DID FERTILITY GO UP AFTER THE OKLAHOMA CITY BOMBING? AN ANALYSIS OF BIRTHS IN METROPOLITAN COUNTIES IN OKLAHOMA, 1990–1999*

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Political and sociocultural events (e.g., Brown v. Board of Education *in 1954 and the German reunification in 1989) and natural disasters (e.g., Hurricane Hugo in 1989) can affect fertility. In our research, we addressed the question of whether the Oklahoma City bombing in April 1995, a man-made disaster, influenced fertility patterns in Oklahoma. We defined three theoretical orientations—replacement theory, community influence theory, and terror management theory—that motivate a general expectation of birth increases, with different predictions emerging from time and geographic considerations. We used two different empirical methodologies. First, we fitted dummy-variable regression models to monthly birth data from 1990 to 1999 in metropolitan counties. We used birth counts to frame the problem and general fertility rates to address the problem formally. These analyses were organized within two design structures: a control-group interrupted time-series design and a difference-in-differences design. In these analyses, Oklahoma County showed an interpretable, consistent, and significant increase in births. Second, we used graphical smoothing models to display these effects visually. In combination, these methods provide compelling support for a fertility response to the Oklahoma City bombing. Certain parts of each theory helped us organize and understand the pattern of results.*

Many people believe that human reproduction is highly sensitive to influences from the surrounding sociocultural milieu. After the terrorist attacks in New York City and Washington, DC, on September 11, 2001 (hereafter 9/11), newspaper articles, speeches (e.g., by First Lady Laura Bush), and general speculation posited that U.S. birth patterns would change after 9/11 (e.g., "Baby Miniboom" 2002). Other reports were more cautious (e.g., "No Sign" 2002). However, even this latter relatively cautious and careful report included the following quote: "Dr. Michael Silverstein . . . at New York University's School of Medicine, said many of his patients told him the events of September 11 motivated them to have a child." Two years after the terrorist attacks, on September 15, 2003, *The New Yorker* published an evocative poem written by Deborah Garrison that explicitly stated the link between the terrorism in New York and a desire for childbearing: "When I learned of / The uncountable, the hellbent obscenity, / I felt, with shame, a seed in me, / Powerful and inarticulate: / I wanted to be pregnant" (p. 68).

Do disasters—either natural or man-made—generally influence birth patterns? Popular belief is not always correct. Newspapers confidently reported a "mini baby boom" in New York City hospitals exactly nine months after the famous power blackout in November 1965, but the blackout effect did not actually show up in a careful analysis (Udry 1970). However, negative results like Udry's did not preclude speculation about the "blackout baby-boom effect" following the most recent major U.S. power blackout in August 2003 in the northeastern United States; any number of newspaper articles and columns predicted a "recurrence" of the discounted 1965 effect. Other even more subtle

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birth effects have been proposed, accepted, but then relegated to the category of "urban legend" (Brunvand 1993).[1]

The question posed in this article is whether a particular man-made disaster—the Oklahoma City bombing in April 1995—had an effect on human fertility behavior. We begin with a brief review of examples in which birth patterns did respond to well-known events of the time. Next, we describe the events surrounding the Oklahoma City bombing. We then define some theoretical orientations that have helped us to understand and organize our thinking about fertility responses to the Oklahoma City bombing and develop predications of what might be expected in response to the Oklahoma City bombing. Next, we report the results of our empirical study of 10 years of birth patterns in metropolitan counties in Oklahoma.

LITERATURE REVIEW AND THEORY

Are there previous and documented examples in which birth patterns shifted in response to cultural/political events, terrorism, and natural disasters? A number of such examples exist in the demographic and other social science literature. First, there was a measurable reduction in births in the southern United States following the 1954 *Brown v. Board of Education* court ruling that ended legal segregation of schools (Rindfuss, Reed, and St. John 1978). Researchers interpreted that reduction—which began around 12 months following the court decision—as a behavioral reaction to giving birth to children in a sociopolitical environment that was at odds with the prevailing southern culture during that period. More recently, birth rates declined dramatically (by about 60% between 1989 and 1994) in East Germany following the German reunification in 1989. This response was called "the most substantial fall in birth rates that has ever occurred in peacetime" (Conrad, Lechner, and Werner 1996:331) and was interpreted as a "demographic shock" caused by the difficulty of assimilation during the transitional period after reunification.[2] An example of fluctuations in birth patterns following a natural disaster was reported in relation to Hurricane Hugo (Cohan and Cole 2002). Following the hurricane in 1989, births (as well as marriages and divorces) increased in the 22 affected counties in South Carolina, compared with those that were not affected. Other recent work also suggested a reduction in divorces immediately following the Oklahoma City bombing (Nakonezny, Rodgers, and Reddick 2004).

In the Oklahoma City bombing, a man-made disaster that occurred on April 19, 1995, 168 people were killed, and hundreds more were injured. Of particular relevance is that 19 of those who were killed were children in the Murrah Building day care center. The press paid considerable attention to the deaths and injuries of the children. The dominant visual image that emerged from the bombing was a picture of a fireman carrying the body of a baby, Baylee Almon, out of the wreckage.

The Oklahoma City community responded to the bombing with a community sense of "pulling together." Media attention focused on the positive and community-oriented response in the face of the disaster. Workers came from outside the Oklahoma City area to assist, but the majority of the restoration effort came from within the community itself. These two features of the Oklahoma City bombing—the role of the children and the response of the community—are important in the interpretation of our findings.

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1. In fact, a whole system of urban legends has developed regarding fertility and/or sexual behavior in relation to apparently plausible external stimuli. One story involves the existence of a small town with an extraordinary number of children. The story claims that the excess fertility is caused by a train passing through the town very early every morning, blowing its whistle loudly, and awakening couples to fulfill their parental calling. See Brunvand (1993) for this and other stories of urban legends.

2. Lechner (2001) provided a partial reinterpretation of the East German fertility decline, suggesting that the effect was, at least in part, a change in the timing of births, as the East Germans postponed childbearing to match the patterns in West Germany. Whether the decline reflects a change in the quantum or tempo of fertility (or, perhaps, both), this literature documents a strong fertility response to reunification.

We collected data from Oklahoma vital statistics records on births in each of the 12 metropolitan counties in Oklahoma for each month from 1990 to 1999; both raw birth counts and general fertility rates (GFR) were defined and analyzed. Six counties are part of the Oklahoma City metropolitan area. Oklahoma County, which includes urban Oklahoma City, is where the bombing actually occurred. The other six counties are in other parts of the state, five in the Tulsa metropolitan area (about 100 miles northeast of Oklahoma City) and one that includes the small city of Lawton (about 90 miles southwest of Oklahoma City).

The demographic literature contains a broad treatment of how and why fertility changes. The "long" perspective of fertility change is typically cast in the context of demographic transition theory (e.g., Notestein 1945), which accounts for and attempts to explain the timing of and relationships among declining mortality, declining fertility, and economic/technological development. Theoretical developments that followed included Becker's (1960) household economic perspective, which applied theory from microeconomics to fertility decision making; Easterlin's (1978) supply-and-demand perspective linking economic and sociological theory; and Davis's (1963) "multiphasic theory" of demographic change, which combined contraceptive decision making and stresses within the household in explaining fertility change. More recent reformulations and challenges have been offered by Knodel and van de Walle (1979), who suggested that culture is more important than economics in accounting for fertility change, and by Lesthaeghe's (1983) ideational theory, which further developed the importance of accounting for culture in explaining fertility change. For a review of these theories of the determinants of fertility change, see Hirschman (1994).

Do these broad theoretical perspectives have relevance for understanding the possible effect of the Oklahoma City bombing on birth patterns in metropolitan counties in Oklahoma? The answer is partly yes, but in a general sense. In this article, we present three focused and specific theoretical formulations that helped us understand fertility responses in Oklahoma City, each of which draws in some key elements from these broader perspectives. The concept of the demand for children that emerged from earlier economic theories of fertility change is especially relevant. As we consider what happened within households in Oklahoma during the second half of the 1990s, the bombing could have influenced couples in a number of different ways, through their planning, thinking, and even unconscious expectations and desires for children. Although our theoretical development emerged from these earlier broader theories, our empirical analyses do not in any sense test these broad perspectives. Rather, we defined theories that make specific and sharp distinctions between what might have happened in Oklahoma County itself, in the broader Oklahoma City metropolitan area, and in other metropolitan counties in Oklahoma. In other words, our theories were designed to help us understand and organize our thinking about the ways in which the Oklahoma City bombing might have influenced birth planning and birth patterns.

Our specific prediction was that births would increase in response to the bombing. But there are more-subtle and -nuanced statements that emerge from various theories than that births should simply increase. The demographic literature distinguishes between the quantum and tempo of fertility. Bongaarts and Feeney (1998:290) stated that "quantum refers to the average number of children born to women in a cohort, and tempo to the timing of births by age of mother within the cohort." Our analysis was of a specific period effect on fertility—the effect of a single historical event. Within this context, we considered tempo effects, which may (or may not) also be ultimately realized as quantum effects (depending on whether women within this cohort eventually had more children than they would have had otherwise or whether any additional babies born after the bombing reflected earlier childbearing, but not an overall increase in childbearing).

The three specific theoretical perspectives we used to help motivate our prediction of increased births following the bombing are not broad perspectives like those stated earlier; rather, they were specifically chosen because they apply to disaster situations like the one in Oklahoma City in April 1995. Two of the theories were partially borrowed from other sources and then further developed explicitly in relation to the Oklahoma City bombing. The third is a psychological theory that was explicitly defined to model responses to terrorism. The three perspectives agree in predicting an increase in births following the bombing. More specifically, they predict an increase in births in certain areas compared with the counterfactual consideration of the number of births if the bombing had not occurred. Obviously, critical design innovations are required to evaluate this type of counterfactual causal reasoning—specifically, the inclusion of a time series (to observe the momentum and patterns preceding the bombing) and of comparison counties (to observe effects in settings that should have responded differently from those that were directly involved in the bombing area). The two (equivalent) design structures that we used—the control-group interrupted time-series design from the evaluation literature and the difference-in-differences design strategy from the econometric literature—have been widely applied for this type of purpose.

The three focused and specific theoretical perspectives that we used included community influence theory, replacement/insurance theory, and terror management theory. Community influence theory suggests that parents want to raise children in a positive and supportive community. Parents are presumed to have discovered that Oklahoma City was such a community through the response to the bombing. Replacement/insurance theory suggests that parents observed the loss of life, especially the loss of life of children in the day care center, and thus felt that life was more fragile than before. They responded by having more children. We posit this response as a psychological one in which parents ensure against the potential loss of their own children (or, in a sense, parents proactively replace that potential loss). Terror management theory (Solomon, Greenberg, and Pyszczynski 2000) suggests that when mortality becomes salient, people behave increasingly according to traditional values. Having children and raising families would be such a traditional response.

Although these three theories each predict increasing birth rates, they have different short- and long-term implications and geographic predictions. Community influence theory suggests a long-term effect, building over time as the positivity of the community becomes more and more salient (and lasting as long as the community response continues to be positive and supportive). Within this perspective, the effect should be the strongest in the actual location in which the disaster occurred (Oklahoma County), fairly strong in proximate locations (the other five Oklahoma City metropolitan counties), and less powerful in other parts of the state (where, for example, residents might have been impressed by the positive community environment in Oklahoma County, but would not expect to accrue much personal value from this environment). In relation to the broader theories of fertility change, community influence theory is strongly tied to the cultural features of ideational theory; in fact, it suggests a shift in the "birth culture" caused by a disaster, including a new recognition of positive features of the community culture that were already present, but that may not have been recognized.

Replacement/insurance theory would suggest a more immediate response, possibly dampening over time (in much the same way that someone might take out extra life insurance immediately following an unexpected death in the family and let it drop later). This type of effect should be observed broadly in Oklahoma City and other communities in which individuals feel personally tied to Oklahoma City, including the Oklahoma City suburbs and the other Oklahoma metropolitan counties. The dampening period may be fairly long term in relation to a disaster of this size. There is a strong link in this theory to demand/socioeconomic theories, in that couples are assumed to be responding to their (possibly unconscious) desire for children or, more specifically, for a certain number of children.

Terror management theory would suggest effects on those who were the most immediately influenced at a deep psychological level by the disaster, those for whom the bombing made their own mortality vivid and realistic. Those effects may dampen fairly quickly as the feelings of immediate threat to life decline and those who are affected return to the routines of everyday life. Or if media attention results in the "threat to life" remaining salient, the effect could persist for some time. Because the terror-management effect depends on the strength of the feeling of threat, the effect should be observed strongly in Oklahoma City and, to a relatively small extent, in other Oklahoma City counties and other metropolitan areas of the state. This theory would predict a potentially broad geographic effect of the bombing. However, the major effect should have occurred in Oklahoma City itself.

Any or all of the processes that are implied by these three theoretical perspectives can occur simultaneously. Empirical patterns can distinguish between the predictions of the theories, but they are not mutually exclusive. Thus, if there are measurable fertility responses to the bombing—within the context of our design structures—the patterns across time and geography will provide insights into which of the processes described in these theories are relevant in explaining fertility responses to disaster settings like the Oklahoma City bombing.

METHOD

Empirical Study

We begin with a description of two powerful design structures that helped us address the question posed in the title of this article. The two design structures are similar, but emerged from different disciplinary perspectives, one from evaluation/psychometric settings and the other from econometrics. The first design is an interrupted time-series design, with comparison counties acting as nonequivalent control conditions (see Cook and Campbell 1979:214). Cook and Campbell suggested that "the ability to test for the threat of history is the major strength of the control group time-series design" (p. 215). Our design is more powerful than a simple interrupted time-series design because of the presence of the comparison counties in other parts of the state to create a set of quasi-experimental control conditions against which to compare our Oklahoma City and Oklahoma County birth patterns. Shadish, Cook, and Campbell (2002) referred to the interrupted time series as a "particularly strong quasi-experimental alternative to randomized designs when the latter are not feasible and when a time series can be found" (p. 172). They followed by stating that "Interrupted time series . . . gain their advantage from the pretreatment series that allows many potential threats [to validity] to be examined" (p. 206).

The second is the difference-in-differences design, which is commonly used in the econometric literature. The term *difference-in-differences* refers to the comparison of a before-after pattern (a difference) across two settings, one that involves a social or political intervention and one that does not (i.e., a comparison condition). Heckman et al. (1998) stated that "a standard method for evaluating social programs uses the outcomes of nonparticipants to estimate what participants would have experienced had they not participated. . . . Outcomes of participants before and after they participate in a program are differenced and differenced again with respect to before and after differences for members of the comparison group" (pp. 1017 and 1019).[3]

3. It is symptomatic of disciplinary insularity that these two similar and powerful design structures have, apparently, not been treated together or compared to one another within the broad social science literature. At the least, a January 2005 search of several keyword databases using the Internet did not identify even a single co-occurrence of these two designs. For example, the PsychInfo database listed 154 articles with the keyword "interrupted time series" and 547 with "difference-in-differences"; the EconLit search engine listed 18 articles with a keyword of "interrupted time series" and 158 with "difference-in-differences"; the Sociological Abstracts listed 56 articles with a keyword of "interrupted time series" and 3 with "difference-in-differences." But none of these overlapped. In this footnote, we present a few comments on the similarities and differences in these two designs. First, the two designs have the same fundamental structure and goal; both the control-group interrupted time-series design and the difference-in-differences design compare change between a treatment and comparison condition, a comparison that eliminates many threats to the internal validity of the conclusions drawn from studies that use these designs. The difference-in-differences design does not typically require a time series and, in this sense, is a slightly weaker

The data that we used were county-level birth counts and GFRs for each of the 12 Oklahoma metropolitan counties for each month from 1990 through 1999; thus, we had 12 time series of 120 observations each. The birth counts were obtained directly from the vital statistics registries. The population counts of females aged 15–44 that were used to construct GFRs were obtained from the 1990 and 1999 vital statistics data (each from July of the relevant year) and a linear interpolation procedure. No population records are collected or published monthly at the county level. To estimate monthly county-level populations of females aged 15–44, we divided the transition from the 1990 and 1999 census figures into 108 equal segments and used these segments to define monthly population figures for each county from January 1990 until December 1999 (a few of these estimates are actually extrapolations, rather than interpolations, for January through June 1990 and from August through December 1999). Then, these monthly county population estimates of females aged 15–44 were divided into the monthly county birth counts, resulting in a set of statistics that placed counties with highly variable population values into a common metric. This interpolation procedure assumes linear growth across the 10-year period from which our data were obtained.[4]

When the date of the bombing—April 19, 1995—was lagged by a normal gestation, the earliest possible response was about nine and a half months later, in February 1996. Thus, we have approximately six years of data before the earliest possible effect of the bombing, whose trends we compared to the almost four years of postbombing data. The other counties provide comparison groups at both the local and statewide levels. We restricted our interest to metropolitan counties because the bombing was so strongly tied to its urban setting.

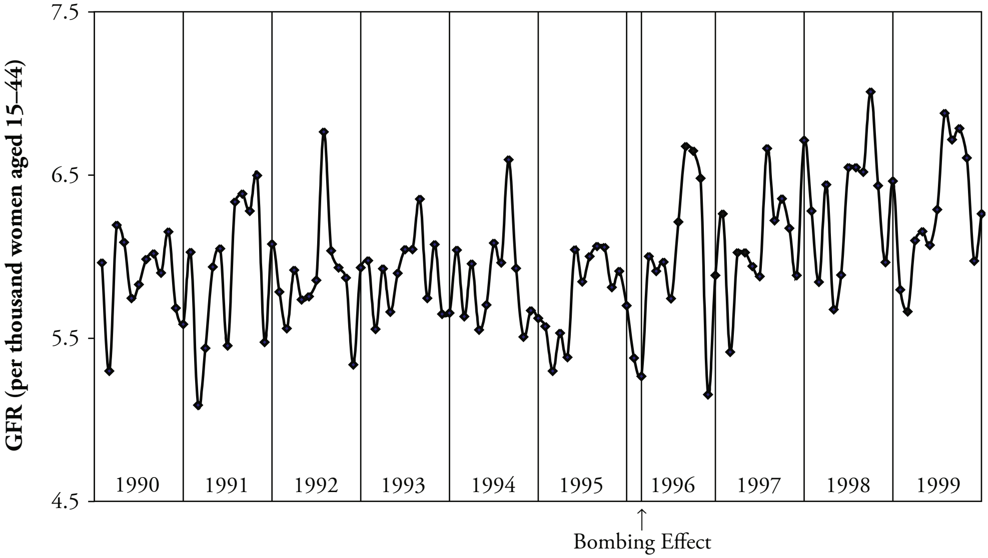
Birth data fluctuate widely. For example, in Figures 1a and 1b we present the monthly GFRs for Oklahoma County (the largest county in Oklahoma) and for McClain County (the smallest metropolitan county in Oklahoma) during the 1990s. The earliest timing of a possible bombing effect is marked on each graph at February 1996. Systematic monthly variability can be observed in these graphs. Furthermore, the scales on the *y*-axes of Figures 1a and 1b are obviously quite different. The Oklahoma County GFRs are less variable than those in McClain County (as a result of the larger population size, and thus lower standard errors, in the larger county). This difference is demonstrated graphically in Figure 1c, where the GFRs for Oklahoma County are equated to the scale for McClain County in Figure 1b.

design. On the other hand, the econometric literature provides considerable treatment of estimation and statistical issues arising from the difference-in-differences design (e.g., Bertrand, Dufli, and Mullainathan 2004; in fact, again reflecting disciplinary focus, there are many more references to "difference-in-differences estimation" than to "difference-in-differences design"). However, treatment of the interrupted time-series designs focuses on design issues, such as threats to validity and practical implementation issues, and are often separated from statistical issues (see Shadish et al. 2002:174). We view these different focuses as arising more from disciplinary style than from fundamental distinctions between the designs themselves. The literature on each design can inform the literature on the other. Originally, we focused our treatment in this article on the interrupted time-series design; through the encouragement of two reviewers, we broadened our thinking to include the conceptualization offered by the difference-in-differences design. Our data are certainly time-series data, and the Oklahoma City bombing naturally leads to the question, "is there an 'interruption' in the time-series pattern existing before the bombing?" The difference-in-differences method led us to give additional focus to the question, "how did the counties around Oklahoma City differ in their fertility differences before and after the bombing?," which further sharpened our methodology. The regression coefficients associated with our bombing-interaction dummy variables are "difference-in-differences" estimates, in units of the original raw births or GFRs, depending on the analysis.

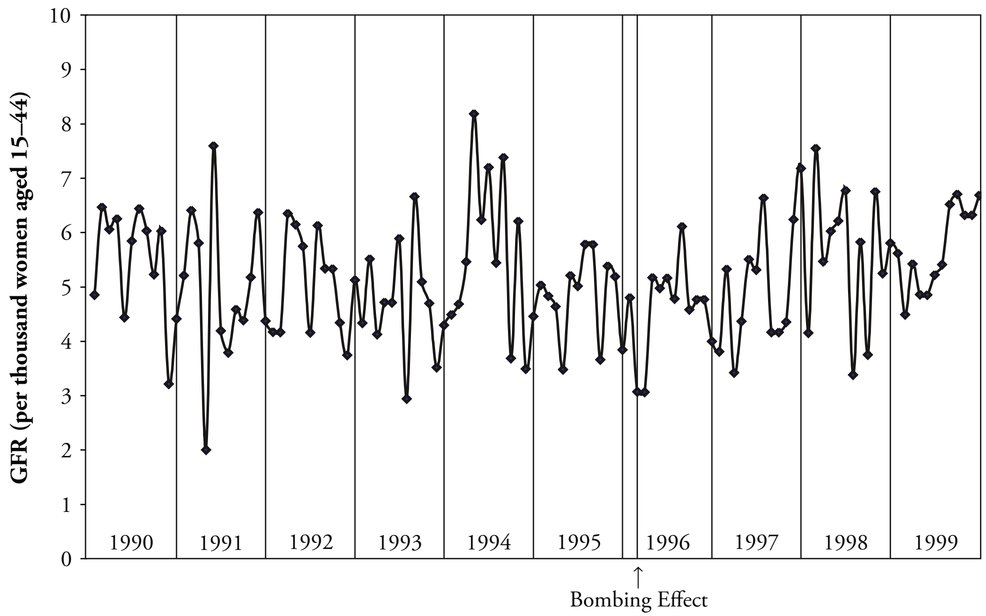
4. This assumption may not be tenable for periods within this time interval. However, because our goal is to compare across time periods and across counties, not to model the county-level population itself, this procedure should give close approximations for comparison purposes. In other words, to the extent that nonlinearities in county population growth are similar across the counties, assuming a linear growth pattern is a valid method for comparing across the counties using these estimated GFRs.

Figure 1. GFRs for Two Oklahoma Metropolitan Counties: Oklahoma County (the Largest Metropolitan County) and McClain (the Smallest Metropolitan County)

a. Oklahoma County GFRs



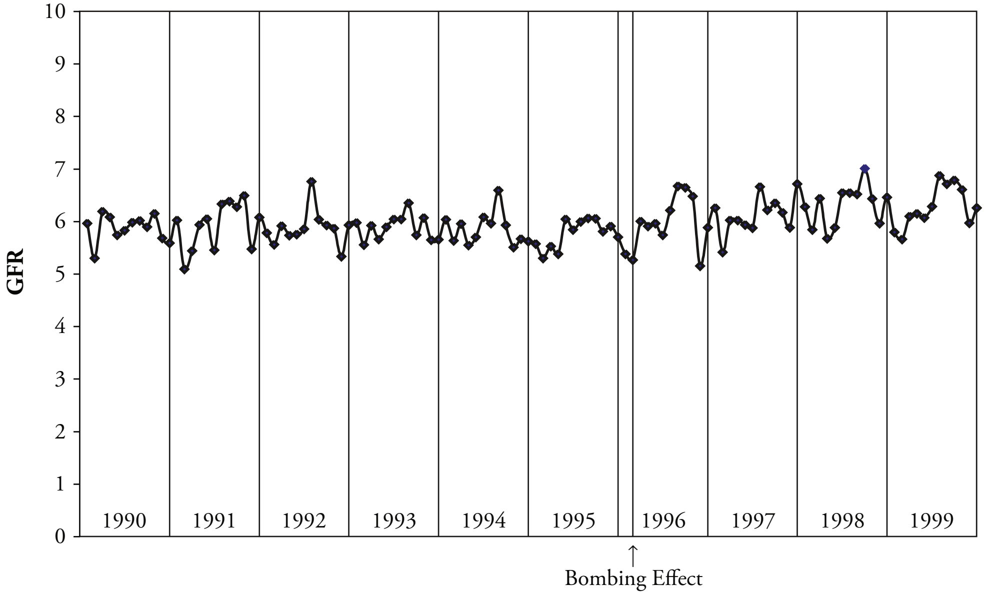
b. McClain County GFRs



(continued)

(Figure 1, continued)

c. Oklahoma County GFRs, With Scale Redefined to Match McClain County



Is an effect of the bombing apparent in these graphs? It is difficult to observe changes in birth patterns against such a statistically noisy background.[5] This variability is primarily attributable to two sources, differences between counties and differences between months, with the preponderance of the variability arising from the former. Even after we adjusted for population size by using GFRs, we found substantial differences in fertility among the counties. We fitted dummy-variable regression models to control for this extraneous variation. This methodology is routinely used in research on the seasonality of births, in which modeling the seasonality is of primary interest (e.g., see Rodgers and Udry 1988; Seiver 1985; see Ostrom 1978 for a more general treatment of regression approaches to analyzing time-series data). This methodology "measures" the deviation from the mean level that is associated with each dummy variable—that is, the deviation associated with January, with February, and so forth for the monthly dummy variables and the deviation associated with being in Oklahoma County, in Cleveland County, and so forth for the county dummy variables. When these dummy variables are included in the model, the structural variance associated with differences in monthly and county birth rates is moved out of the residuals (i.e., out of the error term) and is included in the model; as a result, the bombing effects in which we are interested are then "net of" the variance that is associated with months and counties.

5. Several years of data are required before a time trend can be established and evaluated in relation to this statistically noisy background. Furthermore, vital statistics reports of county birth records are usually not available for many months—or even years—after their collection. For these reasons, studies of demographic effects of the Oklahoma bombing could not be run until after 2000. Nor were early reports of apparent changes in birth, marriage, or divorce rates in relation to other disasters like the 9/11 attacks likely to be credible.

Many models that account for seasonality fit log transforms of the birth observations (e.g., Lam and Miron 1996). However, we retained the units of births in our dependent variables to interpret directly the regression coefficients in units of births (for the raw counts) or in units of births per female of childbearing age (for the GFRs). Finally, we footnote several technical issues surrounding time-series modeling that are beyond the scope of this study, but which may be of interest to experts in evaluating our findings (see, e.g., Cromwell, Labys, and Terraza 1994 for an explanation of the technical details).[6]

Graphical Analysis

Although the regression results are presented in an interpretable metric (changes in births in each county per month and changes in GFRs in each county per month), the information in a table is not as readily interpretable as a graphical portrayal. We fitted, through the GFR time-series patterns, moving averages that we defined in cycles of 12. To define the fit line, the estimation routine replaces each data point in the time series with the mean of the point and the 11 previous points in the time series. These graphs serve a number of purposes. First, they show the statistical variability in the birth data that we "modeled out" of the time series so that we may more directly observe any bombing effect. Second, they show the structure underlying each county's birth patterns. Third, they provide a visual means for county comparisons.

RESULTS

Preliminary Results: Raw Birth Data

In preliminary analyses, we fitted models to the raw monthly birth data. Dummy variables were included in the model that extracted the variability that was due to county differences and to monthly seasonal patterns to remove much of the statistical noise. In addition, we also fitted a linear trend term to remove the slight drift in births over time. To this model we added indicator variables to test the bombing hypotheses. The value of the analyses of raw births is the interpretability of the coefficients; they measure change in units of raw births. The weakness is that differences in county size are not accounted for in the measurement process (although this difference in county size is partially removed statistically by adjusting for differences in births—which are highly correlated with population size—across counties). The results of the raw birth analyses are shown in Table 1.

The first analysis added a bombing dummy variable to the model just described. This analysis evaluated whether there was a change in the number of births consistently across all the Oklahoma metropolitan counties. We found a significant increase of 9.9 births per county per month after the bombing. Next, this overall dummy variable was disaggregated into dummy variables for each calendar year—1996 (after January), 1997, 1998, and 1999—to account for the changing raw number of births. We found support for a bombing-related change across all the counties in each year: an increase of 3.9 births in 1996, 15.1 births in 1997, 22.4 births in 1998, and 22.8 births in 1999.

6. For example, arithmetic integrated moving average (ARIMA) modeling would be an attractive alternative to dummy-variable regression. It would not provide directly interpretable regression coefficients, like those we obtained from dummy-variable regression. On the other hand, the dummy-variable regression model makes certain statistical assumptions that can be directly accounted for in ARIMA modeling, in particular, assumptions of stationarity and independence. Weak stationarity requires stability of the population mean and variance across the time series, and independence technically requires that the joint distribution of the random variables defining the time series be equal to the product of the marginal distributions (e.g., Cromwell et al. 1994). We used a Dickey-Fuller test of stationarity and Box-Pierce and Turning Point tests of independence (Cromwell et al.:13–15, 25–28), applied to both the original county birth counts and then to the residuals of the model before we fitted the bombing and interaction dummy variables. Many of the counties showed both stationarity and independence in the raw time-series data. After fitting the model accounting for county and monthly differences and trend to the

Table 1. Raw Birth Increases (net of the model) in Oklahoma Metropolitan Counties in the Four Years Following the Oklahoma City Bombing in April 1995

Geographic Region	Overall	1996	1997	1998	1999
Overall Oklahoma	9.9***	3.9	15.1***	22.4***	22.8***
Counties in Oklahoma City Metropolitan Area	7.5***	10.1***	6.8*	7.7*	5.7
Canadian	–5.5	–2.5	–2.1	–8.8	–8.4
Cleveland	5.0	7.7	5.8	7.5	–0.7
McClain	–5.6	0.4	–6.6	–9.2	–6.5
Oklahoma	41.3***	23.2***	34.1***	54.1***	51.7***
Logan	–7.8	0.7	–6.9	–10.1	–14.1
Pottawattami	–2.7	3.7	–2.2	–8.6	–3.3
All but Oklahoma County	–5.2	3.1	–3.7	–9.2	–10.4
Counties in Tulsa Metropolitan Area	–2.3	–6.7	–5.1	–1.5	3.7
Creek	–4.5	7.2	–4.5	–10.8	–8.9
Osage	–10.9	–3.6	–9.3	–16.5	–13.6
Rogers	–4.4	3.7	–5.6	–8.8	–5.6
Tulsa	17.9***	–30.1	9.5	41.1***	47.1***
Wagoner	–5.6	1.4	–6.6	–9.6	–7.2
County in Lawton Metropolitan Area					
Comanche	–17.3	–11.8	–5.8	–20.7	–30.5

*$p < .05$; ***$p < .001$ (upper-tailed tests)

Next, we added additional dummy variables to account for the interaction between the overall bombing dummy variable and the four overall time-related dummy variables, with a variable accounting for whether the observation came from Oklahoma County. This analysis evaluated whether there was a different number of births in response to the bombing in Oklahoma County than in the other 11 metropolitan counties in Oklahoma (i.e., an evaluation of Oklahoma County using the other 11 counties as nonequivalent control conditions). Averaged over the four years, the result showed a significant interaction with a positive coefficient of 41.3 births, suggesting that the increase in births in Oklahoma County was 41.3 births per month greater from February 1996 through December 1999 than the average across the other months and counties in the context of this model.

When we divided the one postbombing Oklahoma County dummy variable into four separate dummy variables accounting for each calendar year, we could evaluate changes in the fertility response during the four years following the bombing. In Oklahoma County (compared with the mean from the other metropolitan counties), we found an increase of 23.2 births per month in 1996, 34.1 in 1997, 54.1 in 1998, and 51.7 in 1999.

To evaluate further the specific nature of these increases, we repeated the analysis for each metropolitan county. That is, we used each county as the target county and evaluated

raw birth counts, we found that the residuals for all the counties were both stationary and independent, supporting the use of the dummy-variable regression procedure to test for the bombing effect.

the change in that county's births net of the average across the other metropolitan counties. The results of these analyses are summarized in Table 1.

Two features of Table 1 deserve attention. First, the strongest (and only significant) effects occurred in Oklahoma and Tulsa Counties, the two largest metropolitan counties in Oklahoma. Cleveland County, the third-largest metropolitan county in Oklahoma, also showed a positive birth effect after the bombing, although the effect was not strong enough to be significant. Furthermore, these were the only three counties with a net overall increase in births during the entire period following the bombing. In other words, the overall state effect reported in the first analysis was actually a result of a strong effect in the three largest metropolitan areas of Oklahoma. Second, only in Oklahoma County did a significant effect show immediately and persist through the four years that we evaluated. The effect took some time to appear in Tulsa County and was never strong (and finally dampened) in Cleveland County.

Our final analysis of the raw birth patterns provided additional evidence linking the observed effects directly to the Oklahoma City bombing. When we shifted the timing of the original bombing dummy variable as though the bombing effect had occurred earlier than it actually had—for example, in August 1995 or November 1995—the "first-year effect" dampened substantially, particularly in Oklahoma County. It appears that this effect for raw births—focused within the major metropolitan counties in Oklahoma—began specifically around February 1996, nine and a half months after the bombing occurred.

The effect size of the bombing effect is not dramatically large—by 1998 and 1999, it amounted to a maximum of about 50 or more births per month in Oklahoma County. However, this is not trivial, either. Over the entire year, well over 600 births in Oklahoma County during this period may be attributable to the bombing (or, of course, to other events that occurred concurrently with the bombing).

Primary Results: GFRs and Other Population Adjustments

It is notable that the results reported so far show a positive effect for the three largest metropolitan counties in Oklahoma. Because we used raw birth counts, there is concern that the patterns are at least partly artifactual, resulting from the fact that there were more births in these counties. We addressed this concern in several different ways.

In our primary analysis, we defined GFRs, as described earlier, which adjust for differences in county population sizes. The analyses described in the previous section were rerun using the GFRs instead of the raw birth counts. The results were slightly different, but similar in certain critical ways, and provided an additional focus on the most important findings associated with the results in the previous section. First, the overall effect observed for the entire state of Oklahoma was still highly significant; there was an increase of .17 births per thousand women of childbearing age across the state of Oklahoma (see Table 2). Just as in the raw birth analysis, this effect took a year to develop and is apparent in the results for 1997, 1998, and 1999.

When each county was used as a target county, two counties showed a significant increase in births following the bombing—Oklahoma County (which increased by a GFR of .32 per month per thousand women of childbearing age) and Pottawatomie County (a county that is directly east of and part of the metropolitan area of Oklahoma City, which increased by .28 per month in its GFR per thousand women of childbearing age). When the Oklahoma County overall dummy variable was separated into four yearly dummy variables, the resulting parameter estimates were for a .37 increase in the GFR in 1996, a .23 increase in 1997, a .31 increase in 1998, and a .37 increase in 1999. Neither Cleveland County nor Tulsa County showed significant increases in births in the GFR analysis, although both showed generally positive effects. When a dummy variable was defined to account for all six Oklahoma City–area metropolitan counties, the dummy variable was significant and showed a GFR increase of .20 per month per thousand women of childbearing age. Furthermore,

Table 2. GFR Increases (in thousandths and net of the model) in Oklahoma Metropolitan Counties in the Four Years Following the Oklahoma City Bombing in April 1995

Geographic Region	Overall	1996	1997	1998	1999
Overall Oklahoma	.171**	–.003	.330**	.489**	.471**
Counties in Oklahoma City Metropolitan Area	.200**	–.047	.154	.323	.225
Canadian	–.105	–.105	.050	–.139	–.153
Cleveland	.024	.183	.021	.029	–.122
McClain	.122	–.342	–.130	.351	.571
Oklahoma	.317**	.366*	.231	.309	.367*
Logan	.011	–.013	.060	.389	–.392
Pottawattami	.283*	.276	.272	.118	.466*
All but Oklahoma County	.105	–.205	.086	.235	.116
Counties in Tulsa Metropolitan Area	–.181	–.051	–.258	–.303	–.101
Creek	.102	.501	.055	–.099	–.014
Osage	–.400	–.482	–.288	–.543	–.295
Rogers	–.238	–.002	–.344	–.342	–.235
Tulsa	.105	–.097	.010	–.193	.300
Wagoner	–.147	–.073	–.253	–.175	–.078
County in Lawton Metropolitan Area					
Comanche	–.071	–.122	.316	–.090	–.415

*$p < .05$; **$p < .01$ (upper-tailed tests)

five of the six metropolitan counties in the Oklahoma City area showed an overall positive fertility response to the bombing.[7]

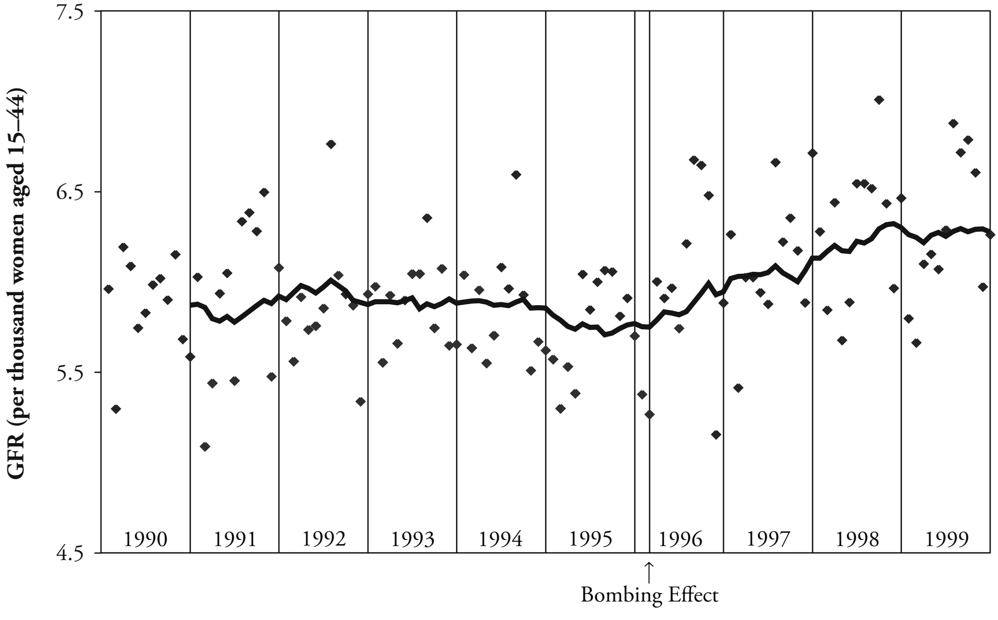
Graphical Analysis

In Figures 2a–2e, we present models—superimposed on the raw data—for several counties using moving averages fitted to the monthly county birth patterns. These moving averages were defined in cycles of 12 months. In addition to moving averages, we also used several other smoothing methods, including lowess, spline, and kernel smoothers; when they

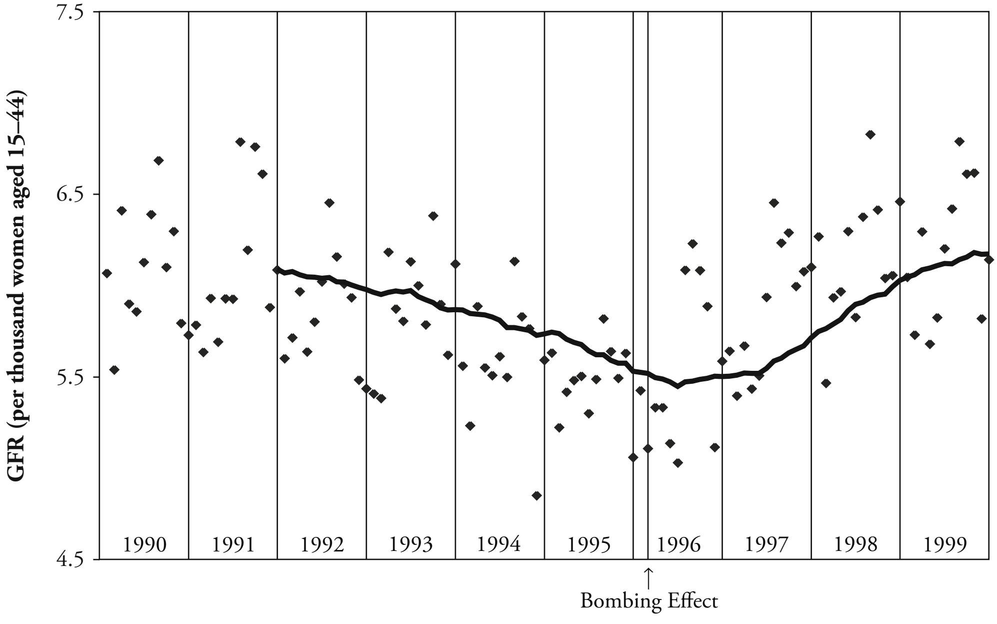
7. As another approach to handling the problem of different county population sizes—and thus different county birth rates—we ran these same analyses using crude birth rates in addition to GFRs. The patterns of results were identical to the GFR results. We also aggregated several counties for comparison to Oklahoma County (a design approach, rather than a statistical or measurement approach, to handling the differential population problem). The 2000 Oklahoma County population increased 60,837 from its 1990 base of about 600,000 (an approximate 10% increase). When combined, the five suburban counties around Oklahoma County (i.e., those in the Oklahoma City metropolitan area that did not include Oklahoma County; see Table 1) had a similar net increase in overall population of 63,670 from 1990 to 2000 from a base of about 359,000 (about a 17% increase). Thus, the five suburban Oklahoma City counties can be used as a comparison sample for Oklahoma County, one with a greater percentage increase than that in Oklahoma County, and with a baseline population that was slightly smaller but of the same order of magnitude. Table 1 includes the birth results for these five counties combined, suggesting an immediate birth increase in 1996 that dropped off from 1997 to 1999. Clearly, an increase of about 60,000 that adds 10%–20% to the population base does not automatically lead to the type of generally increasing pattern that was actually observed in Oklahoma County within the context of this particular statistical model.

Figure 2. GFRs and Moving-Average Fits for Five Oklahoma Metropolitan Counties

a. Oklahoma County GFRs, With a Moving-Average Trend Line



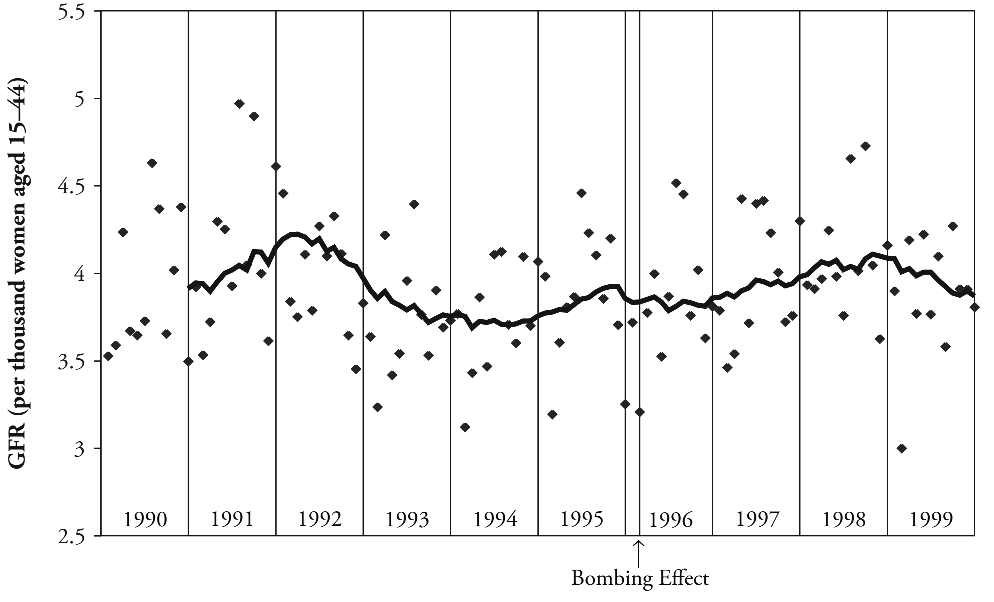
b. Tulsa County GFRs, With a Moving-Average Trend Line



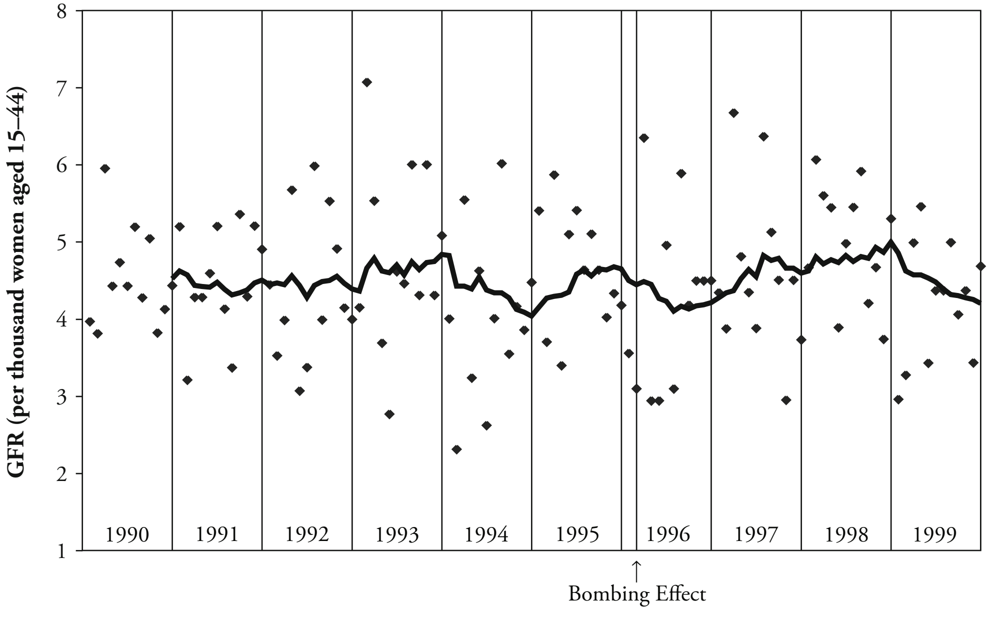
(continued)

(Figure 2, continued)

c. Cleveland County GFRs, With a Moving-Average Trend Line



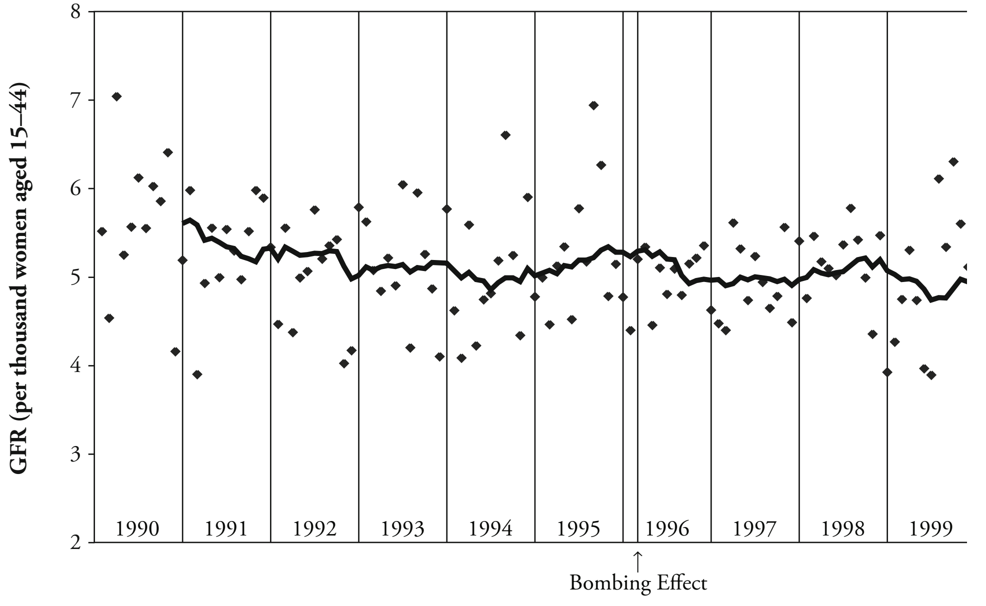
d. Logan County GFRs, With a Moving-Average Trend Line



(continued)

(Figure 2, continued)

e. Rogers County GFRs, With a Moving-Average Trend Line



were tuned to similar bandwidths, the results were very similar to those from the moving averages. Figures 2a–2c show the results from the three largest metropolitan counties in Oklahoma, and the ones for which long-term effects of the bombing were the most prominent in the dummy-variable regression. In Figures 2d and 2e, we show patterns from two other metropolitan counties in Oklahoma, Logan and Rogers counties, to give perspective to Figures 2a–2c.

In Figure 2a, for Oklahoma County, the broad pattern shows an increase beginning exactly at the "bombing effect" month, nine and a half months after the bombing; as soon as GFRs from on or after February 1996 enter the moving average, the moving average trends upward. In Tulsa County (Figure 2b), there was an apparent increase following the bombing; however, it was more than a year before this increase began. In Cleveland County (Figure 2c), there was a gradual increase that dampened after three years. In all three counties, the long-term rise from the period around the bombing is visible. Lines fit to the raw birth counts (and to the crude birth rates as well) are similar to those shown in Figure 2. In particular, in each plot for Oklahoma County, there is a marked increase at exactly the time of the "bombing effect." In Figure 2d, the pattern in Logan County (a suburb of Oklahoma City) bounces around somewhat, but is generally flat. The pattern in Figure 2e, for Rogers County (a suburb of Tulsa), shows a slight decline across the four years after the bombing effect.

DISCUSSION

There is one strong, consistent result from the empirical analysis of the 1990–1999 Oklahoma county monthly birth data. Oklahoma County, in particular, and the counties around Oklahoma City, to a lesser extent, had increased births (see the "Overall" column of Table 2). The result showed up in raw birth data, in two different types of population-adjusted birth data (in particular, in the GFR statistics from our primary analysis), and in both a statistical modeling exercise and a graphical analysis. Furthermore, the Oklahoma County result showed up not as just an observable and apparent increase that started about February 1996, but (critically) in comparison with other metropolitan counties in Oklahoma—in the context of a control-group interrupted time-series design and a difference-in-differences econometric design.

To summarize, the three major empirical findings are as follows: first, the immediate effect of the bombing appeared in and around the Oklahoma City area, not elsewhere (see the first column for the results for "Counties in the Oklahoma City Metropolitan Area" in Table 2). Second, the overall persistence of the effect, as well as the magnitude of the effect, was primarily in Oklahoma County. In Oklahoma County, the effect accelerated in the raw births and was relatively stable for the GFR analysis (see the Oklahoma County rows for Tables 1 and 2). Third, the effect of the bombing can be observed in the three largest metropolitan counties in raw births and, to a lesser extent, in the GFR patterns (see the rows for Oklahoma, Cleveland, and Tulsa County in Tables 1 and 2).

The immediate response in GFRs in three of the six Oklahoma City counties (Oklahoma, Cleveland, and Pottawattami), reflected in the first finding, which dampened somewhat after the first year, appears consistent with the predictions of replacement/insurance theory. As we suggested earlier, replacement/insurance behavior should occur quickly and then dampen and should be fairly localized. The theory that best accounts for a strongly localized effect like that in the second finding is terror management theory. This theory relies on the response of those who feel a vivid threat to their own mortality and who respond with a strengthening of their traditional values. It appears that this type of effect occurred primarily in Oklahoma County itself and persisted for several years. The theory that best accounts for an urban effect like that in the third finding would appear to be some form of community influence theory.

There are other ways to evaluate the value of these particular theoretical formulations beyond their empirical success. In addition to helping us structure and understand our empirical findings, each of the three theories can also be identified in media responses to the bombing. The strong sense of community that arose in response to the bombing has been widely noted in the press and was the motivation for our suggestion of a community influence theory. The sense of immediate terror—the motivating force behind terror management theory—has also been discussed, including suggestions of longer-term effects on mental stability (e.g., Serrano 1999). Finally, anecdotal evidence that a replacement/insurance process may indeed have been at work is provided in the media attention to Baylee Almon's mother's next pregnancy (covered in both the local and national press; e.g., "Baylee Almon's Mom Expecting" 2000); this pregnancy occurred a full five years after the bombing and was typically interpreted as an explicit effort to replace her lost child. Furthermore, a recent article related to the 9/11 terrorist attacks suggested a replacement process in a quote from a 36-year-old woman who became pregnant following the attacks: "It's almost a way to replace people who were lost" ("Baby Mimiboom" p. 2B).

We have addressed a number of threats to the internal validity of these findings, by using different ways to operationalize the fertility outcome, different design structures (including both time-series pre-post structure and comparison conditions), different specifications of the timing of the bombing effect, and different analytic methods. The results are robust across these different methods and are most vividly portrayed in the graphical pattern for GFRs in Oklahoma County shown in Figure 2a. One other potential threat to the internal validity of a bombing effect on fertility should be explicitly noted. Because this pattern is correlational, there is no way to state conclusively that the bombing itself was the single cause of the increase in births. Some factor that was unrelated to the bombing could have been the cause or part of the cause. However, this factor would have to have been of a magnitude to have a measurable effect on births; to have occurred sometime very close to April 1995; and to have been localized in its effect on Oklahoma County proper and, to a lesser extent, on the Oklahoma City metropolitan area.

Man-made disasters and natural disasters have different components, although the predictions that emerge from the theories defined in this article would appear to be quite similar for settings involving terrorism versus natural disasters. In both cases, a community response is required to handle the ensuing problems, a sense that parents need to "ensure themselves" against additional threats to their children's lives may emerge, and people may call into question their own mortality.

Studying fertility responses to disasters—both man-made and natural disasters—typically occurs within a natural laboratory. Several other such disasters can be used to evaluate some of the processes that we have defined as important in relation to the Oklahoma City bombing. Birth responses (as well as marriage and divorce responses) to the devastating May 1999 tornado that passed through Oklahoma City—the largest ever recorded by weather instruments—would provide one relevant comparison (although these effects would be confounded with the persistent effects of the Oklahoma city bombing). Other relevant and informative empirical data will be provided by the demographic responses to the 9/11 terrorist attacks. Fertility responses to the Florida hurricanes in the fall of 2004 and to the devastating tidal wave in Asia in December 2004 will each shed light on birth responses to natural disasters.

Each disaster, however, has its own unique features. The Oklahoma City bombing was unique in several ways—the highly visible and widely reported deaths of babies, the immediate capture of the perpetrator, the apparently small number of individuals who were involved in plotting the bombing, and the focused and local nature of the damage (all in contrast to the 9/11 attacks). Future research on the demographic responses to these other disasters will enlarge our empirical and theoretical understanding of humans' behavioral responses to disasters.

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