Dynamic Foreign Policy Behavior

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How best to classify event counts of directed dyadic foreign policy behavior and how best to model them are points of disagreement among researchers. Should such series be modeled as unit roots ("perfect" memory) or as stationary ("short" memory)? It is demonstrated that the dichotomous choice between unit root (I(1)) and level stationarity (I(0)) is overly restrictive. The intermediate (and more general) possibility of fractional integration (0 < I < 1), a concept proven useful in studies of aggregate opinion, is applied. Results show that fractional integration is extremely common and that error correction mechanisms (ECMs) can still be appropriate in the absence of unit-root series. Fractional ECMs are used in action–reaction models of bilateral relationships to demonstrate this. Given the frequency of fractional integration, its flexibility, and the problems encountered when ignoring it, scholars should incorporate fractional integration techniques into their models.

Keywords: *fractional integration; error correction mechanisms; foreign policy; action-reaction*

Action–reaction models have dominated the statistical analysis of foreign policy behavior (e.g., Ward 1982; Dixon 1983, 1986; Goldstein 1991; Goldstein and Freeman 1990, 1991; Rajmaira and Ward 1990; Goldstein and Pevehouse 1997). These models are evaluated in a time-series setting, and scholars interested in estimating the parameters of action–reaction models have generally turned to the econometric literature to identify useful techniques for estimating parameters. We continue that tradition by introducing and then using a relatively recent innovation in the analysis of time series: fractional integration.[1]

In brief, the concern for the level of integration of a time series matters both for our understanding of individual variables and for the modeling choices we make when investigating the relationships between variables. Aside from wanting to understand how the past of a series affects the present, we also wish to understand that part of the

1. Our presentation is not technical, but we provide references for readers who want to use the techniques.

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variable not explained by internal trends (the stochastic component) using independent variables. The standard solution is to de-trend a series before running regressions, and for a number of years, the standard approach to de-trending series was to take the first difference of the series and use these differenced series in regressions.[2] Failure to deal with the trends of each of our series leads to the problem of spurious regression. That is, it is surprisingly easy to conclude falsely that two series are causally related when they share a common trend.

The literature on fractional integration shows that one need not be restricted to the choice of using the series in levels (i.e., the raw data) or taking the first difference: One can take what is known as the fractional difference (described below). This is useful because the fractional integration literature also shows that over-differencing and under-differencing produce biased parameter estimates and bias summary statistics, such as the Durbin-Watson score and R^2. More specifically, the bias affects the size of the coefficient and standard errors and can lead one to infer that relationships are stronger than they actually are. Overall, fractional techniques take much more precise measurements of the empirically observed behavior of time series and allow the specification of more exact models.

We study a number of directed-dyadic foreign policy series to evaluate whether they are fractionally integrated. We also report the results of estimating an action–reaction model using data that we differenced, fractionally differenced, and left in level form. Our results indicate that scholars who study foreign policy series would be well advised to familiarize themselves with the fractional integration literature and add these diagnostic tests to their statistical toolkit.

The study proceeds in five sections and a conclusion. In the first section, we briefly review the literature on action–reaction models of foreign policy behavior. We then introduce the literature on fractional integration and follow with a section in which we discuss the processes that generate foreign policy series and some reasons why we expect them to be fractionally integrated. In the section that follows, we discuss our research design and the data that we use to create the series that we study. We then present our results in the fifth section and conclude the article in a final section.

ACTION–REACTION MODELS OF FOREIGN POLICY BEHAVIOR

One of the more common theories of behavior in the social sciences is the action–reaction theory (Sandberg 1978). It is expressed in the notion that actors respond in kind to either hostile or cooperative behavior from another actor, and the theory has received wide application in many areas of inquiry. The causal argument is simple: the behavior of actor A will be driven, at least in part, by the behavior of actor B. Some-

2. The first difference is the value of an observation minus the preceding observation (i.e., $y_t - y_{t-1}$). Rather than using the level values of the series (i.e., y_t) in regressions, one uses the first differences.

times, the causal mechanism is understood as contemporaneous (i.e., actor A responds to actor B's present behavior), but it is generally specified as a retrospective response.[3]

Ward (1982) introduced the action–reaction framework to the study of foreign policy behavior, and Dixon (1983, 1986) contributed additional analyses. Goldstein (1991, 1995) and his colleagues (Goldstein and Freeman 1990, 1991; Goldstein and Pevehouse 1997; Pevehouse and Goldstein 1999) set the present standard for action–reaction models in the study of foreign policy behavior. These models can be described generally using the following two equations:

$$Y_t = \gamma Y_{t-1} + \delta X_t + \alpha \tag{1}$$

$$X_t = \varepsilon X_{t-1} + \zeta Y_t + \beta \tag{2}$$

δ and ζ are the action–reaction coefficients: if they are positive, then Y and X covary positively with the contemporaneous or past values of X and Y. The γ and ε coefficients represent the extent to which Y and X are responsive to their own past values. They are generally understood to represent bureaucratic processes such as standard operating procedures or budget maximization (e.g., Goldstein and Freeman 1990 specify that they represent policy inertia). As such, they are expected to be positive. Finally, α and β are constants that represent the level of hostility or cooperation the country would exhibit toward the other in the absence of action—reaction and policy inertia. The model has proved itself to be very useful in a variety of contexts: cooperative as well as hostile foreign policy behavior, great power and small power interactions, and so forth.

Rajmaira and Ward (1990), Ward and Rajmaira (1992), and Rajmaira (1997) develop a prospective modification of the action—reaction model. Building on the work of Axelrod (1984, 1986), Keohane (1986), and Axelrod and Keohane (1985), they argue that the directed-dyadic foreign policy interactions between rivals will be characterized by short-run reciprocity within the context of a long-memoried equilibrium process that is driven by each actor's expectations of the other's behavior.

All of these studies estimate the parameters of the models they propose and do so using directed-dyadic time series. In this study, we are especially interested in making use of relatively recent advances in the study of time series and asking whether extant studies may suffer from either spurious correlation or biased parameter estimates. The concern arises from the fact that the action–reaction modelers generally do not address the issue of integration of the series they study.

Recent advances in time-series econometrics cast a shadow over all published time-series analyses of reciprocity in foreign policy. To make an explicit case, at least six published studies estimate parameters using data reported in levels without testing for the level of integration (Ward 1982; Dixon 1983, 1986; Goldstein 1991; and Goldstein and Freeman 1990, 1991), two studies test for the level of integration and use data reported in levels (Goldstein and Pevehouse 1997; Pevehouse and Goldstein 1999),

3. In fact, most contemporaneous specifications are driven more by the level of aggregation used rather than reference to an explicit conceptualization of simultaneous interaction.

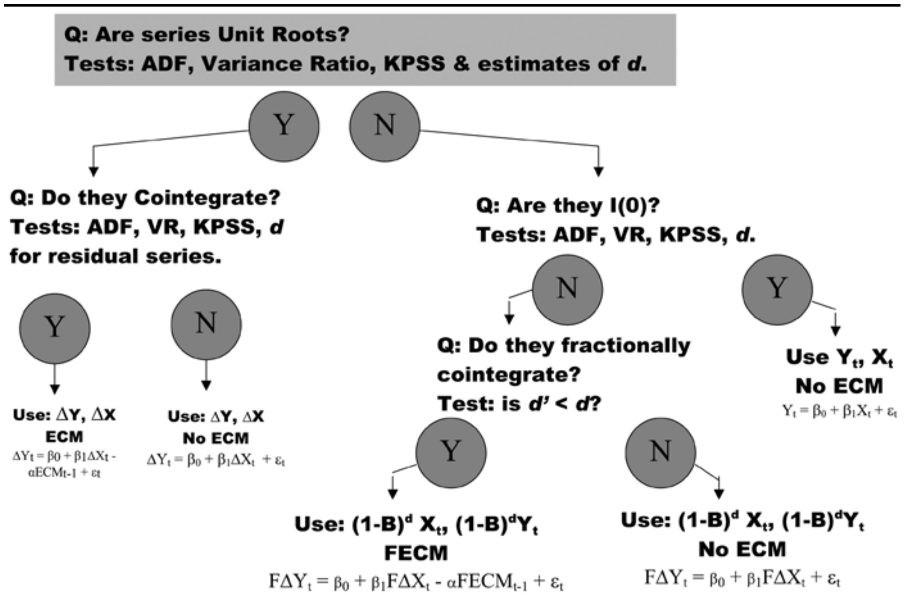

Figure 1: When to Use a Fractional Error Correction Mechanism

and three studies test for the level of integration and use the first difference of the series (Rajmaira and Ward 1990; Ward and Rajmaira 1992; Rajmaira 1997). We argue below that there is reason to believe that the type of foreign policy series used in these studies is unlikely to be integrated of either order 0 or 1. We describe a series of steps that scholars studying these series ought to take to determine the best method for estimating parameters. Those steps are outlined in Figure 1.

We describe the issues sketched in Figure 1 in some detail below. Here, we briefly review the steps one should take. The first question is, do the individual series contain unit roots (i.e., are they integrated of order 1)? A stationary series forgets changes (shocks) and returns to a constant mean level, whereas a series with a unit root remembers changes perfectly and meanders with no constant mean. Because the tests for unit roots have low power, it is important to use several of them, including a test to estimate the value of d, the fractional differencing parameter. If the series contain unit roots, then Granger (1980) suggests that a linear combination of the series might be stationary, which is to say that the two series may be cointegrated. Two unit root series are said to be cointegrated if a linear combination of the two is mean reverting (i.e., stationary). If the series contain unit roots, then the next step is to determine whether they are cointegrated, and several tests are available to make such a determination.

If the series are not cointegrated, then one should take the first difference of each and use the differenced variables in one's action–reaction model. However, if the series are cointegrated, then an error correction model is appropriate (again, using first differences). If one rejects the presence of a unit root, one must also determine whether to reject or embrace the conclusion of zero order integration. In Figure 1, this decision is represented as answering “no” to the questions, “Do the series contain unit roots?” and “Are the series I(0)?” If the individual series are fractionally integrated, then they may be fractionally cointegrated (which is to say they may contain a long-run relationship). Again, a diagnostic test is available. If one rejects fractional cointegration, then one should estimate one’s action–reaction model using fractionally differenced variables. However, if one accepts the presence of fractional cointegration, then one would want to estimate a fractional error correction model.

Our figure suggests that scholars using time series to study reciprocity in foreign policy will want to estimate parameters using one of five models. To date, people have selected among three of those models. We show that two other useful models are available. Furthermore, although there are undoubtedly cases in which the three models that people have been using will serve us well, we present the argument that it is likely the case that many foreign policy series are fractionally integrated and, given the prevalence of reciprocity in foreign affairs, that many pairs of foreign policy series are likely fractionally cointegrated. To make our case, we begin with a discussion of integration.

INTEGRATION: 0, 1, OR SOMEWHERE IN BETWEEN?

Traditionally, researchers using time-series data have concerned themselves with the question of whether their data are *stationary* or *nonstationary.* A stationary series (not integrated or integrated of order 0) is one that, regardless of short-term shifts, maintains a constant mean (or equilibrium) level (see series A in Figure 2). As events that move the series from its mean value are quickly forgotten, the series is characterized as having “short-memory” only. Such a series may oscillate around its equilibrium level, but it will be characterized by mean reversion as well as stationary variance and covariance.

In contrast, for an integrated series (also known as a nonstationary, random walk, unit root, or I(1) series), shocks are remembered perfectly from one time period to the next, thus accumulating over time without any discounting toward an equilibrium level (see series B in Figure 2). The series will meander with a nonstationary mean and will exhibit infinite variance and infinite covariance.

Parameter estimation with integrated series can be problematic as spurious regressions are common (Yule 1926; Granger and Newbold 1974; Lebo, Walker, and Clarke 2000).[4] To gain an intuitive sense of the problem, consider the fictitious series in Figure 3, each of which grows over time. In general, as one series grows, the other declines, so they appear to share a long-run equilibrium. But is the relationship spurious? It turns out that lots of series grow over time, and because they do, they share a common trend. Series that share a common trend but no causal relationship will produce a statistically

4. Spurious regressions occur when estimation techniques falsely reject the null hypothesis of no relationship between variables. With time-series data, this is a particular problem because one can mistakenly conclude that a pattern visible in one variable (such as perfect memory) explains a similar pattern in a second variable.

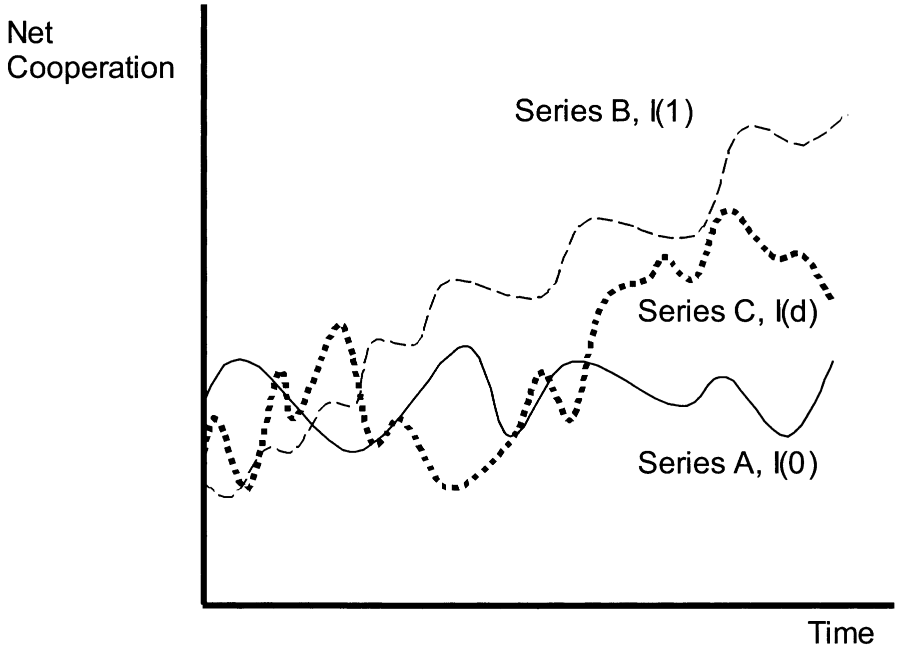

Figure 2: I(0), I(1), and I(*d*) Series

significant relationship. The key, then, is to remove the common trend before testing for a relationship.

To remove the trend, I(1) series should be differenced prior to modeling. Only when all series are rendered I(0) can one have confidence in the inferences taken from models that include them. Thus, time-series modelers have come to rely on tests of stationarity such as the Dickey-Fuller test (Dickey and Fuller 1979, 1981) to guard against these threats.

Substantively, conclusions about whether a series is integrated imply a great deal about the variable of interest. For variables measuring a government's foreign policy behavior, concluding stationarity implies an equilibrium policy level that remains constant despite short-term actions or long-term effects. On the other hand, concluding that such a variable is nonstationary implies the belief that actors continually update their actions based on new information and that no equilibrium behavior exists. Neither of these characterizations seems to fit our intuitive notions about foreign policy behavior, a point to which we return below.

Recently, researchers in political science have questioned the strict dichotomy of classifying and treating variables as having integer levels of integration and have introduced the concept of fractional integration first described by Granger (1980; also see Box-Steffensmeier and Smith 1996, 1998; Lebo and Clarke 2000; Clarke and Lebo forthcoming). Rather than making the strict choice between I(0) or I(1), fractional integration generalizes the traditional autoregressive integrated moving average

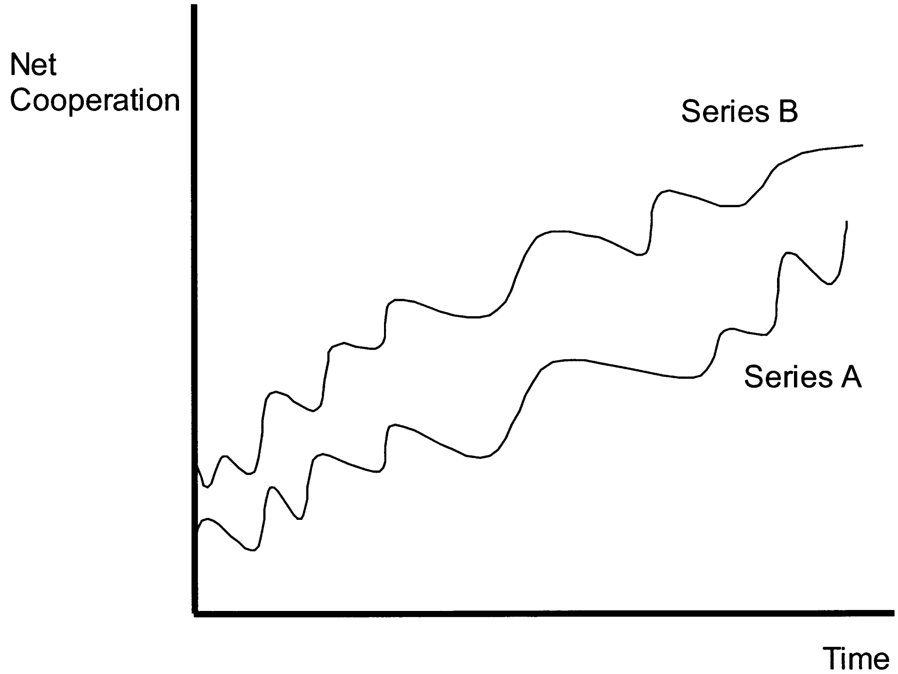

Figure 3: A Spurious Relationship?

(ARIMA) model to become an autoregressive fractionally integrated moving average (ARFIMA) model. A fractionally integrated series will have characteristics of both stationary and nonstationary series and possess long, rather than short or perfect, memory. That is, it will be mean reverting but only over a much longer period than with a stationary series (Box-Steffensmeier and Smith 1996, see series C in Figure 2). Equation (3) specifies the ARFIMA model for variable Y_t:

$$(1-B)^d Y_t = \frac{\theta(B)\varepsilon t-1}{\phi(B)} \qquad (3)$$ see Errata

In equation (3), (B) represents the "backshift operator" such that ("B)$X_t = X_{t-1}$. Furthermore, ϕ and θ represent stationary autoregressive and moving average parameters, and ε_t is the error term, which is distributed normally with mean 0 and variance σ^2. Of central importance here is d, the fractional differencing parameter. When $d = 0$, equation (3) reduces to a stationary ARMA process. When $d = 1$, equation (3) reduces to an unit-root ARIMA process that will require differencing to render it I(0). Studies of popular political variables, such as approval ratings, have found that most series fall in the range $0 < d < 1$ (Box-Steffensmeier and Smith 1996; Lebo, Walker, and Clarke 2000; Byers, Davidson, and Peel 2000; De Boef 2000). Fractional levels of integration are common because these variables are constructed by aggregating the behavior of

see Errata

many individuals, each of whom may behave differently in terms of his reliance on past opinions or actions to make current decisions. We contend that because the series of country-level behavior are created by aggregation in several respects (discussed below), they may well be fractionally integrated. To account for fractional integration, fractional differencing must be employed to guard against threats to inference similar to those encountered when dealing with wholly integrated data (Lebo 2000; Clarke and Lebo forthcoming).

Given that ARIMA models can be generalized to ARFIMA models (to account for fractional integration), it is not surprising that cointegration methods can also be generalized to allow for fractional cointegration (Abadir and Taylor 1998; Box-Steffensmeier and Tomlinson 2000; Clarke and Lebo forthcoming). Traditional cointegration specifies that a cointegrating relationship between variables requires each series to be I(1) and some linear combination of the variables to be I(0) (Banerjee et al. 1993). Generalizing this, fractional cointegration requires the original (or "parent") series to be I(d), where $0 < d < 1$, and the combination of variables to have a lower level of integration, d', such that $d' < d$. When two series are (fractionally) cointegrated, they will have an equilibrium relationship, moving very close together over the long term. A shock that moves the series apart will quickly dissipate in the case of traditional cointegration, but re-equilibration will be much slower where cointegration is fractional.

For scholars interested in action–reaction processes, fractional cointegration is important because action–reaction processes will generate a long-run equilibrating or error-correction relationship. If the series are not I(1), then action–reaction models imply that they should be cointegrated: I(1) series that have a long-run equilibrium relationship will be cointegrated. However, if the series are I(d), where $0 < d < 1$, and have a long-run equilibrating or error-correction relationship, then they will be fractionally cointegrated. As we describe in more detail in the following section, the prevalent use of action–reaction theories to describe directed-dyadic foreign policy behavior provides good reason to investigate the possibility that these series are fractionally cointegrated.

INTEGRATION AND FOREIGN POLICY SERIES

Because of the threat to inference, it is important to test for fractional integration and cointegration. However, doing so may well be more than an "econometric fix," for there is reason to believe that some individual foreign policy series are fractionally integrated and that some pairs of them are fractionally cointegrated. As Crescenzi and Enterline (2001) have recently emphasized, most students of international politics believe that the past matters. The order of integration of a series has implications for the manner in which past events influence present behavior. First, consider the argument we raised briefly above. If a foreign policy series is stationary, it always reverts to its mean, which suggests that (1) policy is constant over time and (2) events do not have an impact for long. This strikes us as a description that is unlikely to comport with most scholars' sense of foreign policy behavior: although foreign policy is certainly sticky, it does change over time and sometimes quite dramatically. Furthermore, events may well have a lasting effect: their impact will likely decay over time, but they are unlikely to be quickly forgotten.

Let us now consider a unit-root foreign policy series: here, the impact of past events never decays—they have just as much of an effect on policy today as they did when they first occurred. This description strikes us as even less likely to comport with scholars' intuition of foreign policy behavior. The third option, a fractionally integrated series, is one in which memory is long but not perfect. In the context of foreign policy series, this suggests that events from the past have an impact long into the future—long enough that we cannot model them with autoregressive or moving average terms—but that the impact of the past decays over time. Furthermore, different countries (and pairs of countries) might exhibit different patterns. Fractionally integrated series can account for such variation and seem to better match our intuitions about foreign policy than either stationary or unit-root series.

As noted above, if the series are generated in such a way that the researcher aggregates across heterogeneous data-generating processes, the series will likely be fractionally integrated. Thus, in addition to making our case based on intuition, we also put forth an argument about sources of heterogeneity that might exist in foreign policy series. We identify two such sources below: different actors and different issues.

The most likely source of short-memoried and long-memoried heterogeneity is aggregation across different actors. One manner in which researchers might study the behavior of multiple actors is to aggregate across multiple countries. Most studies of foreign policy examine directed dyads that are pairs of countries, but in a few cases researchers have aggregated the behavior of several countries to create a single series (Davis and Ward 1990; Goldstein and Pevehouse 1997). For example, Goldstein and Pevehouse (1997) study the behavior of the United Nations (UN) and NATO countries toward Serbia during the Bosnian conflict of the 1990s. They thus created an international actors series that was the sum of the behavior of each actor (i.e., the UN and the NATO countries). Because there is little reason to believe that the UN and each of the NATO countries used the past in the same way when responding to the Serbs, this international actors series is an aggregation across heterogeneous actors. Thus, we argue that whenever researchers create an aggregate series that combines the behavior of two or more countries toward another, that series is likely to be fractionally integrated.[5]

The second reason why series might be understood as an aggregation of the behavior of multiple actors is that foreign policy is not the behavior of a unitary state: execu-

5. We are less sanguine that an aggregate series of countries toward a single actor will be fractionally integrated. Our thinking is that aggregating the behavior of a single actor—whether an individual country or a corporate actor, such as NATO—toward all countries will aggregate over the heterogeneous behavior of that actor toward others. That is, we suspect that any given actor will have variance over the importance of past events in its relations with different countries. Yet, we are less confident that this will be so for a noncorporate group of actors, such as the behavior of all countries in the world toward a given country. It is certainly plausible that there will be heterogeneity in the importance of memory, but it also seems to us plausible that there will be rather limited heteroegeneity. This might especially be so with respect to a hegemon such as the United States. That is, most third-world countries might have rather similar response patterns to U.S. behavior, thus limiting the heteroegeneity across such actors.

tives, bureaucrats, and military officials all contribute behavior to the foreign policy series we study, and it is rather likely that some of them will use the past differently when forming their judgments. To the extent this is so, actors with somewhat heterogeneous information generate the foreign policy behavior of a given country.

The second point concerns the claim that countries interact over specific issues (Vasquez and Mansbach 1984; Dixon 1986; Vasquez 1993; Hensel 2001). By this argument, the foreign policy series that scholars study are aggregates of foreign policy interactions across different issue areas. For example, Dixon (1986) argues that different action—reaction processes described U.S.-Soviet interactions in political, military, and cultural issue areas. A similar argument is raised by scholars who contend that cooperative behavior and hostile behavior should be measured on two dimensions, instead of a single cooperation-hostility dimension. To the extent that foreign policy behavior is somewhat distinct across issue areas, actors might well have different time horizons for different issues. To the extent that this is so, a single series that aggregates across issue areas will be fractionally integrated.

This discussion implies a few expectations. First, we conjecture that foreign policy series created from events data are likely to be fractionally integrated. In some series, a consistent foreign policy across multiple issues may well produce stationary series. We are not ruling those out. Similarly, there may be a few series that exhibit perfect memory (i.e., a unit root), although we are circumspect about the likelihood of observing such series. However, we suspect that at a minimum, many, and likely most, foreign policy series are fractionally integrated. Second, and more specifically, we suspect that foreign policy series that are aggregated across actors will be fractionally integrated and exhibit longer-memoried processes than directed-dyadic series composed of one country's behavior. Third, given the prevalence of reciprocity models of foreign policy in the literature, we suspect that some, and perhaps many, dyadic foreign policy series are fractionally cointegrated. In the following section, we specify a reciprocity model and describe the data and research design we use to explore these expectations.

RESEARCH DESIGN

Because we are interested in reciprocity in foreign policy, we specify and estimate an action–reaction model. As noted above, if the series have a long-run equilibrium relationship, then an error correction model will help us model that relationship. An error-correction relationship is captured via the difference of the lagged values of two series. If we have two series, say the foreign policy behavior of country x toward country y (call that series X_t) and the foreign policy behavior of country y toward country x (call that series Y_t), then the error-correction mechanism (ECM) can be written as $(X_{t-1} - Y_{t-1})$.[6]

6. This specification of the error correction mechanism imposes the simplifying assumption that both countries respond to one another in a perfectly reciprocal fashion. A generalized error correction mechanism (GECM) can be written as $\Delta X_t = -\alpha(X_{t-1} - \lambda Y_{t-1})$. We assume that $\lambda = 1$. The virtue of this assumption is that it simplifies the analysis. See Banerjee et al. (1993, 50-61) for a discussion of how to estimate the GECM and DeBoef (2001) for an applied model.

To see why the ECM helps one model a long-run equilibrium relationship, consider what happens to the change in X_t when the difference between X_{t-1} and Y_{t-1} is zero: $\Delta X_t = -(X_{t-1} - Y_{t-1})$. In such a circumstance, there will be no change in X_t. Now imagine that the difference is positive (i.e., $X_{t-1} < Y_{t-1}$). In that situation, ΔX_t will have a negative value as it is revised downward to bring it back in line with Y_t. If the difference between X_{t-1} and Y_{t-1} is negative, then ΔX_t will have a positive value. see Errata

Of course, according to action–reaction models, Y_t will also be influenced by the difference of the lagged value of the two terms, and we can write that as ($Y_t = (X_{t-1} - Y_{t-1})$. Note the absence of a negative sign in front of the ECM in this equation. This ensures that when the difference between X_{t-1} and Y_{t-1} is positive (i.e., $X_{t-1} < X_{t-1}$), ΔY_t will be positive, bringing Y_t back in line with X_t. Furthermore, when the difference between X_{t-1} and Y_{t-1} is negative, ΔY_t will be negative. Thus, the ECM is a convenient term for modeling a long-run equilibrium relationship in a regression. Because action–reaction theory leads us to anticipate such a relationship, we add an ECM term to equation (1) above. see Errata see Errata

There are, of course, an enormous number of pairs of countries (or dyads) one might study. We selected Egypt and Israel, the United States and China, the United States and Russia, the United States and France, and the United States and Israel in honor of Ward's (1982) initial study in this area, which focused on those countries.

This spatial domain does not permit us to generalize beyond the sample—it is not a random sample of directed dyads. However, we have no cause to believe that it suffers from any specific sample selection bias and thus cannot argue that the results are unrepresentative of the population of directed dyads. We study monthly foreign policy behavior, and the temporal domain of the study varies in accord with the data set we used: 1948:1 to 1978:12 (Cooperation and Peace Databank [COPDAB], 1966:1 to 1991:12 (World Event Interaction Survey [WEIS]), and 1987:1 to 1997:6 (Kansas Events Data System [KEDS]). We study several data sets to see whether our results were dependent on a specific coding scheme. All directed dyads are available in the COPDAB and WEIS data, but the KEDS project has a more limited set of options. Because the U.S.-China directed dyad was available in the KEDS data, we selected it as the directed dyad to study across all three data sets.[7]

All three data sets take the same general approach to measuring foreign policy behavior: they code news reports of events using a scheme in which an actor and target are identified, the type of behavior sent by the actor to the target is coded on an ordinal scale that measures a cooperative to hostile dimension, and the date of the event is recorded. The COPDAB and WEIS data were created using human coders, and the KEDS data were created with machine-assisted coding.

We use the net score of the weighted events, where net score equals the difference of cooperative and hostile events aggregated over the month. The COPDAB weights were created by surveys of experts by Azar (1993) and are reported in the COPDAB manual. Goldstein (1992) created a set of weights for the WEIS data, and the KEDS project has produced a slightly modified set of Goldstein weights for its data.[8] These

7. Due to considerations of space and ease of presentation, we focus the bulk of our analysis on one data set, COPDAB.

8. These weights are available online at http://www.ukans.edu/~keds/KEDS.WEIS.code.html.

weights are used to create interval-like data from the ordinal COPDAB and WEIS scales. To aggregate the series into monthly intervals, we calculated the mean of all weighted events during the month.

ESTIMATION AND RESULTS

We examine the properties of several popular events time series used in the international relations literature. We begin with a univariate examination of the individual series to determine whether they are (1) stationary, or I(0); (2) fractionally integrated, or I(d), where $0 < d < 1$; or (3) integrated I(1). We find that with one exception, there is strong empirical evidence that these foreign policy series are all fractionally integrated. After outlining our series of tests, we present the results of a multivariate analysis that estimates parameters for an action–reaction model in a fractional cointegration framework.[9]

Table 1 shows the results of multiple tests of stationarity.[10] The Dickey Fuller and Augmented Dickey-Fuller each tests a null hypothesis of a unit root, making it susceptible to false acceptance of unit roots when data are insufficient for significant *t* scores. Diebold and Rudebusch (1991) further demonstrate the low power of Dickey Fuller tests when faced with fractional alternatives. For every variable in Table 1, we can reject the null hypothesis of unit-root behavior. However, given the limitations of these tests and the possibility of fractional integration, we do not stop at this point and use additional tests to further diagnose our series.

The variance ratio test tests a null hypothesis of a random walk with drift versus an alternative hypothesis of fractional noise (Diebold 1989). Again, we reject the null hypothesis of a random walk for every series of interest here. Rejection of unit-root/random-walk hypotheses does not necessarily imply that a series is I(0), and thus additional tests with null hypotheses of stationary behavior are useful.

Two such tests are developed by Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (1992). Each of the KPSS tests tests a null hypothesis of a stationary, strong mixing process. The KPSS η_τ test includes an intercept and linear time trend, whereas the KPSS η_μ test does not. Table 1 shows that in most of our series, the null hypothesis of stationarity is rejected by one or both of these tests.

The last column of Table 1 summarizes the findings of these four tests. In 7 of 13 series, the tests agree that we should reject both extremes and conclude fractional integration. For another two series (United States to China and Israel to Egypt), the tests are contradictory, suggesting either fractional integration or level stationary. Tests of the remaining 4 series indicate level stationarity. Given this sometimes contradictory evidence and tests based on dichotomous choices, formal estimates of d become extremely useful at this point to diagnose the precise level of integration.

9. In the interest of conserving space, Table 3 presents only one set of parameter estimates, but we estimated parameters using all of the COPDAB series. Those results are similar, although not always as strong, and will be made available in a replication data set.

10. For a brief comparative summary of the tests to follow, including estimators for d, see Lebo, Walker, and Clarke (2000).

TABLE 1
Summary of Stationarity Diagnostics

Data Set, Year, Variable Name	*DF/ADF*	*Variance Ratio*	*KPSS*(η_τ)	*KPSS*(η_μ)	*Diagnosis*
KEDS 87:1-97:6					
China to United States	Reject $d = 1$	Reject $d = 1$	$d = 0$	$d = 0$	$d = 0$
United States to China	Reject $d = 1$	Reject $d = 1$	$d = 0$	$d = 0$	$d = 0$
WEIS 66:1-91:12					
China to United States	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
United States to China	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	$d = 0$	$0 \leq d < 1$
COPDAB 48:1-78:12					
China to United States	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
United States to China	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
United States aggregate sent	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
United States aggregate Received	Reject $d = 1$	Reject $d = 1$	$d = 0$[a]	$d = 0$	$d = 0$
Egypt to Israel	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
Israel to Egypt	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	$d = 0$[a]	$0 \leq d < 1$
United States to USSR	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
United States to France	Reject $d = 1$	Reject $d = 1$	Reject $d = 0$	Reject $d = 0$	$0 < d < 1$
United States to Israel	Reject $d = 1$	Reject $d = 1$	$d = 0$	$d = 0$	$d = 0$

NOTE: DF = Dickey Fuller; ADF = Augmented Dickey-Fuller; KEDS = Kansas Events Data System; WEIS = World Event Interaction Survey; COPDAB = Cooperation and Peace Databank.
a. Reject at .1 level.

Table 2 shows the results of our *d* estimates. Each estimate of *d* is tested against both the possibility that the series is I(0) and that it is I(1)—*t* values shown are based on how many standard errors away from 0 and 1 estimates are thus giving a much better ability to pinpoint the level of integration than any or all of the tests Table 1 provides. Based on the *d* estimates, we can conclude that *d* does not equal 0 for 12 of our 13 series. One possible exception is United States to China in the KEDS data: behavior between the United States and China in each of the KEDS, WEIS, and COPDAB data sets; between Egypt and Israel in the COPDAB data set; and for aggregate measures of United States behavior in the COPDAB data. American behavior toward Israel, for which our estimate of *d* is 0, is the only series that appears to be level stationary. Note that the 4 series with the lowest estimates of *d* (United States to Israel $d = 0$, United States to China $d = .10$, United States received, and China to United States $d = .15$) are the 4 series for which our stationarity tests cannot reject the possibility that $d = 0$. The general agreement between the unit-root/stationarity tests and the *d* estimates demonstrates the value of employing *multiple* tests of stationarity to first home in on the correct order of integration and then pinpoint it using the direct estimates.

see Errata

Furthermore, Table 2 tells us that we can be very confident that *d* does not equal 1 for any of these series. This result indicates that using first differencing would over-difference the series.[11] Thus, fractional integration characterizes all but one (or per-

11. For the consequences of over-differencing, see DeBoef and Granato (1997) and Lebo (2000).

TABLE 2
Estimates of *d* from (0, *d*, 0) Models

Data Set, Year, Variable Name	*Estimate of* d	*Standard Error*	t *Value,* d*(0)*	t *Value,* d*(1) see Errata*
KEDS 87:1-97:6				
China to United States	0.15	0.07	2.06*	–11.65**
United States to China	0.10	0.07	1.37	–12.34**
WEIS 66:1-91:12				
China to United States	0.24	0.05	4.75**	–15.05**
United States to China	0.21	0.05	4.16**	–15.64**
COPDAB 48:1-78:12				
China to United States	0.21	0.05	4.46**	–16.80**
United States to China	0.33	0.05	7.02**	–14.24**
United States aggregate sent	0.53	0.05	11.27**	–9.99**
United States aggregate received	0.14	0.05	2.98**	–18.28**
Egypt to Israel	0.47	0.05	9.99**	–11.27**
Israel to Egypt	0.55	0.05	11.69**	–9.57**
United States to USSR	0.29	0.05	6.17**	–15.09**
United States to France	0.17	0.05	3.61**	–17.65**
United States to Israel	0.00	0.05	0.00	–21.26**

NOTE: KEDS = Kansas Events Data System; WEIS = World Event Interaction Survey; COPDAB = Cooperation and Peace Databank. Estimates of *d* are based on Robinson's (1995) Gaussian semiparametric estimator using regression analysis of time series procedure (RGSER). RGSER is available at http://www.estima.com or by request. To obtain the *d* estimate of the undifferenced series, one must first difference the series creating a (0, 1 + *d*, 0) series, then estimate *d* and finally add 1 to the *d* estimate obtained (see Lebo, Walker, and Clarke 2000 for an explanation of these and other estimators of *d*).
$*p < .05$. $**p < .01$.

haps two) of these series. Each of these series will be mean reverting in the long term, but events will have far more enduring effects than researchers who have concluded stationarity have assumed. These results support our expectation that foreign policy event count series are fractionally integrated. Finally, these results tell us that cointegration in the traditional sense cannot be present, and thus traditional use of ECMs is not appropriate. However, given fractional integration, fractional cointegration may exist, allowing for the use of fractional error correction mechanisms (FECMs).

Given the frequency with which series like these will be fractionally integrated, new methods must be applied to effectively judge the relationships between two or more such variables. Two major areas are important here: first, the practice of fractional differencing must be applied to ensure that variables are not under- or over-differenced; second, because none of these variables is a unit root, traditional cointegration techniques will not apply. We must acquaint ourselves with how to test for, and model with, the more general fractional cointegration techniques.[12]

12. See De Boef (2001) for a discussion of error correction models in the context of near integration, a topic that is beyond the scope of this study.

As our example here, we estimate parameters for an action–reaction equation that captures Egyptian actions toward Israel as compiled for the 1948 to 1978 period in the COPDAB data set. As seen in Table 2, both the Egypt-Israel and Israel-Egypt series are fractionally integrated. Given the history between the two countries, we would certainly expect a close relationship between the two series: actions by one are likely to be reciprocated by the other. To judge the closeness of this relationship in a simple regression framework, we would need to first fractionally difference each series.[13]

Before estimating this model, however, we test for evidence of fractional cointegration. Again, given that neither series is I(1), traditional approaches to cointegration would not allow the possibility of testing for the existence of a long-run equilibrium relationship between the two. However, we can test for a fractionally cointegrating relationship by relaxing this qualification and testing to see if some combination of two variables has a lower level of integration than either of the two parent series. For the Egypt-Israel directed dyad, the residuals of a simple regression are integrated of a significantly lower level ($d' = .17$) than are either of the parent series (Egypt-Israel $d = .47$, Israel-Egypt $d = .55$). Thus, finding that $d' < d$ for both Egypt-Israel and Israel-Egypt, we conclude that a fractionally cointegrating relationship exists between the two series. That d' is more than six standard errors below d for either parent series provides confidence in this conclusion. Thus, an equilibrium relationship exists between the two variables such that an event that moves them apart will be impermanent (Clarke and Stewart 1995). With fractional cointegration, however, the rate at which the two series return to their equilibrium following such an event is much slower and nonconstant than in a cointegrating relationship; that is, the error correction term itself is long memoried. Given this relationship, a FECM is appropriate to model the equilibrium relationship (Clarke and Lebo forthcoming).

Having found evidence of fractional cointegration, we now estimate equation (1) with an ECM term added to capture directly the error-correction process. We report three sets of estimates in Table 3: a set in which we have fractionally differenced the series, a set in which we difference the series as would be done if one determined that the series were unit roots, and a set in which the parameters were estimated using the level series as would be done if one determined that the series were I(0). Thus, we can compare whether the estimates are influenced by these decisions. Although the signs and significance of the parameters do not vary across the three models, the size of the parameters and some of the summary statistics vary in precisely the fashion anticipated in the literature on integration.

Column 1 of Table 3 shows our multivariate model of Egyptian actions toward Israel. The dependent variable is fractionally differenced by its own value of d (.47) using the filter $(1 - B)^{.47}$ prior to estimation. Included as independent variables are Israeli actions toward Egypt (filtered by $(1 - B)^{.55}$) and a FECM (filtered by $(1 - B)^{.17}$).

The close relationship between Egyptian and Israeli actions is evident. The coefficient of .29 on the Israel to Egypt variable and the t statistic of 6.75 indicate that Egypt reciprocates Israel’s hostile behavior with behavior that will on average be about one-

13. Whereas first differencing applies the filter $(1 - B)$ to a given series, fractional differencing applies the more general filter $(1 - B)^d$. The regression analysis of time series (RATS) code for fractionally differencing the series will be included in our replication data set.

TABLE 3
Egyptian Behavior toward Israel, 1948 to 1978:
ARFIMA, ARIMA, and ARMA Models

Independent Variable	*Fractional Model*[a]		*Differenced Model*[b]		*Level-Form Model*[c]	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	3.20**	0.83	0.05	0.83	–9.61**	1.08
Israel to Egypt	0.29**	0.04	0.36**	0.04	0.50**	0.04
t	6.75		9.65		13.04	
FECM{1}	–0.39**	0.05	–0.88**	0.05	— see Errata	
t	–7.75		–16.90			
Durbin-Watson	1.89		2.05		1.84	
Sum of squared residuals	88,225		93,917		98,033	
Standard error of estimate	15.50		15.98		16.28	
Centered R^2	0.20		0.47		0.31	

NOTE: ARFIMA = autoregressive fractionally integrated moving average; ARIMA = autoregressive integrated moving average; ARMA = autoregressive moving average; FECM = fractional error correction mechanism.
a. ARFIMA: Dependent variable differenced by 0.47; Israel to Egypt differenced by 0.55; error correction mechanism differenced by 0.17.
b. ARIMA: All variables differenced by 1.
c. ARMA: All variables left in level form, no error correction mechanism estimated.
$^{**}p < .01$, one-tailed test.

third as hostile as Israel's behavior. More specifically, if Israel were to mobilize troops or impose sanctions (a weighted score of 29 on the COPDAB scale), then on average Egypt can be expected to respond with an 8.4 level event, which is closest to a diplomatic statement expressing dissatisfaction with the action (a weighted score of 6 on the COPDAB scale). But this coefficient tells only part of the story.

The FECM parameter is also statistically significant, indicating that an equilibrium relationship exists between the two. Thus, actions that move these variables apart will eventually dissipate as the two re-equilibrate 39% in the first period and $(1 - B)^{.39}$ in subsequent periods. Put differently, Egypt's initial response will be measured—only one-third as hostile as Israel's act. However, Egypt will on average continue to raise its conflict toward Israel in subsequent months: the effect of the troop mobilization or sanctions would not dissipate with Egypt's initial response. Thus, failure to include the FECM term would misconstrue the effect of Israel's behavior on Egypt's foreign policy toward Israel (which we will explore below). How does the FECM model compare with a traditional ECM model?

The second column in Table 3 shows that using a traditional ECM here would overestimate Egypt's average response to Israel and the speed with which equilibrium will be regained once lost. In the differenced model, the variables are differenced in a traditional (0, 1, 0) format, and an ECM is used as though the series cointegrate in the traditional sense. First, note that the estimated coefficient for the Israel to Egypt variable is .36. This also implies a roughly one-third average response rate by Egypt to Israeli hostility, although .36 is larger than .29. The larger bias is found in the estimated parameter of the ECM versus the FECM: .88 compared with .29. If we relied on the differenced model and ECM, we would conclude that 88% of a shock that moved the two variables apart would be forgotten one month later, and another 88% of what remained would be forgotten in the month after that. The FECM of the correctly specified model of the first column demonstrates that re-equilibration is a much more gradual process: Egypt "remembers" events far longer than the differenced model suggests. If these results generalize to other dyads, then Rajmaira and Ward's (1990) cointegration findings with respect to the U.S.-USSR rivalry overestimate the speed at which they return to equilibrium.

Furthermore, the second column of Table 3 demonstrates the several problems we introduce by failing to properly account for fractional integration in our variables. The values of *t* statistics are biased, as is the R^2 statistic, which more than doubles from .20 to .46, making evident the tendency of over-differenced models toward finding relationships where none exist.

Last, the third column of Table 3 treats the variables as though they were level stationary and uses them in their original form. The results are biased in the estimates of coefficients and model fit.[14] First, the coefficient for the Israel to Egypt variable suggests that on average, Egypt metes out about one-half of Israel's hostile behavior. Continuing with the example from above, if Israel mobilized troops or imposed sanctions, this suggests that Egypt would respond with a 14.5-level event, perhaps by a warning retaliation (which is closest with a weighted COPDAB score of 16). However, that event will not have an impact in subsequent months.

Most important, the fractional model is true to the nature of the data-generating process as tested, whereas the differenced and level-form models are not. The fractional model incorporates the memory of the variables of interest as precisely estimated, whereas the second and third models proceed from the false assumption that *d* must equal 0 or 1 and guess work about which extreme should be appropriate.

Substantively, one goal of action–reaction studies can be to analyze the responsiveness of each party to the behavior of the other party (or, in more complex action–reaction models, the behavior of a third party). Although the purpose of this article is to demonstrate new tools, our results do have some substantive implications. First, the low estimates of *d* suggest that although the past matters, memory is finite: the estimates suggest that the series are long memoried, but, relatively speaking, not exceptionally long memoried (events do not continue to have an impact years or decades later). This finding implies that hawkish perspectives that emphasize the impossibility of cooperation between rivals are politicized claims rather than reality-based claims (see also Goldstein and Freeman 1990). Second, the fractionally differenced estimates of the error-correction action–reaction model indicate that although Egypt was unwilling to drift apart from Israel for too long during the Nasser and Sadat years, it was willing to drift apart for longer than one would infer if one did not fractionally difference the series. Thus, with respect to the main purpose of the article, this example shows the importance of incorporating fractional integration in studies of international behavior.

14. These problems are not solved by including a lagged endogenous variable.

CONCLUSION

Extant time-series studies of foreign policy behavior are subject to criticism because they have confined their modeling choice to either stationary or nonstationary behavior. This oversimplification leads us to misunderstand both the nature of individual variables and the relationships among variables. We have argued that foreign policy series aggregate over heterogeneous data-generation processes and are thus likely to be fractionally integrated. These expectations are met because our estimates of the fractional differencing parameter, d, indicate that fractional integration is prevalent among these series. We further find support for our contention that memory will be longer (and d values larger) in relationships between friendly nations.

Choosing a level of integration to describe one's variables of interest is not simply a matter of modeling choice. Rather, it implies important assumptions about the nature of the variables themselves. Limiting ourselves to just two such choices is an oversimplification that leads to our misunderstanding the nature of the variables. Furthermore, using methods such as ARIMA that allow for only integer levels of integration leads to large problems when we estimate the relationships between variables. Using ARFIMA models instead allows us a much more precise explanation of the data and increases our ability to understand complex political relationships.

In our example above, we found that the relationship between Israel and Egypt for the period from 1948 to 1978 is fractionally cointegrated. Thus, as suggested by Rajmaira and Ward (1990), cointegration techniques are appropriate for the study of foreign policy in rivalries; however, these authors may well overstate the closeness of the cointegrating relationship. We find evidence that although these two series exist in a long-term equilibrium, disruptions to this equilibrium will take a long time to dissipate.

Future studies that use directed-dyadic foreign policy series and other measures of international behavior over time should carefully consider the construction of their series and be aware of the particular problem aggregation engenders. The use of fractional integration and fractional cointegration techniques should greatly enhance researchers' abilities to specify the dynamics of international behavior.

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Errata

Note: the corrigenda listed here were corrected for the final version.

Page 13: add "ARFIMA" to keywords

Page 19: Equation 3. The right-hand side of the equation looks like an exponent, i.e. the print is too small. The right-hand side should be the same font as the left-hand side of the equation.

Page 19: Second paragraph, first line. Reads: ("B)Xt….
The quotation marks before the B shouldn't be there, and B should be italicized. It should read: $(B)X_t = X_{t-1}$

Page 23: first paragraph, 4th line. Reads: (i.e., $X_{t-1} < Y_{t-1}$)
It should say: (i.e., $X_{t-1} > Y_{t-1}$)

Page 23: second paragraph, 2nd line. Reads: ($Y = (X_{t-1} - Y_{t-1})$
It should say: $\Delta Y = (X_{t-1} - Y_{t-1})$

Page 23: second paragraph, 4th line. Reads: (i.e., $X_{t-1} < X_{t-1}$)
It should say: (i.e., $Y_{t-1} < X_{t-1}$)

Page 25: first paragraph, 3rd sentence. It reads:

> Based on the *d* estimates, we can conclude that *d* does not equal 0 for 12 of our 13 series. One possible exception is United States to China in the KEDS data: behavior between the United States and China in each of the KEDS, WEIS, and COPDABdata sets; between Egypt and Israel in the COPDABdata set; and for aggregate measures of United States behavior in the COPDAB data.

Please revise so that it reads as follows:

> Based on the *d* estimates, we can conclude that *d* does not equal 0 for 12 of our 13 series: behavior between the United States and China in each of the KEDS, WEIS, and COPDAB data sets; between Egypt and Israel in the COPDABdata set; and for aggregate measures of United States behavior in the COPDAB data. One possible exception is United States to China in the KEDS data.

Page 26: Table 2. Row of headings. Column headings are incorrect.
Change: "t value, d(0)" to "t value, $d \neq 0$"
Change: "t value, d(1)" to "t value, $d \neq 1$"

Page 28: Table 3. *Independent Variable* column. The term FECM{1} should read: (F)ECM{1}. In column two it is an FECM term, but in column three it is an ECM term, hence the parentheses around F.