duration dependence, the hazard rate increases over time, and it becomes more likely that the phenomenon will end with each passing moment. By contrast, if data exhibit negative duration dependence, the phenomenon in effect exhibits some tendency toward self-perpetuation. Either tendency may be substantively important, but the latter case may be particularly interesting because we are often interested in whether certain phenomena become institutionalized over time. State or national policies, adherence to a constitution, loyalty to a leadership, and government structures are all examples of phenomena that can become more stable and difficult to change the longer they last. We can use duration analysis and specifically the value of the duration dependence parameter in a Weibull model to test hypotheses about such institutionalization. For instance, Bennett (1997) used a Weibull model to test the argument that alliances tend to become self-perpetuating over time. One might expect alliances such as NATO to become self-perpetuating because they develop robust organizational structures that can respond to a changing environment, compete successfully for the sponsoring states' budget dollars, or develop military efficiency in joint activities that make the alliance an effective and valuable tool. However, an analysis of 207 alliances suggested that alliances generally do *not* exhibit this type of institutionalization. In fact, the duration dependence parameter p was actually estimated to be significantly greater than one, suggesting *positive* duration dependence, and raising questions about the institutionalization argument.

Because duration dependence has clear substantive implications, parametric duration models may actually be chosen specifically to test particular hypotheses. For instance, the specification of a Weibull model in the above example was necessary to test the argument that institutionalization in alliances increases continually and monotonically over time. Although the results of the test do not prove that the Weibull is the "true" model (some other unspecified model might fit the data better), the absence of negative duration dependence casts doubt on the hypothesis of continuing and consistent institutionalization. The results of the test suggest that at this point additional theory about institutionalization is called for.

The hope that we can use parametric duration models in this way points out the difficulty in using the more general Cox proportional hazards model. As discussed by Box-Steffensmeier and Jones (1997) and Beck (1998), the Cox model makes no assumptions about form and so has the advantage for modeling purposes of not overfitting the data by forcing a particular parameterization. The Cox model, however, achieves this generality by not directly estimating *any* parameters that would inform the analyst about the shape of the hazard ($h_0(t)$ is not estimated). Although the baseline hazard can be recovered and plotted in an effort to ascertain the shape of the curve (which is tied to the functional form of any duration dependence), no set of parameters or standard errors concerning the shape of the hazard function are estimated. Since the baseline hazard plot may be noisy, interpretation may be difficult, and only a general idea about fundamental features of the data such as monotonicity is likely to be obtained. While such a judgement may be useful to verify that a functional form in the right ballpark is used, if it is important to estimate the magnitude of institutionalization over time or reach a judgement about whether duration dependence is statistically significant at some level, the Cox model does not readily allow us to make such a judgement.

5. Duration Dependence Cannot Be Separated from Substantive Model Specification

5.1 Substantive Variables Can Affect Apparent Duration Dependence

Another important issue regarding duration dependence is that the appearance of duration dependence is intertwined with model specification on variables of substantive interest. In the Weibull model, duration dependence is captured in a single parameter, p; when p is significantly different from 1, it suggests that there is duration dependence in the data. However, conclusions about the presence or absence of duration dependence drawn by examining p are not independent of the other explanatory variables included in an analysis, because such variables (especially given time-varying data) can account for observed duration dependence. Duration dependence captured by p is essentially unexplained variance in future duration that is statistically related to past duration. The pattern of this variance may have substantive implications for theory, but p itself tells us only that there is a pattern. Unless we can anthropomorphize and assume that the phenomenon we are examining truly has a life of its own, then the pattern or covariation over time that we observe is somehow, somewhere, driven by a variable or set of variables that characterizes the world. If the causal factor driving duration dependence is measured and included in the model as an independent variable, then unexplained duration dependence in the form of a significant p may disappear, even if the hazard rate *is* changing consistently over time. The interaction between covariates and apparent duration dependence is especially important because few studies of duration are likely to be interested in duration dependence alone. Rather, most analysts are interested in reaching conclusions about how particular variables affect duration and estimate models that include a variety of independent variables. If some of these variables also account for changes in the hazard rate that are correlated with time, then conclusions about unexplained duration dependence (p) may change as the specification of the substantive model changes. In particular, an initial underspecified model may suggest duration dependence which disappears when we seek out theories and add variables intended to explain duration dependence, or when we take into account heterogeneity in the data.[5] In fact, we actually may want to work to eliminate unexplained duration dependence by incorporating substantive variables in our models, working from the assumption that a theoretical understanding of why the hazard rate changes is superior to relying on a parameter that only describes the shape of the data.

The effect of substantive variables on unexplained duration dependence may be particularly strong when the included variables are time-varying. It is difficult to understand how a variable that is constant over time could affect duration dependence, which by definition is dynamic. However, it seems quite reasonable for a variable that changes over time to have an effect on other parameters estimating time-related effects, particularly if the variable in question shows some trend. Bennett and Stam (1996) is a recent example in which the inclusion of time-varying covariates affected conclusions about duration dependence. Bennett and Stam argue that earlier studies which found that the duration of interstate war was negatively duration dependent (e.g., Morrison and Schmittlein 1980; Vuchinich and Teachman 1993) were mispecified. This misspecification resulted from the omission of several important sources of states' willingness and ability to keep fighting over time. In a larger model, Bennett and Stam include a set of independent variables argued to affect duration both directly and through time dependence, particularly measures of strategy and adaptation, relative capabilities (which rise and fall over time), and total resources such as population (which affect the ability to absorb costs over time). When these variables were included in a Weibull analysis, unexplained duration dependence became insignificant, essentially becoming variance attributed to some other variable(s) and calling into question the argument that wars tend to be self-perpetuating. More generally, this type of result suggests

[5]It is also mathematically possible for added variables to reveal duration dependence in data that did not appear to have such dependence, although this may be rare in practice. Intuitively, adding variables to any model adds a dimension to the search space within which the likelihood function is being maximized. There is no guarantee that once the search optimizes in the new dimension that the same values will be found in other dimensions. In a likelihood conception, duration dependence parameters are no different from other parameters in that they represent a value on a particular dimension. Movement in any direction is mathematically possible when a new parameter and dimension is added. However, while possible, it is difficult to make a theoretical argument that adding a new parameter should *reduce* the ability of other substantive variables to explain duration dependence, which is the only way that a new finding of unexplained dependence would emerge after variables are added.

that it is particularly important for analysts to think about how their time-varying covariates may affect duration dependence.

Variable inclusion to measure important characteristics of the units in the population also drives the problem of "unobserved heterogeneity" in duration analysis (e.g., Allison 1984, 32; Greene 1993, 724; Blossfeld and Rohwer 1995, 238). Parametric models of duration are based on an assumption that the survival distribution is homogeneous across individuals. If in fact there are different survival distributions across systematically different subsets of individuals, parameter estimates may be inconsistent, standard errors may be inappropriate, and negative duration dependence may appear in data within which hazards are actually constant over time. The problem is widely discussed in textbooks because it can occur even in data with minimal heterogeneity. For instance, assume that a population contains two distinct subgroups, such as men and women. Assume that all individuals within the first group have the same constant hazard rate over time and that all individuals within the second group have a constant hazard rate, but that the hazard rate is unequal between the two groups. If group membership is not an included variable, an appearance of a *declining* hazard rate over time will appear in analysis. Intuitively, the appearance of a declining hazard occurs because individuals from the higher risk or higher hazard group exit from the data set early. This leaves units with the lower hazard rate in the data for a longer period, and as these units tend to make up a larger proportion of the population over time, the ongoing hazard for the entire population appears lower. In this case, an analysis performed without a properly specified model would contain an artificial finding of negative duration dependence.

If unobserved heterogeneity in a data set is suspected, some corrections can actually be made without knowing the source of the heterogeneity. In particular, the hazard in a Weibull model can be modified by incorporating a second distribution to capture heterogeneity (see Greene 1993, 724). Because the Weibull hazard is nested inside the model with heterogeneity, we can test for heterogeneity using a likelihood ratio test. Again, the underlying theoretical concern with heterogeneity is identical to that of including appropriate substantive variables, namely that misspecification can affect findings about duration dependence.

5.2 Modeling Duration Dependence Can Affect Inference about Substantive Variables

A related situation can occur which is the reverse of the above problem. It is quite possible for changes in the functional form of a model to affect the inferences we draw about variables of substantive interest, implying that the selection of the model's functional form deserves more careful attention than it is sometimes given. For instance, suppose a duration model with an exponential specification (which assumes no duration dependence) is estimated against some set of data, and the results suggest that variable X has a significant influence on duration. If the data are in fact duration dependent, then while the estimated coefficients are consistent (but inefficient), their standard errors are *not* consistent. If a Weibull model were estimated and a duration dependence parameter p significantly different from 1 was found, inferences about X might be quite different, with a different coefficient and standard error obtained for X. The dangers of inappropriately using an incorrect distribution have been demonstrated in Beck and Tucker (1997) and Beck, Katz, and Tucker (1998), which used a Weibull specification to reestimate Bennett's (1996) model of rivalry duration and Oneal and Russett's (1997) model of interdependence. The initial studies in question used exponential distributions in estimation, with Bennett using an exponential duration model and Oneal and Russett using logit to analyze binary time-series cross-sectional data. The results of the reestimation suggest that Bennett's argument that security conditions drive rivalry duration and Oneal and Russett's contention that trade contributes to peace may have been incorrect. In both cases the significance of key variables may have been inflated because duration dependence was present but not taken into account in the original articles.

The relationship between duration dependence and substantive variables is particularly problematic because little clear guidance exists about why a particular form (or, in the case of the Cox model, the lack thereof) should be chosen for estimation. Kiefer (1988, 661) notes, for instance, that the family of duration distributions may be chosen "on the basis of a particular economic theory, convenience, and perhaps some preliminary plotting of data." Because it is easy to estimate different models quickly using current software packages, it is easy to select a functional form because it makes certain variables appear more or less significant. Naturally, the form of the underlying hazard model should not be chosen in this manner. But other alternative decision algorithms are not much more helpful. Plotting the frequency of duration times may give us some idea of the distribution of the data, but once the effect of covariates are "subtracted out" of the plot, leaving the unexplained duration dependence pattern that we want the duration model to capture, the shape could appear rather different. Performing an initial Cox estimation with the important substantive variables and examining the baseline hazard plot also avoids selecting a particular parametric form *a priori*; we could then try to choose the parametric functional form to fit the shape of the plot. However, this approach may be a problem if the plot is noisy. While using a Cox model does avoid overfitting the data to a particular parameterization, it cannot give us precise statistical estimates about the magnitude or form of shape that parametric estimates provide, and thus the model still does not provide us with an easy way to judge whether (and how) data are duration dependent. A final option, examining a variety of parametric models to obtain a "feel" for form and to see how coefficients and shape parameters change with specification, also may be problematic because many parametric models are not nested (the progression from an exponential to a Weibull to a Weibull with gamma heterogeneity is an exception). This has the effect of making direct testing for the precise shape of the correct model through the use of standard likelihood-ratio tests impossible, since only a subset of such models can be directly compared. Unfortunately, no single approach appears perfect for selecting the model to underpin duration analyses.[6]

Ideally, the model underlying estimation should be chosen on the basis of substantive theory about the processes under study, specified assumptions about the data at hand, or to test specific hypotheses such as the monotonic institutionalization argument. In practice, the choice is more difficult, and for that reason the main "lesson" of this section is simply that variable specification and model selection are closely interrelated. The implications of choices in both areas should be considered before models are estimated, and the sensitivity of the results to specification should be explored.

5.3 Duration Dependence is Not Merely a Statistical "Nuisance"

Some discussions of duration dependence tend to treat it as more of a statistical nuisance that will disappear once a properly specified model is used than as a useful element of duration models. For instance, Beck (1998, 200) emphasizes that the main reason for properly specifying the form of the hazard rate is to avoid statistically incorrect estimations while noting that "these corrections hardly provide satisfying explanations of the phenomenon under study." The argument here suggests that this interpretation is too narrow. While it is true that the appearance of duration dependence may be affected by specification, the presence or absence of apparent duration dependence may in some cases inform us theoretically. For instance, as the examples above suggest, if an analysis interested in institutionalization over time were to find no evidence of duration dependence even when direct measures of institutional factors were left out of a model, it might call into question the institutionalization hypothesis. While duration dependence is indeed theoretically unexplained variance, the pattern of that dependence is informative. In addition, finding duration dependence is useful because it demonstrates a pattern of covariation that analysts can seek to explain substantively. While the ultimate goal might be to make unexplained duration

[6]The problem of selecting the correct underlying form of a model is not, of course, unique to duration analysis.

dependence disappear, its presence along the way during the research process still informs us, and a proper final specification might not be achieved without focusing on it.

6. Time-Varying Covariates Are Fundamental

Box-Steffensmeier and Jones suggest that including time-varying predictors in studies is useful because they allow us to "generate novel conclusions about longitudinal processes" (1997, 1440). However, time-varying covariates are more fundamental to our analyses than this statement suggests, and it is important to examine the relationship between duration dependence and time-varying data. Many of the variables that we study change over time, in some cases dramatically, and dynamic processes are often seen as fundamental to politics. Given time-varying data and dynamic processes, there is no compelling reason to use data in a time-invariant form. As an example, consider economic conditions, which have the potential to dramatically affect an array of dependent variables such as parliamentary stability, the behavior of central banks, presidential popularity, election results, and war. In many countries fluctuations in the economy are reported and assessed at monthly or quarterly intervals. But to use such economic data in an analysis with time-invariant covariates, we must aggregate our data to a single value for each spell. There are two problems with this aggregation. First, losing variations over time in our data results in a loss of precision, since our data are recast in a form that contains less information. Second, if we aggregate data over the course of a spell, the aggregation is necessarily ex post. That is, if we include a variable for a spell such as "average unemployment level," we cannot create the variable until we know the spell is concluded. If we instead use data measured on a regular basis and include multiple observations per spell, we can use all of the available information to assess the hazard rate ex ante. As argued above, though, when we include time-varying data we must be especially careful to think about the relationship between those data and duration dependence.[7]

The use of time-varying covariates in studies of duration in political science is actually fairly recent. In particular, while it has always been obvious that variables vary over time, software allowing analysts to deal with such

[7]Analysts should also be careful to consider whether they are including time-varying covariates that are actually endogenous. If duration affects the values of an independent variable which in turn drives duration, then we may overestimate the effect of the independent variable. For instance, while Bennett and Stam (1996) argue that a leader's choice of military strategy affected the duration of international wars, one might wonder whether or not anticipated duration also affected the choice of strategy. The problem of endogeneity here is similar to the problem in other types of statistical analysis. However, since the time-varying covariates approach focuses our attention on variables that we know vary over time, we should be especially careful to consider exogeneity.

data is relatively new.[8] As one example of a research program where the use of such data contributed to our substantive understanding of a significant issue, consider the series of studies of cabinet dissolution by King et al. (1990), Warwick (1992, 1994), and Warwick and Easton (1992). These studies used event history methods to model parliamentary stability by examining (1) how the attributes of cabinets and parliamentary systems affect the durability of cabinets and (2) how the occurrence of critical events according to some stochastic process affects the process of cabinet dissolution. The initial studies on this question used time-invariant data with one observation per cabinet (spell) and found that cabinet duration was positively duration dependent. Because the data used were time-invariant, however, critical events were assumed to affect cabinet stability mainly through the ability of different systems to withstand shocks. Neither the precise timing of individual critical events nor differences between different types of critical events (such as political vs. economic shocks) could be examined. When time-varying data were used in subsequent analysis, the conclusion that cabinet duration was positively duration dependent was shown to be mistaken. In particular, Warwick's (1994) data included variables measuring economic conditions over time; when analysis including economic variables was performed, there appeared to be no significant duration dependence present in the process of cabinet dissolution. As in Bennett and Stam (1996), analysis incorporating time-varying covariates here led to quite different conclusions about the underlying patterns in the data than analyses that had excluded such variables.

7. Conclusions

I have made three points about duration models to supplement the overview of event history methods provided in Box-Steffensmeier and Jones (1997). First, the duration dependence parameter estimated as part of using duration or hazard analysis can have an important substantive interpretation, for example, indicating institutionalization over time. Since duration dependence is the key element that event history models add to more common models, we should focus additional attention on exploring and interpreting it. Second, there is an "interaction" in estimation between parameters indicating duration dependence and the covariates included in estimated models. Duration dependence is an unexplained pattern of time dependence and can

[8]This is important because analysis of most substantively interesting questions cannot proceed without software. As Box-Steffensmeier and Jones note, there are substantial variations among software packages in their treatment of time-varying data. For instance, SPSS still does not allow time-varying covariates in parametric duration models, a substantial limitation. Even considering the full set of software available, there remain gaps. Again, for instance, there is no software of which I am aware that will allow estimation of a competing risk model while using time-varying covariates.

go away (or appear) if the "right" variables are included in analysis, especially if those variables are time-varying. Third, time-varying covariates are fundamental to analyses of dynamic processes in politics, and many of the variables we are most interested in change over time. If we have variables measured over time, we will rarely want to reduce them to time-invariant data and need not do so.

These points are important because they regularly arise as practical issues when conducting duration analysis. Without understanding the interactions present in duration models between these elements, we may unnecessarily draw mistaken inferences, a problem to be avoided if possible.

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