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Valuing morbidity effects of wildfire smoke exposure from the 2007 Southern California wildfires☆

Ikuho Kochi[a,c,*], Patricia A. Champ[b], John B. Loomis[c], Geoffrey H. Donovan[d]

[a] Universidad Autónoma de Ciudad Juárez, Ciudad Juárez, Chihuahua, Mexico
[b] US Forest Service, Rocky Mountain Research Station, Fort Collins, CO, United States
[c] Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO, United States
[d] US Forest Service, Pacific Northwest Research Station, Portland, OR, United States

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ABSTRACT

This study estimated the economic costs associated with morbidity from the wildfires that occurred in 2007 in southern California. We used the excess number of hospital admissions and emergency department visits to quantify the morbidity effects and used medical costs to estimate the economic impact. With data from 187 hospital facilities and 140 emergency departments located in five counties in southern California, we found evidence of significant acute adverse health reactions to wildfire-smoke exposure. Specifically, we found approximately 80 excess respiratory-related hospital admissions, 26 excess acute cardiovascular-related hospital admissions, nearly 760 excess respiratory-related emergency department visits, and 38 excess acute cardiovascular-related emergency department visits. We estimated that the associated medical costs were over $3.4 million. Since these cost estimates do not consider costs related to other adverse health effects, such

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* Corresponding author at: Universidad Autónoma de Ciudad Juárez, Ciudad Juárez, Chihuahua, Mexico.
E-mail address: ikuho.kochi@uacj.mx (I. Kochi).

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as mortality, symptoms that were not severe enough to warrant going to the emergency room or hospital, or the costs of avoiding exposure to wildfire smoke, our estimates do not reflect the full health-related costs of wildfire smoke exposure.

Introduction

Wildfire damages are of great concern to residents of fire-prone areas. While the physical damage caused by wildfires, such as destroyed homes, injuries, and fatalities directly linked to the fire, is well accounted for, it does not represent the full costs of catastrophic wildfires. An important social cost that is rarely quantified is the morbidity caused by wildfire-smoke exposure.

Wildfires emit substantial amounts of smoke that contains particulate matter (PM) among other air pollutants. It is well documented that exposure to PM is linked to significant increases in mortality and morbidity (USEPA, 2004). Particles smaller than 2.5 μm in diameter ($PM_{2.5}$) and particles smaller than 10 μm in diameter (PM_{10}) are of particular concern. However, most past studies of the health effects of air pollution have examined exposure to PM originated from fossil fuel combustions in urban areas. As discussed by Kochi et al. (2010), less is known about the public-health effects of short-term exposure to high levels of PM from burning vegetation. Understanding such effects and estimating the associated economic cost are critical for informing wildfire policy.

In this study, we quantify the adverse health effects of wildfire smoke exposure and estimate the associated economic costs. We focus our analysis on morbidity effects, measured by hospital admissions and emergency department visits, for large wildfires that occurred in southern California in 2007.

The following section provides an overview of the relevant literature on the economic costs of wildfire smoke exposure. The third section presents a description of the wildfire events examined in this article, while the fourth section presents the analytical method for estimating the economic costs, the data, and estimation results. The final section provides the discussions and conclusions.

Previous studies on the economic costs of wildfire smoke exposure

Adverse health effects from wildfire smoke exposure range from minor discomfort to mortality. To date, only a few studies have estimated the community-level economic costs associated with morbidity effects of wildfire smoke exposure in the United States (US) (Butry et al., 2001; Martin et al., 2007; Moeltner et al., 2013).[1] These few studies have looked at one or more health related costs including hospital admissions, emergency department visits, outpatient treatment, doctor's office visits, labor loss due to restricted activity days and respiratory symptoms.

Butry et al. (2001) evaluated the morbidity costs of smoke exposure from the large wildfires that lasted for 6 weeks burning more than 382,000 acres in St. John's River Water Management District in northeastern Florida in 1998. The authors concluded that the excess asthma-related health costs caused by wildfire smoke exposure were between \$403,000 and \$868,000, which included the costs of hospital admissions, emergency room visits, outpatient care and doctors' office visits.[2] Butry et al. (2001) noted that the hospital admissions and emergency department visits were responsible for the majority of the health costs. Martin et al. (2007) estimated the health costs of smoke exposure from a hypothetical 6,400 acres prescribed fire in Kaibab National Forest in the US. The authors estimated

[1] Studies that evaluated the community-level economic costs associated with wildfire smoke exposure that occurred outside of the US are summarized in Kochi et al. (2010).

[2] All monetary values are adjusted to the price level of year 2007.

between $90,000 and $185,000 in health costs due to the excess hospital admissions, respiratory symptoms, restricted activity days and work days loss. Although the estimated excess hospital admissions due to prescribed fires were very small (between one to three cases), the hospital admission costs were one of the major components of health costs due to its high unit cost.

Moeltner et al. (2013) estimated the morbidity costs of smoke exposure from 24 major wildfires in northern California and Nevada between 2005 and 2008 that burned 1.2 million acres. The authors concluded that the cost of excess cardiorespiratory-related hospital admissions due to smoke exposure was $2.2 million during the intense fire season in 2008, which burned over 850,000 acres. In general, the estimated costs of wildfire smoke exposure in previous studies varied greatly, depending on the magnitude of the fire. Among the morbidity costs, the costs related to hospital admissions accounted for the largest portion of total health costs.

Most of the previous studies in this area used the same approach to estimate the economic costs of wildfire smoke exposure.[3] First, the adverse health effects from exposure to the wildfire smoke, such as an excess number of hospital admissions, were estimated. Second, these excess adverse health effects were multiplied by a unit cost to provide an estimate of the total economic cost. To estimate the excess adverse health effects, some studies have used primary health data while others relied on a "transfer" approach using existing dose-response functions from somewhat similar but distinct contexts such as exposure to urban air pollution (see Kochi et al. (2010) for an extensive literature review).

As pointed out by Smith et al. (2000), the critical assumption to justify the practice of such transfer approach is the similarity of the context. When employing the transfer approach to estimate the adverse health effects of wildfire smoke exposure, it is ideal to use an existing dose-response function based on wildfire smoke exposure to satisfy the condition of similarity. Unfortunately, no study has estimated a dose-response function based on wildfire-induced emergency department visits in the US, and only two studies have estimated dose-response functions between wildfire smoke exposure and hospital admissions.

Delfino et al. (2009) and Moeltner et al. (2013) estimated dose-response functions between $PM_{2.5}$ levels and cardiorespiratory-related hospital admissions during the 2003 southern California wildfires, and a series of wildfires in northern California and Nevada, respectively. Although both authors found significant relationships between $PM_{2.5}$ contained in wildfire smoke and some health outcomes, there were limitations with respect to the ability of the estimated functions to evaluate the overall adverse health effects of wildfire smoke exposure. Delfino et al. (2009) acknowledged that their $PM_{2.5}$ dose-response functions explained only part of the excess hospital admissions during the 2003 southern California wildfires, likely because other unaccounted factors associated with wildfire smoke, such as delayed effects, effects caused by other air pollutants, psychological stress due to wildfire smoke or toxic air pollution from structure burnings during a wildfire event could also be responsible for the observed increase in adverse health outcomes. Such limitations may also be present in Moeltner et al. (2013)'s estimation. If this is the case, solely using previously estimated $PM_{2.5}$ dose-response functions and recorded $PM_{2.5}$ levels during a wildfire event may incorrectly calculate the total adverse health effects of wildfire smoke exposure.

Since the connection between wildfire smoke exposure and adverse health effects has not been well described in previously estimated dose-response functions, we used primary health data to estimate the adverse health effects of wildfire smoke, instead of employing the transfer approach.

Description of wildfires

Southern California experiences many wildfires every year, but the scale and intensity of the multiple wildfires that occurred in October and November of 2007 were exceptional. Appendix A presents the list of 2007 southern California wildfires and associated property damages, injuries and mortalities reported by California Department of Forestry and Fire Protection. There were 22 wildfires burning

[3] The exception is Richardson et al. (2012), which focused on estimating per unit cost of one day of symptoms from wildfire smoke exposure using a sample of smoke exposed population, instead of estimating a community-level health cost associated with wildfire smoke exposure.

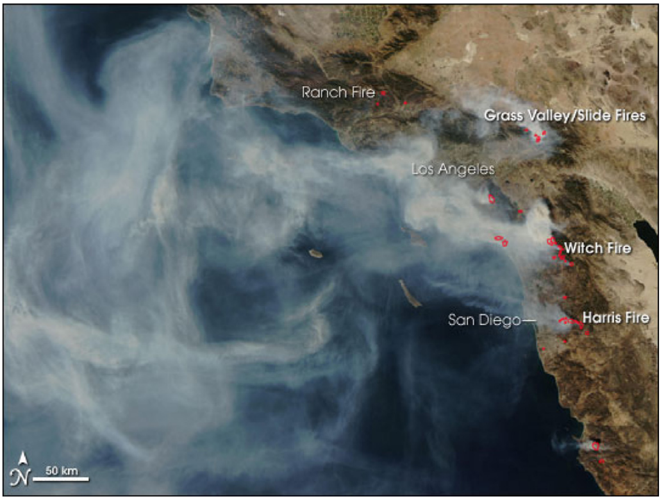

Fig. 1. Satellite image of southern California on October 24, 2007.
Source: NASA's Earth Observatory http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19225.

nearly simultaneously across southern California between October 20 and November 9th. We refer to these wildfires as *the 2007 wildfires.* As shown in the satellite image (Fig. 1), the smoke from the 2007 wildfires affected densely populated coastal areas. In total, the 2007 wildfires burned over 516,700 acres, destroyed 3,200 structures and damaged 257 structures, causing 161 injuries and 7 fatalities. The property damages were concentrated in San Diego County (83%) followed by San Bernardino County (14%). The majority of injuries occurred to firefighters while all fatalities were civilians. The total cost of suppressing the 2007 wildfires was $140 million.

Fig. 2 shows daily PM levels during the 2007 wildfires at the selected monitoring stations mapped in Fig. 3. We obtained PM data from California Environmental Protection Agency Air Resources Board (CEPAARB). Fig. 2 shows that the daily average PM levels recorded at North Long Beach, Riverside, and Escondido monitoring stations increased dramatically from below 50 $\mu g/m^3$ to above 150 $\mu g/m^3$ once the first wildfire ignited on October 20th.[4] These peak PM levels were well above the California standard of 50 $\mu g/m^3$ for PM_{10}, and the national standard of 35 $\mu g/m^3$ for $PM_{2.5}$. The PM levels returned to normal by October 30th. The increase in PM levels recorded in Los Angeles and San Diego monitoring stations were less dramatic, but unusually high for these areas reaching 107 $\mu g/m^3$ and 71 $\mu g/m^3$, respectively. The most intense air pollution was recorded at Lake Elsinore monitoring station in Riverside County (not shown in Fig. 2), as the daily PM_{10} level reached to 362 $\mu g/m^3$ on October 21st. Generally, the intense air pollution levels were observed in the first week of the 2007 wildfires between October 21st and 27th.

Ozone also increased substantially during the 2007 wildfires. Fig. 4 shows the change of the 8 hour (8-h) average levels of ozone. Ozone levels exceeded the California standard of 0.070 ppm in Escondido, Riverside, and Los Angeles during the wildfire period. Daily maximum 1 hour (1-h) average of NO_2 levels also slightly exceeded the national standard of 0.1 ppm in Los Angeles and North Long Beach for one day as shown in Fig. 5. There were also slight increases in daily maximum 1-h average of SO_2 and CO levels, but the concentration levels were well below the both California and national standards.

Even though the morbidity caused by the 2007 wildfires was understood to be an important component of the social costs, there has been limited analysis as to the effects. For example, Dohrenwend et al. (2013) analyzed the changes in respiratory-related emergency department visits at Kaiser Permanente hospitals in the metropolitan area of San Diego. With a simple comparison of the number

[4] Information of national and California state air pollution standard is available from CEPAARB webpage: http://www.arb.ca.gov/research/aaqs/caaqs/caaqs.htm.

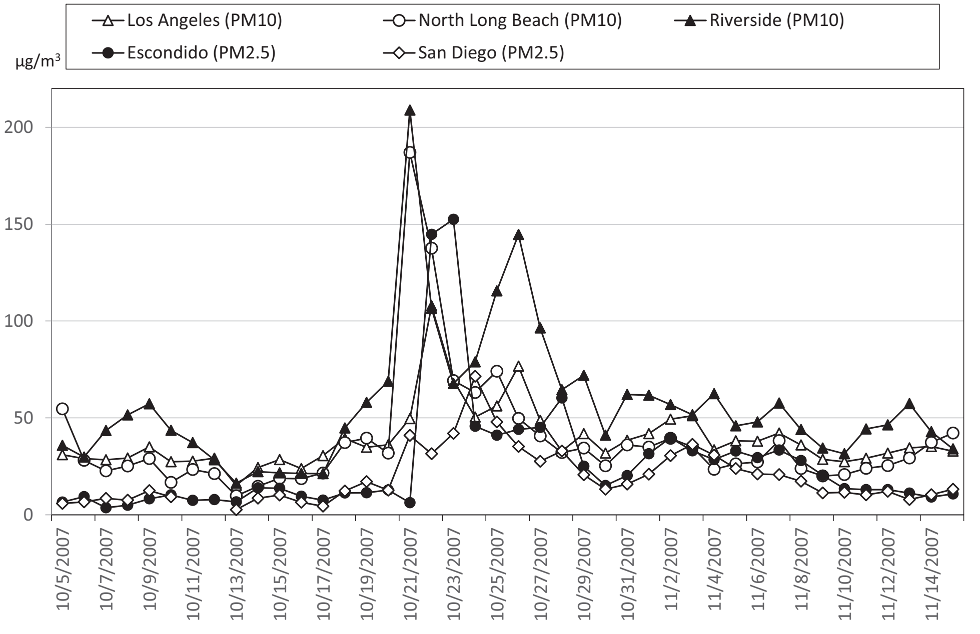

Fig. 2. PM levels at five monitoring stations in southern California in October–November.

of visits during the pre-fire and fire periods, the authors found a significant increase in respiratory-related emergency department visits during the wildfire period. However, this analysis has several important limitations. First, since the 2007 wildfires affected not only the metropolitan area of San Diego, but also large urban areas in Los Angeles, Riverside, Orange, San Bernardino Counties, the total adverse health effects associated with this wildfire event should be much larger than the effects measured by Dohrenwend et al. (2013). Second, previous studies indicated that excess hospital admissions are also an important component of social costs of intensive wildfire smoke exposure (Kochi et al., 2010). Third, a simple comparison of hospital visit levels before and during the wildfires may not be an appropriate way to measure the adverse health impact of wildfires, since there may be other factors that affect the level of hospital uses, such as weather conditions or seasonal effects.

This study aims to understand the adverse health effects associated with the 2007 wildfires in a more comprehensive manner. Specifically, we analyze the excess cardiovascular-, and respiratory-related emergency department visits and hospital admissions at a much larger scale by including all hospitals located in the smoke affected urban areas in five southern California counties. Also, we employ regression models that control for relevant confounding factors to obtain unbiased estimators of the adverse health effect of wildfire smoke exposure.

Estimation of the economic costs of wildfire smoke exposure

Quantification of morbidity effects

We obtained daily counts of hospital admissions and emergency department visits for the years 2005 through 2007 from the Patient Discharge Data (PDD) and Emergency Department Data (EDD) provided by the Office of Statewide Health Planning and Development (OSHPD) in the state of California. We used weather data from National Centers for Environmental Information (NCEI), National Oceanic and Atmospheric Administration (NOAA) (http://www.ncdc.noaa.gov/).

To estimate the morbidity effects of wildfire smoke, we followed a similar analytical approach as that used in Kochi et al. (2012) to analyze the mortality effects of wildfire smoke. We categorized diseases into groups. We focused on diseases related to the acute circulatory symptoms including

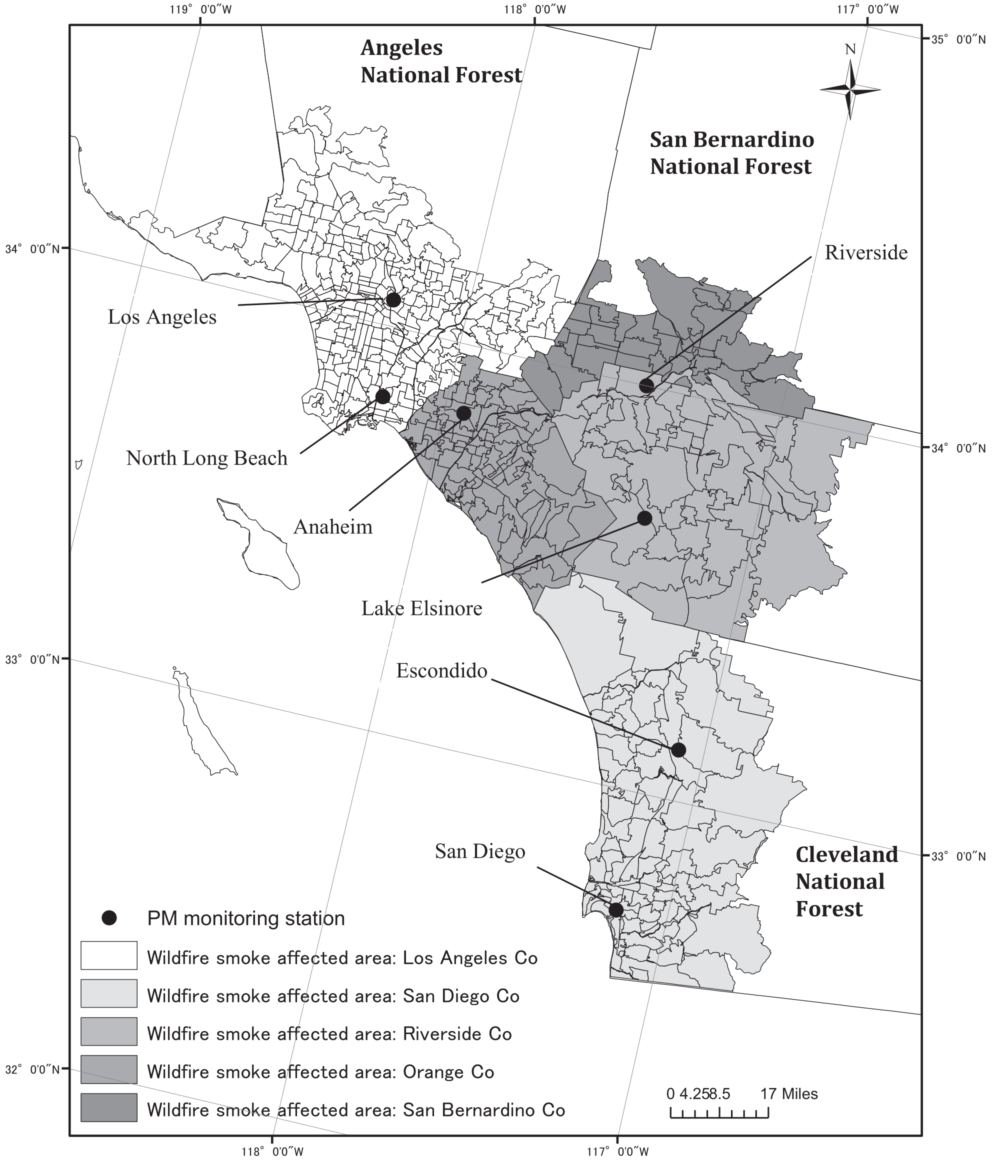

Fig. 3. Map of wildfire smoke-affected areas in southern California. *Note*: zipcode area layer is obtained from http://www.census.gov/geo/www/cob/z52000/html#shp.

heart attack and stroke (hereafter referred to as *acute cardiovascular-related disease*) and all types of respiratory systems, excluding influenza (hereafter referred to as *respiratory-related disease*). We defined the disease group according to the 5th version of *The International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM (1997)).[5] Since medical coding is updated every year, we checked modifications of definition for each year so that our disease categorization was consistent

[5] We followed Moeltner et al. (2013) for the categorization of disease to be used in the analysis. We assigned the acute cardiovascular-related disease category if the principle diagnosis code of the patient was 410 (acute myocardial infarction) or

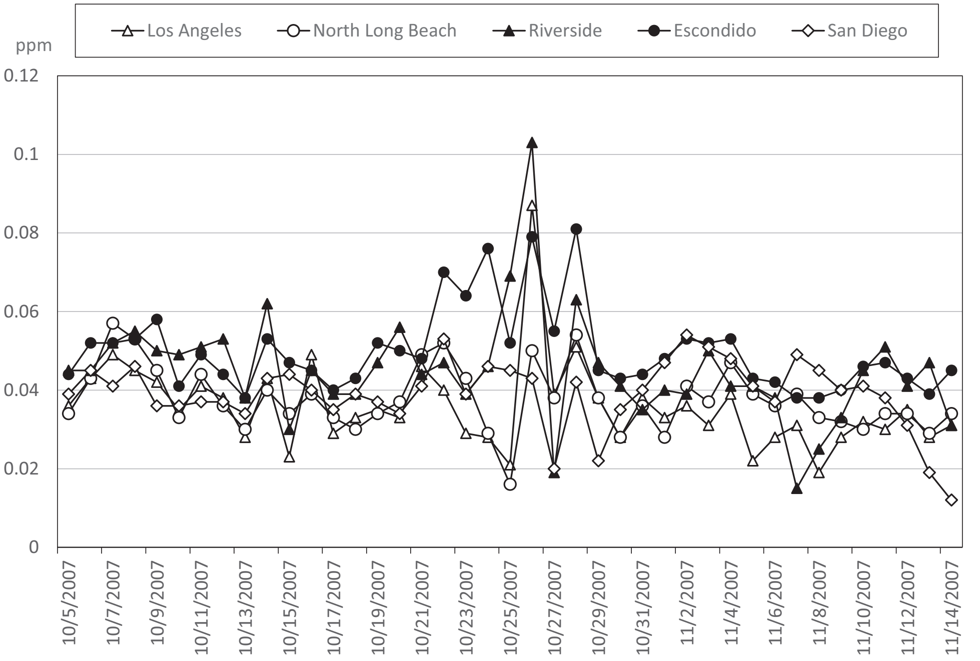

Fig. 4. Ozone 8-h average levels at five monitoring stations in southern California in October–November.

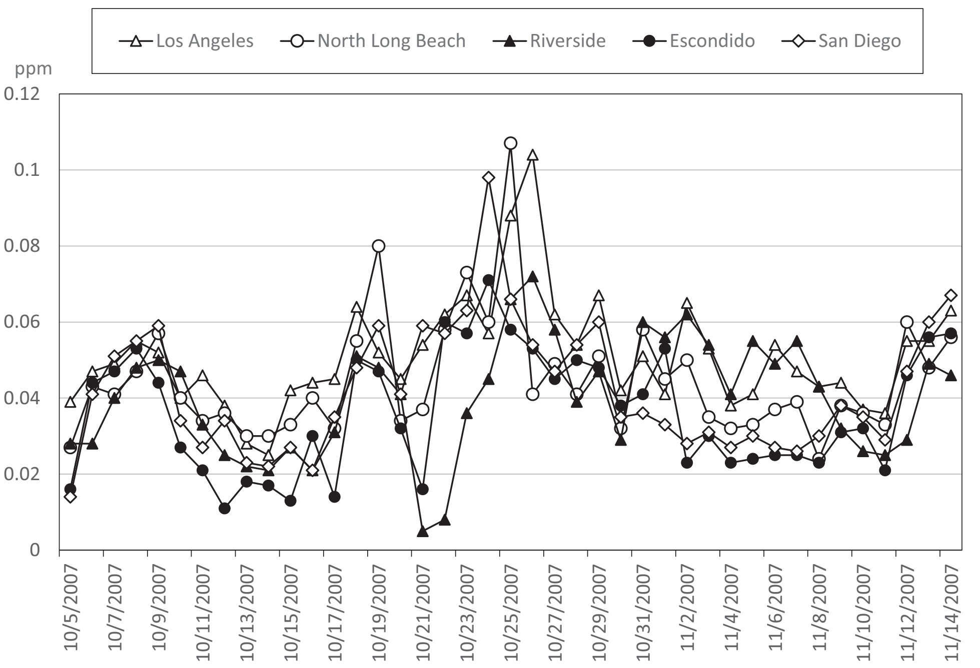

Fig. 5. Daily maximum NO_2 levels at five monitoring stations in southern California in October–November.

over time. In addition, we categorized patients into three age groups: minor (under 18 years), adult (between 18 and 64 years), and senior (over 64 years old) to capture adverse health effects for different age groups.

We created daily counts of hospital admissions and emergency department visits based on the hospital ZIP code, disease category, and age group from the two data sources (i.e., PDD and EDD).[6] We then aggregated the daily hospital admission and emergency department visit counts by the "smoke-affected area." The "smoke-affected area" includes most of the urban areas in each county that were likely affected by wildfire smoke as mapped in Fig. 3.

Our analytical approach compared the levels of hospital admissions and emergency department visits between the wildfire period and the period prior to the wildfire period (reference period). If hospital admissions or emergency department visits increased during the wildfire period compared with the levels prior to the wildfires, holding other factors constant, such increases are attributed to wildfire smoke exposure. We defined the reference and wildfire periods in the following way. As hospital admissions and emergency department visits fluctuated substantially by the day of the week, both the reference and the wildfire periods should contain the same proportion of weekends and weekdays. We defined the reference period as a two-week period immediately prior to the first day of the sharp increase in PM levels (October 7–20) to minimize any seasonal confounding factors. For the emergency department visit analysis, we defined the wildfire period as the one-week period between October 21st and 27th that contained all the high air pollution days associated with the wildfires. Viswanathan et al. (2006) suggested a possible mild delay (1–1.5 days) in excess emergency department visits in response to extensive smoke exposure. Since most of the smoke-affected areas we analyzed experienced a sharp increase in PM levels during the first couple days of the wildfire period, such mild delayed effects should be also captured with a week-long wildfire period. We used a two-week wildfire period (October 21–November 3) for the hospital admission analysis because the hospital admission levels may exhibit a more extended lagged effect as Delfino et al. (2009) observed for the 2003 southern California wildfire event.[7]

An important limitation of a simple comparison of hospital admissions and emergency department visit levels between the reference and wildfire periods is the potential existence of an underlying seasonal trend as discussed in Delfino et al. (2009). For example, higher respiratory-related hospital admissions may occur in late October relative to early October, irrespective of wildfire events, due to changing weather patterns. To control for the seasonal trend, we estimated the following time-series model using the data from the reference period and the wildfire period from the year the wildfire event occurred (the year 2007), and the same periods from control years where the intense wildfire smoke did not occur (the years 2005 and 2006).[8]

$$HS_t = \beta_0 + \beta_1 fire\_yr_t + \beta_2 fire_t + \beta_3 fire\_yr \times fire_t + Z_t\gamma + \mu_t \quad (1)$$

where t is the time indicator, HS is the measure of health outcome (daily count of hospital admissions or emergency department visits); *fire_yr* is a dummy variable which takes 1 if the year of the observation is 2007 (the wildfire year) and 0 otherwise; *fire* is a dummy variable which takes 1 if the date of the observation is in the wildfire period, and 0 otherwise; $fire\_yr \times fire$ is an interaction term between variables *fire_yr* and *fire*; Z is a vector of control variables that includes a time trend variable (*time*) that assigns a sequential value based on the date to eliminate spurious correlation, and dummy variables for the day of the week (*monday*, *tuesday*, *wednesday*, *thursday*, *friday*, and *saturday*) to control the daily fluctuation of hospital use volume within a week where Sunday is used as a base category. We also included weather variables to further control for changing weather patterns. USEPA (2004) reviewed

between 430 and 438 (stroke). We assigned a "respiratory system" related disease category if the principle diagnosis code of the patient was between 460 and 519 (respiratory diseases), and 786 (respiratory-related symptoms), excluding 487 (influenza).

6 We eliminated observations who did not report their age or whose length of stay in hospital was longer than 30 days.

7 Delfino et al. (2009) reported that the significant adverse health effects were observed frequently during the post-wildfire period, which was defined as around October 29 and November 15, 2003 while the high PM levels were observed between October 21 and 30, 2003.

8 Although the Esperanza fire occurred in October 2006 in Los Angeles, Riverside, Orange, and San Bernardino Counties, the air pollution monitoring data did not show any unusual increase of PM levels in October 2006.

the large body of epidemiology literature on mortality and morbidity effects of PM and concluded that weather factors play an important role as confounding factors and extreme weather conditions are of particular concern. Therefore, we included *minhum*, the lowest relative humidity level of the day, *maxhum*, the highest relative humidity level of the day, *mintemp*, the lowest temperature of the day, and *maxtemp*, the highest temperature of the day.[9] Finally, μ is an i.i.d. error term.

It is important to emphasize that we did not intend to estimate the marginal effect of each air pollutant in our analysis. Instead, we aimed to estimate the effect of the 2007 wildfire event itself. For this reason, Eq. (1) does not contain any air pollutant variables. The dummy variable $fire\_yr \times fire$ captures the overall effect of exposure to increased levels of multiple pollutants, such as PM, ozone, and NO_2, contained in wildfire smoke. The parameter β_3 measures the net changes in hospital admissions or emergency department visits due to the wildfire event during the wildfire period in comparison with the reference period, after controlling for weather conditions and the baseline seasonal trend.[10] We estimated equation (1) for each subgroup separately where each subgroup is a combination of one of the health outcomes (i.e. hospital admission or emergency department visit), one of the five smoke-affected areas (i.e., Los Angeles, San Diego, Riverside, Orange, or San Bernardino), one of the two disease categories (i.e, acute cardiovascular or respiratory) and one of the three age groups (i.e, under 18, 18–64, or over 64 years old). In other words, there are 60 subgroups.

Since some subgroups contained small counts of daily hospital admissions or emergency department visits, we estimated all models through time-series count model. To control for possible over-dispersion, we estimated negative binomial models. In addition, Newey-West standard errors that are robust to heteroskedasticity and the first order autocorrelation were estimated.[11]

We calculated the total excess hospital admissions and emergency department visits in the following manner. First, we converted the estimated coefficient of β_3, the approximate proportional change, to the absolute proportional change by taking the exponential of the estimated coefficient and subtracting 1. Then, we multiplied the calculated absolute proportional change with the daily average hospital admissions or emergency department visits of the corresponding area and age group during the reference period of the study year, as well as with the number of days included in the corresponding study period.

Estimation of the economic costs of adverse health effects

The costs associated with adverse health effects are generally grouped into four categories: costs related to health care (medical expenses), loss of wages (labor loss), costs related to mitigating adverse health effects, and utility losses caused by discomfort and suffering due to illness (Freeman, 2003). As discussed by Kochi et al. (2010), an individual's willingness to pay (WTP) to avoid the adverse health effects is considered to be the most comprehensive measurement of the costs since it encompasses all four categories. However, it is challenging and costly to measure the intangible values associated with health damage, such as discomfort. Therefore, we have focused on health care costs while recognizing that this approach does not reflect the full economic cost of morbidity effects related to wildfire smoke exposure.

Hospitalization

To estimate the total medical costs associated with hospitalization, we multiplied the estimated excess hospital admissions by the average medical cost per admission for the corresponding county,

[9] We averaged the weather data from all weather stations located inside of each smoke-affected areas that recorded the daily relative humidity and temperature. In the case that there was no weather station inside the smoke-affected area, we used the weather record from the station(s) located closest to the smoke-affected area.

[10] Eq. (1) does not differentiate between data from the year 2005 or 2006 as a control. Thus the baseline seasonal trend is captured by averaging the hospital admissions or emergency department visits levels in 2005 and 2006.

[11] Following the analytical approach of Moeltner et al. (2013), we also estimated the following five types of count models: Poisson model, generalized linear Poisson model (GLM Poisson Model), fully robust Poisson model through quasi-maximum likelihood approach (QML Poisson model), negative binomial I and negative binomial II models. In general, there were only marginal differences across estimation methods. All models were estimated with statistical software STATA (http://www.stata.com/). See details about estimating count data models using STATA in Cameron and Trivedi (2010).

disease category, and age group. We obtained the medical cost data by averaging the total hospital cost of each patient obtained from the OSHPD hospital discharge data.[12] The hospital cost only includes the hospital charges and excludes charges billed by other providers such as laboratory tests and physicians fees. Appendix B shows the average hospital cost and duration of stay per admission (also obtained from OSHPD hospital discharge data) by county, disease category and age group. Acute cardiovascular-related hospital admissions involved an average 4–5 day stay and an average cost that varied substantially across counties but less so across age groups. In contrast, the average hospital charges for respiratory-related admissions varied considerably across age groups. The older age groups tended to stay in the hospital for a longer period and, therefore, incurred higher hospital-related costs compared to the younger age groups. Respiratory-related admissions involved an average stay of 2–6 days and an average cost between $10,000 and $46,000 per admission depending on the age group and county.

Emergency department visits

To estimate the total medical costs associated with emergency department visits, we multiplied the estimated excess emergency department visits by the average medical cost per visit for the corresponding county, disease category, and age group. Since the EDD database does not include information about hospital-related costs, we estimated the average cost per emergency department visit in the following manner. According to the EDD data between years 2005 and 2007, almost 50% of the patients who received a respiratory-related diagnosis during their emergency department visit received procedures code of "Emergency Room Visit" (hereafter referred as ERV). Almost 35% of patients received procedures code of "ERV, level 2 (low to moderate severity)" or "ERV, level 3 (moderate severity)." In the case of acute cardiovascular-related emergency department visits, nearly 30% of the patients received procedures code of "ERV" and 25% of patients received procedures code of "ERV, level 2" or "ERV, level 3." We calculated the average cost associated with "ERV, level 2" and "ERV, level 3" procedures among 70 hospitals located in the smoke-affected areas from Hospital Chargemasters available from the OSHPD website (http://www.oshpd.ca.gov/Chargemaster), and used this cost as a representative cost of emergency department visits. Appendix B shows the average cost per emergency department visit in each area.

Results

We analyzed the data from187 hospitals and 140 emergency departments in the smoke-affected areas in five counties in southern California.[13] When a patient visited an emergency room and was later transferred to an inpatient care, we included this patient both in emergency department visits and hospital admissions sample. We analyzed a total of 127,654 emergency department visits and 53,713 hospital admissions due to acute cardiovascular- and respiratory-related disease.

Before we get to the results of interest, we summarize the model results related to the estimated coefficients from the control variables (see Appendix C). The coefficient estimates on the day of the week variables are statistically significant across a number of the models. The hospital admissions and emergency department visits were generally lower during the weekends than weekdays for all age groups across disease categories. One exception was respiratory-related emergency department visits for children, which were significantly higher during the weekends compared to weekdays. Generally, coefficient estimates on the weather variables were not consistent in sign and statistical significance across the areas. The Los Angeles area tended to show a significant positive effect of daily maximum temperature and daily minimum relative humidity levels. The San Diego, Orange, and San Bernardino areas tended to show a positive effect from daily minimum temperature. In some subsamples, the estimated coefficient on *fire* was positive and significant, reflecting a seasonal trend of hospital admissions being higher during the wildfire period compared to the reference period during the control years.

[12] We only used data of 2007 from hospitals included in our analysis. To calculate the hospital cost, we eliminated observations with zero hospital cost, which often occurs with Kaiser Permanente Hospitals where they collect medical expenses in an alternative manner.

[13] This represents nearly 100% of acute cardiovascular- and respiratory-related hospital admissions and emergency department visits during the period examined in our analysis, as we only eliminated hospital admission data from two hospital facilities and emergency department visits data from one emergency department facility due to data reporting problems.

Table 1
Estimated proportional changes of cardiorespiratory-related emergency department visits and hospital admissions during the wildfire periods by the smoke-affected area, the disease group, and the age group (N = 63 for emergency department visits models, N = 84 for hospital admissions models). Models are estimated through negative binomial model with Newey-West standard errors that are robust to heteroskedasticity and the first-order autocorrelation (Standard error is shown in parenthesis).

	Emergency department visits			Hospital admissions		
	Acute cardiovascular	Respiratory	Control	Acute cardiovascular	Respiratory	Control
Under 18 years old						
Los Angeles		0.1125	0.0641**		−0.0422	−0.0587
		(0.073)	(0.027)		(0.076)	(0.049)
San Diego		0.0375	−0.1188***		−0.2026	0.0142
		(0.095)	(0.034)		(0.157)	(0.126)
Riverside		0.1632***	−0.0015		0.5258**	0.2979
		(0.053)	(0.060)		(0.234)	(0.232)
Orange		0.2150***	0.0276		−0.0107	−0.0948
		(0.080)	(0.046)		(0.178)	(0.085)
San Bernardino		−0.0207	−0.1266**		0.2614	0.4238**
		(0.094)	(0.064)		(0.272)	(0.171)
18–64 years old						
Los Angeles	−0.0910	0.0208	−0.0013	0.0116	0.0108	0.0116
	(0.104)	(0.036)	(0.015)	(0.074)	(0.042)	(0.074)
San Diego	0.4902***	0.1764***	−0.0754***	0.1079	−0.0673	0.1079
	(0.158)	(0.049)	(0.026)	(0.144)	(0.081)	(0.144)
Riverside	0.3006	0.0970	−0.1382***	0.3678*	0.1692	0.3678*
	(0.290)	(0.061)	(0.039)	(0.203)	(0.108)	(0.203)
Orange	−0.0704	0.1403**	0.0029	−0.1072	0.0356	−0.1072
	(0.169)	(0.055)	(0.016)	(0.120)	(0.084)	(0.120)
San Bernardino	−0.1297	0.1801**	0.0032	−0.0179	0.0142	−0.0179
	(0.261)	(0.083)	(0.032)	(0.194)	(0.120)	(0.194)
Over 64 years old						
Los Angeles	0.0142	0.0095	−0.0570	−0.0833	−0.1610***	−0.0703***
	(0.069)	(0.040)	(0.043)	(0.076)	(0.058)	(0.027)
San Diego	0.1374	0.1609***	−0.0148	−0.0090	0.0572	−0.0979*
	(0.128)	(0.058)	(0.053)	(0.093)	(0.086)	(0.054)
Riverside	0.0137	−0.0875	−0.1413**	−0.0095	−0.1650	−0.1578*
	(0.151)	(0.067)	(0.060)	(0.142)	(0.111)	(0.082)
Orange	−0.0170	0.1060	0.0460	0.0072	0.0885	0.0296
	(0.125)	(0.069)	(0.037)	(0.111)	(0.084)	(0.043)
San Bernardino	−0.2131	−0.0573	−0.1633**	0.0642	0.2522*	−0.0303
	(0.163)	(0.159)	(0.069)	(0.158)	(0.138)	(0.089)

* Significant at α = 0.10 level.
** Significant at α = 0.05 level.
*** Significant at α = 0.01 level.

Table 1 presents the estimated β_3 coefficients for each subgroup defined by the smoke-affected area, the disease category, and the age group. Table 1 does not present the estimated coefficients for excess acute cardiovascular-related hospital admissions and emergency department visits for those who are younger than 18 years old because such events were extremely rare.

The estimated coefficients of β_3 capture the proportional change in daily hospital admissions or emergency department visits, as all models were estimated with count models. A significant positive sign of β_3 indicates the excess hospital admissions or emergency department visits during the 2007 wildfires. Conversely, a significant negative sign reflects a reduction in the hospital admissions or emergency department visits during the 2007 wildfires. Such results are plausible if there were external factors that affected negatively the volume of total hospital use, such as major evacuations of residents from the affected areas.[14] For example, Viswanathan et al. (2006) observed the decline of

[14] Kirsch et al. (2009) reported that there were as many as 500,000 residents displaced from their home during the 2007 wildfires.

the total emergency department visits in several days during the 2003 large wildfire in San Diego area when "the school children and employees were asked to remain at home" (p. 65). To incorporate the effect of such external factors, some previous studies analyzed the changes in the total hospital visits, or the changes of the proportion of cardiorespiratory-related hospital uses over the total hospital uses during the wildfire period (Kochi et al., 2010).

To assess the effect of external factors, we also estimated Eq. (1) using the control disease group for each subgroup. We created the control disease group to capture the external factors that might *negatively* affect the volume of hospital use in general. For this reason, we eliminated the disease categories that might be positively affected by the wildfire events, such as digestive system-related disease or injuries. Additionally, we eliminated the pregnancy-related hospital uses due to the lack of access to the data.[15]

The second, third, and fourth columns of Table 1 show the estimated results of β_3 for each subgroup for acute cardiovascular-, respiratory-, and control disease-related emergency department visits, respectively. First, we observed a significant reduction of control disease-related emergency department visits for the San Diego, Riverside, and San Bernardino areas, where most property damages or intensive air pollution levels were recorded, indicating that there might have been a large volume of evacuations from these areas.

We found a significant increase in acute cardiovascular-related emergency department visits for the San Diego area for the adult group. We also found significant increases in respiratory-related emergency department visits for the subgroup of the Riverside and Orange areas for those who are younger than 18 years old, for the subgroups of the San Diego, Orange, and San Bernardino areas for the group of adults, and the subgroup of the San Diego area for those who are older than 64 years.

The fourth, fifth, and last columns of Table 1 show the estimated β_3 for each subgroup for acute cardiovascular-, respiratory-, and control disease-related hospital admissions, respectively. We found a significant increase in acute cardiovascular-related adult hospital admissions in the Riverside area. In addition, we found a significant increase in respiratory-related hospital admissions for the group of minors in the Riverside area, and for those over 64 years in the San Bernardino area. We found a negative significant value of β_3 for respiratory-related hospital admissions at the Los Angeles area for those who are older than 64 years. This decline may reasonably be attributed to the external factors that negatively affected the total volume of hospital admissions, as the control disease group also showed a significant decline during the wildfire event.

Column 3 of Table 2 presents the point estimate and 90% confidence interval for total estimated excess hospital admissions and emergency department visits due to wildfire smoke exposure for the subgroups in which we found significant positive results for β_3 in Table 1. In addition, Table 2 presents associated total hospital costs. Hereafter, we discuss the estimated results of adverse health effects and associated total costs using the point estimate and present the 90% confidence interval (90% CI) in parenthesis.

We estimated a total of 79 (90% CI: 10–172) excess respiratory-related hospital admissions and 26 (90% CI: 2–59) acute cardiovascular-related excess hospital admissions during the wildfire period.[16] The estimated total hospital costs are $3.0 million (90% CI: $262,000–$6.6 million). We also estimated a total of 759 (90% CI: 288–1285) excess respiratory-related and 38 (90% CI: 15–67) acute cardiovascular-related emergency department visits during the wildfire period. The estimated total hospital costs related to the excess emergency department visits are $398,000 (90% CI: $148,000–$680,000).

We also examined the validity of applying the benefits transfer approach to estimate the morbidity effects by comparing our results with the estimation based on the dose-response function estimated in Delfino et al. (2009). Delfino et al. (2009) estimated that each increment of 10 $\mu g/m^3$ of 2-day moving average of $PM_{2.5}$ would increase the respiratory-related hospital admissions by 2.4% (95% confidence interval (CI): 0.5–4.4%) and 3.0% (95% CI: 1.1–4.9%) for the 20–64 years old group and the over 64 years old group, respectively.

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[15] We decided not use the proportional data for the dependent variable, because this type of measurement may underestimate the effect of the adverse health effects when there was an increase of control disease-related hospital uses for any reason.

[16] The sum may not be consistent with the individual numbers presented in Table 2 due to rounding.

Table 2
Estimated economic costs related with excess hospital admissions and emergency department visits during the 2007 wildfires.

	Estimated coefficient (standard error)	Total estimated excess hospital admissions/emergency department visits. **point estimate** (90% CI)	Total hospital cost (unit $1000) **point estimate** (90% CI)
Respiratory-related hospital admissions			
Under 18 years old			
Riverside	0.5258**	**28**	**280**
	(0.234)	(6–60)	(58–606)
Over 64 years old			
San Bernardino	0.2522*	**52**	**1802**
	(0.138)	(4–112)	(140–3894)
Respiratory-related emergency department visits			
Under 18 years old			
Riverside	0.1632***	**96**	**40**
	(0.053)	(42–156)	(17–66)
Orange	0.2150***	**163**	**84**
	(0.080)	(57–284)	(29–146)
18–64 years old			
San Diego	0.1764***	**189**	**89**
	(0.049)	(97–289)	(46–137)
Orange	0.1403**	**132**	**68**
	(0.055)	(43–229)	(22–118)
San Bernardino	0.1801**	**114**	**66**
	(0.083)	(24–218)	(14–127)
Over 64 years old			
San Diego	0.1609***	**65**	**31**
	(0.058)	(25–110)	(11–52)
Acute cardiovascular-related hospital admissions			
18–64 years old			
Riverside	0.3678*	**26**	**932**
	(0.203)	(2–59)	(62–2151)
Acute cardiovascular-related emergency department visits			
18–64 years old			
San Diego	0.4902***	**38**	**17**
	(0.158)	(15–67)	(7–31)
Total			**3413**
			(410–7333)

* Significant at $\alpha = 0.10$ level
** Significant at $\alpha = 0.05$ level
*** Significant at $\alpha = 0.01$ level.

We calculated the excess $PM_{2.5}$ by subtracting the average of the 2-day moving average $PM_{2.5}$ levels during the reference period from the 2-day moving average $PM_{2.5}$ levels during the wildfire period. Since daily $PM_{2.5}$ were recorded in limited areas during the 2007 wildfires, we only analyzed areas near Los Angeles, Anaheim and San Diego monitoring stations (mapped in Fig. 3). Table 3 shows the total excess $PM_{2.5}$ at each monitoring station. To estimate excess hospital admissions, we limited our analysis to hospitals near these monitoring stations. For Los Angeles and San Diego monitoring stations, we only analyzed the hospitals located within the 15 miles radius from the monitoring station, and for Anaheim monitoring station, we analyzed all hospitals in Orange County.[17]

Table 3 shows the daily average respiratory-related hospital admissions in each area during the reference period (the third column) and estimated total excess admissions based on Delfino et al. (2009) (the fifth column). The estimated total excess respiratory-related hospital admissions near

[17] More specifically, we analyzed hospitals that located in a zipcode area whose center locates within the 15 miles radius from the Los Angeles and San Diego monitoring station.

Table 3
Comparison of levels of respiratory-related hospital admissions during the reference and study periods, and estimated excess admissions from the transfer approach.

Monitoring station	Total excess 2-days moving average $PM_{2.5}$ ($\mu g/m^3$) during wildfire period	Daily average respiratory-related hospital admissions		Estimated total excess admissions based on Delfino et al. (2009)
		Reference period	Wildfire period	
18–64 years old				
Los Angeles	100.67	67.92	67.35	16.4 (3.4–30.0)
Anaheim	150.17	26.07	24.92	9.3 (1.9–17.2)
San Diego	119.66	19.85	18.00	10.2 (2.1–18.7)
Over 64 years old				
Los Angeles	100.67	76.21	70.50	23.0 (8.4–37.5)
Anaheim	150.17	31.28	33.57	14.0 (5.1–23.0)
San Diego	119.66	19.85	23.28	12.8 (4.6–20.9)

Los Angeles, Anaheim and San Diego areas are the following (95% CI presented in parenthesis): 16.4 (3.4–30.0), 9.3 (1.9–17.2) and 10.2 (2.1–18.7), respectively for the adult population, and 23.0 (8.4–37.5), 14.0 (5.1–23.0) and 12.8 (4.6–20.9), respectively for the senior population. The total excess respiratory-related hospital admissions in these three areas are 36.0 (7.5–66.1) and 49.9 (18.3–81.5) for the adult population and senior population, respectively.

The fourth column of Table 3 also shows the daily average respiratory-related hospital admissions during the wildfire period to examine the validity of the transfer approach. The results of the transfer approach are markedly different from the results based on the primary health data approach for the adult population, as the simple comparison between reference and wildfire periods shows that there was practically no change or even negative changes of the daily average respiratory-related hospital admissions during the wildfire period in these three areas. This was also the case for seniors in Los Angeles, where the daily average respiratory-related hospital admissions were substantially lower during the wildfire period than reference period. A poor ability to predict the excess admissions based on the marginal effect of $PM_{2.5}$ during the wildfire event confirms the complexity of the relationship between outdoor air pollution levels and morbidity effects as pointed out by Delfino et al. (2009).

Discussion and conclusions

This is the first large-scale analysis to estimate the economic costs associated with adverse health effects due to the massive 2007 wildfires in southern California. We used the excess number of hospital admissions and emergency department visits to estimate the adverse health effects and used hospital costs to estimate the associated economic costs. To determine the morbidity related economic costs across the various geographic areas, we used the hospital admission data from 187 hospital facilities and emergency department visits data from140 emergency department facilities in five counties in southern California.

It is evident that there were substantial acute adverse health effects from the intense wildfire smoke exposure as emergency department visits increased substantially during the wildfires. The increase in hospital admissions was moderate and found in limited areas. We estimated the total direct health-related costs to be \$3.4 million with 90% confidence interval of \$410,000–\$7.3 million. The majority of the excess hospital admissions and emergency department visits were associated with respiratory-related illness, but the excess cardio-related hospital uses were also observed among the adult population. Although the number of excess hospital admissions was substantially smaller than the excess emergency department visits, 90% of the total cost were attributed to the excess hospital admissions.

Previously, Dohrenwend et al. (2013) found excesses of 38 dyspnea (i.e., breathing difficulties) and 31 asthma-related emergency department visits in Kaiser Permanente hospitals in the city of San Diego during the 2007 wildfires. We found over 250 excess respiratory-related and nearly 40 excess acute cardiovascular-related emergency department visits using data from all hospitals located in the San Diego smoke affected area. We also found that other smoke-affected areas in Riverside, Orange, and San Bernardino Counties experienced significant increases in respiratory-related emergency department visits.

Our estimates of the excess hospital admissions are relatively large compared with Moeltner et al. (2013) that applied a similar analytical approach on the same health outcomes. Moeltner et al. (2013) estimated a cost of approximately $2.2 million for the excess cardiorespiratory-related hospital admissions in Reno/Sparks areas in Nevada from the multiple wildfires that burned 850,000 acres in northern California and Nevada. Our study estimated a cost of $3.0 million for the excess cardiorespiratory-related hospital admissions from the wildfires that burned 516,000 acres. It is difficult to identify the source of this divergence because of the differences in the study design and targeted population, but one of the factors that may explain the difference could be the proximity of the fires to the urban areas and the higher population density of the southern California metropolitan areas.

We have improved the methodology to quantify the adverse health effects of wildfire smoke exposure in several ways. First, we incorporated the baseline seasonal trend of hospital uses by including the control years in the analysis, which has not been fully done in previous studies in southern California area (Delfino et al., 2009; Dohrenwend et al., 2013; Viswanathan et al., 2006). We also examined the external factors that may affect the adverse health effects. The control disease group analysis showed a significant reduction of emergency department visits in the San Diego, Riverside, and San Bernardino areas and significant reduction of hospital admissions in the Los Angeles and Riverside areas in some subsamples. Such decline of the control disease-related hospital use may be the result of evacuations or strong aversion to going outdoors during intense wildfire smoke. Our results are conditional on averting behavior, and without such effective averting actions, the estimated adverse health effects from wildfire smoke exposure would likely be higher.

We emphasize that the estimated costs do not reflect the full health cost associated with the 2007 wildfire events. We only took into account the direct medical costs associated with hospital admissions and emergency department visits. We did not consider averting costs, labor loss and utility loss associated with hospitalization and emergency department visits. Also, we did not take into account other types of health outcomes, such as mortality and minor adverse health effects that did not require medical attention at the hospital.

There are several findings worth noting. First, although previous studies found significant relationships between the levels of PM from urban pollution and cardiorespiratory hospital admissions (USEPA, 2004), we found that not all wildfire affected areas showed significant increases in cardiorespiratory hospital admissions during the 2007 wildfires despite the exceptionally high PM levels recorded in these areas. It is well documented that residents near wildfire areas take substantial averting actions to mitigate their exposure to smoke (Richardson et al., 2012), which may have reduced the likelihood of adverse health effect of outdoor air pollution.

Second, we observed the majority of adverse health effects in the form of the respiratory-related disease, but we also found evidence of increased acute cardiovascular-related incidences (heart attack and stroke) during the wildfires with some subgroups, which is consistent with the findings of Delfino et al. (2009) and Moeltner et al. (2013). Third, excess acute cardiovascular-related hospital use was concentrated among adults, not elderly. We found excess respiratory-related emergency department visits across all age groups while we only observed excess respiratory-related hospital admissions among those who are under 18 years old and older than 64 years. This indicates that although all ages experienced some respiratory symptoms, children and seniors faced more risk of developing severe conditions that require inpatient care.

Fourth, we found a weak association between the levels of excess emergency department visits and hospital admissions during the wildfires. Although six subgroups showed a significant increase of respiratory-related emergency department visits during the 2007 wildfires, only one subgroup (under 18 years old in the Riverside smoke-affected area) also showed a significant increase of respiratory-related hospital admissions. It is possible that residents in smoke-affected areas took extra precautions during wildfires and sought medical attention at an emergency department for symptoms too mild to require inpatient care. Such behavior could explain the significant increases in emergency department visits that were not accompanied by increases in hospital admissions.

There has been an increased focus in the US on research to understand the health impacts of wildfire smoke exposure. Most studies in the US generally focused on the epidemiological evidence to link the air pollution levels during the wildfire events and health outcomes such as Viswanathan et al. (2006) and Delfino et al. (2009) but only few studies translate such physical damages to economic costs. This research has improved our understanding of the health-related economic costs of wildfire smoke exposure. The morbidity costs of wildfire smoke are an important issue for public-land managers. Most managers are aware that wildfire smoke can have negative public-health effects, but a lack of information makes it difficult to fully consider health impacts when making suppression decisions. In the future, more studies are required to fully understand how such costs can be reduced. One important area to be investigated in the literature is the effectiveness of wildfire smoke health warning systems and averting behavior of residents to mitigate adverse health effects. Since wildfires are generally short term events, taking averting actions such as staying indoors is feasible for many residents in affected areas.

Another important area to be studied is the evaluation of health damages avoided from fuel reduction programs to clarify the economic returns associated with hazardous fuel reduction investments in the wildland-urban interface. If fuel treatments moderate subsequent wildfire behavior, then large wildfires may produce less smoke as Moeltner et al. (2013) found a weaker effect of wildfire on the $PM_{2.5}$ levels when the fuel load is low than when the fuel load is higher. Releasing small increments of PM during prescribed fires would have a smaller public-health impact. Quantifying such benefits would be useful to inform public policy makers.

The number and the size of wildfires have been increasing in the last couple of decades in the western US (Dennison et al., 2014). With climate change, the number of wildfires is expected to increase in the future worldwide particularly in fire-prone areas (Moritz et al., 2012). Given the fact that future climate conditions will likely increase the number of large wildfires, it is important to further advance the research in public health impacts of wildfires and take such social costs into consideration when making fire management decisions.

Acknowledgement

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Appendix A. List of the 2007 southern California wildfires.

	Name of fire	County[§]	Date fire started	Date fire contained	Acres burned	Property damages (residential structures, commercial buildings and outbuildings)	Injuries (fire fighters and civilians)	Control cost (million)
1	Ranch	LA	10/20	11/1	58,401	10 structures destroyed		$9
2	Canyon	LA	10/21	11/1	4,521	22 structures damaged	3 injuries	$5.8
3	Sedgewick	SBa	10/21	10/30	710			
2	Harris	SD	10/21	11/5	90,440	548 structures destroyed. 15 structures damaged.	61 injuries 5 fatalities	$21
5	October	LA	10/21	10/30	20			
6	Nightsky	VE	10/21	11/1	35			
7	Witch	SD	10/21	11/6	197,990	1634 structures destroyed. 102 structures damaged	40 injuries 2 fatalities	$18
8	Buckweed	LA	10/21	11/1	38,000	63 structures destroyed. 30 structures damaged.	4 injuries	$7.4
9	Roca	RS	10/21	11/1	270			
10	Santiago	OR	10/21	11/9	28,400	24 structures destroyed. 20 structures damaged.	16 injuries	$21.6
11	Coronado Hills	SD	10/22	10/30	250	2 structures destroyed		
12	Walker	SBe	10/22	10/30	160			

Appendix A (*Continued*)

	Name of fire	County[§]	Date fire started	Date fire contained	Acres burned	Property damages (residential structures, commercial buildings and outbuildings)	Injuries (fire fighters and civilians)	Control cost (million)
13	Cajon fire	SBe	10/22	10/30	250			
14	Magic	LA	10/22	10/31	2,824			
15	Rice	SD	10/22	11/1	9,472	248 structures destroyed.	5 injuries	$6.5
16	Slide	SBe	10/22	11/6	12,759	275 structures destroyed. 43 structures damaged.	9 injuries	$23.3
17	Grass Valley	SBe	10/22	11/6	1,247	176 structures destroyed. 25 structures damaged.	1 injury	$6.9
18	Rosa	RS	10/22	10/31	411	2 structures destroyed.		
19	Martin Ranch	SBe	10/23	10/30	123	1 structure destroyed.	1 injury	
20	Meadowridge	LA	10/23	10/30	40			
21	Poomacha	SD	10/23	11/9	49,410	217 structures destroyed.	15 injuries	$20.6
22	Ammo	SD	10/23	10/29	21,004		6 injuries	$0.7
	Total				516,737	3200 structures destroyed 257 structures damaged	161 injuries 7 fatalities	$140

§ Name of county is abbreviated in the following manner; LA: Los Angeles, SBa: Santa Barbara, SD: San Diego, VE: Ventura, RS: Riverside, SBe: San Bernardino.

Source: California Department of Forestry and Fire Protection http://cdfdata.fire.ca.gov/incidents/incidents_archived?archive_year=2007&pc=50&cp=0 retrieved on April 27, 2011.

Appendix B. Average hospital-related cost and days of hospital stay by county, disease category and age group in 2007.

	Acute cardiovascular		Respiratory (non-influenza)		
	Average Hospital cost per hospital admission (unit: $)	Average days of hospital stay	Average Hospital cost per hospital admission (unit: $)	Average days of hospital stay	Average cost per emergency department visit (unit: $)
Under 18 years old					
Los Angeles			19,004	3.25	582.63
San Diego			16,557	2.62	476.12
Riverside			10,148	2.33	424.82
Orange			24,146	3.08	516.83
San Bernardino			11,546	2.64	582.79
18–64 years old					
Los Angeles	63,025	5.01	32,560	3.81	582.63
San Diego	61,192	4.67	29,922	3.91	476.12
Riverside	36,174	4.12	21,609	3.42	424.82
Orange	66,603	4.12	28,982	3.21	516.83
San Bernardino	49,167	4.24	26,643	3.69	582.79
Over 64 years old					
Los Angeles	53,477	5.29	46,177	5.98	582.63
San Diego	47,036	4.87	35,017	5.21	476.12
Riverside	27,724	4.20	24,930	4.54	424.82
Orange	49,152	4.39	37,895	4.83	516.83
San Bernardino	43,360	4.57	34,743	5.40	582.79

Appendix C. Full estimation results by smoke affected area. Models are estimated through negative binomial model with Newey-West standard errors that are robust to heteroskedasticity and the first-order autocorrelation (Standard error is shown in parenthesis).

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
Emergency department visits, acute cardiovascular-related disease, 18–64 years old group (N = 63)					
t	0.0106	−0.0155	−0.0396**	0.0123	−0.0316*
	(0.008)	(0.011)	(0.016)	(0.008)	(0.019)
fire_yr	0.0809	−0.0724	−0.0500	0.0844	−0.1584
	(0.066)	(0.087)	(0.114)	(0.083)	(0.151)
fire	−0.1687*	−0.0489	0.4618	−0.3087***	0.4986**
	(0.097)	(0.203)	(0.310)	(0.116)	(0.254)
*fire_yr*fire*	−0.0910	0.4902***	0.3006	−0.0704	−0.1297
	(0.104)	(0.158)	(0.290)	(0.169)	(0.261)
monday	0.1240	0.1468	0.0240	0.2419*	0.3093
	(0.125)	(0.109)	(0.179)	(0.134)	(0.239)
tuesday	0.0573	0.0432	−0.1285	0.1343	0.3275
	(0.111)	(0.132)	(0.206)	(0.161)	(0.240)
wednesday	0.1545	0.1110	0.1668	−0.0246	0.3860
	(0.097)	(0.103)	(0.194)	(0.124)	(0.259)
thursday	0.0248	0.1715*	0.0826	−0.0515	0.3754*
	(0.097)	(0.098)	(0.179)	(0.130)	(0.227)
friday	−0.1648	−0.0690	−0.0786	0.1015	0.2640
	(0.121)	(0.091)	(0.256)	(0.142)	(0.253)
saturday	0.0147	−0.0919	−0.2195	−0.1329	0.1128
	(0.105)	(0.203)	(0.190)	(0.130)	(0.212)
minhum	−0.0046	−0.0079*	0.0099	−0.0018	−0.0061
	(0.004)	(0.005)	(0.007)	(0.003)	(0.009)
maxhum	0.0038	0.0043	−0.0087	−0.0024	−0.0018
	(0.003)	(0.003)	(0.008)	(0.004)	(0.008)
mintemp	0.0161	0.0059	−0.0024	−0.0114	0.0002
	(0.015)	(0.028)	(0.028)	(0.019)	(0.025)
maxtemp	0.0006	−0.0461***	0.0107	0.0003	−0.0077
	(0.011)	(0.015)	(0.011)	(0.008)	(0.020)
Constant	2.1726***	5.2458***	1.4823	2.9761**	2.5849
	(0.609)	(1.988)	(1.832)	(1.356)	(2.206)
Emergency department visits, acute cardiovascular-related disease, over 64 years old group (N = 63)					
t	0.0095**	0.0117	−0.0043	−0.0067	−0.0251
	(0.004)	(0.008)	(0.010)	(0.009)	(0.017)
fire_yr	0.0536*	0.1141	0.0869	0.0504	0.0022
	(0.033)	(0.073)	(0.105)	(0.075)	(0.123)
fire	−0.0874	−0.1678*	0.1088	0.1424	0.3126*
	(0.060)	(0.094)	(0.156)	(0.126)	(0.180)
*fire_yr*fire*	0.0142	0.1374	0.0137	−0.0170	−0.2131
	(0.069)	(0.128)	(0.151)	(0.125)	(0.163)
monday	0.0921	0.2134***	0.0969	0.1231	−0.1204
	(0.079)	(0.071)	(0.142)	(0.145)	(0.205)
tuesday	0.0716	−0.1264	0.1271	−0.0519	0.1566
	(0.086)	(0.079)	(0.148)	(0.124)	(0.132)
wednesday	0.0390	0.0873	0.1899	0.0531	−0.0226
	(0.073)	(0.084)	(0.134)	(0.103)	(0.168)
thursday	0.0358	0.0994	0.2202*	0.1063	−0.0510
	(0.072)	(0.098)	(0.132)	(0.118)	(0.163)
friday	0.0163	0.0465	0.3065**	0.1030	0.0172
	(0.076)	(0.082)	(0.135)	(0.097)	(0.149)
saturday	−0.0780	−0.1108*	0.0790	−0.1282	−0.2750
	(0.094)	(0.065)	(0.126)	(0.116)	(0.220)
minhum	−0.0016	0.0068*	0.0028	0.0035	−0.0044
	(0.002)	(0.004)	(0.003)	(0.003)	(0.006)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
maxhum	−0.0009	0.0033	−0.0050*	0.0009	0.0090*
	(0.002)	(0.003)	(0.003)	(0.003)	(0.005)
mintemp	−0.0157*	−0.0165	0.0060	−0.0024	0.0218
	(0.009)	(0.019)	(0.016)	(0.016)	(0.018)
maxtemp	−0.0034	0.0281**	−0.0007	0.0068	−0.0002
	(0.004)	(0.013)	(0.007)	(0.006)	(0.016)
Constant	5.1460***	1.0689	2.0247*	2.2426**	0.1840
	(0.622)	(1.727)	(1.073)	(0.969)	(1.328)
Emergency department visits, respiratory-related disease except influenza, under 18 years old group (N = 63)					
t	−0.0092**	0.0043	−0.0094*	−0.0038	−0.0043
	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
fire_yr	0.1528***	0.2227***	0.3285***	0.0930**	0.2515***
	(0.034)	(0.044)	(0.046)	(0.041)	(0.040)
fire	0.1037*	0.0828	0.1832***	0.0172	0.0501
	(0.060)	(0.072)	(0.060)	(0.081)	(0.070)
*fire_yr*fire*	0.1125	0.0375	0.1632***	0.2150***	−0.0207
	(0.073)	(0.095)	(0.053)	(0.080)	(0.094)
monday	−0.1780***	−0.1838**	−0.2210***	−0.1670**	−0.0460
	(0.047)	(0.081)	(0.053)	(0.069)	(0.053)
tuesday	−0.2822***	−0.4007***	−0.3448***	−0.4289***	−0.2248***
	(0.059)	(0.079)	(0.075)	(0.060)	(0.062)
wednesday	−0.3089***	−0.3011***	−0.3032***	−0.3907***	−0.2005***
	(0.058)	(0.060)	(0.056)	(0.060)	(0.063)
thursday	−0.3438***	−0.3344***	−0.2735***	−0.3919***	−0.2545***
	(0.053)	(0.057)	(0.053)	(0.068)	(0.066)
friday	−0.3044***	−0.3322***	−0.3394***	−0.3710***	−0.2054***
	(0.063)	(0.061)	(0.054)	(0.075)	(0.054)
saturday	−0.1216**	−0.2300***	−0.1934***	−0.1119*	−0.0172
	(0.049)	(0.066)	(0.051)	(0.064)	(0.075)
minhum	0.0045**	0.0015	−0.0007	0.0066***	0.0032
	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)
maxhum	0.0021	−0.0032*	0.0053***	−0.0003	0.0024
	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
mintemp	−0.0052	0.0119	0.0157***	0.0047	0.0022
	(0.007)	(0.013)	(0.006)	(0.007)	(0.009)
maxtemp	0.0146***	0.0078	0.0012	0.0141***	0.0148***
	(0.005)	(0.009)	(0.003)	(0.004)	(0.005)
Constant	4.9535***	3.3773***	2.9364***	3.1616***	2.6096***
	(0.533)	(0.900)	(0.465)	(0.440)	(0.572)
Emergency department visits, respiratory-related disease except influenza, 18-64 years old group (N = 63).					
t	−0.0018	−0.0061**	−0.0014	0.0011	0.0002
	(0.002)	(0.003)	(0.005)	(0.003)	(0.004)
fire_yr	0.0447***	0.0868***	0.0623**	0.0445*	0.0865***
	(0.015)	(0.030)	(0.031)	(0.025)	(0.033)
fire	0.0424*	0.0801**	0.0440	−0.0326	−0.0275
	(0.024)	(0.033)	(0.048)	(0.056)	(0.054)
*fire_yr*fire*	0.0208	0.1764***	0.0970	0.1403**	0.1801**
	(0.036)	(0.049)	(0.061)	(0.055)	(0.083)
monday	0.1067***	0.2618***	0.1398***	0.0804**	0.1835**
	(0.019)	(0.033)	(0.045)	(0.038)	(0.075)
tuesday	0.0476***	0.1752***	0.0574	0.0435	0.1293**
	(0.014)	(0.038)	(0.041)	(0.049)	(0.060)
wednesday	0.0278*	0.1467***	0.1201**	0.0754*	0.1317*
	(0.015)	(0.036)	(0.055)	(0.043)	(0.070)
thursday	0.0555**	0.1647***	0.0577	−0.0355	0.0856
	(0.024)	(0.040)	(0.044)	(0.040)	(0.073)
friday	0.0277	0.1083***	0.0147	−0.0504	0.0229
	(0.029)	(0.040)	(0.059)	(0.042)	(0.058)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
saturday	−0.0513*	0.0468	−0.0188	−0.0551	−0.0573
	(0.027)	(0.031)	(0.054)	(0.042)	(0.068)
minhum	0.0028***	−0.0000	−0.0001	0.0013	−0.0002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
maxhum	−0.0022***	−0.0005	−0.0001	0.0011	0.0016
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
mintemp	−0.0012	0.0148**	0.0037	0.0110**	0.0019
	(0.003)	(0.006)	(0.007)	(0.006)	(0.008)
maxtemp	0.0060**	0.0022	−0.0015	0.0040	0.0040
	(0.003)	(0.005)	(0.003)	(0.002)	(0.005)
Constant	5.7427***	3.7813***	4.2751***	3.6950***	3.7252***
	(0.248)	(0.572)	(0.495)	(0.309)	(0.525)
Emergency department visits, respiratory-related disease except influenza, over 65 years old group (N = 63)					
t	0.0008	0.0059	0.0076	−0.0023	0.0018
	(0.004)	(0.005)	(0.006)	(0.005)	(0.010)
fire_yr	0.0654**	0.0549	0.0418	−0.0262	0.0351
	(0.033)	(0.038)	(0.043)	(0.037)	(0.066)
fire	−0.0420	−0.0017	−0.0051	−0.0211	−0.0454
	(0.042)	(0.062)	(0.079)	(0.064)	(0.137)
*fire_yr*fire*	0.0095	0.1609***	−0.0875	0.1060	−0.0573
	(0.040)	(0.058)	(0.067)	(0.069)	(0.159)
monday	0.1710***	0.1387**	−0.0065	0.2081***	0.1704
	(0.047)	(0.065)	(0.047)	(0.055)	(0.129)
tuesday	0.0653	0.0922*	−0.0683	0.2115***	0.1241
	(0.040)	(0.051)	(0.061)	(0.076)	(0.152)
wednesday	0.0768*	0.0462	−0.0968	0.1017	0.1651
	(0.046)	(0.068)	(0.076)	(0.065)	(0.132)
thursday	0.0631	0.0576	−0.0615	0.1362**	0.1192
	(0.044)	(0.061)	(0.074)	(0.058)	(0.165)
friday	0.1367***	−0.0338	−0.1165*	0.0772	0.1643
	(0.036)	(0.049)	(0.065)	(0.066)	(0.172)
saturday	0.0200	0.0763**	−0.1265**	0.0822	0.1894
	(0.043)	(0.037)	(0.057)	(0.076)	(0.127)
minhum	0.0029**	0.0022	0.0049**	−0.0068***	0.0051
	(0.001)	(0.002)	(0.002)	(0.002)	(0.005)
maxhum	0.0009	−0.0034**	0.0010	0.0045***	−0.0038
	(0.001)	(0.002)	(0.002)	(0.002)	(0.004)
mintemp	0.0067	0.0008	0.0143	0.0251***	−0.0188
	(0.004)	(0.010)	(0.010)	(0.007)	(0.016)
maxtemp	0.0095***	0.0074	0.0113**	−0.0097**	0.0088
	(0.003)	(0.006)	(0.005)	(0.004)	(0.013)
Constant	3.6865***	3.4090***	1.3648*	3.0987***	3.2831**
	(0.385)	(0.646)	(0.728)	(0.561)	(1.588)
Emergency department visits, control disease, under 18 years old group (N = 63)					
t	−0.0019	−0.0005	−0.0055	−0.0012	−0.0016
	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
fire_yr	0.0537***	0.1618***	0.2125***	0.1142***	0.1605***
	(0.018)	(0.022)	(0.034)	(0.022)	(0.045)
fire	0.0014	0.0606*	0.1253*	0.0571*	0.1664***
	(0.027)	(0.036)	(0.066)	(0.032)	(0.051)
*fire_yr*fire*	0.0641**	−0.1188***	−0.0015	0.0276	−0.1266**
	(0.027)	(0.034)	(0.060)	(0.046)	(0.064)
monday	−0.0519**	−0.1065***	−0.0070	−0.0468	0.0017
	(0.021)	(0.041)	(0.064)	(0.035)	(0.037)
tuesday	−0.1249***	−0.2413***	−0.0307	−0.1054***	−0.0273
	(0.021)	(0.044)	(0.052)	(0.036)	(0.046)
wednesday	−0.1839***	−0.2578***	−0.0719	−0.1542***	0.0049
	(0.024)	(0.043)	(0.047)	(0.037)	(0.059)
thursday	−0.1537***	−0.1998***	−0.1814***	−0.1926***	−0.0929**
	(0.024)	(0.034)	(0.061)	(0.041)	(0.045)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
friday	−0.1508***	−0.2019***	−0.0560	−0.1457***	−0.0805***
	(0.022)	(0.039)	(0.046)	(0.035)	(0.030)
saturday	−0.0172	−0.0828*	0.0617	0.0000	−0.0107
	(0.018)	(0.048)	(0.069)	(0.033)	(0.047)
minhum	0.0027***	−0.0013	−0.0010	0.0004	−0.0072***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
maxhum	0.0003	0.0029***	−0.0001	−0.0006	0.0018
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
mintemp	−0.0023	0.0034	−0.0025	−0.0012	0.0071
	(0.003)	(0.007)	(0.005)	(0.005)	(0.005)
maxtemp	0.0101***	0.0005	−0.0006	0.0032	−0.0166***
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)
Constant	5.6654***	4.5204***	4.6609***	4.9404***	5.3061***
	(0.182)	(0.599)	(0.461)	(0.401)	(0.425)
Emergency department visits, control disease, 18-64 years old group (N = 63).					
t	−0.0004	−0.0030*	0.0002	−0.0026***	−0.0031
	(0.001)	(0.002)	(0.002)	(0.001)	(0.003)
fire_yr	0.0168***	0.0394***	0.0953***	0.0014	0.0973***
	(0.005)	(0.012)	(0.013)	(0.009)	(0.021)
fire	−0.0097	0.0175	0.0393	0.0351***	0.0181
	(0.010)	(0.026)	(0.027)	(0.012)	(0.036)
*fire_yr*fire*	−0.0013	−0.0754***	−0.1382***	0.0029	0.0032
	(0.015)	(0.026)	(0.039)	(0.016)	(0.032)
monday	0.0996***	0.1201***	0.0937***	0.0191	0.1232***
	(0.012)	(0.021)	(0.016)	(0.018)	(0.031)
tuesday	0.0664***	0.0747***	0.0330**	−0.0113	0.0950***
	(0.012)	(0.028)	(0.016)	(0.018)	(0.028)
wednesday	0.0352***	0.0371	0.0607***	−0.0486***	0.0874***
	(0.012)	(0.026)	(0.018)	(0.015)	(0.028)
thursday	0.0177	0.0169	0.0268	−0.0444**	0.0856***
	(0.011)	(0.024)	(0.021)	(0.018)	(0.030)
friday	0.0332**	0.0013	−0.0057	−0.0772***	0.0638**
	(0.013)	(0.023)	(0.030)	(0.015)	(0.030)
saturday	0.0167	0.0067	−0.0168	−0.0928***	−0.0221
	(0.012)	(0.021)	(0.017)	(0.021)	(0.025)
minhum	0.0012***	−0.0009	−0.0005	−0.0008*	−0.0000
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
maxhum	−0.0002	0.0025***	−0.0008	0.0003	0.0006
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
mintemp	0.0015	0.0073**	0.0041	0.0064***	0.0112***
	(0.001)	(0.003)	(0.003)	(0.002)	(0.004)
maxtemp	0.0046***	0.0021	−0.0009	−0.0000	0.0003
	(0.001)	(0.003)	(0.002)	(0.001)	(0.003)
Constant	6.9663***	5.4726***	5.4924***	5.8782***	4.8561***
	(0.094)	(0.244)	(0.228)	(0.122)	(0.354)
Emergency department visits, control disease, over 64 years old group (N = 63)					
t	−0.0007	−0.0043*	−0.0161***	−0.0042*	−0.0056
	(0.002)	(0.002)	(0.004)	(0.002)	(0.006)
fire_yr	0.0432**	0.0923***	0.1187***	0.0003	0.1178**
	(0.019)	(0.022)	(0.028)	(0.018)	(0.049)
fire	0.0172	0.0744**	0.2465***	0.0038	0.1185
	(0.033)	(0.038)	(0.046)	(0.033)	(0.079)
*fire_yr*fire*	−0.0570	−0.0148	−0.1413**	0.0460	−0.1633**
	(0.043)	(0.053)	(0.060)	(0.037)	(0.069)
monday	0.1155***	0.1332***	−0.0222	−0.0325	0.0272
	(0.020)	(0.036)	(0.068)	(0.033)	(0.052)
tuesday	0.1063***	0.0752*	−0.0209	0.0273	0.0599
	(0.024)	(0.039)	(0.041)	(0.036)	(0.055)
wednesday	0.0896***	0.0941***	−0.0040	−0.0655*	0.0319
	(0.022)	(0.028)	(0.046)	(0.039)	(0.058)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
thursday	0.0736***	0.0710**	0.0767*	0.0015	0.1555***
	(0.028)	(0.033)	(0.044)	(0.035)	(0.045)
friday	0.1001***	0.1146***	0.0707	0.0792***	0.0518
	(0.031)	(0.036)	(0.046)	(0.028)	(0.067)
saturday	0.0344	0.1382***	−0.0894	0.0109	−0.0419
	(0.030)	(0.036)	(0.056)	(0.027)	(0.083)
minhum	−0.0012	−0.0015	−0.0013	−0.0018	−0.0004
	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)
maxhum	−0.0004	0.0016	0.0017	0.0010	−0.0027
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
mintemp	0.0032	0.0007	0.0082	0.0174***	0.0209**
	(0.003)	(0.005)	(0.009)	(0.005)	(0.009)
maxtemp	−0.0007	0.0001	−0.0007	−0.0034	−0.0033
	(0.002)	(0.004)	(0.003)	(0.003)	(0.006)
Constant	5.9647***	4.7465***	3.7417***	4.2459***	2.9817***
	(0.257)	(0.458)	(0.598)	(0.404)	(0.552)
Hospital admissions, acute cardiovascular-related disease, 18-64 years old group (N = 84).					
t	0.0052	−0.0045	−0.0179	0.0075	−0.0261**
	(0.005)	(0.010)	(0.013)	(0.008)	(0.012)
fire_yr	0.0652	−0.0126	−0.1869	0.0874	−0.1260
	(0.060)	(0.092)	(0.139)	(0.065)	(0.129)
fire	−0.1236	0.0208	0.1076	−0.1542	0.4623**
	(0.084)	(0.174)	(0.278)	(0.132)	(0.217)
*fire_yr*fire*	0.0116	0.1079	0.3678*	−0.1072	−0.0179
	(0.074)	(0.144)	(0.203)	(0.120)	(0.194)
monday	0.2676***	0.4105***	0.1836	0.3812***	0.4191**
	(0.102)	(0.127)	(0.173)	(0.111)	(0.166)
tuesday	0.2346**	0.2322	−0.3170	0.2080*	0.3529*
	(0.094)	(0.155)	(0.199)	(0.120)	(0.183)
wednesday	0.2992***	0.5033***	0.1246	0.1645	0.3041*
	(0.089)	(0.113)	(0.172)	(0.126)	(0.158)
thursday	0.2136**	0.2442*	−0.0105	0.2858***	0.3078**
	(0.084)	(0.133)	(0.183)	(0.099)	(0.150)
friday	0.0075	0.1986*	−0.2073	0.1433	0.3254*
	(0.103)	(0.115)	(0.251)	(0.118)	(0.193)
saturday	0.0328	0.1226	−0.1683	0.0051	−0.0342
	(0.079)	(0.169)	(0.147)	(0.125)	(0.157)
minhum	−0.0032	−0.0032	0.0117**	0.0010	−0.0036
	(0.003)	(0.005)	(0.006)	(0.004)	(0.008)
maxhum	0.0026	0.0052	−0.0094	−0.0035	0.0015
	(0.002)	(0.003)	(0.007)	(0.004)	(0.007)
mintemp	0.0156	0.0200	−0.0258	−0.0061	0.0254
	(0.012)	(0.021)	(0.021)	(0.016)	(0.020)
maxtemp	−0.0025	−0.0105	0.0197*	0.0058	−0.0071
	(0.008)	(0.016)	(0.010)	(0.007)	(0.018)
Constant	2.5489***	1.3105	1.9917	2.1854**	0.7239
	(0.603)	(1.527)	(1.521)	(1.070)	(1.691)
Hospital admissions, acute cardiovascular-related disease, over 64 years old group (N = 84).					
t	−0.0001	0.0084	−0.0105	−0.0083	−0.0170*
	(0.004)	(0.006)	(0.008)	(0.008)	(0.010)
fire_yr	0.0699*	0.0619	−0.0070	0.0140	−0.0162
	(0.040)	(0.060)	(0.093)	(0.080)	(0.128)
fire	−0.0001	−0.1139	0.1907	0.1642	0.2927**
	(0.070)	(0.090)	(0.148)	(0.117)	(0.140)
*fire_yr*fire*	−0.0833	−0.0090	−0.0095	0.0072	0.0642
	(0.076)	(0.093)	(0.142)	(0.111)	(0.158)
monday	0.3062***	0.3382***	0.2561*	0.3728***	0.3899**
	(0.066)	(0.093)	(0.140)	(0.081)	(0.162)
tuesday	0.2914***	0.1186	0.3495***	0.2545**	0.4428***
	(0.072)	(0.107)	(0.129)	(0.100)	(0.111)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
wednesday	0.2538***	0.2070**	0.5242***	0.2224***	0.4304***
	(0.066)	(0.095)	(0.108)	(0.084)	(0.123)
thursday	0.2616***	0.2575***	0.4557***	0.2728***	0.3074**
	(0.063)	(0.089)	(0.121)	(0.078)	(0.140)
friday	0.2881***	0.2308**	0.4304***	0.2304***	0.4623***
	(0.063)	(0.093)	(0.136)	(0.080)	(0.136)
saturday	−0.0312	−0.0991	0.1113	−0.0116	−0.0436
	(0.074)	(0.093)	(0.119)	(0.109)	(0.165)
minhum	−0.0019	−0.0033	−0.0022	0.0037	−0.0050
	(0.002)	(0.003)	(0.004)	(0.003)	(0.006)
maxhum	0.0007	0.0036	−0.0018	0.0045	0.0122***
	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
mintemp	−0.0002	0.0111	0.0231*	0.0076	−0.0089
	(0.009)	(0.014)	(0.012)	(0.011)	(0.015)
maxtemp	−0.0013	0.0041	−0.0087	0.0085	−0.0066
	(0.004)	(0.010)	(0.009)	(0.005)	(0.013)
Constant	4.0706***	1.6307	1.4899	1.1648*	1.9706
	(0.672)	(1.168)	(1.095)	(0.681)	(1.315)
Hospital admissions, respiratory-related disease except influenza, under 18 years old group (N = 84).					
t	0.0009	−0.0198*	−0.0074	−0.0036	−0.0134
	(0.005)	(0.012)	(0.016)	(0.012)	(0.015)
fire_yr	0.0473	0.3776***	−0.2819*	0.0591	−0.0939
	(0.042)	(0.133)	(0.155)	(0.127)	(0.187)
fire	0.0525	0.5344**	−0.0022	0.0083	0.2668
	(0.088)	(0.229)	(0.229)	(0.189)	(0.248)
*fire_yr*fire*	−0.0422	−0.2026	0.5258**	−0.0107	0.2614
	(0.076)	(0.157)	(0.234)	(0.178)	(0.272)
monday	0.4047***	0.1340	0.3252	0.1297	0.3830*
	(0.067)	(0.184)	(0.272)	(0.161)	(0.215)
tuesday	0.2278***	0.1034	0.1599	−0.0674	0.1835
	(0.062)	(0.157)	(0.232)	(0.151)	(0.228)
wednesday	0.0824	0.1255	0.1260	0.0587	0.0868
	(0.061)	(0.134)	(0.252)	(0.155)	(0.233)
thursday	0.1920**	0.0548	0.1217	−0.1379	0.2002
	(0.076)	(0.149)	(0.229)	(0.138)	(0.258)
friday	0.1362**	0.0909	0.3076	−0.0238	0.3672
	(0.065)	(0.148)	(0.210)	(0.138)	(0.229)
saturday	0.0906	−0.2388	−0.0734	−0.3799**	−0.1560
	(0.064)	(0.166)	(0.266)	(0.148)	(0.232)
minhum	−0.0000	0.0026	−0.0083	−0.0100*	0.0055
	(0.002)	(0.005)	(0.007)	(0.005)	(0.010)
maxhum	0.0012	−0.0024	0.0128**	0.0049	0.0008
	(0.002)	(0.003)	(0.006)	(0.005)	(0.007)
mintemp	0.0038	−0.0129	0.0310	0.0296*	−0.0127
	(0.008)	(0.020)	(0.025)	(0.016)	(0.030)
maxtemp	0.0043	0.0024	−0.0026	−0.0098	0.0076
	(0.005)	(0.016)	(0.014)	(0.012)	(0.018)
Constant	2.7140***	2.5865*	−0.9957	1.2572	1.2414
	(0.593)	(1.524)	(1.775)	(1.311)	(2.190)
Hospital admissions, respiratory-related disease except influenza, 18-64 years old group (N = 84).					
t	−0.0053**	−0.0029	−0.0081	0.0024	0.0057
	(0.002)	(0.005)	(0.006)	(0.005)	(0.007)
fire_yr	0.0219	0.0699	−0.0751	0.0151	0.0329
	(0.025)	(0.054)	(0.079)	(0.064)	(0.088)
fire	0.0730*	0.0485	0.0525	−0.0980	−0.1117
	(0.042)	(0.079)	(0.114)	(0.092)	(0.108)
*fire_yr*fire*	0.0108	−0.0673	0.1692	0.0356	0.0142
	(0.042)	(0.081)	(0.108)	(0.084)	(0.120)
monday	0.2669***	0.3893***	0.2686**	0.3404***	0.3540***
	(0.040)	(0.082)	(0.120)	(0.058)	(0.109)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
tuesday	0.3203***	0.3131***	0.2865***	0.2422***	0.3267***
	(0.038)	(0.081)	(0.083)	(0.082)	(0.122)
wednesday	0.2613***	0.1840**	0.2457***	0.2117***	0.3545***
	(0.031)	(0.082)	(0.078)	(0.074)	(0.132)
thursday	0.3424***	0.2931***	0.3096***	0.2341***	0.2806**
	(0.036)	(0.090)	(0.082)	(0.079)	(0.117)
friday	0.3076***	0.2203***	0.3192***	0.1858***	0.1882*
	(0.031)	(0.072)	(0.087)	(0.071)	(0.097)
saturday	−0.0317	0.0516	0.0109	−0.0446	−0.0729
	(0.047)	(0.089)	(0.103)	(0.075)	(0.118)
minhum	0.0009	−0.0077**	0.0038	−0.0011	−0.0001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.005)
maxhum	−0.0025*	0.0030	−0.0040	0.0001	0.0015
	(0.001)	(0.002)	(0.004)	(0.002)	(0.004)
mintemp	0.0021	0.0176	0.0008	0.0020	0.0156
	(0.004)	(0.012)	(0.009)	(0.008)	(0.016)
maxtemp	−0.0008	−0.0195**	0.0016	−0.0050	0.0033
	(0.004)	(0.009)	(0.005)	(0.004)	(0.009)
Constant	4.5484***	3.4036***	2.7953***	3.3597***	1.1779
	(0.339)	(0.957)	(0.758)	(0.493)	(1.131)
Hospital admissions, respiratory-related disease except influenza, over 64 years old group (N = 84).					
t	0.0029	−0.0027	−0.0095	0.0044	0.0083
	(0.003)	(0.005)	(0.008)	(0.004)	(0.008)
fire_yr	0.0677	0.1056*	0.0731	−0.0864*	−0.0515
	(0.041)	(0.058)	(0.079)	(0.045)	(0.093)
fire	0.0083	0.1124	0.1382	−0.0711	−0.1383
	(0.042)	(0.100)	(0.124)	(0.073)	(0.153)
*fire_yr*fire*	−0.1610***	0.0572	−0.1650	0.0885	0.2522*
	(0.058)	(0.086)	(0.111)	(0.084)	(0.138)
monday	0.3224***	0.3698***	0.2804***	0.3696***	0.2783**
	(0.053)	(0.071)	(0.100)	(0.072)	(0.122)
tuesday	0.2827***	0.1441	0.2079*	0.2671***	0.0934
	(0.046)	(0.089)	(0.109)	(0.091)	(0.144)
wednesday	0.2656***	0.1397*	0.1008	0.2444***	0.0770
	(0.051)	(0.076)	(0.103)	(0.080)	(0.121)
thursday	0.2651***	0.2637***	0.1333	0.1869**	0.1822
	(0.053)	(0.092)	(0.118)	(0.081)	(0.139)
friday	0.3227***	0.0987	0.2695**	0.1894**	0.2508*
	(0.050)	(0.071)	(0.106)	(0.080)	(0.147)
saturday	0.0881**	0.0698	0.1278	0.0948	0.0689
	(0.044)	(0.070)	(0.090)	(0.085)	(0.138)
minhum	0.0020	−0.0006	0.0058*	−0.0015	0.0017
	(0.002)	(0.004)	(0.003)	(0.002)	(0.005)
maxhum	−0.0009	−0.0023	0.0010	0.0030	−0.0021
	(0.002)	(0.002)	(0.004)	(0.002)	(0.005)
mintemp	0.0031	0.0127	0.0144	0.0063	0.0043
	(0.006)	(0.011)	(0.011)	(0.009)	(0.017)
maxtemp	0.0075*	−0.0052	0.0100	0.0002	−0.0048
	(0.004)	(0.010)	(0.008)	(0.004)	(0.012)
Constant	3.7675***	2.9359***	0.9003	2.7362***	2.6263*
	(0.518)	(0.961)	(0.872)	(0.541)	(1.443)
Hospital admissions, control disease, under 18 years old group (N = 84).					
t	0.0038	0.0129*	−0.0131	0.0010	0.0165
	(0.003)	(0.008)	(0.014)	(0.006)	(0.012)
fire_yr	0.0315	0.0104	−0.1785	0.1228*	−0.1736
	(0.032)	(0.094)	(0.190)	(0.067)	(0.134)
fire	−0.0268	−0.2310*	0.2205	0.0524	−0.2932
	(0.045)	(0.123)	(0.212)	(0.096)	(0.215)
*fire_yr*fire*	−0.0587	0.0142	0.2979	−0.0948	0.4238**
	(0.049)	(0.126)	(0.232)	(0.085)	(0.171)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
monday	0.6280***	0.8542***	0.4134**	0.6092***	0.4775**
	(0.047)	(0.101)	(0.169)	(0.089)	(0.212)
tuesday	0.5720***	0.8854***	0.5182***	0.4939***	0.2640
	(0.052)	(0.123)	(0.184)	(0.080)	(0.231)
wednesday	0.4967***	0.6385***	0.2894	0.5165***	0.4149**
	(0.056)	(0.103)	(0.203)	(0.082)	(0.206)
thursday	0.5182***	0.7082***	0.0140	0.4195***	0.2825
	(0.059)	(0.139)	(0.218)	(0.094)	(0.183)
friday	0.4926***	0.6298***	0.1206	0.5548***	0.2850
	(0.052)	(0.112)	(0.193)	(0.080)	(0.195)
saturday	0.0048	0.0315	−0.1304	0.0059	−0.1190
	(0.064)	(0.127)	(0.259)	(0.092)	(0.191)
minhum	0.0005	−0.0024	0.0045	−0.0003	−0.0029
	(0.002)	(0.004)	(0.005)	(0.002)	(0.008)
maxhum	0.0030**	0.0089**	−0.0033	0.0006	0.0032
	(0.001)	(0.004)	(0.009)	(0.002)	(0.007)
mintemp	0.0001	−0.0005	−0.0293	−0.0041	0.0118
	(0.006)	(0.017)	(0.020)	(0.008)	(0.024)
maxtemp	0.0059	−0.0119	−0.0005	0.0009	−0.0048
	(0.004)	(0.013)	(0.011)	(0.005)	(0.016)
Constant	3.0714***	2.4528*	3.0686*	2.5803***	0.9677
	(0.393)	(1.378)	(1.771)	(0.615)	(1.692)
Hospital admissions, control disease, 18-64 years old group (N = 84).					
t	0.0052	−0.0045	−0.0179	0.0075	−0.0261**
	(0.005)	(0.010)	(0.013)	(0.008)	(0.012)
fire_yr	0.0652	−0.0126	−0.1869	0.0874	−0.1260
	(0.060)	(0.092)	(0.139)	(0.065)	(0.129)
fire	−0.1236	0.0208	0.1076	−0.1542	0.4623**
	(0.084)	(0.174)	(0.278)	(0.132)	(0.217)
*fire_yr*fire*	0.0116	0.1079	0.3678*	−0.1072	−0.0179
	(0.074)	(0.144)	(0.203)	(0.120)	(0.194)
monday	0.2676***	0.4105***	0.1836	0.3812***	0.4191**
	(0.102)	(0.127)	(0.173)	(0.111)	(0.166)
tuesday	0.2346**	0.2322	−0.3170	0.2080*	0.3529*
	(0.094)	(0.155)	(0.199)	(0.120)	(0.183)
wednesday	0.2992***	0.5033***	0.1246	0.1645	0.3041*
	(0.089)	(0.113)	(0.172)	(0.126)	(0.158)
thursday	0.2136**	0.2442*	−0.0105	0.2858***	0.3078**
	(0.084)	(0.133)	(0.183)	(0.099)	(0.150)
friday	0.0075	0.1986*	−0.2073	0.1433	0.3254*
	(0.103)	(0.115)	(0.251)	(0.118)	(0.193)
saturday	0.0328	0.1226	−0.1683	0.0051	−0.0342
	(0.079)	(0.169)	(0.147)	(0.125)	(0.157)
minhum	−0.0032	−0.0032	0.0117**	0.0010	−0.0036
	(0.003)	(0.005)	(0.006)	(0.004)	(0.008)
maxhum	0.0026	0.0052	−0.0094	−0.0035	0.0015
	(0.002)	(0.003)	(0.007)	(0.004)	(0.007)
mintemp	0.0156	0.0200	−0.0258	−0.0061	0.0254
	(0.012)	(0.021)	(0.021)	(0.016)	(0.020)
maxtemp	−0.0025	−0.0105	0.0197*	0.0058	−0.0071
	(0.008)	(0.016)	(0.010)	(0.007)	(0.018)
Constant	2.5489***	1.3105	1.9917	2.1854**	0.7239
	(0.603)	(1.527)	(1.521)	(1.070)	(1.691)
Hospital admissions, control disease, over 64 years old group (N = 84).					
t	−0.0013	0.0003	−0.0103**	0.0022	0.0071
	(0.002)	(0.004)	(0.005)	(0.003)	(0.005)
fire_yr	0.0517***	0.1070***	0.0257	0.0031	0.1095*
	(0.016)	(0.036)	(0.056)	(0.031)	(0.065)
fire	0.0440	0.0434	0.1710**	−0.0212	−0.0769
	(0.033)	(0.060)	(0.078)	(0.057)	(0.077)

Appendix C (*Continued*)

Variables	Los Angeles	San Diego	Riverside	Orange	San Bernardino
*fire_yr*fire*	−0.0703***	−0.0979*	−0.1578*	0.0296	−0.0303
	(0.027)	(0.054)	(0.082)	(0.043)	(0.089)
monday	0.8395***	0.9313***	0.4881***	0.8796***	0.7155***
	(0.027)	(0.053)	(0.073)	(0.053)	(0.066)
tuesday	0.8676***	0.8068***	0.5541***	0.8597***	0.7961***
	(0.029)	(0.055)	(0.063)	(0.051)	(0.087)
wednesday	0.8203***	0.7453***	0.4350***	0.7322***	0.6354***
	(0.026)	(0.053)	(0.067)	(0.049)	(0.081)
thursday	0.7531***	0.6929***	0.4742***	0.6871***	0.5731***
	(0.027)	(0.052)	(0.069)	(0.054)	(0.079)
friday	0.7229***	0.6381***	0.4679***	0.6564***	0.5172***
	(0.026)	(0.049)	(0.070)	(0.057)	(0.091)
saturday	0.0948***	0.1099*	−0.0830	0.0261	0.0780
	(0.030)	(0.061)	(0.075)	(0.063)	(0.091)
minhum	−0.0015	−0.0003	−0.0016	−0.0001	−0.0009
	(0.001)	(0.002)	(0.002)	(0.001)	(0.003)
maxhum	−0.0009	0.0022	0.0010	−0.0018	0.0020
	(0.001)	(0.002)	(0.003)	(0.002)	(0.003)
mintemp	0.0026	0.0017	0.0046	0.0012	0.0183*
	(0.003)	(0.007)	(0.008)	(0.006)	(0.010)
maxtemp	−0.0041	−0.0020	−0.0006	−0.0016	−0.0006
	(0.002)	(0.006)	(0.004)	(0.003)	(0.007)
Constant	5.3528***	3.5717***	2.9837***	4.0186***	1.5513**
	(0.258)	(0.698)	(0.734)	(0.478)	(0.704)

* Significant at $\alpha = 0.10$ level.
** Significant at $\alpha = 0.05$ level.
*** Significant at $\alpha = 0.01$ level.

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