FIRE SUPPRESSION POLICY, WEATHER, AND WESTERN WILDLAND FIRE TRENDS

An Empirical Analysis

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Over the period 1970–2003, the United States witnessed an increase in wildfire activity, as shown in Figure 9.1. The increase in large wildfires (we define large, for reasons explained below, as those exceeding 400 hectares in extent) was particularly striking, especially in the western part of the country.

During several of these years, wildfires were catastrophic, in terms of the sheer acreage destroyed, as with the Yellowstone fires of 1988; lives lost, as in 1994, when 34 firefighters died; or extensive property damage, as with the Cerro Grande Fire in 2000, a prescribed (intentionally set) fire in New Mexico that burned out of control and destroyed part of the Los Alamos National Laboratory. After yet another catastrophic fire season in the summer of 2002—with 21 firefighter deaths, over 7 million acres burned, and 3,000 structures destroyed (Hashimoto 2006)—the president and Congress reacted in 2003 with the Healthy Forests Initiative (HFI) and Healthy Forests Restoration Act (HFR), respectively. Both of these 2003 policy responses reflected a view stated in the 2001 Interagency Fire Plan that a decades-long policy of fire suppression by the Forest Service in particular had led to major ecological changes in many forest types, with a buildup of diseased and dying trees and forest floor litter that set the stage for major forest fires during periods of drought (see Glickman and Babbitt 2000).

Fire ecologists generally agree that decades of aggressive fire suppression policy could well have set the stage for more wildfires, but only in forest regimes that under natural conditions would have been subject to relatively frequent low-intensity fires, such as the open ponderosa pine forests found in the lower elevations of the Southern Rockies (see Turner et al. 2003). They have been skeptical, however, that even decades of aggressive fire suppression could have made much difference in forest regimes that under natural conditions were subject to very infrequent, albeit severe fires, such as the high-elevation ponderosa pine and spruce fir forests found in the Northern Rockies (Stephens 2005; Turner et al. 2003). In such stand-replacing fire regimes, fire ecologists believe that it is climate, and not policy, that is the major determinant of whether large wildfires occur in a given summer.

A number of recent studies have provided empirical support for the hypothesis that summer weather—more specifically, severe regional drought—is a major determinant of fire season severity. A consistent finding, appearing in both studies of 20th-century wildfire trends and also longer-term studies, is that drought and wildfire are statistically correlated (Trout et al. 2010; Westerling and Swetnam 2003). In stand-replacing fire regimes such as characterize the Northern Rockies, recent work has found a statistically significant correlation between the number of fires and periods of drought (Schoennagel et al. 2004, 2007), and an apparently robust positive statistical association between the area burned by wildfires and dry and warm conditions in the fire season and preceding seasons (Littell et al. 2009).  

None of this empirical literature attempts to control for changes in forest management policy or in other variables, such as changes in land use, which might be expected to influence the number of large wildfires. Fire suppression policy in fact underwent a virtual sea change early in the period 1970–2003—precisely the study period of so much research on climate and wildfire trends. During this period (beginning even earlier, in the 1960s, in some national parks), fire suppression policy moved from immediate suppression of fires toward what is now
known as “wildland fire use” (and, on a more limited basis, prescribed fire). Wildland fire use means “managing lightning-caused fires as they burn naturally instead of putting them out,” whereas prescribed fire is defined as a “manager ignited fire” (Wells 2009, 2).

To be sure, a radical change in fire suppression policy was not the only important change that occurred during the period 1970–2003 that might have been expected to contribute to the increase in large wildfires over the period. As discussed in Chapter 5, beginning around 1990, the Forest Service cut back greatly on timber harvest from national forests, managing national forests in a way that private forest managers at least perceived as greatly increasing the risk of catastrophic wildfire. In addition, housing density near many western national forests and parks dramatically increased during this period, and housing density is known to correlate positively with the number of fire ignitions. Gan (2006), the only study of which we are aware that actually attempts to statistically test for multiple causality in western wildfire time series, indeed finds that wildfire trends may be more sensitive to urban population density trends than to climate or timber harvest.

Below we provide extensive qualitative detail on the series of changes in Forest Park Service wildland fire suppression policy that occurred over the period 1970–2003, and we also describe the vast expansion of settled areas near national forests and parks. We then take a closer statistical look at observable measures of potentially important policy change, the change in initial suppression policy as coded by on-the-ground Park and Forest Service personnel.

We do not attempt here to present a statistical analysis of all the factors—including inter alia development density and fire fuel loads—that might be expected to have contributed to the recent trend of an increasing number of large wildfires. Rather than attempt such a complete statistical analysis of all the variables that might be expected to have contributed to the recent multi-decadal increase in western wildfires, we instead focus our analysis on simple specifications that add measures of policy change to climate measures. The importance of our results is not in providing a full explanation for recent western wildfire trends, but rather in cautioning against drawing policy implications from the observed correlation between climate and wildfire trends. Our results indicate the value of letting the statistical analysis reveal potential causal relationships and their significance, rather than simply rejecting some potential causal variables on a priori grounds.

Additionally, our results show that in estimating the impact of climate variables on fire frequency and sizes, omitted variables bias must be taken into account. Specifically, omitted variables bias arises when the researcher fails to control for variables that affect the outcome (in this case, fire metrics) and are correlated with the explanatory variables of interest (climate metrics). Effectively, the estimated correlations represent both the true relationship and part of the effect of the omitted variable (see, e.g., Hamilton 1994; Wooldridge 2002). In the presence of such biases, it is not possible to confidently assess either the underlying direction of any relationship between fire outcomes and climate variables or the statistical significance of the estimated relationships. Even if the researcher has sufficient ancillary reasons and evidence to believe the direction of the estimated effect and its statistical significance, biased parameter estimates will make the estimates unsuitable for policy purposes. For example, though the estimated effect may suggest that a particular policy intervention is cost justified, if the true relationship were known, it could be the case that a benefit-cost analysis would lead to the opposite conclusion.

Nonclimatic Factors Influencing the Number of Large Wildland Fires

In this section, we describe qualitatively a number of changes that occurred in the western United States over the period 1970–2003, all of which could plausibly have contributed to an increase in the number of large wildland fires over this period. We focus on two such changes: in public wildland fire management policies and in land development in what is known as the wildland-urban interface, settled areas adjacent or close to wildlands. In the next section, we explain the consequences of omitting one potentially important explanatory variable—fire suppression policy change—from statistical analyses of wildland fire time trends.

Changes in Forest Service and National Park Service Wildland Fire Management Policies

In response to widespread fires after severe droughts during the 1930s, the USDA Forest Service (USFS) in 1934 adopted the “10 a.m. policy” (Pyne et al 1996). Under this policy, the USFS aimed to get wildland fires under control by 10 o’clock the morning following report of a fire, or if unsuccessful, by the next day, and so on ad infinitum. Under the 10 a.m. policy, the USFS attempted to put out all reported fires, even those in remote wilderness areas or low-value backcountry.

By the 1960s, this policy of immediate fire suppression had come under criticism. The creation of the National Wilderness System in 1964 heralded a new philosophy of natural fire use (Stephens and Ruth 2005). It was recognized that fires were part of the native ecology and that to preserve or restore ecosystems, natural, lightning-set fires had to be tolerated and “surrogate, prescribed fires” sometimes deliberately set (Pyne et al. 1996). According to some observers, the managers in the Selway-Bitterroot and Gila Wilderness Areas had begun to implement a program of prescribed natural fires as early as the late 1960s; others record the prescribed burn policies in these wilderness areas as beginning a bit later—in 1971 in the Big Sage Management Unit of the Modoc National Forest (Husari and McKelvey 1996), in 1972 in the White Cap Fire Management Area in the Selway-Bitterroot, and by 1975 in the Gila Wilderness (van Wagendonk 2007). During this early period in the movement to natural fire use, the USFS operated under a planning objective of confining 90 percent of all such prescribed natural fires to 10 acres or less (Husari and McKelvey 1996). Yet as early as 1973, the Fritz Creek Fire, a prescribed natural fire, escaped the bounds of its management
area and burned over 1,600 acres in the Whitecap Management Area of the Bitterroot National Forest (plus another 1,600 outside the remote Whitecap Creek drainage) (van Wagendonk 2007; Wells 2009). By 1978, the USFS officially replaced the 10 a.m. rule with a trio of wildland fire suppression strategies: control, old-fashioned aggressive firefighting that continued until the fire was out; confine, limiting the fire within natural or preconstructed barriers, with little or no suppression effort; or contain, an intermediate strategy of keeping the fire within a control line (Husari and McKelvey 1996). Under the new policy, the strategy mix was to be chosen to accomplish a cost-effective approach to fires that escaped initial attack. In that very same year, a prescribed natural fire in the Gila Wilderness Area in New Mexico burned 1,296 hectares (van Wagendonk 2007).

A similar transition occurred during the late 1960s and 1970s in the National Park Service (NPS). In 1968, the NPS edited the “Greenbook” and recognized fire as an ecological process (Rothman 2007). Sequoia–Kings Canyon National Park immediately changed its policy by establishing a natural fire management zone (for areas above 3,000 meters) within the park and beginning to allow experimental prescribed fires (two during the initial year). By 1971, 52 fires had been allowed to burn in Sequoia–Kings Canyon, with the largest burning 183 hectares (van Wagendonk 2007). Other national parks soon followed: in 1972, both Yellowstone and Yosemite began prescribed natural fire programs, with natural fire zones in both parks gradually enlarged by 1975 to include elevations down to 1,220 meters in Yosemite and the entire park other than developed areas in Yellowstone (Rothman 2007; van Wagendonk 2007). By 1974, all major national parks had prescribed fire programs, and lightning-caused fires could be allowed to burn within more than 3 million acres of designated natural fire zones within national parks (Kilgore 2007; Rothman 2007). That same year, the first prescribed fire in Yosemite, the Starr King Fire, burned over 1,500 hectares (van Wagendonk 2007).

By 1978, both the USFS and the NPS had officially adopted prescribed natural fire policies. The NPS was first, in 1977 implementing NPS-18, which superseded all existing fire management policies for national parks by delineating guidelines for prescribed fire uses and distinguishing between prescribed fires that were to be suppressed and those that were to be allowed to burn (Rothman 2007). In 1978, the Forest Service officially scrapped the 10 a.m. policy, along with the related 1971 management objective that had set 10 acres as the wildfire containment goal, replacing it with a new policy favoring prescribed natural fire (Husari and McKelvey 1996; Pyne et al. 1996). That same year, a prescribed natural fire, the Lagstroth Fire, burned 1,295 hectares in the Gila Wilderness in New Mexico, and the Ouzel Lake Fire in Rocky Mountain National Park was allowed to burn for over a month in a high-altitude, low-risk zone of the park before it spread and burned over 1,000 acres, threatening the mountain town of Allenspark (Perry 2008; van Wagendonk 2007).

During the 1980s, fire management planning, as it came to be called, moved to the forefront in both the national parks and national forests. In 1983, federal agencies were allowed to use “confine, contain, and control” as strategies during initial attack firefighting (Husari and McKelvey 1996). The number of national parks with prescribed natural fire policies steadily increased, reaching a total of 26 park units by 1988 (Kilgore 2007).

Just when the prescribed natural fire policy had become well established, it encountered the extremely hot and dry summer of 1988, when a series of large fires in Yellowstone burned out of control, including nine major fires that destroyed almost 1.4 million acres of parkland. Fifty fires started within the park, six were ignited outside the park, and four were human-caused (Wells 2009). Of the fires that started inside the park, 28 were allowed to burn naturally, but in what has since been generally perceived as a political decision, after July 21 all the 1988 Yellowstone fires were actively suppressed (Sanders 2000). That same summer, the Canyon Creek Fire escaped the Bob Marshall Wilderness in the Lewis and Clark National Forest, eventually burning over 100,000 hectares and threatening the town of Augusta, Montana (van Wagendonk 2007).

After the Yellowstone and Canyon Creek Fires of 1988, the Secretaries of Agriculture and Interior temporarily suspended all prescribed natural fire programs in parks and wilderness areas until new plans could be prepared. By 1990, however, Yosemite, Sequoia, and Kings Canyon National Parks reinstated their prescribed natural fire programs, with 20 such fires burning in Yosemite’s prescribed natural fire zone that year, and in 1994, the Howling Fire in Glacier National Park was allowed to burn over 906 hectares despite public outcry and calls for suppression (van Wagendonk 2007). In 1995, the Joint Federal Wildland Fire Management Policy and Program Review was released. Interestingly, prior to the mid-1990s, no Forest Service wilderness area in California had adopted a prescribed natural fire program, and even by 1996, wilderness areas with such programs were rare in the state (Stephens and Ruth 2005).

Thus the period 1970–2000 was a time of major change in federal wildland fire policy, with the beginning of this period corresponding almost perfectly to the onset of a move to allow at least some natural fires to burn. By the period 1983–2000, the general, system-wide official federal wildland fire policy had changed to allow the least aggressive policy of natural confinement even as an initial attack strategy. As described by the ecologist in charge of the Forest Service wildland fire use program in 2009, the goal of the wildland fire use policy was not simply to “let fires burn,” but instead called for “actively managing fires—protecting values at risk while achieving resource benefits in those places where fire has a positive effect” (Wells 2009, 2). Still, it is inevitable that some managed wildland fires will escape the predesignated areas in which they are supposed to be confined. As one Forest Service manager put it, “It’s chainsaw surgery. I can’t draw a line and promise the fire will stay on this side. I’m dependent on weather: wind, temperature, humidity—[it’s] not scalp surgery” (Wells 2009, 5). Many of the largest and most damaging fires that occurred in western national forests and parks during the 1970–2000 period—from the Fitz Creek Fire in Montana and the Ouzel Lake Fire in Colorado in the 1970s to several of the Yellowstone fires of 1988 and on to the Cerro Grande and Grand Canyon Fires of the last decade—were allowed
to burn or were deliberately set under the new policy of natural wildfire. Moreover, as discussed above, the change in wildland fire suppression policy implemented by the Forest and Park Services during the 1970s and 1980s was directed to higher-elevation fires—since lower-elevation fires almost invariably risk danger to settled areas if not immediately controlled. It seems at least plausible that a policy change intended to confine rather than immediately put out higher-elevation fires in remote areas of national parks and forests could have contributed to some extent to the observed increase in large higher-elevation fires occurring over the period during which such policy was implemented.

The existing literature recognizes that differences and changes in forest fire suppression policy can strongly influence the number of large fires and acres burned by fires. Stephens (2005, 218), for example, observes that over the period 1940–2000, the relative number of fire ignitions in national forests in California significantly increased, but without any significant increase in the relative area burned. Stephens infers from this that “California’s initial attack system has been effective in preventing the burned area from increasing; no other area in the USA had significant increases in ignitions without a corresponding increase in relative area burned” (2005, 218). Thus both anecdotal and more systematic evidence strongly suggests that policy changes, including the 1983 decision to allow federal agencies to adopt the least aggressive “confine” strategy as an initial control strategy, might well have contributed to an increase in the number of large fires over the study period 1970–2000.

Ignition Factors: The 1980s–1990s Expansion in the Wildland-Urban Interface

Federal firefighting policy is not the only important determinant of time trends in the frequency and severity of western U.S. forest fires on the federal lands. Another important factor identified in the literature is the tremendous growth in the so-called wildland-urban interface (WUI) that occurred in recent decades in the western United States. While there is no single standardized definition, the WUI is the area where “houses and wildlands meet or overlap” (Stewart et al. 2007, 202). From 1980 to 2000, there was a large expansion in the amount of housing located in and near forests (Radeloff et al. 2005), with a nationwide increase of 52 percent in the WUI from 1970 to 2000 (Theobold and Romme 2007). Higher housing density is known to contribute significantly to higher rates of human-caused wildfire ignitions (Cardille et al. 2001; Sapsis 1999). By one estimate, fire ignition rates increase by 0.17 fires per square mile per year with the addition of every 100 housing units (Spero 1997).

If these numbers on ignition rates and housing density are even roughly accurate, then they suggest that expansion in the WUI could explain some of the increase in large western wildland fires over the period 1970–2000. The reason, according to Theobold and Romme (2007), is that the states that had the greatest proportionate expansion in the WUI were mostly in the west, with approximately 50 percent of western WUI being found in high-severity forest fire regimes—those that are prone to large and catastrophic fires. In southern California alone, more than 6 million people live in the WUI, with over 800,000 living in the highest wildfire hazard zones (Xu and Wu 2009). California, Oregon, and Washington all experienced rapid housing growth in the WUI in the 1990s; during that decade, 10 percent of all new housing units built in these three states were located in the WUI, and the size of the WUI in these states increased by 11 percent (Hammer et al. 2007). By 2000, homes had been built on 14 percent of the forested wildland interface in the west, with some of the largest areas of WUI found in northwest Montana and northern Idaho (Gude et al. 2008). Lands within national forests (so-called inholdings) and near wilderness areas are especially prized for development: housing near 50 kilometers of wilderness areas grew at rates exceeding 400 percent over the 1990–2000 period over much of the west, and housing growth within national forests consistently exceeded the national average since 1970 (Radeloff et al. 2010).

Although the analysis of how changes in the WUI has influenced fire risk is still in its infancy, researchers in the lead of this effort have recently concluded that “current housing growth patterns are exacerbating wildland fire problems in the WUI” (Hammer et al. 2007, 263). There are, it seems, strong regional differences in how WUI expansion has impacted forest fires: there is a very strong positive correlation between population density and fire frequency in southern California, but no relationship between housing count and fire in, for example, northern Florida (Syphard et al. 2007). Still, any time-series analysis of trends in western wildfires that fails to attempt to control in some way for the rapid expansion in the WUI over the past several decades will be missing one of the pieces of the wildland fire trend puzzle: a monotonic increase in ignition sources over this period.

Climate, Policy Change, and Western Wildfire Trends: The Omitted Variables Bias Problem

As lucidly explained in Chapter 10 of this book, a number of problems confront a researcher attempting to statistically identify the various factors that may be causally related to recent wildfire trends. First, as a matter of model specification, it is not enough to consider only changes in policy; for one has to properly account for how various policies affect the incentives of private landowners to manage their lands in a way that reduces fire risk and then take steps to suppress fires that do occur (see Chapter 3). Second, when one takes account of both private and public incentives, causal relationships may be much more complex than they would appear at first. Consider, for example, the relationship between federal fire suppression expenditures and the number of large wildfires. Over recent decades, as the number of large wildfires has been increasing, so too have been the fire suppression expenditures of the USDA Forest Service, the major federal fire agency (see Chapter 4). As an a priori matter, it may seem obvious that an increase in total
acres burned by wildfires has caused an increase in federal fire suppression expenditures. But upon closer and more nuanced analysis, one sees that the causal relationship could run in the other direction—that an increase in the amount spent on fire suppression could have contributed to the increase in large wildfires. This is because as a matter of economic incentives, federal fire suppression acts to subsidize development of private lands in fire-prone areas. Kousky and Omland (2010) show that the move back to active fire suppression in the aftermath of the 1988 Yellowstone fires had a statistically significant impact in stimulating development of nearby private lands. Inasmuch as development of the wildland-urban interface is known to positively relate to the ignition rate, the possibility that active fire suppression could actually contribute to the increase in large wildfires is perhaps not so implausible as a priori reasoning might suggest.

The lesson from this recent work is that climate, policy, and land development incentives interact in complex ways to explain recent wildfire trends. A large fraction and the most highly publicized of the recent work by fire ecologists and climate researchers, however, singles out climate change as the potential cause of recent increases in the number of large wildfires. For example, Westerling et al. (2006) find that temperature and a melt variable (i.e., an indicator for whether the spring snowmelt occurred early or in a given year) are statistically significant positive predictors of fire frequency and the duration of the fire season, with the relationship between climate and large-fire frequency found to be particularly pronounced in mid-elevation (2,130 meters) in the Northern Rocky Mountain Region. Without attempting to statistically control for either land use or policy changes during their study period, Westerling and colleagues assert that “increased wildfire activity over recent decades reflects sub-regional responses to changes in climate” and argue that the warmer springs and summers predicted for western forests by some climate models “will accentuate conditions favorable to the occurrence of large wildfires, amplifying the vulnerability the region has experienced since the mid-1980’s” (2006, 942, 943).

Such an approach exhibits a fundamental problem with respect to statistical identification. By relying merely on time series variation, the researchers have no contemporaneous counterfactual. That is, in such analysis, all regions are exposed to the same temperature and melt measures. Implicitly, this kind of analysis relies on the hope that what happened in previous years is a good guide to what will happen in future years. However, such an assumption is often incorrect, given that many factors other than temperature influence forest fires and change over time. A failure to control for such factors will lead to a statistical bias if those factors are correlated with the temperature trend. This omitted variables bias can affect the magnitude and even the sign of an estimated relationship. Worse yet, the extent and the sign of the bias are generally not discernible, since they depend on the conditional correlation between the omitted variables and the temperature variable, as well as the conditional correlation between the omitted variables and the outcome (i.e., fire) variable.

An Illustration

For purposes of illustration, one plausible omitted variable bias story suggests that there could be either upward or downward bias in the relationship between fire outcomes and climate metrics. Assume that the volume of visitors to U.S. forests is positively related to temperature, since people like to hike when it is warm. Further, assume that hikers have a tendency to start fires. (For our purposes, it does not matter whether this tendency is the result of carelessness or intentional acts.) In this case, failure to account for the changing visitation patterns would lead to an upward bias in the relationship between temperature and fires. It is simple to come up with an example with an opposite bias by simply changing the assumption that hikers are encouraged by warmer weather to one where hikers prefer cooler weather. In that case, the relationship between temperature and fires would be biased downward. The omitted variable bias could be even more complicated. Perhaps hikers do not like weather that is too hot or too cold, in which case the effect of the bias is nonlinear, with the resulting bias being positive or negative depending on the domain of the temperature data in the sample. In some cases, the bias could average to zero by complete chance.

Even more complicated bias stories can be imagined. For example, perhaps lagged temperatures and expected future temperatures affect the price of timber. Current and expected prices of timber will affect cut practices, which will affect the potential fuel load available for fires, leading to fewer big fires when a larger area has been timbered. Because past, present, and future temperatures are correlated, these influences lead collectively to a bias.

Unfortunately, pure time series data do not generally provide much confidence in causal inferences. Even if a researcher were to include data on use by hikers in the analysis, dozens of other sources of bias may be lurking in the background. Further, as suggested by the timber price example, some of the relevant omitted variables may be inherently difficult to quantify, such as people’s expectations about future temperatures and the effect of those expectations on timber prices. Other omitted variables, such as a metric capturing fuel load, are very likely to be measured with error, leading to attenuation bias with respect to the relationship between fires and fuel load, which will then generate bias in the other estimated relationships as well.

The Impact of Considering Variables Omitted from the Fire-Climate Model

In our view, it is likely that the factors considered earlier—a virtual revolution in federal fire management policy that allowed many natural fires to burn while being monitored and a dramatic increase in housing density near national forests and parks—contributed to the increase in large wildfires that occurred in the western national parks and forests over the period 1970–2000. We view it as also almost obviously true that summertime weather contributed, in that the western summers
with a large number of big wildland fires in areas such as the Northern Rockies (stand-replacing fire regimes) were also anomalously hot and drought-prone. The point of statistical analysis is to try to get some more precise sense of the relative importance of the potential contributing factors. In this section, we provide some initial evidence that because of omitted variables bias, the importance of climate may be overstated in analyses such as that done by Westerling et al. (2006).

**The Basic Relationship between Large-Fire Frequency and Summertime Weather**

In order to draw comparisons with previous results in the literature, we focus on data from what Westerling et al. (2006) call the “Northern Rockies” region, which is where they find the greatest weather-related increase in large wildfires. Again to provide some point of comparison with previous results in the literature, we define "large" wildfires as those exceeding 400 hectares in scope.

As do Westerling and colleagues, we find that the basic relationship between the number of large fires and mean summertime temperature is well specified using a second-degree polynomial of the temperature variable. This is confirmed in Figure 9.2, which uses the lowest regression technique (a variant of locally weighted regression) to allow for a nonlinear relationship between temperature and the fire frequency variable. For simplicity of comparisons, we will instead use the natural log of the number of fires as our outcome variable, since, as is also shown in Figure 9.2, the relationship between this transformed measure and temperature is linear, except for the single outlier for which the mean temperature is 55 degrees Fahrenheit.

![Figure 9.2](image)

**FIGURE 9.2** The relationship between fire frequency and mean temperature

Note: Fitted values generated by locally weighted regression technique.

**TABLE 9.1** Relationship between ln(number of fires) and temperature

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<thead>
<tr>
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<th>(i)</th>
<th>(ii)</th>
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<tbody>
<tr>
<td>Temperature</td>
<td>1.05***</td>
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<td></td>
<td>(0.17)</td>
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<td>Early melt</td>
<td>—</td>
<td>1.15**</td>
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Notes

Heteroskedasticity robust standard errors are in parentheses. Each regression includes an unreported constant term.

*** p < 0.01 (against a two-sided test of a zero effect)
** p < 0.05 (against a two-sided test of a zero effect)
* p < 0.10 (against a two-sided test of a zero effect)

For purposes of a baseline comparison, we present the results of an ordinary least squares regression of ln(number of fires) and temperature in column (i) of Table 9.1. Column (ii) presents the relationship using the early melt indicator.

These results indicate a strong positive relationship between the summertime weather metric and fire frequency. However, as suggested before, it is difficult to rule out the possibility that part or all of this relationship is the result of an omitted variables bias.

**Fire Suppression Policy Change**

Although, as mentioned above, a number of factors might have been expected to contribute to the increase in large western wildfires over the 1970-2000 period, one specific factor that seems a priori likely to have caused a causal impact is changing federal policy toward fire suppression. As discussed above, federal fire suppression policy started to undergo some major changes at the very outset of the 1970-2000 study period, and by the mid to late 1970s, more and more natural wildland fires were being allowed to burn in western national parks and forests. By 1983, federal agencies were officially allowed to use the least aggressive "confine" strategy—under which natural fires were allowed to burn within predetermined boundaries—even as an initial attack firefighting strategy.

The data we rely upon for measures of fire suppression policy change clearly depict these changes in policy. Our data come from the Forest Service’s Kansas City Fire Access Software (KCFAS) database (formerly National Interagency Fire Management Integrated Database, or NIFMD) (see USFS 2011). This database contains extensive data on fires for each national forest and every national park with a fire management plan. For national parks, over the period 1972-2009, this dataset allows us to identify fires that were coded as “wildland fires ignited by
lightning ... or other natural ignition sources and managed as wildland fire use for resource benefit. As the literature suggests that the wildland fire use policy has been implemented more cautiously in California national parks and wilderness areas, we compared changes over time in the fraction of fires managed for wildland fire use in major California national parks with those in the Northern Rockies region: Yellowstone, Grand Teton, and Glacier. As can be seen in Figure 9.3, the fraction of fires managed for wildland fire use dramatically increased during the 1970s and 1980s in the Northern Rockies and then rapidly declined, whereas in California national parks, although there was an increase during the 1970s, wildland fire use remained an uncommon approach and eventually began a slow but continuing decline.

In the national forests, for the period 1983–1999, our dataset gives us a coding for the initial suppression strategy of confine, contain, or control, and during this period, official policy allowed forest managers to choose among these as an initial suppression strategy. This possibility appears to be borne out in Figure 9.3, which shows the fraction of time that the least aggressive wildland fire use strategy of “confine” was used in the Northern Rockies region. As we can see from Figure 9.4, the use of the confine strategy increased substantially as of the mid-1980s in national forests in the Northern Rockies region.

**Impacts of Fire Suppression Policy Change on the Number of Large Fires and Estimated Weather Effects**

When we look solely at the time series of the number of large fires in the Northern Rockies, depicted by Figure 9.5, it does seem that the number of large fires began to increase most rapidly in the late 1970s, just as Forest and Park Service policy had strongly moved toward wildland fire use. Panel (b) in Figure 9.5 shows that this change in the rate of increase holds even when we partial out the summertime temperature effect. This suggests that the mid to late 1970s—the period when more and more national forests and parks were moving to a policy of allowing prescribed
natural fires—does mark a turning point in large-fire frequency. Even more
significantly, it suggests that an important influence has not been accounted for in
the statistical analysis of the relationship between fires and summertime weather.

To examine more closely the influence of fire suppression strategy on fires and
the extent to which controlling for differential strategies affects the estimated
relationship between temperature and fires, we looked at KCFAS data for the
Northern Rockies national forests for the period 1983–1999. As noted above, during
this period, national forest fire supervisors generated an informative report of initial
suppression strategy (confine, contain, or control), and official policy allowed them
to choose among these as an initial suppression strategy. We then collapsed the
individual fire data into year X national forest region unit (national forest) cells, notating
how many fires occurred in each cell, as well as the total number of acres
involved. We also created a metric for the share of fires for which the service used
aggressive suppression tactics.

We do not make claims of causality in the analysis that follows. It is almost
surely the case that the estimated strategy effect suffers from a reverse causality
problem (a form of omitted variables bias itself) in that the service is likely to use
more intensive measures for larger fires. We merely present the analysis to illustrate
how volatile estimated effects are when no strong statistical identification strategy
is available.

For baseline comparison purposes, Table 9.2 examines the relationship between
the climate metrics and the natural log of the number of acres involved in fire
during the season. We use Huber-White standard errors to account for hetero-
skedasticity in the error term.

Using this dataset, we again find the basic result in the literature (as in Westerling
et al. 2006) that the total acreage destroyed by fires is positively associated with
the climate metrics, with both higher temperatures and an early snowmelt leading
to more fires. The results are statistically significant.

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<tr>
<th>TABLE 9.2 Relationship between ln(acres involved) and temperature</th>
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<td>(i)</td>
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<tr>
<td>Temperature</td>
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<td>Early melt</td>
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</tbody>
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Notes:
Each regression includes a separate unreported constant term and linear trend
for each forest unit. Heteroskedasticity robust standard errors are in parentheses.
*** p < 0.01 (against a two-sided test of a zero effect)
**  p < 0.05 (against a two-sided test of a zero effect)
*   p < 0.10 (against a two-sided test of a zero effect)

If we allow the forest units to have differential baseline fire rates through the
use of a so-called fixed effects model, as well as a unit specific trend, things change
little, as seen in Table 9.3.

However, when we add the suppression strategy metric—the percentage of fires
fought most aggressively (the “control” strategy)—we observe more of a change,
as seen in Table 9.4.

Although the statistically significant positive result for summertime weather
variables still shows up, the point estimate has moved substantially. If we compare
the weather coefficients between Tables 9.3 and 9.4, we can reject the hypothesis
that the two column (i) temperature coefficients are equal at better than the 1 percent

<table>
<thead>
<tr>
<th>TABLE 9.3 Relationship between ln(acres involved) and temperature, including fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Early melt</td>
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</tbody>
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Notes:
Each regression includes a separate unreported constant term and linear trend
for each forest unit. Heteroskedasticity robust standard errors are in parentheses.
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<table>
<thead>
<tr>
<th>TABLE 9.4 Relationship between ln(acres involved) and temperature, conditional on fire suppression strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
</tr>
<tr>
<td>Temperature</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Early melt</td>
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<tr>
<td>Percent of fires</td>
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<tr>
<td>fought aggressively</td>
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</tbody>
</table>

Notes:
Each regression includes a separate unreported constant term and linear trend
for each forest unit. Heteroskedasticity robust standard errors are in parentheses.
*** p < 0.01 (against a two-sided test of a zero effect)
**  p < 0.05 (against a two-sided test of a zero effect)
*   p < 0.10 (against a two-sided test of a zero effect)
level (F > 30) and the hypothesis that the two column (ii) early melt coefficients are equal at a comparable Type 1 error level (F > 37).

We provide these examples for illustrative purposes only. The unfortunate reality of models lacking statistical identification is that it is not possible to tell which of various models generates estimates that lie closer to the truth. Including an additional variable that was formerly incorrectly omitted might move the estimate closer to the correct parameter, but if other variables were incorrectly omitted, it can just as easily move the estimate away from the true parameter. Lacking a strong identification strategy, the best we are left with is a search for model robustness. That is, in a well-identified model, inclusion of additional covariates should not move parameter estimates significantly. However, as is the case here, in poorly identified models, inclusion of additional control variables will generally lead to significant variation in estimates. Again, we have no confidence in the coefficients we estimate for the fire suppression effect, since the design does not rely on plausibly exogenous measures of this strategy. We do have confidence, on the other hand, that if the estimated climate effects are correct, they are so only by chance.

Conclusions

As suggested before, our results are not provided to suggest that the existing estimates in the literature regarding the association between temperature and wildfires are necessarily “wrong.” In fact, our results suggest that even if conventionally estimated effects are too big, there does seem to be an association between temperature and fire frequency. However, we flag the identification problem and show how the addition of a plausibly important covariate substantially changes the parameter estimates. This suggests it is problematic to draw policy conclusions from findings generated by models where the only statistical identification comes from time series variation.

The upshot of our exercise, in addition to suggesting that policy and other land use variables are potentially important in analyzing the relationship between large fires in the Northern Rockies and mean annual temperatures, is to demonstrate the fragility of parameter estimates arising from statistical models that lack a strong identification strategy. In principle, a strong identification strategy could yield results that are then stronger support for the climate-driven wildfire hypothesis just as easily as it could undermine claims in the literature.

From the point of view of policy design, it is crucially important to get reliable estimates of the true causal impact of the various variables that contribute to wildfire trends. As described clearly in Chapters 4 and 10, the human and monetary cost of large western wildfires is large and increasing. But policy responses to the wildfire problem themselves are costly. If one thinks that climate alone is responsible—an interpretation contradicted by statistical analysis found in recent noneconomic work—then one will underestimate the contribution of climate. Such an overestimation of the role of climate in causing recent wildfire trends not only will lead to a systematic bias in climate policy design, with the potential benefits of, for example, greenhouse gas emission reductions overestimated, but also likely will affect wildland fire policy. If one believes incorrectly that climate alone is responsible, then one can easily miss changes in federal land use and fire suppression policies that could be much more cost-effective in altering the amount of land lost to and damage done by wildland fires. Fire ecologists severely criticized the Healthy Forests Restoration Act as ignoring scientific work on the natural role of fire in different types of forest ecosystems. Such a commitment to science-based wildland fire policy requires that increased effort be devoted to work analyzing the role of economic incentives in influencing wildland fire trends, and to statistical analysis of the complex causes of wildland fire trends that properly controls for the omitted variables and identification bias problem that we have identified here.

Acknowledgments

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Notes

1. Differently, in dry southwestern forests, Littell et al. (2009) find that one- and two-year lagged rainfall associates positively with fire frequency.
2. The “Greenbook” is the budget justification that accompanies every annual budget request by the Park Service and contains wildland fire suppression budget requests.
3. Note that attenuation bias occurs even if the error is random, as distinct from the case of measurement error in the outcome variable. If the outcome variable is measured with random error, the resulting model will be less precisely estimated but will not suffer from a systematic bias. Measurement error in a predictor, on the other hand, leads to bias even in the case of a completely random error.
4. As can be gleaned from Figure S2 in the supporting online material for Westerling et al. (2006), what they call the “Northern Rockies” region consists of Glacier, Yellowstone, and Grand Teton National Parks; Forest Service Region 1 (the USFS’s Northern Region); plus the Malheur, Ochoco, Umatilla, Wallowa Whitman, and Colville Forests from USFS Region 6 (the USFS’s Pacific Northwest region).
5. The lowest method is similar to the standard ordinary least squares regression technique while allowing for nonlinearity in the model. This is accomplished by fitting a low-order polynomial model to the data weighting local observations more heavily than more distant observations at each observation in the data.
6. This is the definition of fires coded as “49” in the KCFast database. For this definition, see www.nifc.blm.gov/fire_reporting/annual_dataset_archive/index.html.
7. After 1999, the definitions for initial suppression strategy changed, with old coding numbers reused for different definitions, leading to numerous inconsistencies in reporting and, finally, completely uninformative reporting.
8. Models were estimated allowing for joint estimation of the variance-covariance matrix given the non-independence of the models using a seemingly unrelated regression technique.
9. Whitlock (2004, 28), for example, called the HFRA a “travesty that limits scientific analysis and public participation in decision-making and policy.”
References


