Effect of Tornadoes on Local Labor Markets

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Abstract

In this paper, I examine the change in local labor markets caused by extreme tornadoes that occur in counties of the contiguous United States. I also investigate the effect these tornadoes have on neighboring counties and evaluate the labor market response in urban and rural counties separately as well. Using a generalized difference-in-difference approach on quarterly data spanning from 1975 to 2016, I find that violent tornadoes lead to persistently higher wage growth at the end of two years following the tornado. Reviewing the data by urban and rural counties shows that the effect is stronger for rural counties. Further, evaluating the response of labor markets by sectors reveals the industrial sectors that experience increased labor market activity. The response of the labor market varies based on the intensity of the tornado.

1 Introduction

On May 22, 2011, the seventh most deadly tornado in U.S. history struck Joplin, Missouri, resulting in losses over $2 billion in 2011 US Dollars[1]. The U.S. experiences about 1,200 tornadoes that on average, kill 60 people, injure 1,500 people and cause more than $400 million in damages each year [2]. These damages do not take into account the economic impact in the aftermath of the tornado. In this paper, I examine the economic impact of tornadoes on local economies.

[1] http://www.noaanews.noaa.gov/stories2011/20110920_joplin.html
https://www.joplinmo.org/DocumentCenter/View/1985/Joplin_Tornado_factsheet
https://www.thebalance.com/tornado-damage-to-the-economy-3305667

[2] http://www.crh.noaa.gov/Image/dvn/downloads/quickfacts_Tornadoes.pdf

On average, the U.S. experiences 1,200 tornadoes each year which is more than almost any other natural disasters that occur in the United States. Unlike hurricanes that mostly occur in the Gulf and the Southeastern states, and earthquakes that mostly occur in the west, tornadoes can occur almost anywhere in the US[3]. Hence, they are also geographically dispersed across the country as can be seen in figure 1. Despite the frequent occurrence and the vast geographic dispersion, very few studies focus on the effects of tornadoes on the local economy.

In this paper, I focus on the effects of tornadoes across the contiguous US on employment and wages. I find that while violent (EF4 and EF5) tornadoes result in no significant change in employment growth of a directly affected county for a two year duration after the event, growth in wages per worker is persistently higher in the affected counties at the end of the same duration. The results show that the effects of a violent tornado are not as short lived as one would expect. However, these effects do fade out with time. The results also imply that at the end of two years demand due to reconstruction efforts surpasses the supply leading to a rise in wage growth.

Several papers by Ewing et al. (2003, 2004, 2009) that focus on the effect of specific tornado incidents on employment growth are related to this paper. Ewing et al. (2003) focuses on the 2000 Fort Worth tornado, while Ewing et al. (2004) examines the 1998 Nashville tornado, and Ewing et al. (2009) focuses on the 1999 Oklahoma City tornado. These papers focus on specific tornadoes that occurred within a few years of each other. However, examining several tornadoes simultaneously over an extended period allows me to present a more comprehensive analysis of the effect of tornadoes on labor markets. This strategy also allows for time effects.

Ewing et al. (2004, 2009) also examine the response of labor markets of different industrial sectors. They find that construction experienced a positive shift in employment growth while the finance, insurance and real estate sector experienced a positive shift in employment growth in Oklahoma City and a negative shift in Nashville in the wake of F5 tornadoes. This suggests that the effect of tornadoes can be ambiguous on the labor markets of different sectors. This paper examines the response of labor markets by sectors to deduce the response that can be expected in the aftermath of a tornado.

[3] https://www.spc.noaa.gov/faq/tornado/#f-scale1

The sectors examined in this paper are construction; manufacturing; finance, insurance, and real estate (FIRE); trade, transportation, and utility (TTU); services; mining; and agriculture. Investigating the response of the labor market of each sector to tornadoes exhibits the heterogeneity between sectors. I find that the construction sector experiences higher labor demand a quarter after the tornado as suggested by the higher employment growth and wage growth. I also find that growth in wages per worker in agriculture are higher contemporaneously for neighboring counties and they fall with a lag for the directly affected county.

Other papers that are closely related to this paper are papers by Belasen and Polachek (2008, 2009) who examine the effect of hurricanes on local labor markets and Pietro and Mora (2015) who evaluate the effect of an earthquake on labor markets. Belasen and Polachek (2009) focus on hurricanes that occur in Florida counties between 1988 and 2005. Using a generalized difference-in-difference method, they find that hurricanes decrease employment while increasing wages in the county that suffers the hurricane, indicating that hurricanes result in a negative shift in the supply curve of the labor market of the affected county. Belasen and Polachek (2008) also examine the effects that hurricanes have on the labor markets for broadly defined industrial sectors. Using the same data and methodology as Belasen and Polachek (2009), they find that hurricanes generally trigger demand shocks in the labor markets of directly hit counties since employment and earnings move in the same direction for each of the industrial sectors. Pietro and Mora (2015) focus on the earthquake in L'Aquila, Italy, that occurred on April 6, 2009. They examine quarterly data from 2009 to 2010 using difference-in-difference approach and find that the earthquake led to a decline in the probability of participating in the labor force for a period of nine months after the earthquake.

Studies evaluating the economic effect of natural disasters have been both cross-country and cross-US county. Cross-country studies examine the effect of several types of natural disasters on economic growth and the channels through which they affect growth. Some of these studies find that natural disasters have a positive effect on growth (Albala-Bertrand, 1993; Skidmore and Toya, 2002). However, the vast majority of studies find that natural disasters influence growth negatively (Raddatz,2009; Jaramillo, 2009; Cavallo et al., 2013; Hochrainer, 2009; Cuaresma et al.,2008; Hallegatte and Dumas, 2009; Noy and Nualsri,

2007). Other studies focus on the differential effects of natural disasters on developing and developed countries and find that the adverse effect on the growth of developing countries is much larger than on developed countries (Noy, 2009; Fomby et al. 2013). Focusing on counties in the United States provides a unique opportunity to examine a smaller economy within a developed country. Cross-US county studies have the advantage of focusing on some microeconomic activities that affect the macro-economy of these smaller economies. Several studies have taken advantage of this unique situation. Boustan et al. (2017) make use of this advantage by examining the effect of natural disasters on migration and housing prices at the US county level. Strobl (2011) explores the effect of hurricanes on income growth of coastal counties, and Belasen and Polachek (2008, 2009) evaluate the effect of hurricanes on local labor markets in Florida. This paper adds to this body of natural disaster literature by focusing on the effect of a specific natural disaster, tornado, and its effect on the local labor market.

Fomby et al.(2013) find that the response to natural disasters varies between agricultural and non-agricultural growth. This would suggest that there may exist heterogeneous effects between urban and rural regions. Focusing on counties for this study allows me to study the heterogeneous effects of tornadoes on urban and rural counties following the cross-country literature that examines the differential effects between developed and developing countries. Estimating the model separately for rural and urban counties, I find that violent tornadoes have no significant effect on the labor market outcomes of urban counties. However, rural counties experience a strong positive influence on labor demand.

2 Economic Framework of a Tornado Shock

In a standard labor demand and labor supply model an exogenous negative shock has the potential to influence both labor supply and labor demand. A tornado shock can be that exogenous negative shock to the labor market, since a tornado could result in disruption of production and regular economic activity due to the destruction of capital stock and even the loss of human life, though, casualties in the United States due to tornadoes tend to be small. Boustan et al. (2012) find that on net young men move away from areas

struck by tornado to areas experiencing floods. As people flee the destruction caused by extremely large tornadoes creating a negative influence on labor supply, businesses attempt to fill this void created by fatalities, injuries and even migration of people, which creates positive pressure on labor demand. This initial effect is unknown due to the two counter-acting forces. After the initial shock of the tornado, once reconstruction efforts kick in, labor demand would further experience a positive movement, and labor supply may flow in to offset the demand. The later shifts in labor supply and labor demand could shift the labor market equilibrium. Whether this is a positive or negative shift in equilibrium is ambiguous, and may differ by sector.

The response to a negative shock can depend on the perception that agents in an economy have of the shock. A persistent negative shock may lead to more long lasting responses. Studies by Boustan et al. (2012) and (2017) suggest that there are individuals that perceive a tornado shock to be persistent. Boustan et al. (2012) find that on net young men out-migrate from areas that experience a tornado. Boustan et al. (2017) find that counties affected by severe disasters experience greater out-migration. Therefore, a county may experience an inward shift in labor supply due to out-migration. However, at the same time there are individuals that stay in the county despite the massive destruction. Lucas and Rapping (1969) find that individuals tend not to alter their long term expectations if they perceive a shock to be temporary. It can be because these individuals perceive the tornado shock to be temporary that they don't alter their long-term expectations and stay in the same area. Hence, the magnitude of the shift in labor supply is ambiguous and depends on the perceptions and decisions of individuals in the area.

Over the years, technology has made it possible to issue advance warnings of tornadoes. The average lead time of tornado warnings is 13 minutes[4]. Simmons et al. (2013) normalize tornado damages in the United States and find a sharp decline in tornado damages. Simmons and Sutter (2005) find that expected fatalities and injuries fell significantly after the installation of WSR-88D radars across the country. However, the more accurate warning system is not the fail-safe that it could be. People also rely on other sources of information like a visual of the tornado to heed a tornado warning during the daytime (Bakkensen, 2016). Even though technology has made it possible to reduce casualties,

[4] http://www.noaa.gov/stories/tornadoes-101

the warnings are unable to stop or reduce the destruction of physical capital.

A decline in physical capital increases the marginal product of capital, giving rise to increased investment. This in turn, should speed up recovery (Barro and Sala-i-Martin, 2003). Financial aid, disaster assistance, clean-up and recovery tend to be a counter-acting positive shock (Horowich, 2000). After the initial shock of the tornado, once reconstruction efforts to restore the damaged physical capital kicks in, demand for labor would increase. This increase in labor demand would be offset by in-migration of individuals that foresee labor market opportunity leading in a shift in the labor market outcomes from its pre-tornado levels. With time labor demand and supply may adjust as reconstruction requirements evolve. As a result, the labor market may experience some fluctuation around its steady state. These shifts and adjustments inform us about a relatively longer period effect of a tornado on the labor market outcomes.

The proximity of counties means that individuals living in tornado struck counties may be employed in a neighboring county. This would suggest some spill-over effects in the neighboring counties due to out-migration. A neighboring county may also receive some spill-over from disaster assistance. For instance, first responders may choose a neighboring county as a base of operation and increase economic activity in that county. Belasen and Polachek(2008, 2009) find some spillover effects of hurricanes. They find that extremely large hurricanes lead to no significant change in employment but a decrease in wages of neighboring counties.

3 Methodology

Local labor markets may be influenced by state business cycles (Erwing et al., 2009; Belasen and Polachek, 2008, 2009). Therefore, along with the exogenous tornado shock the state's labor market variables should be accounted for. Along with counties that are directly struck by a tornado, there exists a possibility that neighboring counties may experience some spill-over effects. Labor markets have a seasonal component that should also be included in the equation. Therefore the final labor market equation can

be described by the following function

$$Y_{i,t} = f(Y_{s,t}, T^D_{i,t}, T^N_{i,j,t}, Q_t) \tag{1}$$

where, $Y_{i,t}$ is a labor market outcome - employment or wages. $Y_{s,t}$ is the corresponding state's labor market indicator that controls for the state's business cycle. The coefficients of $T^D_{i,t}$ capture the direct effect of tornadoes, while the coefficients of $T^N_{i,j,t}$ capture the spill-over effect of tornadoes. Q_t accounts for seasonal effects of the labor market.

I use a generalized difference-in-difference technique to identify the average effect of tornadoes on local labor markets. Like a standard difference-in-difference model, a generalized difference-in-difference method not only allows one to compare affected regions (treatment) to unaffected regions (control), but also allows for multiple exogenous events occurring at different times. The series for employment and wages can be non stationary for some panels. If this is the case for counties as well as for states, it gives rise to the problem of spurious regression. To resolve this I use growth rates of the labor market indicators. Hence, the equation I estimate is as follows

$$\Delta Y_{i,t} = \alpha_0 + \alpha_1 \Delta Y_{s,t} + \sum_{k=-1}^{K} (\delta_k T^D_{i,t-k} + \phi_k . \mathbb{1}(\sum_{j \neq i} T^N_{i,j,t-k} > 0)) + Q_t + \lambda_i + \gamma_{year} + \varepsilon_{it} \tag{2}$$

$T^D_{i,t-k}$ takes the value one if county i experiences a tornado at time t. $T^N_{i,j,t-k}$ takes the value one when a border sharing neighbor j of county i experiences a tornado in time t. The lags of the tornado inform us of the effects of tornadoes over time. Belasen and Polachek(2009) explain that historically destruction from hurricanes is repaired within two years. Compared to hurricanes, tornadoes are more focused in nature. I therefore make an assumption that the repair duration post-tornado is no larger than hurricanes and include eight lags in my analysis. I find that the results are robust to the inclusion of more lags. I report the estimates with 20 lags (5 years) in the appendix. Including a lead of the tornado allows me to test for pre-treatment trends. λ_i and γ_{year} account for county and year fixed effects respectively.

Belasen and Polachek (2008, 2009) use a similar generalized difference-in-difference ap-

proach to examine the effect of hurricanes on local labor markets of counties in Florida. Even though other techniques such as propensity score match may also be suitable approaches, using a generalized difference-in-difference approach takes into account the effects of observed and unobserved characteristics.

4 Data

The data on tornadoes are obtained from National Oceanic and Atmospheric Administration's (NOAA) Storm Events Database. These data include the start date, and the F-scale or the EF-scale of the tornadoes. They also include number of deaths, injuries, and damages (property and crop) caused by a tornado. The Fujita (F) Scale is a scale classifying the damage that a tornado has caused. The F-Scale ranges from F0 to F5, with an F5 tornado causing incredibly extensive damage. This scale was replaced by the Enhanced Fujita (EF) Scale in 2007. The Enhanced Fujita scale is a more precise and robust way of assessing damages caused by tornadoes. This scale ranges from EF0 to EF5 with EF5 being the strongest tornado causing extensive damages. The Storm Events database allows for a clear and exogenous identification of counties that experienced a big tornado based on their F/EF scale classification. As both the F and EF scale are based on damages, there have been tornadoes that have been ranked as F2/EF2 or lower in open areas that could have been classified as F2/EF2 or greater if they hit a sufficiently well-constructed area[5]. Since the classification of tornadoes is in essence a measure of the destruction that it caused, the results of this study could be extended to other disasters, natural or man-made, that cause damages of similar magnitude.

Cavallo et al. (2013) find that only extremely large disasters have a significant impact on output in the short and the long run. Boustan et al.(2017) find that out-migration and housing prices are affected by severe disasters. Following this strain of literature, I focus on violent tornadoes and define a violent tornado as a tornado that has been ranked as either an F-4/EF-4 or F-5/EF-5. I define two tornado variables in my dataset. One accounts for the direct component. This variable takes the value one if the county experiences at least one F4/EF4 or F5/EF5 tornado in a quarter. If a tornado crosses

[5] https://www.spc.noaa.gov/faq/tornado/#f-scale1

county lines, so long as the tornado ranking does not drop below the threshold between counties the variable for directly affected county is 1 for each of these counties. My second tornado variable accounts for a violent tornado in a neighboring county. This variable takes the value one if a neighboring county experiences at least one F4/EF4 or F5/EF5 tornado in a quarter.

The data for employment are from the Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages(QCEW). These data include employment levels by industry for counties at a monthly frequency and total wages by industry at a quarterly frequency. The QCEW occasionally suppresses data to protect the identity or identifiable information of cooperating employers. These observations have a non-disclosure flag associated with them and the value recorded for them is 0. At the more aggregate level of industry and geography, the non-disclosed employment levels and wages are included in the reported values. However, for some counties, data for a few monthly observations are not disclosed even at the all industry level. For these observations, I linearly interpolate the employment levels and the total wages. I aggregate the employment levels to their respective quarters so as to examine a more complete story along with wages per worker. I begin this paper by focusing on all industries in the private sector. I also examine the labor market based on specific industrial sectors, specifically, construction; manufacturing; finance, insurance, and real estate (FIRE); trade, transportation, and utility (TTU); services; mining; and agriculture. I also evaluate the effect of a tornado on employment at a monthly level to inspect the nuances of the changes in employment within a smaller time frame from the time of the tornado. I use census region CPI data made available by BLS to compute real wages.

My final data for all industries and counties consist of an unbalanced panel of 3,106 counties in the contiguous United States spanning from 1975q1 to 2016q4. Data for each of the sectors in all the 3,106 counties is not available. The number of counties for each sector varies from 2,237 to 3,105 counties. Table 1 describes the summary statistics by industrial sectors. This summary shows that, on average, employment growth and growth in wages per worker has been increasing for most sectors between 1975 and 2016, except manufacturing and mining which experienced a decline in their employment growth between 1975 and 2016. Figure 2, shows the maps for violent tornadoes that

occurred between 1975 and 2016. This figure shows that, most violent tornadoes affect the the mid-western and eastern region of the United States. It also shows that a large number of counties have experienced only one violent tornado, although there are counties that have experienced several violent tornadoes as can be seen in table 2. Table 2 also describes the total number of violent tornadoes that have occurred between 1975 and 2016 in the contiguous United States. This shows that there have been 574 violent tornadoes throughout the contiguous United States, a number far greater than the number of violent hurricanes experienced. Between the same period the United States experienced approximately 110 major hurricanes that were classified as category 3, 4, or 5 on the Saffir-Simpson scale[6]. However, far less research has been done on the aftereffects of these tornadoes.

Using United States Department of Agriculture's Rural-Urban Continuum Codes, I identify counties as urban or rural. These codes are updated every 10 years starting with 1974. I define a county to be rural or urban based on its status during a period of plus/minus 5 years from the census year. For instance, a county is defined to be rural or urban between 1998 and 2008 based on its status in the 2003 rural urban continuum codes. I use this to evaluate the heterogeneous effect of a tornado on the labor markets in rural and urban counties. Table 3 reports the summary statistics for rural and urban counties respectively. As would be expected, employment growth and growth in wages per worker in urban counties is higher than in rural counties. Table 2 describes the total number of violent tornadoes that have occurred between 1975 and 2016 in the contiguous United States by rural and urban counties. This table shows that the number of violent tornadoes that occurred in rural counties far exceeds the number that have occurred in urban counties. However, as a percent the occurrence is well-balanced with 15% of rural counties and 15% of urban counties experiencing at least one violent tornadoes.

A potential data concern is whether the labor market data derived around the time of an tremendously extensive tornado is reliable. Garber et al. (2006) review the quick adaptation measures adopted by BLS's QCEW to account for data gathering problems as a result of Hurricane Katrina. They conclude that despite the adjustments in the estimation and imputation procedures to accommodate the situation, due to the high

[6] http://www.aoml.noaa.gov/hrd/tcfaq/E11.html

level of non-response some uncertainty remains regarding the employment and wages measured during that period. It is possible that there may be some uncertainty in the measured employment and wages around the period of a violent tornado, however the adjustments made by the QCEW ensures a relatively lower uncertainty than what it could have otherwise been.

5 The Effects of Violent Tornadoes on Local Labor Markets

Figure 3 plots the multiplier effect of violent tornadoes on employment growth and growth in wages per worker. The panel on top plots the effects of a violent tornado on employment growth over a period of two years, while the lower panel plots cumulative response of wages per employee for the same duration. These results show that violent tornadoes have no significant effect on the growth rate of employment throughout the two year period on the directly affected county. However, the response of employment growth specific to four and eight quarters after the tornado strike displays decreases of 0.31 and 0.32 percentage points respectively. These decreases in employment growth are marginally significant at 90% confidence. On the other hand, the growth rate of wages per worker, on average, experiences a contemporaneous increase of 0.49 percentage points. This increase in wages is statistically significant at the 95% confidence level. Two quarters after the tornado strike, the county experiences an almost equivalently and marginally significant decrease in growth of wages per employee of 0.46 percentage points leading to wage growth returning to its pre-tornado rates. This can be seen in the insignificant change in the multiplier response two quarters after the tornado. The quarter specific response of growth in wages per worker seven quarters after the tornado growth increases by 0.69 percentage points. This increase in wage growth is persistent not only seven quarters after the tornado but also eight quarters after the tornado with an increase of 0.68 percentage points. This multiplier effect increase is statistically significant at the 95% confidence level.

The results support the previous discussion of a fall in employment growth due to potential out-migration, while businesses trying to fill the void created by an increase in

out-migration apply positive pressure on demand leading to mostly insignificant change in employment growth and increased wage growth. Looking through the lens of a standard labor supply labor demand provides further intuition behind the movements of the labor market. Initially labor supply may not change much as individuals prepare for migration and demand experiences positive pressure due to recovery and reconstruction efforts. This leads to the insignificant change in employment growth and a positive change in wage growth contemporaneously. In later quarters, labor supply becomes more scarce as both out-migration due to individuals leaving the area, and in-migration due to people seeking job opportunities created as a result of reconstruction efforts are experienced in the directly affected county. This is evidenced by the mostly insignificant employment growth along with the changing sign of wage growth as it adjusts to this movement in the labor supply and the labor demand. Two years after the tornado, wage growth is persistently higher than it's pre-tornado rates, however this does not necessarily indicate a better labor market outcome nor is it indicative of a permanent shift in the steady state of wage growth. The increase in wage growth dissipates 12 quarters after the violent tornado and the growth in wages per worker returns to its pre-tornado rates and remains as such. The increase in wage growth observed here is in line with findings of Skidmore and Toya (2002) who find that climatic disasters like tornadoes, cyclones, hurricanes, etc. lead to higher economic growth.

The effect of a violent tornado on wage growth of the directly affected counties follow a similar pattern as that observed by Belasen and Polachek (2009) for the effect of hurricanes on earnings. They find that the direct effect of a hurricane on growth of earning is higher and lasts through the seventh quarter after the hurricane. I find that the effects of a tornado on wage growth are felt eight quarters after the tornado. They also find a significant persistent decrease in employment growth rate in the directly affected counties two years after the hurricane indicating a stronger influence of labor supply and potentially migration. On the other hand, I find that employment growth remains mostly unchanged throughout the two year period after the tornado, though wage growth increases and is persistent two years after the tornado. This suggests that even though the change in employment growth from its pre-tornado rates is short-lived that is not the case for wages. The difference in findings could be attributed to the difference in disasters or a difference in geography. Examining the data for the same period as Belasen and Polachek

(2009), I find that employment growth falls. However, this fall in employment growth is only experienced contemporaneously and a quarter after the tornado. After this period employment growth returns to its pre-tornado rate. The difference in my results can be attributed to the difference in sample size, however the path followed by employment growth remains similar to the results with the entire sample implying that the difference in periods is not the sole reason for the difference. Since, there are no violent tornadoes in Florida in my sample, there exists a possibility that the difference in patterns between their findings and mine may be based on geography. Another possibility is that the two disaster types themselves vary. Compared to hurricanes, tornadoes are more focused in nature and for the most part they are not accompanied by the additional damage caused by floods.

The quarter specific response of employment growth in neighboring counties experiences frequent change from quarter to quarter. The effect on employment growth aren't experienced till a quarter after the tornado. The neighboring county experiences a 0.36 percentage points decrease in employment growth. This decline is marginally significant at the 90% significance. However, the multiplier effect shows that there is no significant change in employment growth in the neighboring county throughout the two year period after the tornado. Wage growth, on the other hand, experiences insignificant quarter specific change for all of the quarters after the tornado. However, the multiplier effect shows that growth in wages per worker are higher a quarter after the tornado as well three quarters after the tornado. This multiplier effect of violent tornadoes on wage growth persists until six quarters after the tornado. The initial decrease in the quarter specific response of employment growth along with no significant change in wage growth per employee suggests a negative effect on both supply and demand. Since the data being evaluated accounts for the employment in the county and not the people employed in the county, there may be people who live in the directly hit county that out-migrate, and leave employment in a neighboring county. This leads to a spill-over negative labor supply shift in the neighboring county. The negative shift in demand could be attributed to the anticipated fall in demand for goods and services due to the tornado. Over time, the fluctuating quarter to quarter response of employment growth suggests a rapid adjustment of labor demand and supply to the destruction caused by the tornado while the cumulative increase in wage growth suggests a steady increase in demand for labor for a

short period a year after the tornado.

5.1 Urban Vs. Rural

Demographics and income levels vary between urban and rural counties [7]. As described by the summary statistics in table 3, employment growth and growth in wages per worker between these types of counties also differ. For this reason, it should be expected that the response of the labor market would vary between urban and rural counties.

Figures 4 and 5 show the multiplier effect of a violent tornado on employment growth and growth rate of wages per worker in directly affected counties and neighboring counties respectively by urban and rural counties. These graphs show the average effects on directly affected counties that we observe across the country are driven by the effects of violent tornadoes in rural counties. On average, 15% of both urban and rural counties have experienced at least one violent tornado between 1975 and 2016. This implies that the results that we see are not driven by the greater number of tornadoes striking rural counties.

The effect of a violent tornado on employment growth and wage growth in directly affected urban counties is insignificant for most of the two year period after the tornado that we observe here. Employment growth experiences a marginally significant cumulative rise seven quarters after the tornado, though this increase fades away by the next quarter. This sudden increase in employment growth almost two years after the tornado suggests that reconstruction takes place more gradually than expected.

Rural counties that are directly struck by a violent tornado experience insignificant change in employment growth as shown by figure 4. Wage growth, on the other hand, contemporaneously experiences a statistically significant increase of 0.74 percentage points at the 95% confidence level. This initial increase in wage growth combined with an insignificant change in employment growth indicates along with an assumption that migration does not occur instantaneously an increase in demand due to the immediate need for clean-up and recovery. Two quarters after the tornado the positive effect experienced on wage growth wears out. Even though, the quarter specific response of wage growth after the

[7] https://www.census.gov/newsroom/press-releases/2016/cb16-210.html

contemporaneous quarter is insignificant, the multiplier response shows that wage growth persists to rise in several quarters following the tornado. This leads to persistently higher wage growth of 0.83 and 0.8 percentage points seven and eight quarters after the tornado. This suggests that even though each quarter doesn't see any strong effects to the labor markets, there is a silver lining to the tornado in the directly affected rural county in the form of cumulatively rising wage growth. However, this effect dissipates with more time.

Many rural towns and villages have experienced a loss in easy access to necessities like food and clothing and other goods as local businesses close resulting in residents traveling a greater distance to obtain these goods and services (Glasgow 2000). This implies that the sudden increase in demand of these goods and services would be observed in the labor market as well. The difference in responses between urban and rural counties could potentially be because rural counties may not be equipped to deal with the sudden upsurge in demand for basic goods and services. On the other hand, since urban counties face no such lack in resources or access to these necessities, an increase in demands for goods and services to meet recovery efforts do not translate into a change in the labor demand.

Figure 5 plots the neighboring effect of violent tornadoes on employment growth and growth rate of wages per worker by urban and rural counties. The figure plots the multiplier effect of violent tornadoes on employment growth and wage growth. Urban neighboring counties contemporaneously experience a significant decrease in employment growth of 0.35 percentage points and an increase in wage growth of 1.03 percentage points. This indicates an initial stronger negative influence on labor supply most likely due to out-migration. In consecutive quarters, the fall in employment growth in the neighboring urban county continues and two years after the tornado employment growth is 1.12 percentage points lower than its pre-tornado rate. Wage growth, on the other hand, experiences a significant rise three quarters after the event peaking with an increase of 1.7 percentage points four quarters after the tornado. This rise in wage growth consequently starts to fade out, although, it still persists at a 1.1 percentage point higher growth rate. These results suggest a better outcome for wages two years after the tornado, and a worse outcome for employment in the urban neighboring county. However, this deviation from the pre-tornado state is temporary and over a longer duration these effects wear off.

The quarter specific response of employment growth in rural neighboring counties experiences frequent change from quarter to quarter. The effect on employment growth aren't experienced till a quarter after the tornado. However, the multiplier effect shows no significant change in employment growth in the neighboring rural county throughout the two year period after the tornado. Wage growth, on the other hand, experiences insignificant change for all of the quarters after the tornado. The fluctuating quarter specific response of employment growth in rural neighboring counties suggests a rapid adjustment of labor demand and supply to the destruction caused by the tornado.

5.2 Time Disaggregation

Figure 6 shows the monthly multiplier effect of violent tornadoes on employment growth. This gives a more detailed view of the response of employment growth to a violent tornado. In the month after the tornado employment growth impulsively falls marginally by 0.24 percentage points. However, like with the quarterly frequency, the multiplier effect on employment growth does not change significantly. On the other hand, when examining the neighboring effects of a violent tornado the monthly cumulative response of employment growth shows a similar path as that of quarterly employment growth. However, the fall and rise are sharper revealing brief months of persistent significant fall in employment growth. The graph shows that employment growth falls by 0.27 percentage points contemporaneously. Even though employment growth recovers from this fall in the very next month out-migration probably leads to a persistent fall in employment growth three months after the tornado. Employment growth recovers from this about ten months later. This recovery may be attributed to in-migration by individuals seeking labor market opportunities created by recovery efforts. Neighboring counties experience a second round of falling employment growth from fifteen to twenty-one months after the tornado. This is suggestive of labor market adjustments as recovery efforts make progress. Since wage data are not available at the monthly frequency the details of the change in wages cannot be examined beyond quarters. In this particular scenario, the neighboring effects of employment growth paints a far more detailed picture of the movement in employment. However, direct effects aren't all that different from the quarterly frequency and evaluating the data at the quarterly frequency allows for the inclusions of

wages in the analysis providing a more complete picture of the labor market.

5.3 Does the Intensity of Tornado Matter?

Figure 7 plots the multiplier effect of a broader range of tornadoes on employment growth and growth in wages per worker. The variable Large Tornado takes the value one if county i is struck by at least one tornado in time t that is ranked F2/EF2 or higher. There have been 7,908 tornadoes ranked F2/EF2 or higher between 1975 and 2016. Of these 2,625 tornadoes have occurred in urban counties while 5,283 have been in rural counties. The figure shows that large tornadoes lead to 0.24 percentage points decline in employment growth a quarter after a county experiences a large tornado strike. This decline is statistically significant at the 99% confidence level. In the following quarter employment growth returns to its pre-tornado rate. This path to recovery is over-shot by a marginal increase in employment growth of 0.15 percentage points three quarters after the tornado. However, this increase does not last. The following quarter employment growth returns to its pre-tornado rate and it remains at this rate thereafter. Even as employment growth experiences some effects in the medium run prior to settling back to its pre-tornado rate, wage growth remains insignificant throughout the period of analysis. Even though growth in wages per worker experienced no significant change the path followed is identical to the response to violent tornadoes. The multiplier effect of large tornadoes on employment growth to also follows a similar path as that of its response to violent tornadoes. However, the initial response of employment growth is stronger to large tornadoes. This suggests that unlike with violent tornadoes, the adjustment of labor markets relies on employment more than on wages. At the end of two years change in employment growth and wage growth are insignificant implying that the labor market returns to its pre-tornado position. The difference in labor market response between large tornadoes and violent tornadoes can be explained by the response of the labor markets of different industrial sectors to the different intensity tornadoes. These results are reported in the appendix.

Even though direct effects differ when the intensity of tornadoes is lowered, the neighboring effects seem to follow a similar pattern as the effect of a violent tornado. The figure shows that the multiplier effect of a large tornado on employment growth in a

neighboring county like the response to a violent tornado is insignificant throughout the duration of analysis. The multiplier effect of a large tornado on wage growth is similar to that of its response to a violent tornado in a neighboring county, though the response to a large tornado is comparatively subdued. These results suggest that the labor market in the neighboring county experiences some adjustment in the short run, however, these effects do not persist and employment growth and wage growth return to their pre-tornado states.

5.4 Sector Disaggregation

Examining labor market response by specific sectors can reveal the industries that experience change after a devastating tornado. This uncovers the demands and needs of the county in the aftermath of the tornado. This could potentially aid in establishing policies that strengthen disaster management. Figures 8 and 9 plot the multiplier effect of a violent tornado on employment and wage growth respectively in directly affected county by industrial sectors - construction; manufacturing;finance, insurance, and real estate (FIRE); trade, transportation, and utility (hereafter TTU); services; mining; and agriculture.The results show that the construction and service sector experience a change in employment growth as well as wages in growth per worker after the tornado. TTU experiences a change in employment growth while, manufacturing, mining and agriculture observe a change in their growth in wages in the wake of the tornado.

The TTU sector experiences a marginally significant fall of 1.51 percentage points in employment growth contemporaneously. The sector however, recovers from this drop in employment growth in the next quarter. The results show that employment growth experiences a marginally significant increase in the construction a quarter after the tornado of 2.26 percentage points. In the same quarter growth in wages per worker of this sector increases by 1.42 percentage points a quarter after the tornado. The increase in employment growth and growth in wages per worker is likely due to the start of recovery and reconstruction. This suggests a more dominant increase in labor demand in the construction sector. Employment growth in the service sector falls by 1.67 and 1.81 percentage points contemporaneously and a quarter after the tornado respectively. These decreases in employment growth is marginally significant and fade out in the following

quarter. Growth in wages per worker in the services sector also falls marginally by 0.91 percentage points a quarter after the tornado. This can be attributed to a fall in demand for services in the immediate wake of a tornado. Growth in wages per worker experience another fall of 1.18 percentage points four quarters after the tornado which suggests a further adjustment in demand in the sector.

The other sectors that experience a change in growth in wages per worker are manufacturing, mining, and agriculture. Manufacturing experiences a marginal increase of 0.77 percentage points contemporaneously suggesting an increase in demand for goods translates to an increase in labor demand in the sector. This increase in demand for manufactured goods is indicative of demand for durable goods that were possibly damaged or lost in the tornado. Mining sector experiences a contemporaneous fall of 1.68 percentage points in growth in wages per worker. While the agriculture sector experiences no immediate effect from the tornado, growth in wages per worker falls by 3.38 percentage points five quarters after the tornado. This can be attributed to the fall in agricultural earnings following the destruction of crops from that season due to the tornado. This fall in earnings is experienced with a lag since there is lag in the timing of when the destroyed crops would have gone to market.

Belasen and Polachek (2008) find that hurricanes result in a fall in employment growth of the TTU sector which is in-line with my findings. However, they also find that the drop in employment growth is accompanied by a fall in growth in earnings. Their results for the construction sector show that growth in earnings increases while growth in employment remains unchanged. Their results suggest a stronger demand shock is at play in these sectors in the aftermath of the tornado. I find the same to be true in case of the construction sector, although for the TTU sector that may not be the case. Belasen and Polachek(2008) also find an increase in employment growth and growth in earnings in the services sector while I find a fall in employment growth and no change in wage growth. These differences in findings could be a result of the difference between hurricanes and tornadoes or even the fact that my analysis focuses on the changes observed over time while they focus on the contemporaneous period.

Figures 10 and 11 plot the multiplier effects of a violent tornado on employment and wage growth respectively in a neighboring county by industrial sectors. The results show

that the only sector to experience a change in its employment growth in a neighboring county is the FIRE sector. The remaining sectors experience no significant change in their employment growth. This corroborates with my findings employment growth for all the sectors. Employment growth in the FIRE sector experiences a cumulative fall of 0.79 percentage points a quarter after the tornado. Growth in wages per worker in the neighboring counties experience a change in the construction, TTU, and agriculture sectors. Growth in wages per worker of the construction sector of the neighboring county increases 1.47 percentage points. This coincides with the increase in wage growth and employment growth in the construction sector of the directly affected county suggesting that it's a demand spill-over from the initiation of reconstruction efforts. Wage growth in the TTU sector of a neighboring county experiences a marginal fall of 0.79 percentage points a quarter after the tornado. The sector recovers from this fall in the following quarter and wage growth in the TTU sector returns to its pre-tornado rate. Agriculture experiences an increase of 2.07 percentage points in wage growth contemporaneously. This could be because of the destruction of stored agricultural product in the directly affected county leading to the demand for these products to spill-over into neighboring counties.

6 Key Findings

Violent tornadoes in directly affected counties result in opposing effects on labor supply and labor demand. This is evident from the persistently higher wage growth and insignificant change in employment growth two years after the event. These results suggest that the state of the labor market two years after the tornado is better than its pre-tornado state due to persistently higher wage growth. These results are in line with the positive effect on growth deduced by Skidmore and Toya (2001). Disaggregation of the sample between urban and rural counties shows that this wage growth is driven by rural counties. This difference in response between urban and rural counties can be attributed to the urgency of reconstruction in rural counties. The difference in the response between urban and rural counties suggests that the response to labor markets may vary based on the counties income levels.

Neighboring counties after a violent tornado experience a stronger influence of labor demand that leads to several quarters of persistently higher wage growth. Two years post-tornado the labor market outcomes adjust back to their pre-tornado states. Examining the data separately for urban and rural counties reveals that neighboring urban counties experience a persistent decline in employment growth and increase in wage growth, indicating a stronger labor demand influence. This also implies a worse labor market in the neighboring urban county in the aftermath of a violent tornado due to the lower employment growth.

Examining the labor markets by industrial sectors reveals that the construction sector experiences higher labor demand a quarter after the tornado as suggested by the higher employment growth and wage growth. These higher growth rates, however are not persistent beyond that quarter. Wage growth in agriculture are higher contemporaneously for neighboring counties as they supplement the directly affected county's agricultural stock. The directly affected county experiences a fall in the wage growth of the agriculture sector with a lag as the crops destroyed by the tornado would go to market with a lag.

Lowering the threshold of the tornadoes to F2/EF2 and higher reveals that the counties directly affected experience lower employment growth while wage growth remains unchanged. However, the change on employment growth is not persistent. Within two years of the tornado employment growth returns to its pre-tornado state. Counties struck by violent tornadoes on the other hand, experience a persistently higher wage growth two years after the event. This difference is explained by the results of the responses of labor markets of the various sectors to the tornadoes. These results suggest that since the damage caused by less severe tornadoes is much less severe they can be fixed more gradually as suggested by the cumulatively higher employment growth seven quarters after a large tornado. On the other hand, destruction in the wake of a violent tornado needs more immediate attention as indicated by the increase in employment growth and growth in wages per worker of the construction sector in the immediate quarter after the violent tornado.

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Table 1: Quarterly Summary Statistics

	All	Construction	Manufacturing	FIRE	TTU	Services	Mining	Agriculture
Employment Growth	0.382	0.387	-0.104	0.349	0.123	0.657	-0.118	0.740
	(7.565)	(21.801)	(10.593)	(6.825)	(13.331)	(15.104)	(18.415)	(29.958)
State Employment Growth	0.453	0.403	-0.120	0.467	0.199	0.996	-0.230	0.936
	(2.410)	(10.832)	(2.120)	(2.860)	(4.501)	(2.874)	(8.090)	(20.466)
Growth in Wages per worker	0.114	0.147	0.174	0.233	0.083	0.141	0.163	0.328
	(8.878)	(16.809)	(12.246)	(15.885)	(9.711)	(11.894)	(18.251)	(20.797)
States Growth in Wages per worker	0.137	0.126	0.164	0.325	0.102	0.197	0.224	0.267
	(6.207)	(8.255)	(5.775)	(12.356)	(4.501)	(7.398)	(9.900)	(13.232)
Observations	516,928	512,180	500,354	506,718	516,067	515,676	310,098	453,808
Counties	3,106	3,100	3,058	3,083	3,105	3,105	2,237	3,063

mean coefficients; sd in parentheses

Table 2: Number of Tornadoes

	All Counties	Urban Counties	Rural Counties
Violent Tornado (EF4 and EF5)	574	193	381
Counties with 1 Violent Tornado	340	111	235
Counties with 2 Violent Tornadoes	73	20	50
Counties with 3 Violent Tornadoes	21	10	11
Counties with 4 Violent Tornadoes	5	3	2
Counties with 5 Violent Tornadoes	1	0	1
No. of Counties	3106	1237	2522

Table 3: Quarterly Summary Statistics for Urban and Rural Counties

	Urban Counties	Rural Counties
Employment Growth	0.482	0.339
	(4.859)	(8.460)
Growth in Wages per worker	0.125	0.109
	(7.725)	(9.327)

mean coefficients; sd in parentheses

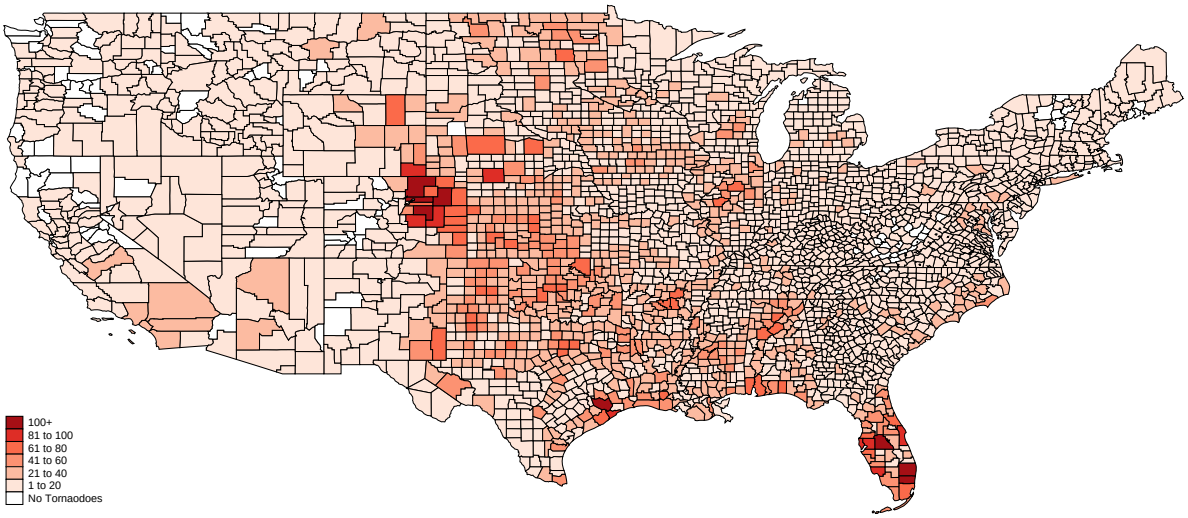


Figure 1: All Tornadoes between 1975 and 2016

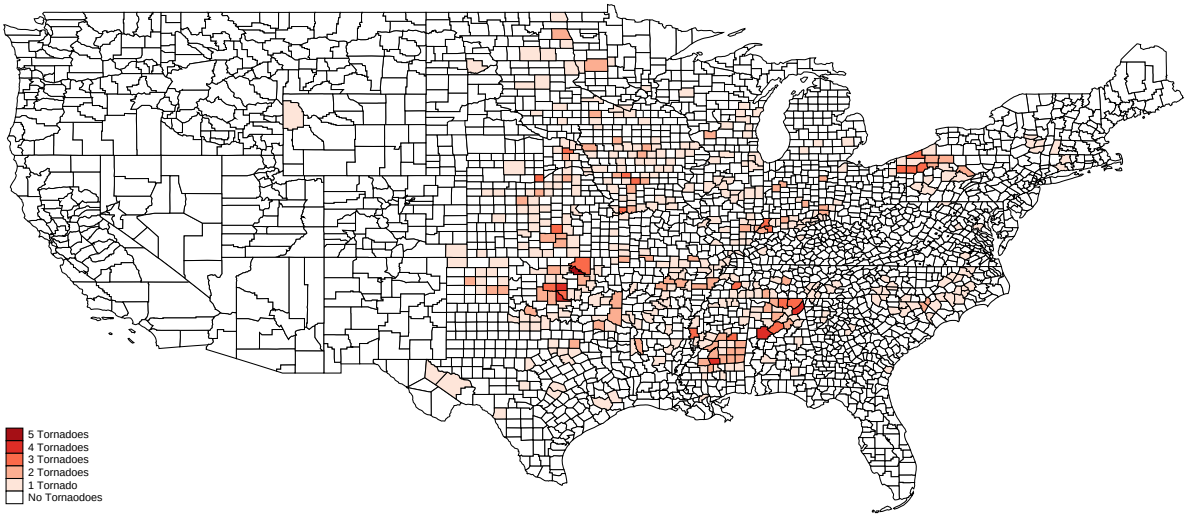
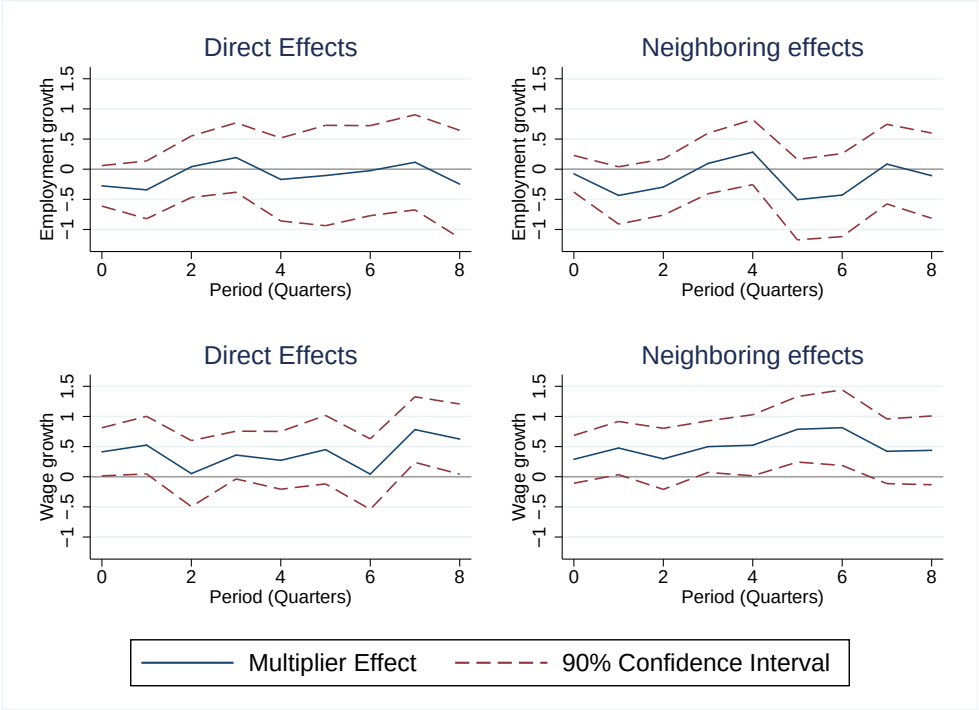
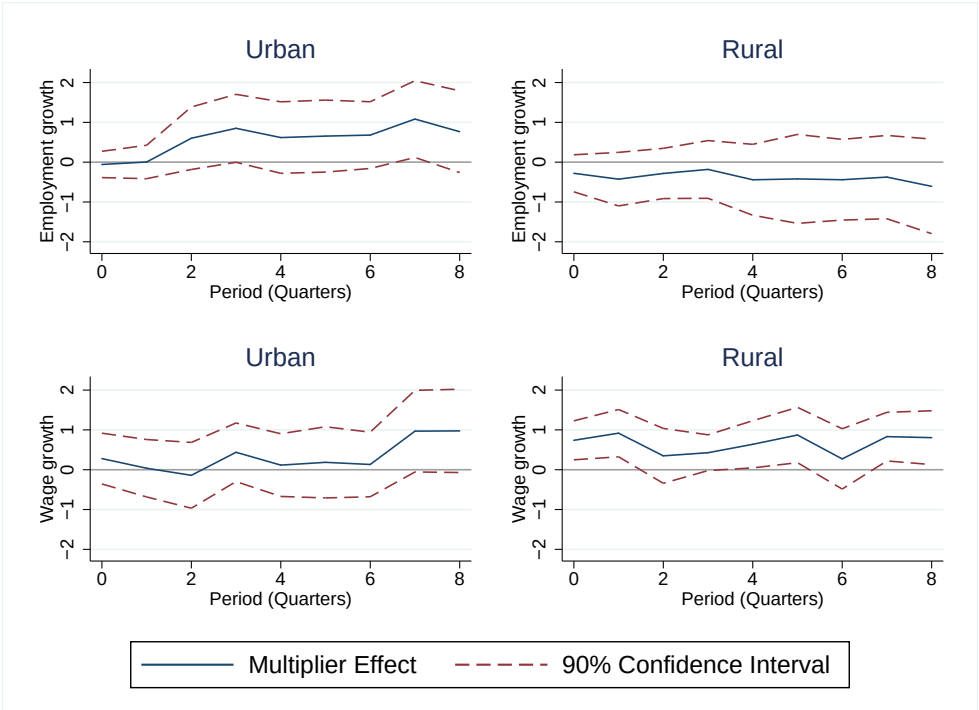


Figure 2: EF4 and EF5 (Violent) Tornadoes between 1975 and 2016



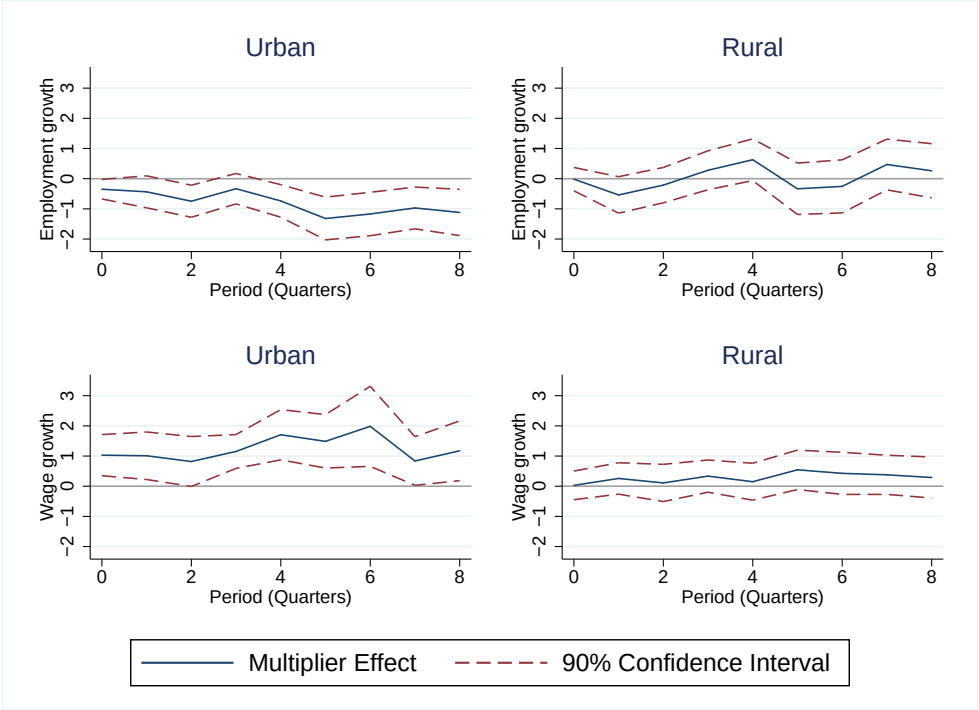
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 3: Multiplier effect of violent tornadoes on labor market outcomes (all industries)



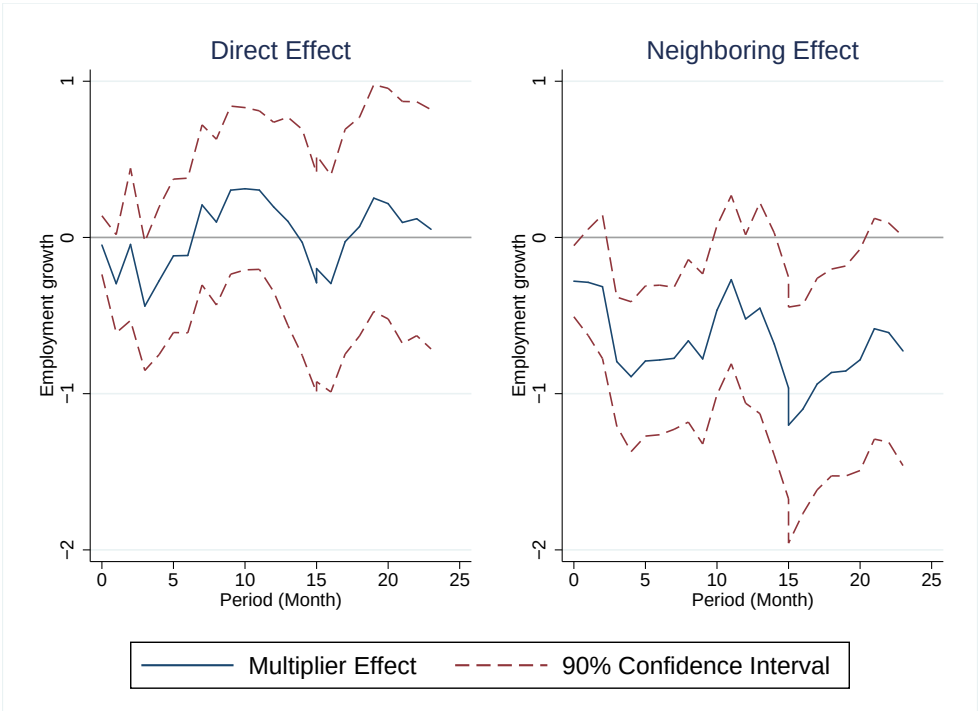
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 4: Multiplier effect of violent tornadoes on labor market outcomes (all industries) of directly affected urban and rural counties



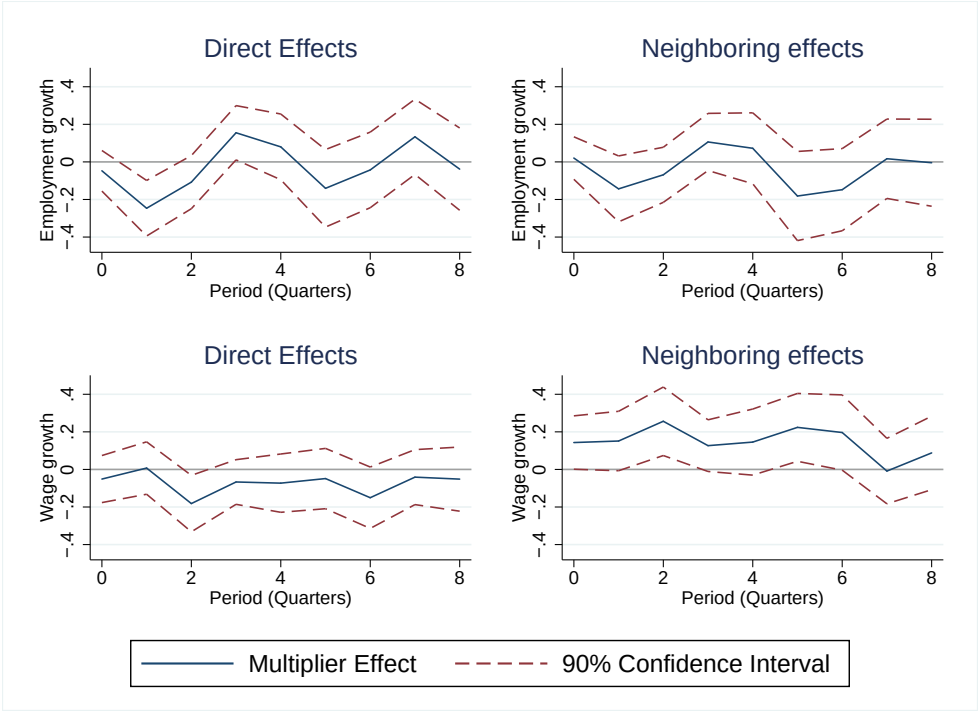
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 5: Multiplier effect of violent tornadoes on labor market outcomes (all industries) of neighboring urban and rural counties



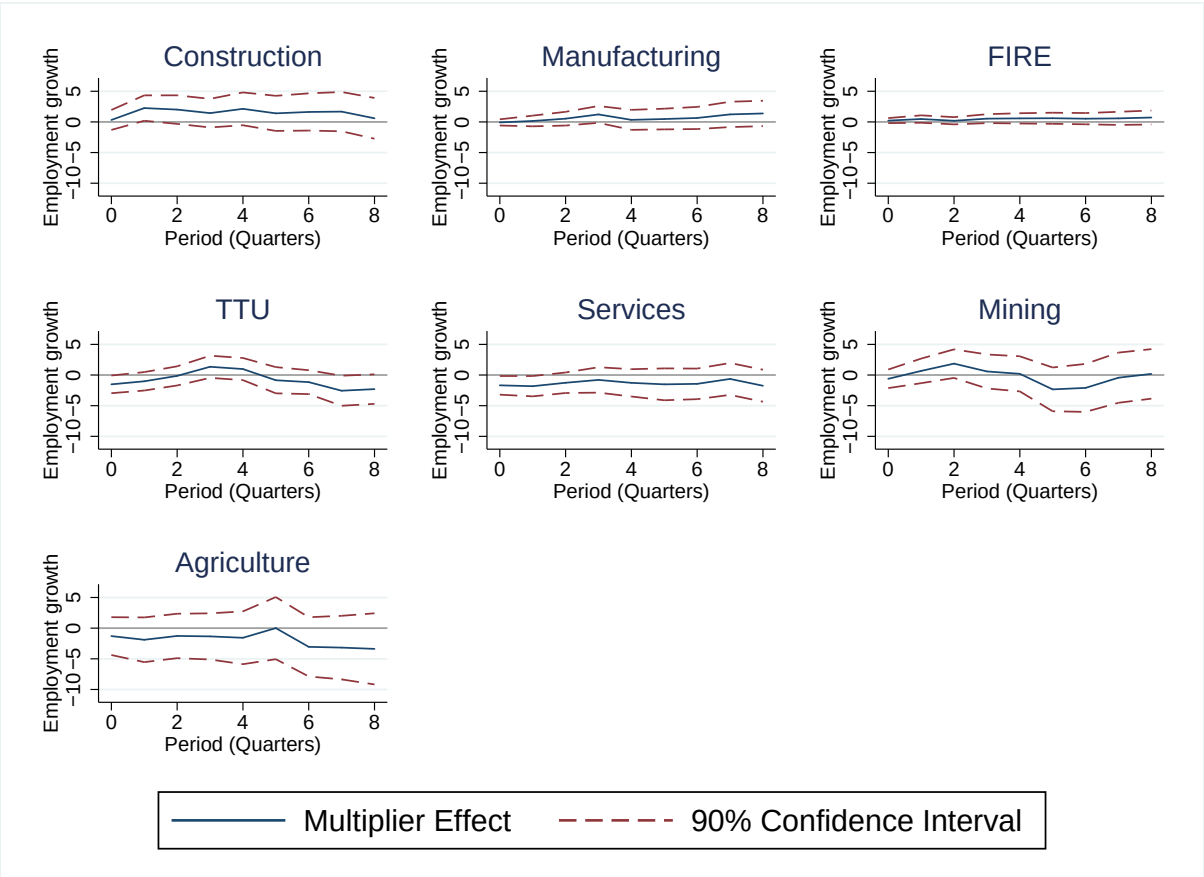
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 6: Multiplier effect of violent tornadoes on employment growth (monthly)



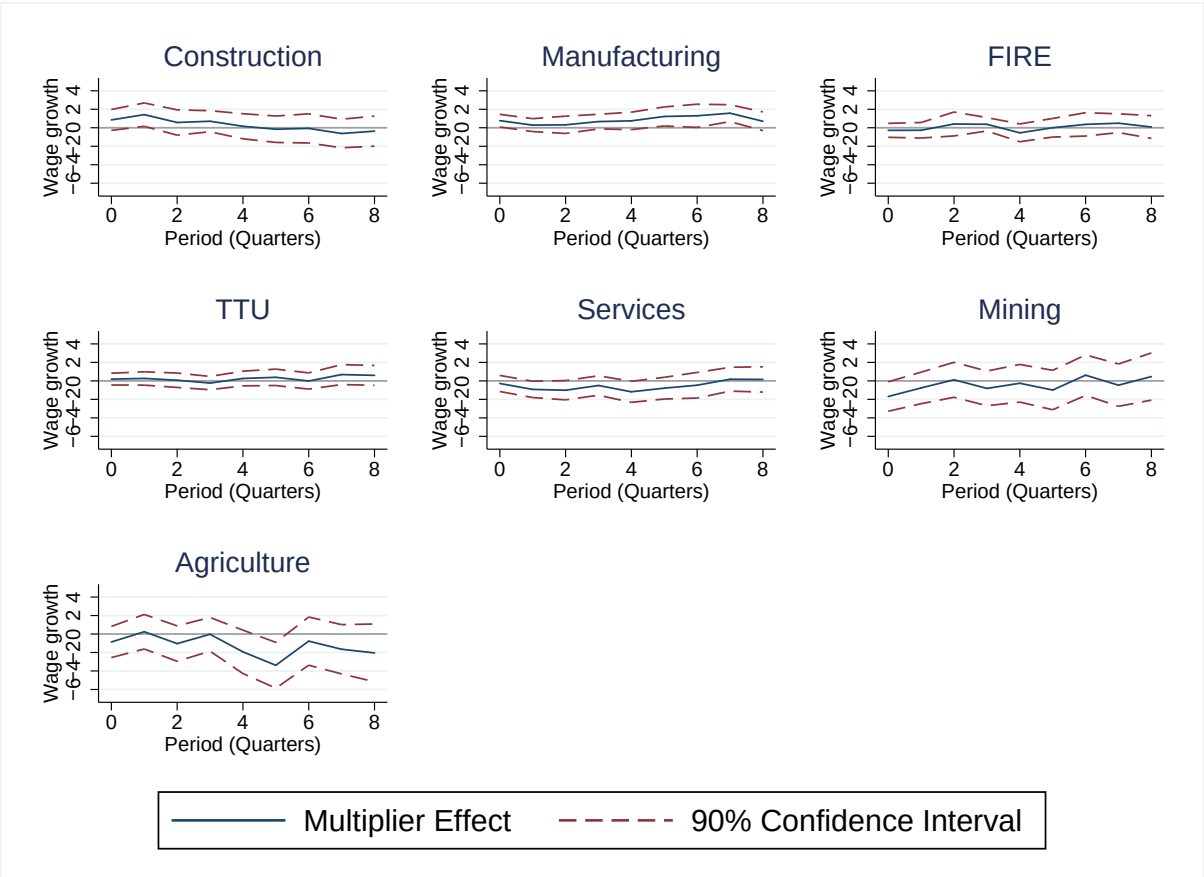
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 7: Multiplier effect of large tornadoes on labor market outcomes (all industries)



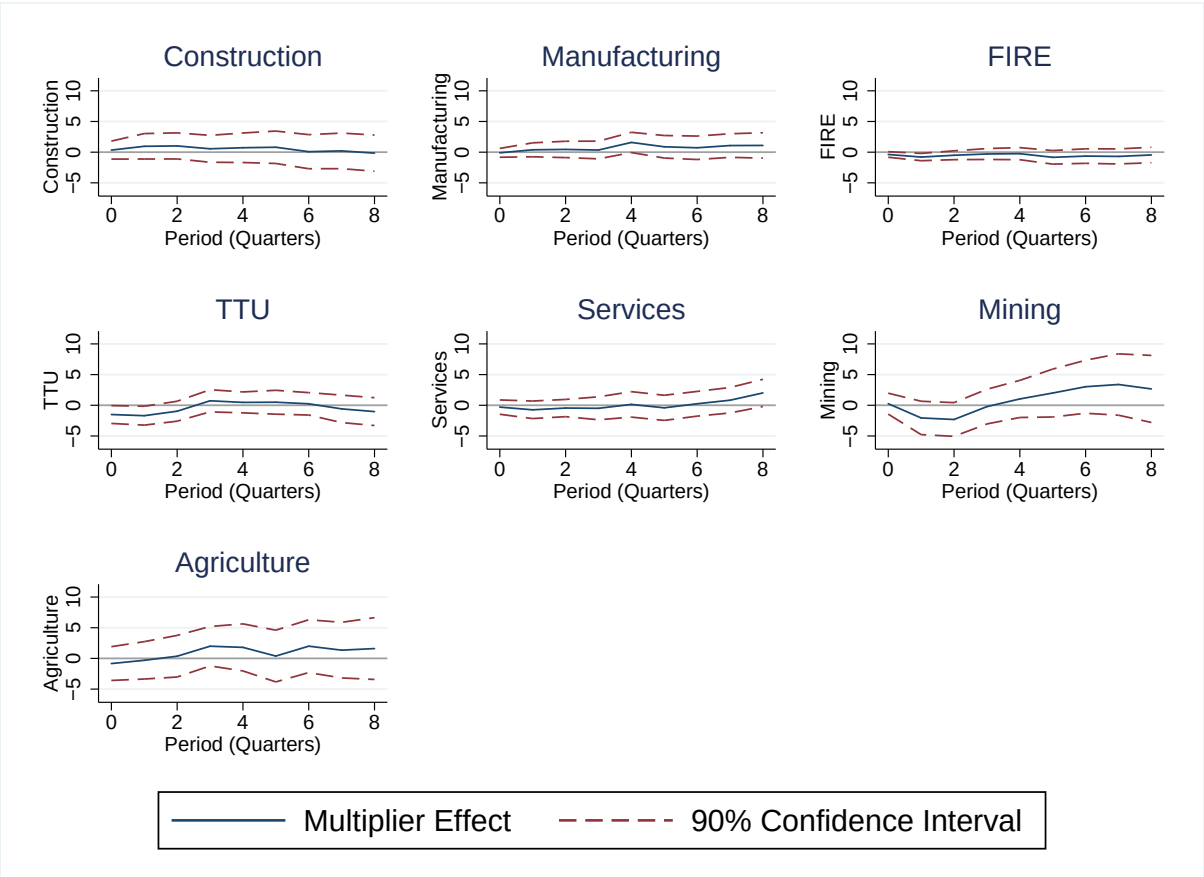
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 8: Multiplier effect of violent tornado on employment growth in directly affected counties



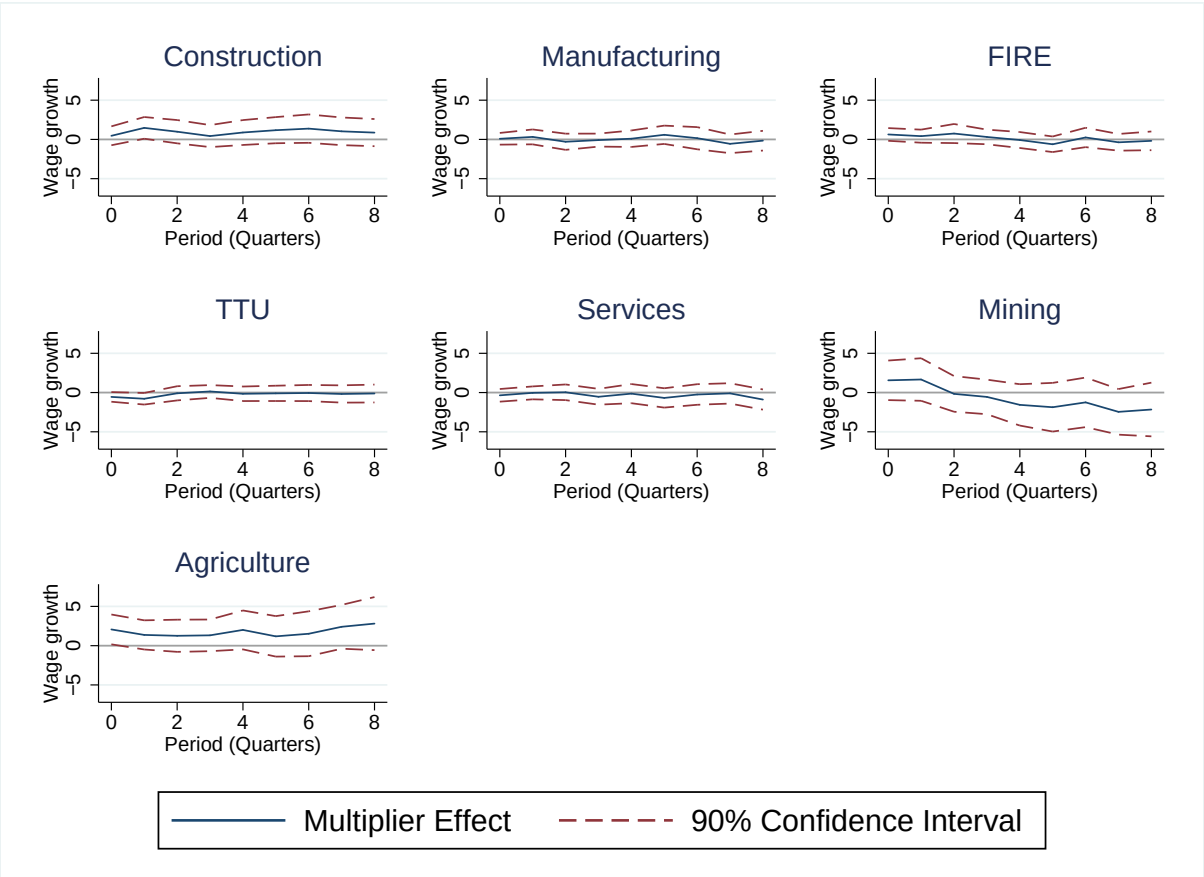
Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 9: Multiplier effect of violent tornado on growth in wages per worker in directly affected counties



Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 10: Multiplier effect of violent tornado on employment growth in neighboring counties



Significance is tested using Wald test. The y-axis defines the percentage points change in the labor market outcomes.

Figure 11: Multiplier effect of violent tornado on growth in wages per worker in neighboring counties