Abstract

The purpose of this study is to uncover general trends in the consumer markets of Oklahoma communities responding to significant (damage of over $3 million) tornado events. The consumer response is measured using a time series consisting of monthly sales subject to tax data for each location included in the study. 30 tornadoes, and 65 areas in and around the immediate impact zones are studied, including counties, cities and some small towns. It is evident from this research that it is impossible to predict what a market response will be, as population data, damage data, and tornado impacts (as extrapolated from multiple regression models) never show any correlations. However, a general trend is evident, as more cases in this study show signs of consumer market growth than show decline. The ratio is 2.5:1 in a short-run period (6 months), and 1.5:1 in a long-run (2 year) period. The cases which are significant (as shown by a simple p-test) are greater for cases of market increase, in both the 6-month and long-run periods, by spreads of 10% over decreasing impact cases. The main conclusions of this study are in two parts; there is no way to predict the economic impact for general cases of tornado damage, but there is a higher probability that the impact on the consumer market will be to increase local sales activity.

Introduction

Tornadoes are a very common phenomenon in much of the United States today. Studies have been conducted which attempt to explain various impacts of single tornado events, but studies that attempt to find general behaviors for an economic impact in numerous events have yet to be attempted. Tornadoes are very sporadic in what they will hit and what that will mean for a local area, unlike larger events such as hurricanes and ice storms, which impact a large area in a fairly uniform manner. This study aims to measure impact of tornadoes on a local economy by examining a time series for sales subject to tax data. The sales subject to tax time series analysis is a descriptive measure of consumer activity, and changes in the series from the intervening tornado are used in this study for three main types of analysis:

1) Overall comparison of likelihood for different effects
2) Individual case study
3) Large-event, large-area study

Multiple regression analysis is performed for each location studied. A range of areas and dates are covered: counties, cities, and small towns, 1980 to present, in the state of Oklahoma. The 'tornado' variable in the output is analyzed for its magnitude (statistical significance at the 95% confidence level), and type of impact; the following four categories for these impacts are noted:

Increase in activity/significant

Decrease in activity/significant

Increase in activity/insignificant

Decrease in activity/insignificant

Economic Background and Research

Any of these outcomes are possible for each location, because several factors are at play within an active consumer market following an event such as a tornado. When a tornado strikes, any number of combinations of structure types in a community will be damaged to varying extents. Dollar damage does not express how many buildings are irreparable, or the significance of a damaged/destroyed business to a local economy. For example, it was obvious to the people of Stroud, OK in 1999 that their local sales revenues were going to decrease drastically following the May 3rd tornado, when the Tanger Outlet Mall was declared unfit for rebuilding, and hundreds of jobs were lost. The $60 million figure for damage in that area did not express any of that story, and in no other cases studied was the impact as obvious as that to Lincoln County (Stroud). For all other locations, a combination of homes, businesses, crops and public buildings were damaged to different extents. Following tornadoes there is reconstruction, a possible rush to stock up on consumer goods such as food and other immediate supplies, and in general a shift to immediate recovery spending. However, many structures/businesses being destroyed takes away a portion of the base for this consumer spending (businesses serve as suppliers, and losing a portion of those businesses will mean there is less supply available to the market). Some people may also move away, businesses may close, and fields of damaged crops could spend the rest of the year lying fallow. There is a distinct dichotomy of simultaneous and opposing forces in the consumer market, and this is expressed in one value in the time series for each month of data.

Attempting to match impacts to general types of damage done is virtually impossible, as detailed records for locations damaged/destroyed simply do not exist. In an ideal situation, the data available would express the damage done to every structure, the ramifications of that damage (is the structure irreparable?), and the significance of that structure to the community. Since that is far from the available pool of data, there is an inherent puzzle here, and the field is wide open for exploring what types of patterns actually do emerge in markets when tornadoes strike – even with these variances of damage.

Many studies have been conducted to observe the reactions within specific areas of local economies to individual tornado events. These measures are good for individual case studies, but none are suitable for the broad analysis that is the aim of this study. In "Catastrophe-Induced Destruction and Reconstruction" (DeSilva et al., 2003), the impact on housing values in Oklahoma City, following the May 1999 tornadoes, was studied. The findings showed a long-term positive impact on damaged units, as structures that needed to be rebuilt grew in value faster than those that had not been damaged. In another study, Analysis of Local Labor Market Responses to Tornadoes (Ewing, et al., 2002), it was found that unemployment and labor market fluctuations actually decreased following recent tornadoes in Oklahoma City and Nashville, and were opposite of this in Fort Worth. In Employment Dynamics and the Nashville Tornado (Ewing et al., 2004), the market was broken into sectors, and the effect of the tornado on each was studied. Many sectors, such as manufacturing, retail trade and the aggregate market, showed marked improvement, whereas the only sector to suffer was in insurance/finance/investment. If this result happens as a rule, it would show up in this study as well, as the sectors that improved are in many ways responsible for the overall sales. These results are mixed, however, there is the suggestion that general positive outcomes are at work in the economy following tornadoes.

Data and Methodology

The primary focus of this study is on the economic ramifications of tornadoes on communities at the county, city, and town levels. Many issues arise when it comes to selecting events for study. Narrowing the focus to what could be the most major events, tornadoes in the state of Oklahoma (since 1980) are sorted by damage estimates, and only those events that caused over $2,500,000 are kept. In some cases, multiple tornadoes may have been responsible for the total damage; however, they were part of the same event, and are grouped together to measure their impact on the same area. For large-scale events such as the May 3, 1999 tornadoes, select cities and counties surrounding the main area of impact (which were impacted themselves, to a much smaller extent) are analyzed as well, to observe the relationship between surrounding areas and direct impact areas following such occurrences. The storm data are online via the NOAA/NCDC (National Climatic Data Center) database, available at: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms. Additional information needed to break apart large events is obtainable from the Storm Data archive. 30 events since 1980 match the following criteria on NCDC: tornado, over $2,500,000. 65 locations are studied here, covering (to varying extents) the counties and cities both directly and significantly impacted (over $2.5 million in damage) and those surrounding main impact areas. See Fig 1 for events included in study.

The decision to study events based on these criteria is not free of problems. First, tornadoes are by nature incredibly variable in what they will strike, how badly/critically that will be damaged, and how important those structures are to a community and its economy. If a single mansion that cost millions to build is completely destroyed, but the rest of a town is not at all critically damaged, then the damage figure will inflate the significance of that damage amount to the community as a whole. However, some communities can have under $2.5 million in damage, and still see significant impacts in the consumer market due to other influences not entirely related to dollar damage. If a community's consumers are all farmers, and the tornado hits the local supplier of irrigation equipment, then the farmers will have to go elsewhere to attain these goods. This could result in a significant decrease in monthly revenues for the area impacted, though the dollar damage to the single business itself would be small. These possible events are not included in this study.

A second main issue is the limitation of the database itself. Records available from 1980 to 1995 were based on a scale system for damage ($50,000 to $5 million, $5 million to $50 million, and $50 million to $500 million, as applicable to this study). Many damage records estimate values at halfway points in the scale ($25 million, $250 million), slightly increasing accuracy of the damage data. From 1996 events to present, damage data is reported in thousands of dollars. This problem is less critical to the modeling of the time series, as numeric damage will not be a factor. However, it impedes any accurate analysis of relationships between numeric damage as applicable to damage per capita correlating to the coefficient of 'tornado' in the multiple regression output, or damage as a percentage of sales as related to the 'tornado' term.

These limitations are inherent to the study of an intervention variable such as a tornado within the societal realm. Even with these issues, the dataset that is generated can be used well as a foundation for analysis.

This study uses sales subject to tax sales data in order to observe the economic ramifications of tornadoes on a community. ‘Sales subject to tax’ refers to the sum of the sales for all items that are taxable (as opposed to sales tax revenue, which is the sum of the taxes collected on taxable items). This way, differing sales tax rates in various areas and at different points in time will not have an effect on the raw data used. Sales subject to tax data is available from 1980 to present for all counties in the state of Oklahoma, as well as for its 50 largest cities and towns. The database is accessible at the following address: http://www.origins.ou.edu/databases/.

There are many different ways to analyze economic impacts from severe weather events on local areas. Many studies have been conducted that are narrower in focus than this one, observing impacts on individual cities, and using variables such as unemployment, labor market stability, income and wealth effects, and even housing values. These can be very descriptive measures, but this study aims to analyze locations together via a simple comparison between the type and significance of the impact of the tornado on a facet of the economy. These other measures require areas to be economically or in some other way definitely similar prior to the event in order to perform cross-comparison analysis. The advantage to sales subject to tax data is that it is a simple time series, and local impacts can be expressed in significance testing of a multiple linear regression. In this way, cities and counties can be put together in groups, locations involved in the same events can be grouped, and patterns of general impact can easily be observed.

In this study, we attempt to observe general patterns of behavior for time series data on local areas following the destruction of tornadoes, using monthly sales subject to tax records (adjusted for inflation- AFI). The time series data were analyzed using multiple regression analysis and E-views software. To capture each tornado event's long-term impact, the sales subject to tax data for roughly two years prior to and following the event were modeled (ex: for May 3, 1999 tornado impact sites, sales subject to tax data from January 1997 to December 2001 were used for the model). For the short-term (6-month) impact, the same rough two-year period before the event was used (January of the prior year), and only the 6 months after the month of the tornado were used to capture the intervention variable. The dummy intervention variable in equation (1), a jump variable, represents the time the tornado hit (1 from that month on, 0 otherwise). The dummy intervention variable is thus defined:

$$(1) \quad \pi_t = \begin{cases} 1, & \text{Month of event – end of period studied} \\ 0, & \text{otherwise} \end{cases}$$

The model, giving monthly returns of sales subject to tax with respect to state returns, seasonality, and deterministic time trend, is given:

$$(2) \quad \xi_t = c_0 + \alpha s_t + \beta z + \gamma T + \delta \pi_t$$

The dependant variable, monthly local sales subject to tax returns ξ_t (AFI), is expressed as a function of: state returns s_t (AFI), seasonal trend z, deterministic time trend T, and dummy intervention 'tornado' variable π_t. The trends account for such fluctuations as the oil bust in the mid-80's in Oklahoma (which would show an automatic downturn in the time series if a tornado occurred at the same time), general US economic trends (time trend), and seasonal patterns (such as sales picking up around Christmas). For the purposes of this study, the sign and magnitude of δ is of the most interest. This is a numeric expression of the type and magnitude of the impact on the local area (negative value being decrease in market activity, and positive value being increase in market activity).

Results and Discussion

To assure that our models properly capture the economic state (as expressed in sales subject to tax returns), two statistics are checked in the output models. R^2 value, expressing how much variation is captured in the model, is best when above the value range .7-.75 (ideal value at 1). The Durbin-Watson statistic measures autocorrelation still present after the modeling, suggesting that the data needs to be de-trended further if the value is far from the best range of 1.5 – 2.5 (ideal being 2). All of the models counted in this study fall in acceptable statistical ranges for accountability of variance and autocorrelation. Some models appear to have statistical abnormalities (such as very low r^2 values, or DW-statistics outside of the acceptable boundary), but further examination of the results and source of the statistical output explains the source of the abnormalities in most cases. For example, in the cases of smaller towns, R^2 values are typically much lower, as most of their variance is explained by more local fluctuations in market activity. However, the Durbin-Watson statistics verify the appropriateness of the models in capturing the deterministic trends shaping the market (no significant positive or negative autocorrelations remained after modeling). Models that cannot be explained are thrown out of the study.

(1) Overall comparison of likelihood for different effects

The analyzation of general impacts is broken down into 6-month (6mo) and (approx.) two-year post-tornado time periods. The longer period is treated as a long-run

(LR), present to catch the dynamic impacts of the tornadoes on each location over a span of time. Four general groups, consisting of *cities* and *counties* both *directly* impacted and *surrounding* the directly impacted area, are studied to note if the impact of the event was an increase or decrease in market activity (and significantly so) as determined by the model outputs. Significance is determined by the p-test corresponding to the ‘tornado’ variable in the multiple regression output models. Impacts as described by model output (looking at the ‘tornado’ variable) are defined as follows:

NN – non-significant negative (indicating slight decrease in market activity)

NP – non-significant positive (indicating slight increase in market activity)

SN – significant negative (relatively large decrease in market activity)

SP – significant positive (relatively large increase in market activity)

These terms are used to describe the impacts on the individual communities studied, discussed at the end of the results section.

The 6mo impacts (See Fig. 2) show a distinct increase in market activity through three of the four main groups studied. The towns directly hit show a strong signature for increase in sales, as 16/18 towns have positive model output, with the only statistically significant cases being positive (5 cases). Counties directly hit also show a strong signature, with 17/24 counties studied demonstrating an increase in sales due to the tornado (5/6 significant cases are for increasing market sales). In general, the ratio of increasing sales to decreasing sales due to the tornado is 47:18, with a 14:3 ratio for significant cases. Roughly 2.5 times more cases are positive than negative in the model output, and cases of significant increase in sales are almost 5 times more frequent.

In the LR models (see Fig 3), the overall economic boost is still prevalent, though not as strongly. Overall, there are roughly 1.5 times more cases of positive model output than negative. Interestingly, the percentage of statistically significant impacts goes up by approximately 10% in both categories (increase and decrease in the market) in LR models as compared to 6mo.

These general tabulations can be understood more in-depth when considering the cases individually, and by noting what happens in different large-scale events. No area studied consistently behaves one way in every event, but each case is individually enlightening as the consumption movement is traceable (especially after large events that had significant ramifications for a sizable area, such as the May 3, 1999 tornadoes). The next section of results highlights significant cases, large-scale events, and interesting patterns found in the 65 cases analyzed for the 30 most damaging tornadoes in the state since 1980.

(2) Individual case study

It is intuitive to think of tornadoes as destructive, thus having negative ramifications on local economies. No other location shows this as well as Lincoln County after the May 1999 tornadoes. The base of its sales was destroyed, and (Fig. 4) makes obvious the effect the outlet mall had on the economy when it was built (1994) and when it was destroyed (1999). In the regression model, the sign of δ was negative and the p-value for the 'tornado' variable was 0.000 (in both 6-month (6mo) and long-run (LR) analysis) – highly significant results. For this same event, the appearance of the time series for Moore, and a linear extrapolation of the trend without the tornado (Fig. 5) deceptively suggests that there was a negative economic impact as well, which would be intuitive for the famed destruction the city endured; however, the appearance of the series is largely accounted for by state, seasonal and time trends, and the tornado actually has a NP impact in the 6mo, and a NN impact on sales in the LR. These are very weak signals.

There are more SP cases than the single good SN case for Lincoln Co., 1999. Exceptional cases are seen in Clinton in 1981 (both Custer County and Clinton show SP in LR, SP in 6mo for Custer only), Altus in 1982 (both city and Jackson County show 6mo SP, only Jackson Co. shows LR SP), Tulsa in 1985 (where both the city and county show SP values in LR and 6mo time periods), and Seminole in 1995 (again, both city and county show SP in LR and 6mo). These locations all have significantly different damage/capita, damage as a percentage of mean sales, and even F-scale ratings for the tornadoes that hit. The particular nature of the damage done at each location also varies. This illustrates well that the economic boost to the consumer market is independent of these situational variables alone.

(3) Large-event, large-area study

The first wider-area included in this study is Tulsa, after the April 19, 1981 tornado there. Interestingly, in the LR models, the signature of impact is SN for Tulsa city, Tulsa county, and suburb Broken Arrow, and is negative for two other suburbs: Bixby and Jenks. None of the suburbs had been hit significantly in this tornado, so they are treated as surrounding areas. In the 6mo models, only Tulsa city and county have negative signatures, while all the suburbs show NP signs. It appears here that initially, the damage done exceeded the resulting rebuilding. Within the next additional year, the surrounding areas were growing in sales once again, but the directly impacted area remained below the pre-tornado projected sales level.

The next large-scale event studied is the series of tornadoes to impact Okmulgee, Creek, and Pawnee counties on April 29, 1984. In both the 6mo and LR models for these counties, Okmulgee and Creek are NP in impact, and Pawnee remains NN. Intriguingly, the small towns within the counties don't necessarily show the same signatures. Mannford (Creek Co) and New Prue (Pawnee Co) show SP signatures in the 6mo and LR regressions, and Morris (Okmulgee Co) is NN for both regressions. The small towns are so small, that their behavior as independent units is not altogether unexpected. It is counter-intuitive that tornadoes that could do that much damage to such small communities, and the communities could have such a strong consumer spending response, overcoming the fact that whatever got damaged was a significant proportion of the net worth of each town. As long as there are businesses still able to sell taxable items, revenues will continue to be collected, and people will need to buy things to make repairs. Everything is dependant on what exactly was hit, and if it was irreparably damaged.

Another large-scale event in this study is that of Edmond/Oklahoma City on May 8, 1986. Edmond was hit primarily, and Oklahoma City endured a significant amount of damage as well. Interestingly, Edmond showed a SP result for both models, and Oklahoma City was NP in the short-run, going to NN in the long-run. Meanwhile, in surrounding suburbs Del City, Moore and Bethany, the impact was positive in both models (SP for Moore in both), and suburb Midwest City was SN for both models. This mixed result demonstrates the reliance on different suburbs for reconstruction after this event; Midwest City was not a hub of sales after the tornado.

The next comprehensive event is that which this study has the most models for: areas impacted by the May 3, 1999 tornadoes. Results continue to be quite varied. This event shows a couple interesting features to note. In the first 6 months after the event, all five surrounding counties in the study (not in the main impact area) show negative changes in sales subject to tax returns. Of the three cities surrounding the main impact area, two of them show negative signatures, following the pattern of the counties. However, of the nine counties directly impacted and in this study, 7 show positive change in the first six months. Also, in the first six months, four of the five cities directly hit by the tornadoes show the same positive signature as their counties. This is a stark contrast between the areas directly hit and those surrounding during the period immediately post-tornado. Long-term signatures aren't as clear. It appears the tornadoes were more significant to the region as a whole in a patterned way only in the short-run.

The final event studied is again in Oklahoma City, for the May 8, 2003 series of tornadoes. Intriguingly, in the first six months after the event, every county in and around the main impact area, and city in and around the impact area, show a NP signature (except surrounding city of Mustang, which was SP). Moving later to the LR, Edmond and Cleveland County (both in the main impact area) change to having NN effects, all others remain NP or SP as in the six-month analysis.

Conclusions

Every area reacts differently to every individual tornado or outbreak of tornadoes, just as every tornado is completely unique. No area is economically consistent, and no tornado follows a pre-formulated pattern of destruction. Given population data, dollar damage, and information about sales before a tornado strikes, it is not possible to predict what the consumer market (for locations directly damaged and their surrounding areas) will do when a tornado hits. In observing the reactions of many areas to tornadoes, it is apparent that predicting the exact economic response of an area to such situations is difficult, if not altogether impossible. The only exceptions are obvious cases such as Lincoln County after the May 3, 1999 tornadoes, where the main base of sales was destroyed and not rebuilt. In this study, such a clear and predictable signal occurred in one case of 65.

Though it is not possible to make an exact prediction about the impact of a tornado on a local consumer market, it is probable that the area will show gains in market activity following the event. In almost every category (breaking impacts down in groups of counties and cities), there was more than a 2:1 ratio of increasing market response vs. decreasing response following a tornado. This does not give economists a tool for prediction, but it does show a somewhat counterintuitive pattern to the way markets react to these events.

References

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