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Job growth and loss across sectors and time in the western US: The impact of large wildfires ☆

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ABSTRACT

The link between economic growth and natural hazards has long been studied to better understand the effects of natural hazards on local, regional, and country level growth patterns. However, relatively little generalizable research has focused on wildfires, one of the most common forest disturbances in the western United States (US). We examined the effect of large wildfires on employment growth across sectors and time in the western US. We matched wildfire occurrences from 2004 to 2008 and their duration with monthly employment data to identify the effect of wildfire on employment growth. Wildfires generally tended to exhibit positive effects on employment during the periods that suppression efforts were active. However, the overall positive effect masks winners and losers across sectors — such as natural resources and mining and leisure and hospitality, respectively. The overall positive effect then transitioned to a negative drag on local employment growth for a period of up to two years following the wildfire. We explore reasons why some sectors win while others lose and explanations for the lingering effects of a large wildfire on the economy as a whole.

1. Introduction

On June 20, 2008, thunderstorms swept across northern California sparking hundreds of wildfires. In Trinity County, the ignitions eventually formed into 13 wildfire complexes. Firefighters spent the rest of the summer, into October, trying to suppress and manage the fires. The United States (US) government alone spent over $150 million on the suppression effort. Although the summer of 2008 in Trinity County has been colloquially referred to as the "lost summer" (Davis et al., 2011), the economic impacts on the local community varied — recreation businesses uniformly reported losses whereas natural resource businesses reported a mix of gains from participating in the suppression effort to losses from having to delay or cancel forest-based projects. The Hayman Fire in Colorado in 2002 tells a similar story (Kent et al., 2003). Butry et al. (2001) find that the 1998 wildfires in northeastern Florida had economic impacts of similar scale to a Category-2 hurricane. These studies and others that have looked at economic impacts from natural hazards such as hurricanes, tornados, and earthquakes suggest that the effects of natural disasters will vary across economic sectors and time (Rose and Lim, 2002; Belasen and Polachek, 2009; Ewing et al., 2009). Wildfires may result in economic winners and losers across industries or time as employment levels adjust upwards to meet the needs of fire suppression and recovery efforts or adjust downwards due to disruptions in normal economic activity.

Understanding the impact of wildfire on local economies is important given that wildfire is one of the most costly and significant disturbances in forests of the western US (Holmes et al., 2008a). The 11 contiguous western US states are home to more than 225 million acres of forests. Over two-thirds of western forests are publically managed, primarily by the US Forest Service (Smith et al., 2001). The average annual US government expenditure on wildfire suppression between 2000 and 2009 was over $1.5 billion per year (in 2009 dollars; Gebert and Black, 2012), most of which was spent on wildfires occurring in the western US. Like in many parts of the world (Flannigan et al., 2009), wildfire activity in the western US is increasing with greater frequency and duration of large wildfires and a longer fire season (Westerling et al., 2006). Although there are many local, regional, and national efforts in policy, collaboration, and forest management to reduce the occurrence and significance of large wildfires, the combination of past fire suppression, climate change, and expansion of the wildland–urban interface (Running, 2006; Gude et al., 2008) ensures that wildfire suppression and management will continue to be an important natural resource, economic, and policy issue for the foreseeable future.

Most investigations into the economic impacts of natural hazards have taken a case study approach — an in-depth inquiry into a specific wildfire (e.g., Butry et al., 2001, Kent et al., 2003), hurricane (Garber et

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al., 2006), tornado (Ewing et al., 2003, 2009), earthquake (Rose and Lim, 2002), or flood (Xiao, 2011). Other studies have analyzed the economic trajectories of countries with respect to the level of risk and frequency of natural hazards (Tol and Leek, 1999; Skidmore and Toya, 2002), showing that, in the long run, natural hazards can result in investments in human capital, economic adaptation, and overall productivity gains. A generalizable approach that isolates the sectoral or temporal effects of a natural disaster on a local economy is rare (e.g., Belasen and Polachek, 2008, 2009). Nielsen-Pincus et al. (in press) showed that wildfires generally create a net increase in local employment and wages during a fire, but that seasonal patterns of employment and wages become amplified for a period of time following a wildfire. High season labor demand gets higher and the low season demand gets lower. Aggregate changes in the labor market and seasonal patterns are important measures of local economic response; however, these measures may mask larger and differential sectoral effects from wildfire and more fundamental non-seasonal trends over time. Our objective is to fill this gap in the literature by reporting a sectoral and temporal analysis of employment growth with respect to large wildfires in the western US.

We examine the effect of large wildfires on local labor markets using a panel study approach that asks two main questions:

1. How does the effect of large wildfires on local employment growth vary by economic sector?
2. How does local employment growth trend change over time following the occurrence of a large wildfire?

We used US federal agency data on wildfire and county-level employment growth to isolate the effects of large wildfires on local employment growth by sector in a panel regression framework. We deseasonalized the labor market data and controlled for temporal trends in employment growth as well as state business cycles to isolate the effect of wildfires on employment growth by sector and over time following a wildfire. Finally, we discuss the economic implications of wildfire and conclude with several important policy considerations for national wildfire management policy.

2. Methods

We use a generalized difference-in-difference modeling approach (see Belasen and Polachek, 2008, 2009) to estimate the effect of large wildfires on local labor markets. The approach compares the impact of a set of exogenous economic shocks (large wildfires in our case) occurring in particular counties to a set of counties that did not experience the exogenous shock. As such, the approach sets up a quasi-experiment with a treatment/control group comparison. Specifically, we examine the effect of wildfires that occurred during the five-year period between 2004 and 2008 on employment growth during periods when active wildfire suppression was occurring. We disaggregate employment growth into high-level economic sectors to examine how the effects of wildfire vary by industry, and we examine the 24-month period following the end of suppression activities to identify whether local economies undergo a period of employment adjustment following large wildfires. We next describe the panel structure of the wildfire and employment data.

2.1. Data

We constructed our panel dataset from two primary sources: (1) we collected employment data from the US Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW), and (2) we collected fire occurrence data from the US Forest Service (FS). QCEW data included county-specific monthly employment levels by economic sector for the 11 western states (AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY) from 2003 to 2008 and is the basis for our dependent variables. We seasonally adjusted the employment data using a 12 month ratio-to-moving-average method (Harvey, 1994) for each economic sector in each county and state using Eq. (1).

$$\Delta N = \frac{(N_t - N_{t-12})}{N_{t-12}} \tag{1}$$

where N represents employment in the relevant sector and geography and the year-over-year calculation removes seasonality. We examined 10 economic sectors: natural resources and mining; construction; manufacturing; trade, transportation, and utilities; information services; financial activities; professional and business services; education and health services; leisure and hospitality services; and the federal government. We calculated employment growth for each of these ten sectors by state and by county.

We obtained wildfire occurrence data for 2004 to 2008 for all wildfires for which the US Forest Service was the lead suppression agency and for which the suppression effort cost the Forest Service more than $1.0 million. Fire occurrence data was obtained from the National Interagency Fire Management Integrated Database, which contains attributes about each incident including the ignition location (Latitude/Longitude), the initial attack date, and the date on which the suppression objectives were met. We assigned each wildfire to the county in which the ignition location occurred and used the suppression dates to identify the set of months for which large wildfire incidents were being actively suppressed. We then summarized the wildfire occurrence data by county and month and joined it with the employment growth data. The panel structure of the data is organized such that each of the 413 counties in the 11 contiguous western US states includes observations for employment growth for the county in aggregate and by sector, employment growth for each county's respective state in aggregate and by sector, and a dummy variable indicating whether a large wildfire was being actively suppressed or not during each time period. The year-over-year ratio for calculating monthly employment growth results in dropping the first year of observations because they have no previous year's observations on which to calculate growth. Therefore temporal observations for growth span 2004 to 2008, matching the time period for which wildfire incident data was obtained and resulting in a total of 60 temporal observations for each county in total and for each county by sector.

2.2. The sectoral and temporal employment growth models

We specified the sectoral employment growth model in SAS 9.3 using the Da Silva panel procedure method, which partitions variance in the dependent variable into components attributed to the explanatory variables (e.g., wildfire), cross-section, time period, and otherwise unaccounted for residual variance.[1] We used a moving average error term that accounted for the fact that, although the employment growth rate calculation does remove seasonality in the data, it does not ensure stationarity across the time series. The functional form of the model is expressed as

$$\Delta N_{it} = \boldsymbol{x_{it}}\beta + a_i + b_t + e_{it} \tag{2}$$

where $\boldsymbol{x_{it}}$ is a vector of p explanatory variables, a_i is a time-invariant cross sectional effect, b_t is a cross-sectionally invariant time effect, and e_{it} is a residual term that is specified as a moving average error structure

[1] Some authors have tested for the effects of natural disasters in neighboring counties on local employment and wages. Belasen and Polachek (2008) tested for the effect of hurricanes on counties adjacent to those that were directly hit by the hurricane and found effects that differed from the effects in the directly hit counties. Nielsen-Pincus et al. (2012) tested for the effect of wildfire in an adjacent county on local employment and wages, and found an effect on average wage growth that was similar to the directly hit county, but no effect on employment growth. Further, Nielsen-Pincus et al. (in press) found that the effect of federal wildfire suppression spending in adjacent counties on local employment was less than 0.1%. Based on these wildfire-specific findings, we did not specify the model to account for spatial autocorrelation or any other spatial effects on employment.

equal to $\alpha_o e_t + \alpha_1 e_{t-1} + \ldots + \alpha_m e_{t-m}$. The span over which past trends effect present employment is m periods. The constant coefficients α_m measure of the effect of employment growth in period m on employment growth in the current period. Given the calculation of ΔN a value greater than 100 indicates that a 1% increase in the employment growth rate in period m will lead to more than a 1% increase in the employment growth rate in the current period. We use three explanatory variables to predict local employment growth: (1) employment growth at the state level, (2) the occurrence of active wildfire suppression during the time period of interest, and (3) an interaction term indicating whether a wildfire observation occurred in a county with a relatively small population or a county designated a metropolitan county with a population greater than 250,000. We use the metropolitan interaction to differentiate effects of wildfires on large and small local economies. We estimated the above model for aggregate employment growth and employment growth in each of the 10 economic sectors to identify whether wildfires affect local economies differentially.[2]

Finally, we respecified the model to examine whether large wildfires affect total local employment levels after active fire suppression has ended, either due to recovery efforts or lingering disruptions in the normal business cycle. We specified a set of 24 lags from the end of active wildfire suppression activities.[3] Lag variables take on the value of 1 if the active wildfire suppression was occurring at the specified lag, and a value of 0 if active wildfire suppression is occurring in the current period or no suppression was occurring at the specified lag. As such, our lag is not a true lag variable, but a measure of time since active wildfire suppression activities ended. Specification in this manner separates the effect of active wildfire suppression from the lingering effects in the post-fire period.

3. Results

From 2004 to 2008, the Forest Service was the lead suppression agency on 346 wildfires in the western US that each cost the agency more than $1 million (Fig. 1) for a total cost of over $2.4 billion. Over one-third of these wildfires occurred in California (n = 137). Idaho and Oregon experienced the next greatest numbers of large wildfires, 49 and 41, respectively; Nevada and Colorado experienced the fewest large wildfires during the study period with 4 and 2, respectively. Large wildfires in the western US ignited in 122 out of the 413 counties in our dataset, 64 of which experienced multiple large wildfires during the five-year period and the remainder experienced only one large wildfire. Of the counties that experienced large wildfires, 23 were metropolitan counties with a population greater than 250,000, and 99 were counties with a population less than 250,000.

Employment growth rates, in total and by sector, for the majority of the 2003 to 2008 study period were positive, but began to fall towards the end of the study period (Table 1). The steep labor market contractions that occurred with the onset of the great recession in December 2007 caused overall employment to decline (Fig. 2). Each sector exhibited slightly different overall trends, with sectors like education and health services and natural resources and mining exhibiting sustained growth over the study period and other sectors like construction and manufacturing exhibiting overall contraction (less employment in December 2008 than in January 2004). Federal employment growth was largely negative until the onset of the great recession at which point federal employment began to grow in the western US through 2008, corresponding in time with federal economic stimulus spending.

To model employment growth, we first identified the structural patterns in the data, removing the seasonality and identifying the overall economic momentum, county-specific and time period-specific effects, and the effects of state business cycles and the great recession. The greatest single source of the variation in local employment in individual sectors and in the economy as a whole is economic momentum. The moving average error term (captured by the residual structure $\alpha_o e_t + \alpha_1 e_{t-1} + \ldots + \alpha_m e_{t-m}$) indicates that past momentum helps predict current employment growth, and that recent momentum is more important than more distant momentum (the lags tail off over time). Momentum in employment growth is strongest in the professional and business services sector ($\alpha_1 = 539.51$) and the natural resources and mining sector (511.32), indicating that positive (negative) year-over-year growth in the previous month leads to greater positive (negative) year-over-year growth in the current month (Table 2). Financial services (89.59), federal employment (74.10), and total employment (28.48) have the weakest employment momentum. For example, a one percent change in total employment growth in the previous month contributes to only 0.28% of this month's employment growth, indicating that other factors play a strong role in determining current total employment growth rates. County- and time-specific effects (a_i, b_t, respectively) also contribute variability to local employment growth rates, with county-to-county differences being substantially greater than time period to time period differences.

The effect of wildfire suppression activities on employment growth is also consistently significant across all sectors in counties with smaller economies (i.e., populations less than 250,000), ranging between −2.71% (leisure and hospitality services) and 2.44% (natural resources and mining). Of the ten major economic sectors we analyzed, in smaller population counties wildfire effects were positive in five sectors (natural resources and mining; trade, transportation and utilities; information services; financial services; and federal employment) and negative in the remaining five sectors (construction, manufacturing, professional and business services, education and health services, and leisure and hospitality services). Total employment growth was also significantly more positive during wildfire suppression events; however, the net effect of gains and losses across sectors balanced the overall margin of growth at a relatively minor level (0.30%).

In counties with large metropolitan populations (greater than 250,000), wildfire suppression activities did not significantly change total employment growth rates. However, effects of wildfire were significantly positive in four sectors (manufacturing; trade, transportation and utilities; financial services; and leisure and hospitality services) and significantly negative in four sectors (natural resources and mining, professional and business services, and education and health services, and federal employment). With the exception of federal employment and employment in leisure and hospitality services, employment growth effects in large metropolitan counties were less than 1% in magnitude.

The effects of wildfire on employment were also dynamic over time. Total employment trajectories grew from expected levels by about a third of a percent during the periods in which wildfire suppression activities were occurring. Employment growth then continued and increased to 0.63% and 0.52% greater than expected levels in the first and second month, respectively, following the end of suppression activities before returning for three months to expected levels. Six months following the end of suppression activities total employment growth begun a prolonged period of negative effects. For 13 of the following 17 periods, employment growth was lower than expected levels. Eleven

[2] The panel procedure is fit using a transformation method that removes the cross section-invariant, time-invariant, and error structure effects from the dependent variable. The resulting model and parameter estimates are interpreted then as the influence of the explanatory variables in the vector $\boldsymbol{x_{it}}$ on the dependent variable. In the case of labor market data like employment growth rates, structural factors such as place, time, and momentum can explain the majority of the variance in labor market fluctuation (Ewing et al., 2009). As such, GDD models that transform employment growth to remove the effect of place, time, and momentum (or that don't account for these structural factors at all) can result in worse model fit than if one parameterized the model with fixed effects for these factors (e.g., Belasen and Polachek, 2008, 2009), indicating the importance of the structural factors to fluctuations in the data over time and across space. We estimated the models with fixed effects for the structural factors to understand the overall explanatory power of the models (R^2 ranged between 0.30 and 0.60); however, we report the transformed panel model due to its simplicity and focus on the explanatory variables.

[3] We initially tested for lagged effects up to 36 months and found that lags beyond 2 years were not significant.

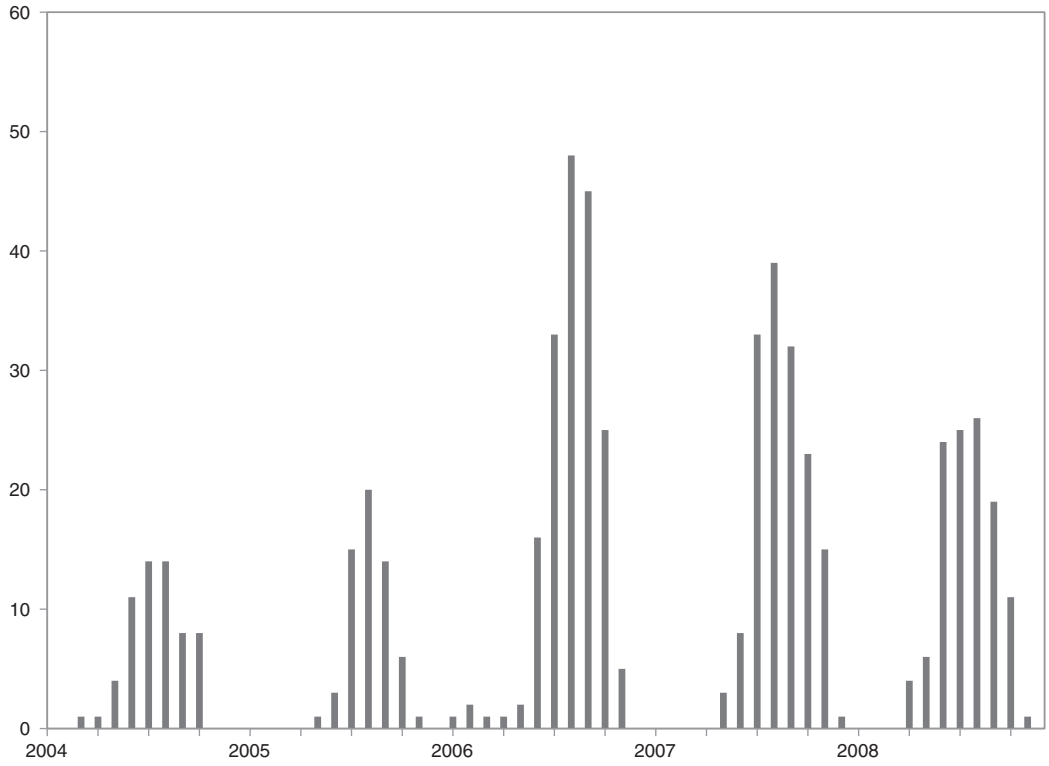

Fig. 1. Large fire frequency by month from 2004 to 2008 in the western US.

of those thirteen periods were statistically significant, with lower growth rates by between 0.47% and 1.82%, and only one period exhibited a statistically positive deviation from the expected growth rate (Fig. 3). A return to expected employment growth levels occured in the final two months of the second year following the end of wildfire suppression activities. Counties with smaller populations mirrored the overall trend, generally exhibiting more extreme effects than the average effect for all counties.

4. Discussion

In this paper, we developed a generalizable model of the effects of wildfire on local employment growth in different economic sectors and across time. We found that the effect of large wildfires on local employment is small compared to broader structural and temporal trends in the economy, and the effect of state business cycles. Nonetheless, the effect of wildfires and related suppression efforts can be isolated. For example, natural resource related sectors experienced an employment growth rate approximately 2.5% greater than expected during periods of wildfire, likely reflecting the importance of the sector in suppression and post-fire restoration efforts like erosion control, replanting, and salvage (Holmes et al., 2008b). In contrast, the leisure and hospitality sector experienced an employment growth rate more than 2.5% less than expected during wildfires, likely reflecting the disruption to tourism and recreation created during wildfires.

Table 1
County-level monthly employment growth rates by sector and in total.

Sector	Mean	Maximum	Minimum	Standard deviation
Natural resources & mining	5.39	71.42	−18.72	16.35
Construction	5.45	51.05	−9.29	15.36
Manufacturing	1.54	52.82	−16.00	11.17
Trade, transportation, and utilities	2.14	73.53	−10.68	6.12
Information services	0.75	42.96	−15.17	12.12
Financial services	2.01	29.63	−8.24	8.12
Professional & business services	5.56	96.45	−15.34	14.75
Education & health services	3.76	35.30	−9.56	7.28
Leisure & hospitality services	2.36	52.42	−7.97	8.66
Federal employment	−0.39	28.77	−9.78	7.94
Total employment	2.05	28.49	−6.11	3.89

Note: Growth rates are based on monthly observations for the period of January 2003 to December 2008.

Like the case study findings reported by Davis et al. (in press) from the Trinity County, California wildfires in 2008 and by Kent et al. (2003) from the Hayman Wildfire in Colorado, we found that the impacts of wildfire on local labor markets varied across sectors and time. In their analysis of the Hayman Fire, Kent et al. (2003) noted the conventional wisdom that wildfires cause economic activity to plummet both during and after the wildfire event, but their findings ran contrary to this belief. Confirming the analysis of Kent et al. (2003) on the Hayman Fire, but contrary to the conventional thinking expressed by the authors, we found that, not only does economic activity (at least as measured by employment) not plummet, but it increases during periods of wildfire suppression. This finding also confirms Davis et al. (in press) that generally the total effect of wildfires is slightly positive, even if a mix of positive and negative effects occurs within the local economy. While the absolute magnitude of wildfire induced growth tends to be small (0.30%), wildfire suppression events can last for months when biophysical or management conditions prevent wildfires from responding to suppression allowing this growth to accumulate.

Many other natural hazards, such as hurricanes and tornados exhibit a negative effect on employment growth during the disaster (e.g., Ewing et al., 2003; Belasen and Polachek, 2008) while wildfires lead to immediate increases in employment. Furthermore, unlike other natural disasters, which often occur over time periods measured in seconds (e.g., earthquakes), minutes (e.g., tornados), or days (e.g., hurricanes), the duration of a wildfire can lead to prolonged positive and negative effects on local employment as periods of increased growth accumulate

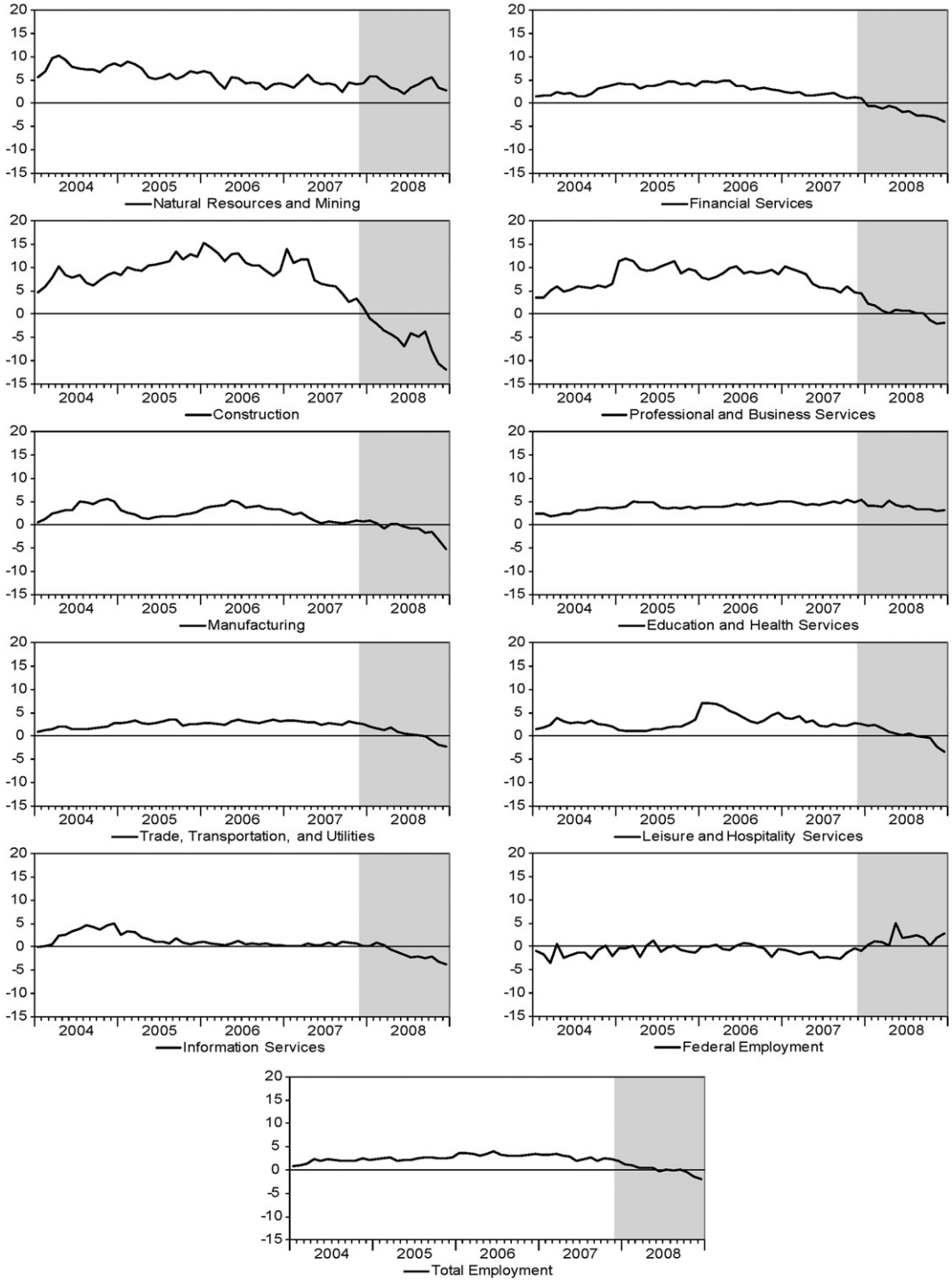

Fig. 2. Average employment growth by sector for the western US. Shaded area represents the period of the great recession.

over time, sometimes for multiple months of suppression activities. Examination of total employment alone, however, masks the dynamic nature of local employment across economic sectors.

Disaggregation of the local economies by population size showed that some sectors are more substantially affected than others during wildfire in small population counties (those with fewer than 250,000 people). Furthermore, in these small population areas, at the sectoral level, a mix of positive and negative effects was exhibited, supporting the findings reported by Davis et al. (2011). Natural resources and mining employment increased by 2.44% during large wildfires, likely responding to demand for resources to assist with wildfire suppression activities. Although some planned business in the natural resource sector (e.g., logging or restoration projects) may get disrupted by a wildfire, our analysis suggests that the demand for the services provided by this sector is likely stronger than the disruptions to planned business activities caused by the wildfire. Second to the natural resource and mining sector, federal employment also responded to wildfire with growth (1.30%) in these small populations counties. Federal wildland firefighters are often a major component of the labor force working the fire lines. Although federal fire crews are mobile and often travel regionally or nationally to where they are needed, our analysis indicated that there was some increase in the use of local federal employees during wildfire events. Although significant, growth effects were substantially weaker in other sectors, further suggesting the importance of the

Table 2
Employment growth regression models.

	Sector										
	Total employment	Natural resources & mining	Construction	Manufacturing	Trade, transportation, and utilities	Information services	Financial services	Professional & business services	Education & health services	Leisure & hospitality services	Federal employment
Intercept	0.82***	3.05***	2.06***	2.07***	−0.30	1.20**	0.24***	2.30***	0.42*	−0.60*	−0.19
State employment growth	0.62***	0.45***	0.92***	0.41***	1.18***	0.03***	0.15***	0.90***	0.93***	1.24***	1.01***
Fire (population<250 k)	0.30***	2.44***	−0.50***	−1.74***	0.41***	0.71***	0.37***	−0.05***	−0.11***	−2.71***	1.30***
Fire (metro population >250 k)	−0.04	−0.71***	0.08	0.17*	0.98***	0.03	0.48***	−0.29**	−0.29***	1.64***	−2.05***
Great recession	−0.49**	−0.03	−0.62*	−2.15***	0.78***	−1.89**	−3.11***	−0.17***	0.24*	−0.19	0.31
First order momentum	28.48	511.32	310.36	254.41	112.68	253.70	89.59	539.51	111.12	139.90	74.00
Variance for cross sections	1.71	18.33	<0.00	1.34	12.58	<0.00	2.36	5.03	3.46	3.25	4.48
Variance for time periods	0.07	0.62	0.13	0.43	0.05	0.92	0.16	<0.00	0.01	0.50	0.65
Cross sections (counties)	411	330	330	316	408	279	366	347	359	392	413
Time periods (months)	60	60	60	60	60	60	60	60	60	60	60
MA error process	12	6	6	6	6	6	6	6	6	6	6
Root MSE	1.44	11.52	11.34	10.85	9.09	11.43	10.72	10.93	10.27	5.61	8.36

*p < 0.10; **p < 0.01; ***p < 0.001.

natural resource and mining sector and the federal government to resources required in suppression events. Other factors, like the distance from a local hub of wildfire suppression capacity (either public or private sector) may also impact the effect of wildfire on local employment across sectors.

In contrast to natural resources and federal government sectors, employment growth dropped substantially in the leisure and hospitality (−2.71%) and manufacturing (−1.74%) sectors in these small population counties. Although not as substantial, employment growth also dropped in construction (−0.50%). As has been reported in case studies, recreation and tourism oriented businesses can suffer during wildfires as tourists and other visitors stay away from places perceived as risky due to wildfire or smoke (Butry et al., 2001; Davis et al., in press). Though some firefighting personnel may stay in local hotels or eat at local restaurants, our analysis found that losses in these sectors clearly outweighed any gains created by the suppression effort. This finding corresponds to current federal suppression practices that rely on self-contained fire-fighting operations that operate out of a fire camp with a full suite of mobile services (e.g., commissary, showers). Losses in other sectors like manufacturing and construction may reflect disruptions to normal business patterns created by smoke, evacuations, or other disruptions to trade and the supply chain (Rose and Lim, 2002).

Larger population counties (those with more than 250,000 people) also exhibited significant effects from wildfire at the sectoral level, although not in total employment. Most effects were relatively small; however, leisure and hospitality services and federal employment both exhibited an effect from wildfire greater than 1.0% and that was in the opposite direction from those same effects in smaller population counties — the leisure and hospitality sector grew and federal employment shrank during wildfires in large population counties. The reasons

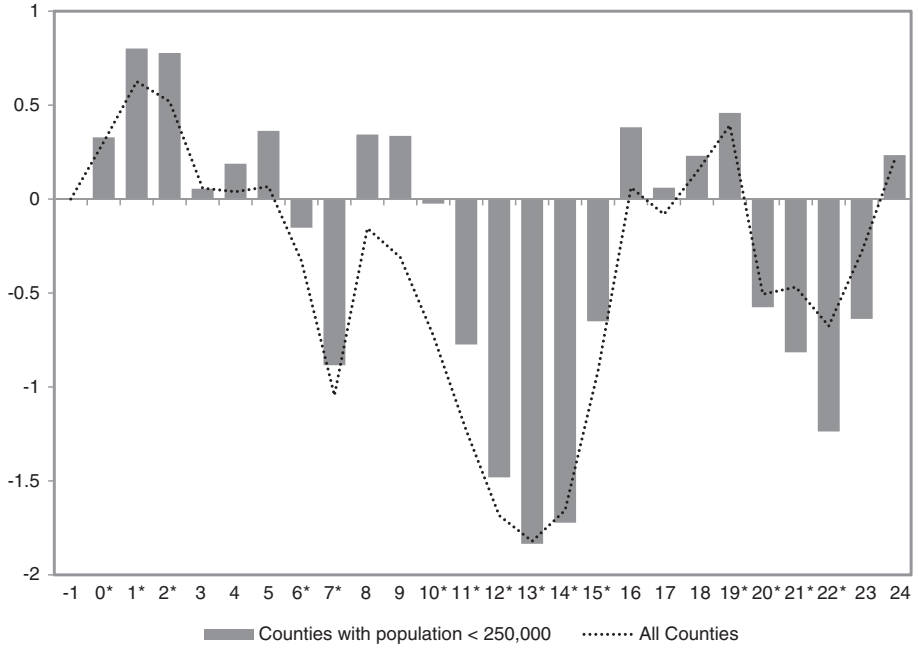

Fig. 3. Changes in employment growth by month following a large wildfire. Zero on the x-axis is a month in which a large wildfire is being actively suppressed; asterisks (*) on the x-axis labels indicate time periods for which the deviation from the expected monthly growth rate for all counties was significant (alpha = 0.05).

for these effects are not altogether clear. The synchrony of large wildfires across wide geographic regions (Holmes et al., 2008a) could make it less appealing for urban denizens to recreate in adjacent rural areas if those areas are also experiencing wildfires leading them to spend their leisure time (and money) locally. In states where the majority of the population is concentrated in relatively few urban areas (e.g., Nevada) local employment growth rates may respond differently to exogenous shocks due to the concentration of economic resources in few key areas. Understanding these findings will require more exploration, as it appears that fires are interacting with these larger, more complex economies differently and less intuitively than with the smaller economies. Case studies that focus on metropolitan areas may be helpful in building up a body of evidence understanding the economic impacts of wildfire in larger economies.

In addition to differential effects to sectors during a wildfire, wildfires also caused differential changes to local employment that persisted over time. Unlike other natural hazards, employment tends to grow during and immediately after wildfires. Growth during and immediately after wildfires likely reflects suppression efforts, cleanup, and post-fire recovery and restoration work. The majority of the wildfires we analyzed occurred in the summer months, indicating that wildfires can lead to summer and fall increases in employment growth rates and a return to expected growth rates lasting through the winter. However, beginning in the following spring, wildfire affected economies in the western US tend to enter a persistent period of slower growth (up to 1.82% slower than expected) that can last between a year and 18 months. This pattern may occur for several reasons. For instance, visitors may not want to return fearing a blackened landscape. Resource management activities may get scrapped because resources may have been lost during the previous years' wildfires. Even though, as noted by Carroll et al. (2005), fires can be a galvanizing influence on communities, implementation of recovery plans created after wildfires may take time, leading to a period of limbo during which local communities try to develop post fire adaption strategies but do not yet have the resources or assistance to carry out plans.

The temporal dynamics suggested by our analysis also add insight to those provided by Nielsen-Pincus et al. (in press), which demonstrated increased employment volatility of both employment and wages for a period of up to two years following a wildfire. We add to this finding by demonstrating that, in addition to seasonal amplification of employment and wage, wildfires can also cause changes to the trends in employment growth for at least two years following wildfires. These findings suggest that wildfires have complex short- and medium-term effects as communities try to respond and adapt to the economic, community, and ecological threats from wildfire. Unlike some extremely large natural hazard events, however, commonly-occurring large wildfires do not appear to result in substantial structural shifts in the economy (e.g., Hurricane Katrina resulted in a major outflow of workers and businesses from the affected areas (Garber et al., 2006)). Instead, the effects of wildfires, while dynamic and differential across sectors and time, tend to be smaller and return to expected levels within a couple of years raising questions about what interventions can be done to make local communities more resilient. For example, does increasing local capacity for wildfire planning and mitigation reduce the negative impacts of wildfire over time or affect the sectoral impacts from wildfire by allowing some local firms to play a greater role in suppression efforts. While policy makers and practitioners experiment with interventions to improve local resilience, indicators of employment such as the unemployment rate will continue to make headlines out of the margins — a 1.0% change in the local unemployment rate would likely be front page news in many counties across the western US and elsewhere.

5. Conclusions

The analysis of labor markets in relation to wildfire is a useful way to understand some of the social and economic implications of wildfire during and after the wildfire. We found that wildfires tended to create an identifiable impact on all major sectors of the economy, especially in areas with smaller populations. Although the impact may be small at the level of an entire county's economy, individual sectors show substantial gains (e.g., natural resources and mining) and losses (e.g., leisure and hospitality services). Our study confirms much previous wildfire case study research with a more generalizable design and suggests that the economic impacts of large wildfires are different than other natural hazards, both in the timing of employment changes and the impacts to particular sectors.

The research also raises several questions for policy makers and fire managers. What are the specific mechanisms (e.g. restoration and recovery spending) that lead to the prolonged drag on employment growth for two years following the end of a wildfire? What policy strategies or planning efforts would help moderate the short- and medium-term effects of wildfires on local economies? A full understanding of the distributional economic effects of large wildfires is needed to answer these questions in a manner that offers local officials, community leaders, and policy-makers better tools to adapt and be resilient to the consequences of large wildfires.

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