The Hazards of Time-Varying Covariates*

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Abstract

I examine the circumstances and consequences of endogenous time-varying covariates in duration models. I explore the effect of endogeneity (or reverse causation) on different hazard models using Monte Carlo simulations. Like simultaneity bias, endogenous time-varying covariates cause bias (and inconsistency) in coefficient estimates. I discuss different solutions to this problem, and then apply the results to estimate the effect of war chests on challenger entry.

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Duration analysis, also known as *survival analysis*, *risk analysis*, or *event history analysis*, has had a brief history in political science. Box-Steffensmeier and Jones (1997) present an introduction to duration models for political scientists, and elaborate on this in Box-Steffensmeier and Jones (2003). Bennett (1999) extends Box-Steffensmeier and Jones' overview to discuss time-varying covariates and duration dependence. Duration models are now being used more frequently in political science, especially as the software exists to implement those models relatively easily.

As in any new econometric method, implementation of models often proceeds more quickly than an understanding of when the models are valid. This may be the case for time-varying covariates in duration analysis.

Durations models analyze how long the dependent variable will last until failure. For example, it may look at how long until a light bulb burns out, how long until a person contracts a disease, how long a cabinet government lasts, or how long a war (or alliance or peace) lasts. Naturally, different covariates (independent variables) are thought to affect these durations, and these are included in the analysis. For example, whether the governments are democratic may affect how long their alliance may last. But some of these covariates may change before the dependent variable fails. For example, inflation (or the unemployment rate, or public approval) may affect how long a cabinet government lasts, and inflation changes over time. If one is to incorporate the effects of a change in independent variable, then one must use time-varying covariates (also called time-dependent covariates). The potential problem of time-varying covariates is whether they are exogenous to the dependent variable.

In this paper, I examine the consequences of using endogenous time-varying covariates. In the following section, I discuss the circumstances where covariates may be endogenous or exogenous. Next, using Monte Carlo simulations, I examine the effects of endogeneity (or reverse causation) on some common estimators of duration models. I then discuss different solutions that have been proposed, and offer one of my own. Then I apply the theoretical arguments to the empirical case of war chests and challenger entry. Finally, I offer some preliminary conclusions.

1 Reverse Causation

If the duration process affects a time-varying covariate, then that covariate is said to be endogenous, and the relationship has reverse causation. Among political methodologists, Beck (1998, 206) and Bennett (1999, 267n7) state that researchers should worry about endogenous covariates, but do not offer any solutions. Reverse causality is discussed in more detail in other disciplines by Tuma and Hannan (1984), Blossfeld, Hamerle, and Mayer (1989), Yamaguchi (1991), Courgeau and Lelièvre (1992), Blossfeld and Rohwer (1995), and Kalbfleisch and Prentice (2002).

Time-independent (or *fixed*) covariates are not subject to reverse causation: Once the initial value of the covariate is set, it cannot be affected by the dependent variable, since it does not change. According to Kalbfleisch and Prentice (2002), *defined* and *ancillary* covariates are time-varying covariates that are not subject to reverse causation. Defined covariates have a determined path; for example, a time trend. Ancillary covariates are the "output of a stochastic process that is external to subjects under study" (Yamaguchi 1991, 135). For example, when studying the how long someone remains employed, the inflation rate is essentially external (not affected) to the individual's employment duration.

Following Tuma and Hannan (1984), there are two ways that internal time-varying covariates can be subject to reverse causation: rate dependence and state dependence. It is important to distinguish these problems from duration dependence. Duration dependence is when the likelihood of failure increases (or decreases) over time net of any other effects. For example, a government may be less likely to fail as the government lasts longer (usually positing an institutional explanation). In such a case, the hazard rate displays negative dependence, i.e. the likelihood of failure decreases over time. Often, unobserved heterogeneity can induce (negative) duration dependence, in a manner similar to state dependence below (Greene 2000).[1]

1.1 Rate Dependence

Rate dependence occurs when the time-varying covariate is *affected by* the likelihood (hazard rate) that a duration will end. As Yamaguchi notes, "we cannot separate the causal effect of a rate-dependent covariate from the consequence of reverse causation in any simple way" (1991, 139). Rate dependence is analogous to simultaneity problems found in regression models. For example, the presence/number of children in a marriage affects the likelihood that the marriage will end (and the presence/number of children can change during the

[1] Unobserved heterogeneity and selection bias also create problems in making causal arguments (Yamaguchi 1991).

course of the marriage). Presence/number of children is a time-varying covariate. But the likelihood that the marriage will end may also affect whether a couple chooses to have (more) children. Thus, presence/number of children is potentially affected by rate dependence.

Many political science applications that use time-varying covariates have potential rate dependence. Bennett and Stam (1996) study the effect of leaders' (time-varying) strategies (among other things) on the duration of wars. As Bennett (1999) points out, the likelihood of the war ending may affect the strategies employed. In their review of the literature on cabinet durations, Grofman and van Roozendaal (1997) identify "factors related to the anticipated consequences of dissolution" as a primary time-varying covariate affecting cabinet duration. These factors—primarily the motivations of political actors (Laver and Shepsle 1996)—could be affected by the likelihood of the government ending. Cabinet governments are also affected by economic factors such as inflation and unemployment (Warwick 1994). Some governments are strong enough to implement macroeconomic programs that affect inflation and unemployment, and in such circumstances the fact that a government may be on the verge of failure may affect whether the government implements such a program. A related argument could be made about duration of individual leadership of a country (e.g. Bienen and van de Walle 1992).

1.2 State Dependence

In addition to rate dependence, there is a second way in which causality can reversed: *state dependence*. The state of the dependent variable (whether the duration has ended) affects the time-varying covariate. Continuing the marriage example, the duration of a marriage depends on whether the husband is employed. During the risk period, marriages do not end, but the whether the husband is employed depends on whether the marriage has ended or not. Thus, as the duration of the marriage increases, those who are unemployed are more likely to leave the risk set, and there will be a smaller portion of the unemployed left in marriage (Yamaguchi 1991).[2] State dependence is a problem unique to duration models: Only in duration models do the (number of) subjects studied change over time. As in the case of rate dependence, state dependence is not easily solved.

A political science example is found in Mintrom (1997). Mintrom studied the effect of policy entrepreneurs on legislative consideration and approval of education reform in states of the U.S. If the existence of a policy entrepreneur increases the probability of legislative consideration and approval, then over time, those states that have not considered (or approved) the reform are less likely to have policy entrepreneurs.[3]

2 Monte Carlo Simulations

In this section, I present Monte Carlo simulations used to illustrate the effects of rate and state dependence on duration models. I examine models frequently used by political scientists: the Cox model (semi-parametric) and the Weibull and Gompertz models (parametric). These methods are implemented as proportional hazard models. In the simulations, the time-varying covariates are unrelated (by specification) to the hazard rate, so this assumption is

[2] State dependence is similar to duration dependence. Rate dependence occurs when a variable is included that should be excluded. Duration dependence can occur when a variable is excluded that should be included (which leads to unobserved heterogeneity).

[3] Policy entrepreneurs may also be subject to rate dependence in that the increased likelihood of consideration or approval may induce entrepreneurs to move to the state.

not problematic. In practice, however, one should test whether the hazards are proportional (Box-Steffensmeier and Zorn 2001).

I report quantiles of the Monte Carlo distribution, root mean squared error (RMSE), median absolute error (MAE), and coverage rates for the 95% confidence interval computed using the usual z-statistics. In the simulations that follow, I examine a ten-period duration model with a constant hazard rate, where the time-varying covariate is constructed to have no relationship with the probability of the duration ending.

$$
\begin{aligned}
t &= 0...9 \\
h(t) &= h_0(t)\exp(\beta x(t)) \\
\beta &= 0 \\
h(t) &= h_0(t) = 0.15\ \forall t
\end{aligned}
$$

2.1 Rate Dependence

To model rate dependence, I allow the covariate to depend on the probability of the duration ending.

$$
\begin{aligned}
x(t) &= [0.5 + \Pr(\text{ending})]\, x(t-1) + \delta \\
x(0) &\sim U[0,1] \\
\delta &\sim U[-0.5, 0.5]
\end{aligned}
$$

If the probability of the duration ending is greater than 0.5, then the covariate increases (net of the random term δ). Table 1 shows the results of the simulation.

	quantiles ($\beta = 0$)							95% CI
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**RMSE**	**MAE**	**Coverage**
Cox	0.256	0.325	0.410	0.495	0.574	0.429	0.410	0.056
Weibull	0.210	0.273	0.346	0.428	0.497	0.369	0.346	0.055
Gompertz	0.236	0.298	0.376	0.462	0.535	0.398	0.376	0.056

Table 1: Time-Varying Covariate with Rate Dependence: n = 300, 1000 replications

None of the estimators do well in the presence of rate dependence. Although there is no relationship between the covariate and whether the duration ends, most of the time the estimators would incorrectly indicate that as the covariate increased, the likelihood of the duration ending would also increase. Among the models shown, the Weibull model seems to do a little better, but still gets the qualitative relationship wrong.[4] I now examine how the estimators perform in the presence of state dependence.

2.2 State Dependence

To model state dependence, I allow the covariate to increase over time until the duration ends (this is related to the application that follows).

$$\begin{aligned} x(t) &= x(t-1) + \varepsilon \\ x(0) &\sim U[0,1] \\ \varepsilon &\sim U[0,1] \end{aligned}$$

Table 2 shows the results of the simulation.

The surprise of these results is how well the Cox model does, and how poorly the Weibull

[4] The simulations are run with a constant hazard rate, or no duration dependence. In the presence of rate dependence, the Weibull model continues to have no rate dependence, but the Gompertz model shows negative duration dependence. Of course, the Cox model treats the baseline hazard rate as a nuisance, and does not estimate it.

	quantiles ($\beta = 0$)							**95% CI**
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**RMSE**	**MAE**	**Coverage**
Cox	−0.168	−0.082	0.005	0.092	0.176	0.130	0.088	0.951
Weibull	−0.866	−0.796	−0.732	−0.662	−0.604	0.739	0.732	0.000
Gompertz	−0.770	−0.689	−0.599	−0.512	−0.442	0.618	0.599	0.001

Table 2: Time-Varying Covariate with State Dependence: n = 300, 1000 replications

and Gompertz models do. It is as if the Cox model is immune to state dependence (at least for this simulation). On the other hand, the Weibull and Gompertz models both incorrectly indicate that as the covariate increases, the likelihood of the duration ending decreases.[5] I now consider how to address rate and state dependence.

3 How Do We Fix It?

Given that a time-varying covariate is either rate dependent or state dependent, what should be done?

The first approach is to drop the covariate entirely. However, this will replace the problem of reverse causation (endogeneity) with omitted variables (and with it, unobserved heterogeneity). It may, however, be superior to leaving in the covariate without modification.

The second approach is to ignore the problem, and include the time-varying covariate in the duration model anyway. Through a theoretical argument, one can determine if the estimated effects would be biased away or toward zero. For example, previous research has shown that low unemployment extends the length of a government cabinet (reduces the probability of termination). The rate dependence one would expect is that if a government

[5] Although the hazard rate is set to be constant, the Weibull and Gompertz models show positive duration dependence.

could manipulate the unemployment rate (say, through government employment), then as the probability of the government ended increased, the unemployment rate would decrease. Rate dependence would cause the effect of unemployment to be underestimated. Thus, if the estimate of the effect was positive and statistically significant, it would give a lower bound to the true effect. There will be times, however, where both the direct and the reverse effect have the same sign. It still may be acceptable to include the time-varying covariate, if the resulting estimates do not seem too far out of line. In examining the effects of simultaneity in linear regression models, Bartels stated that "treating the endogenous regressor as exogenous will be (asymptotically) superior to omitting it entirely if and only if the resulting OLS parameter estimate falls between zero and twice the true parameter value" (1985, 190).[6] Following this logic, if one has a general idea of the magnitude of the effect of the covariate, then one can roughly determine whether it is better to include or exclude the variable.

The third approach is to jointly model the duration and the time-varying covariate. This is the approach suggested by Cox and Lewis (1972), Kalbfleisch and Prentice (1980), and Petersen (1995).[7] However, this is a very complicated approach which has only been developed for a single dichotomous time-varying covariate.

The fourth approach is to apply the ideas of simultaneous equations to duration models. This approach was introduced by Lillard (1993), and has been applied fruitfully by him and his coauthors. Like simultaneous equations, what is required for these models is a set of

[6] I have substituted words for symbols in the Bartels quotation.
[7] There is a difference between these approaches, but it is not worth discussing here. See Petersen (1995) for a comparison of the methods.

exclusion restricts: finding (time-varying) variables that affect the covariate, but not the dependent variable (and vice versa). The difficulty in political science is to find a true instrument (Bartels 1991, Goodliffe 2003). Lillard and Panis (2003) have developed software that implements the simultaneous equations technique for duration models.[8]

The fifth approach, which I explore here, is to include the covariate, but drop the time-varying portion. In other words, to use the initial value of the covariate, and ignore the changes in that covariate. This is a relatively simple solution that incorporates ideas from the first, second and fourth approaches. Dropping the time-varying portion of the covariate takes away the part of the covariate that is most likely to be tainted by reverse causation. It keeps some information, however, instead of omitting the variable altogether. From the simultaneous equations perspective, the initial value of the covariate serves as an instrument for the other times the covariate is observed. This approach will work best when there are not many changes in the covariate. It also has a specific interpretation: At the beginning of a duration, how long is the duration likely to last given the values of the covariates?[9]

I now present Monte Carlo simulations similar to those above that examine the effect of transforming time-varying covariates to time-independent covariates. These simulations were run on the same data as the simulation with rate dependence above (very similar results

[8] The software is *aML: Multiprocess Multilevel Modeling*. In this case, the multiprocess part is the fact that both the duration and the time-varying covariates are processes affected by other variables. The multilevel part is that each subject (or observation) has covariates recorded at different times.

[9] Bennett and Stam (1996) use this approach when they compare results using time-varying covariates with results using time-independent covariates.

	quantiles ($\beta = 0$)							**95% CI**
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**RMSE**	**MAE**	**Coverage**
Cox	−0.297	−0.147	0.023	0.190	0.333	0.250	0.169	0.967
Weibull	−0.331	−0.163	0.026	0.210	0.374	0.280	0.188	0.941
Gompertz	−0.310	−0.156	0.024	0.198	0.351	0.263	0.176	0.956

Table 3: Constant Covariate: n = 300, 1000 replications

are found for the data on state dependence). In this case,

$$\begin{aligned}
t &= 0...9 \\
h(t) &= h_0(t)\exp(\beta x(t)) \\
\beta &= 0 \\
h(t) &= h_0(t) = 0.15\ \forall t \\
x(t) &= x(0)\ \forall t \\
x(0) &\sim U[0,1].
\end{aligned}$$

Table 3 shows the results of the simulation.

The results across all of the models are the same: once the time-varying covariates are converted to time-independent covariates, the effects of rate and state dependence disappear.[10] Of the three models, the Cox model seems to perform best, though not by much. I will apply the Cox model to the (real-world) data that follows.

[10]With time-independent covariates, the Weibull model shows no duration dependence (which it should). However, the Gompertz model still shows negative duration dependence.

4 Application: Do War Chests Delay Challenger Entry?

I now use these methods to examine the question of whether war chests delay (and ultimately deter) challenger entry. This is an empirical question over which there is no consensus.[11] If certain incumbent characteristics delay challenger entry, possibly to the point where no challenger enters during the election cycle (i.e. delay past the primary or filing date), and delayed challenger entry affects election results, then challenger entry should be studied within a temporal context. This is the argument of Box-Steffensmeier (1996), who faults previous empirical analyses for failing to incorporate the temporal nature of war chests. Thus, Box-Steffensmeier examines challenger entry within a duration model framework. In addition, Box-Steffensmeier argues that war chests matter not only at the beginning of an election cycle, but throughout the election cycle. Employing the time-varying covariate of war chests (cash-on-hand) she finds that a large war chest will delay the entry a high quality challenger (treating high quality challengers as independent from low quality challengers).

I first examine the claim that the timing of challenger entry matters and find that it does. I then argue that it is inappropriate to use time-varying covariates to study the effects of war chests on challenger entry. Finally, I examine the effects of implementing two of the approaches above.

[11] Goldenberg, Traugott, and Baumgartner (1986), Goidel and Gross (1994), Hersch and McDougall (1994), Box-Steffensmeier (1996), and Hogan (2001) find that war chests deter high quality challengers from entering (see also Sorauf 1988). In contrast, Squire (1989, 1991), Milyo (1998), Ansolabehere and Snyder (2000) and Goodliffe (2001) argue that war chests do not deter high (or low) quality challengers from entering.

Table 4: Challenger Entry Date's Effect on Incumbent Vote Share

	High Quality		*Low Quality*	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Days Until Entry (100s)	1.41	6.11	1.47	12.86
R^2	0.48		0.58	
N (num. of dist.)	479		2079	

Other independent variables: War Chest × Previous Challenger, War Chest × Tenure, War Chest × Redistricting, War Chest × Grandfather, War Chest × Year, Previous Vote × Previous Challenger, Previous Vote × Tenure, Previous Vote × Redistricting, Previous Vote × Grandfather, Previous Vote × Year, Previous Challenger, Democrat × Year, South × Year, Year, Tenure, Redistricting, Grandfather, Filing Date, and a constant.

Notes: Ordinary Least Squares estimates.
Dependent variable is incumbent's percentage of two-party vote in 1984–1998 U.S. House races with opposed incumbents excluding unusal cases.

4.1 Digression: Does Timing of Challenger Entry Matter?

Whether a challenger enters may not be the only important aspect of congressional races. It may also matter *when* a challenger enters. If an incumbent cannot prevent a challenger from entering, then he may wish to delay her—she may receive less exposure in the media, and hence pose less of a challenge. Thus an incumbent should work to deter challenger entry, and failing in that, work to delay challenger entry. But is this in fact the case? Do challengers who enter earlier do better in the elections? In order to test whether a duration model is appropriate, I ran a regression of challenger entry date on incumbent two-party vote share, for each type of challenger, controlling for other factors. The results are in Table 4. (I do not discuss the variables here. See Goodliffe [2001] for details on the variables. Following

Jacobson and Kernell [1983], high quality challengers hold or have held elected office; low quality challengers have not.)

The results show that the later the challenger enters the race, the better that the incumbent does in the election. For incumbents opposed by high quality challengers, every 200 days the incumbent keeps such a challenger out of the race adds about 3 percentage points (on average) to his winning percentage.[12] Furthermore, of the 119 incumbents that lost in the general election (in this sample), 86 had challengers who entered in the first year of the election cycle, and all but six had a challenger enter within the first four months of the second year of the election cycle. Thus an incumbent has an incentive to delay as well as deter challenger entry. Models that do not take into account the temporal dependence of challenger entry (such as multinomial logit) will have inefficient (but consistent) estimates. By specifically incorporating the temporal dimension of war chests, one should be able to increase the efficiency of estimates. Furthermore, it may also better reflect the strategic choices of challengers.

4.2 War Chests as a Time-Varying Covariate

There are two potential problems with using war chests across an election cycle. First, the analyst must assume that cash-on-hand at the beginning of the election cycle has the same marginal deterrence as cash-on-hand at any other point in the election cycle. This may not be the case, for incumbents often raise and save money throughout the election cycle to

[12] I also ran this with different sets of control variables (for example, including incumbent spending), and the results were qualitatively similar. In a logistic regression (with control variables), the number of days until challenger entry also affects the probability that an incumbent wins the general election.

spend mostly in the last few months of the election.

Second and more problematic, the further into the election one looks at money, the more likely it is for money to be endogenous. That is, the likelihood (rate) and realization (state) of challenger entry affects an incumbent's war chest. This can take place in the two different ways discussed above. If an incumbent knows that the election is going to be close (because a high quality challenger is about to enter, or perhaps because of a scandal revealed during the term), then that incumbent may raise a lot of money for the coming race. An incumbent with a lot of money in the middle of the election cycle may appear to attract challengers, instead of deter them. Thus, an incumbent's war chest is potentially a covariate with rate dependence.

In addition to rate dependence, war chests have state dependence. Incumbents raise money throughout the election cycle. And incumbents who face challengers spend more money than incumbents who are unopposed. In addition, incumbents who face high quality challengers spend more than those incumbents who face low quality challengers. And finally, incumbents spend more against challengers who entered early than those that entered late. Suppose that challengers were not deterred by war chests. If challenger entry were random (with respect to war chests) and incumbents maintain the spending patterns observed, incumbents who have had challengers enter early will have smaller war chests later in the election cycle than those incumbents who have had challengers enter late or not at all. Empirically, it would appear that war chests deter challengers. In fact, this is what is observed: Incumbents with late-entering challengers have larger war chests (cash-on-hand) later in the election cycle than those incumbents with early-entering challengers.

If a duration model is employed to measure the effect of war chests as a time-varying covariate on challenger entry, it is roughly the equivalent of employing ordinary least squares to see the effect of incumbent spending on incumbent vote share: The statistical results do not control for reverse causation, and thus do not measure the effect sought. If it appears that war chests encourage challenger entry, this could be a result of rate dependence. If it appears that war chests delay or deter challenger entry, this could be a manifestation of state dependence. In any case, it will be difficult to make any conclusions using war chests as a time-varying covariate.

4.3 Replication and Extension

I replicate Box-Steffensmeier's study and implement two of the suggested approaches: dropping the covariate and making the covariate time-independent (ignoring/accepting the problem is Box-Steffensmeier's approach). Since there is a high correlation between the war chests measured at different times ($r > 0.9$), war chests at the beginning of the election cycle may serve as a useful instrument.

I was able to replicate Box-Steffensmeier's study without any problems given the data provided on her web site (and at the ICPSR).[13] In the other models, I have made corrections to the incumbent's previous vote share (which were recorded incorrectly by the Federal

[13] However, there is a mistake in the article (Table 2; also reprinted in Box-Steffensmeier and Jones [1997, Table 3]). The war chest covariate is measured in millions of dollars, but stated as being measured in hundreds of thousands of dollars. Thus, the decimal point should be moved one place. In the analysis that follows, I measure war chest in hundreds of thousands of dollars. Similarly, the covariate on previous vote share is stated as being measured in 1%, but is actually 100%. Thus, the coefficient should be moved two decimal places. The "Percent Change in the Hazard Rate" is correct for the stated measurement scales, however.

Variable	B-S	B-S (corrected)	No War Chests	Time-Independent
War Chest-TVC (ending cash)	-0.301^* (−2.17)	-	-	-
War Chest-TVC (beginning cash)	-	-0.332^* (−2.13)	-	-
War Chest (beginning cash)	-	-	-	−0.158 (−1.12)
Previous Vote	-0.070^* (−4.21)	-0.065^* (−3.99)	-0.075^* (−4.51)	-0.068^* (−3.92)
Democrat	0.234 (0.72)	0.214 (0.66)	0.138 (0.43)	0.169 (0.52)
South	−0.438 (−1.03)	−0.464 (−1.09)	−0.441 (−1.04)	−0.457 (−1.08)
Log-likelihood	−197.39	−197.99	−200.55	−199.77

Notes: Dependent variable is weeks until high quality challenger entry for 1990 U.S. House elections, excluding unusual cases ($n = 397$). z-ratios are in parentheses: $^*p < 0.05$ (two-tailed test). War Chest is in units of \$100,000. Previous Vote is measured in 1%.

Table 5: The Effect of War Chests on Challenger Entry

Election Commission), and measure war chests at the beginning of the election cycle. As implemented by Box-Steffensmeier, challengers enter during a reporting period possessing information about the incumbent's cash-on-hand at the end of that same reporting period. Since this does not make temporal sense, I use beginning cash-on-hand instead. I then ignore the time-varying portion of war chests. While there may be some information lost by not measuring throughout the election cycle, the "biased" information is avoided. War chests measured at the beginning of the election cycle function as an instrument for war chests later in the election cycle, for there is a high correlation between the war chests measured at different times ($r > 0.9$), and war chests at the beginning of the election cycle avoid endogeneity. The results can be found in Table 5. I present the results for the Cox model alone, although qualitatively similar results are found for the Weibull and Gompertz model (which both show positive duration dependence).[14]

The first column of results replicates Box-Steffensmeier's findings. The second column uses the beginning cash and the corrected previous vote share. Note that there is not much difference between these two models. They show that war chests appear to delay high quality challenger entry. The third column shows the results of excluding war chests from the model. Not many of the other coefficients change, however. Unfortunately, since war chests are the covariate of interest, excluding them is not helpful for inference. Finally, the last column shows the result of converting time-varying war chests to time-independent war chests. The statistically significant effect of war chests disappears (though it is still in the same direction). I conclude from this that time-varying war chests have more problems with state dependence than rate dependence.

5 Conclusion

Despite the admonition requested by previous political methodologists, too little attention has been paid to the problem of endogenous time-varying covariates in duration models. More caution must be exercised when using time-varying covariates than when using time-independent covariates. At the least, this paper suggests robustness checks when using time-varying covariates in duration models.[15] Specifically, I suggest that when using time-varying covariates that analysts also examine the results when those covariates are converted

[14]With one caveat: War Chest is no longer statistically significant at the 0.05 level in the Weibull model (the coefficient is smaller, but the standard error is about the same). It is significant at the 0.10 level for the original and corrected Box-Steffensmeier models.

[15]I am aware that this is the standard plaintive cry from methodologists.

to time-independent covariates, and if that covariate is not the primary variable of interest, to examine the results when the covariate is excluded.

The next step in this program is to extend the Monte Carlo studies to include Lillard's method of simultaneous equations. Further, Monte Carlo studies will be conducted that examine the effects of state and rate dependence simultaneously, and the effects of state and rate dependence when there is an underlying true relationship between the time-varying covariate and the likelihood of the duration ending.

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