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Local Capacity to Engage in Federal Wildfire Suppression Efforts: An Explanation of Variability in Local Capture of Suppression Contracts

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The US National Cohesive Wildland Fire Management Strategy emphasizes the importance of resilient forests and local community capacity in preparation for and response to wildfires. Despite this emphasis, it is unclear whether local business capacity is a predictor of local participation in federally managed wildfire response. Drawing on concepts from economic geography, we hypothesize that the local capture of federal contracting during large wildfire suppression events will be greater in counties that have more firms experienced with federal natural resource management contracting. To test this hypothesis, we investigated the contracting patterns of 135 large wildfire suppression efforts and found that local capture of suppression contracting was higher for fires that occurred in counties where there were more vendors involved in federal, non-fire-related contracting. Counties with more diversified economies were also more likely to capture suppression contracting opportunities than counties with more specialized economies. Our findings suggest that the resilient forests and fire-adapted community goals envisioned by the National Cohesive Wildland Fire Management Strategy can be supported by the development of natural resource management capacity that is nationally decentralized and locally diversified.

Keywords: economic geography, federal procurement, business capacity, contracting, natural resource management

Wildfire has increased in frequency and extent in the western United States, and climate-fire modeling evidence suggests this trend will likely increase (Lenihan et al. 2008, Yue et al. 2013, Abatzoglou and Williams 2016). Since the adoption of the National Fire Plan in 2000, federal wildfire policy in the United States has focused on restoring fire-adapted ecosystems, increasing community preparation, reducing hazardous fuels, and reducing fire suppression costs (Vaughn and Cortner 2007). Although there has been considerable research on fire-adapted ecosystems (e.g., Schoennagel et al. 2004), community preparation (e.g., Abrams et al. 2015a), and hazardous fuels reduction (e.g., Ager et al. 2016), the literature on wildfire suppression costs and contracting patterns is much more limited (e.g., Gebert and Black 2012, Thompson et al. 2013, Ellison et al. 2015), particularly given the marked transformation that has occurred in wildfire response (Steelman 2016). In the more than 15 years since the roll-out of the National Fire Plan, federal wildfire fighting has become increasingly professionalized, with expansion of interagency coordination (Fischer and Jasny 2017, Lyon et al. 2017), increase in the number of dedicated fire personnel within the Forest Service (US Forest Service 2015), more planning and predictive modeling of suppression needs and costs (GAO 2002, 2007), and more detailed and higher standards imposed for contractors engaged in wildfire activities (e.g., pre-inspection of contracted wildfire equipment prior to issuing agreement; NAPA 2003a).

Numerous government reviews have considered agency efforts to control costs and more effectively protect risks to people and structures in the wildland urban interface (e.g., GAO 2007). These reports have simultaneously called for centralizing the administration and dispatch of wildfire contracting processes (NAPA 2003a)

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as well as increasing use of local wildfire resources (NAPA 2003b). More recently, the National Cohesive Wildland Fire Management Strategy (hereafter "Cohesive Strategy") has emphasized community participation in all phases of wildfire fire management, from pre-fire hazardous fuels reduction and education to post-fire recovery (CS-CW 2011). Supporting the Cohesive Strategy's emphasis on local participation, recent research has indicated that local participation in wildfire management can help mitigate the local economic impacts of wildfires. In Nielsen-Pincus et al.'s (2013) study of wildfire effects on employment and wage dynamics, the authors reported that "*where* state and federal agencies spend wildfire suppression funds was the most important factor influencing changes in employment during a wildfire" (p. 410; emphasis added). Such findings raise important questions about how local capacity in fire management can be effectively built and sustained over time, including whether ongoing natural resource management (NRM) capacity, needed to maintain resilient forests and landscapes, influences communities' participation in wildfire response and recovery.

Local capacity can manifest in many forms, from local government agencies and fire departments at the city or county level, to informal neighborhood groups, nongovernmental community organizations, and private sector businesses. Historically, local capacity to respond to wildfire included private sector businesses that were already engaged locally in forest or NRM activities, such as hazardous fuels reduction or timber management (Huber-Stearns et al. 2016a, b). Economic geography posits that diverse businesses often cluster together in locations that provide a competitive advantage due to the availability of resources and the presence of related and supporting industries, among other factors (Porter 2003, Aguilar 2009). For NRM businesses such as forest products manufacturing, close proximity to the resource base is a competitive advantage and an important influence on firm location (Aguilar 2009). Furthermore, diverse clusters of supporting industries are associated with measures of better regional economic performance (Porter 2003), suggesting that the breadth of firms engaged in a variety of NRM activities may be an important indicator of local performance in wildfire management.

However, given the recent professionalization and centralization of wildfire response, the relationship between local NRM business capacity and contracting during wildfires remains unclear. Changes in wildfire suppression policy or practice may have decoupled federal wildfire contracting from local NRM private sector firms, thereby undermining the capacity building goals of the Cohesive Strategy. As observed by Davis et al. (2014), "poor economic conditions prior to the fire create an environment wherein multiple vulnerabilities are interwoven" (p. 992), suggesting the difficulty of capacity building in some communities experiencing wildfires. In this paper, we examine the contracting patterns of large wildfire suppression events and ask whether the extent of local contracting on federally managed wildfires is influenced by local private sector business capacity. Although imperfect, we use county boundaries to define local. Answers to this question may have implications for local communities in terms of what approaches to choose to implement the Cohesive Strategy, as robust local NRM sectors may be an indicator of both fire-adapted communities and the capacity to maintain resilient forests and landscapes.

Background

Trends in Wildfire Management

When wildfire occurs on federal lands in the United States, federal agencies such as the Forest Service and Bureau of Land Management (BLM) are part of a national interagency fire system that coordinates public and private sector resources across geographic scales, and increasingly calls on non-federal resources for fire suppression support (Booz Allen Hamilton 2012, Lyon et al. 2017, NIFC 2015). Historically, local contractors (e.g., timber operators, tree planters, and other forestry businesses from the local area) comprised a substantial share of wildfire response capacity. These contractors were engaged through emergency contracting mechanisms, yet these mechanisms have declined in favor of more structured preseason agreements (Prestemon et al. 2008; see also VIPR 2016). This change was precipitated by a 2005 USDA–Office of the Inspector General audit that required the Forest Service to create and use more rigorous systems for preseason agreements (USDA 2005). At the time of the audit, many fires were handled by local resources, suppressed in 7–10 days, and did not involve complex or extended firefighting resources (NAPA 2004).

More recently, fires have become more ecologically and socially complex due to increased populations within or adjacent to forests, accumulation of forest fuels, diminished capacity of local units within federal agencies to provide fire suppression, and an overall shrinking federal workforce (GAO 1999, NAPA 2004, North et al. 2015). These trends have continued as the size, severity, and frequency of fires, as well as the associated ecological, social, and environmental costs have increased (Bowman et al. 2009, Barbero et al. 2015). Faced with longer-lasting, larger, multijurisdictional, and complex wildfires, federal agencies began reassessing how to prepare for and respond to wildfire. In 1999, a GAO report recommended that both the Forest Service and BLM increase their firefighting capacity, including increasing federal resources and using more private contract resources (GAO 1999).

Despite the call for increased firefighting capacity, transitions in wildfire management beginning in the 1990s corresponded with the decline in the number of national forest employees and contractors

Management and Policy Implications

Sustaining local capacity to contribute to natural resource management continues to be an important tactic for accomplishing the fire-adapted community goal envisioned by the National Cohesive Wildland Fire Management Strategy. As part of the Cohesive Strategy, fire managers are encouraged to include communities in all stages of fire management, from preparedness and fuel reduction, to fire suppression and post-fire recovery. Community inclusion in all stages of fire management depends in part on having a trained workforce and existing business capacity to contract with the federal government. As intensifying fire trends are likely to continue to increase, there is an amplified need to understand how local communities and their available workforces can prepare for, respond to, and recover from wildfires. As we demonstrate, wildfire suppression contracting can be an important indicator of local capacity to engage in all stages of fire management. Our study provides evidence of linkages between a community being engaged in natural resource management and local participation in fire suppression efforts. However, as the economic geography of wildland fire suppression contracting changes due to the use of more centralized contracts, local community ability to engage during incident response may be impacted. Policymakers, managers, and researchers should continue to examine the ways in which wildfire contracting policy and related dispatch practices are making local communities more or less resilient to wildfire.

working on national forest lands as well as general professionalization of wildfire and other natural hazard response (Donovan 2005, Lueck and Yoder 2015, NIFC 2015). Given these changes, it is no longer clear how much wildfire response capacity resides in communities near national forests (particularly in local businesses) and how wildfire response capacity is related to current NRM capacity. Conventional wisdom has it that the overlap in training, equipment, crew needs, and locations of work drives NRM businesses to conduct both forest management and fire suppression. At the scale of the firm, many well-established and large wildfire suppression businesses in the United States conduct hazardous fuels reduction and other forest management activities. However, it is unclear whether this conventional wisdom scales up to the cluster of local industries whose array of services may be needed during large wildfire suppression events.

Wildfire Suppression Contracting

Federal wildfire response capacity in the United States can be seen as having three major components: (1) federal personnel, travel, and equipment; (2) agreements with state and local wildfire suppression resources; and (3) private sector wildfire suppression contracts (Prestemon et al. 2008). As the costs and complexity of firefighting have increased over time, the use of private suppression contractors has also increased (Donovan 2006); especially for direct attack resources such as aerial resources (e.g., helicopters), firefighter hand crews, and other equipment (e.g., bulldozers, chippers, fellers). In addition to direct attack resources, support services such as fire camp mobilization and operation (e.g., food and showers) are also purchased from the private sector. Prior to the 2000s many businesses were sent out on fires under Emergency Equipment Rental Agreements (known as EERAs), which could be planned in advance or entered into on the spot locally during a fire. However, today most contractors are dispatched to fires after having signed up through a Forest Service–maintained federal system prior to the fire season. Although EERAs are still permitted, they are used much less frequently (Prestemon et al. 2008), and primarily for unusual needs or when a dispatch center cannot fill an order (Lyon et al. 2017).

To participate in fire suppression, firms in the private sector must respond to contract solicitations and meet minimum equipment specifications and quality standards, training qualifications, and, in some cases (e.g., hand crews), acceptable past-performance records (NIFC 2015, USDA FSAM 2016). Agencies dispatch private sector resources as needed, and may utilize local, regional, or national resources, depending on the timing, location, and severity of the fire (NIFC 2015). In 2015, the Forest Service's Virtual Incident Procurement (VIPR) preseason fire suppression contracting system for private businesses contained over 10,000 identified resources. The Forest Service also held contracts with nine private contractors that maintain a workforce of 21 national hand crews (Huber-Stearns et al. 2015). Standard operating procedure generally dictates that when fires are relatively small, fire managers should call upon nearby government cooperators first (first federal, then state and local; NIFC 2015; see also Huber-Stearns et al. 2015). As a fire escalates in complexity and outstrips local resources, the response team may call upon contracted resources or resources that are farther afield (NIFC 2015, GAO 1999).

Dispatching resources is a complex process. Decisions about the resources used on any given fire involve a variety of criteria, including the availability of local resources, preferences of the Incident Management Team, and needs specific to the fire (Huber-Stearns et al. 2015; see also NIFC 2015). However, these criteria may be unclear to local businesses that have entered into preseason contracts. For example, Davis et al. (2014) reported that perceptions about the award of suppression-related contracts to local businesses varied widely after dozens of fires hit North California in the summer of 2008, leaving many in the local community to believe that incident management teams had overlooked available local resources. Even though suppression expenditures showed that contract expenditures were concentrated locally, actual local contracting varied by both economic sector and the incident management team involved at different points during the fire (Davis et al. 2014). Local contracting success may also be influenced by differences in dispatch and incident management systems, including criteria determining when resources are considered available and whether preseason contracts are required.

Forest Management Contracting

As with fire suppression services, federal forest management agencies contract for a variety of NRM services. NRM services support various forest management objectives, including wildfire risk mitigation, forest and watershed restoration, and industrial-scale timber management (Moseley et al. 2014). Firms that provide these services have also evolved over the past several decades, responding to the changing needs and practices of federal forest managers.

Similar to fire suppression, as the federal workforce has declined, federal land management agency budgets have allocated an increasing proportion to contract services for work that was previously conducted in-house (Moseley 2006). The federal procurement process for forest management contracts requires compliance with increasingly complicated federal procurement registration, bidding, and award processes (see 48 CFR, Federal Acquisition Regulations System). Contracts are typically offered based on the contractor providing the best value to the government, meaning that often the contractor offering the lowest price is awarded the contract (Moseley and McDaniel 2006). As with fire suppression contracting, there has been relatively little scholarly research on this sector. Existing research suggests that NRM service contractors operate in regional markets, with some contractors working close to home while others travel relatively long distances, often across state lines, to access work (Nielsen-Pincus and Moseley 2013). Contractors are more likely to travel long distances if that work is labor intensive (e.g., tree planting, hand thinning), while contractors that work on equipment-intensive activities (e.g., road construction and mechanical silvicultural treatments) tend to work closer to home (Moseley and Shankle 2001, Moseley and Toth 2004, Moseley and Reyes 2008), likely due to the expense of equipment mobilization. Work varies seasonally in both fire suppression and forest management service contracting, offering at least the opportunity for contractors to participate in both NRM and wildfire suppression activities.

This paper seeks to understand the extent to which the contracting patterns in large wildfire suppression events are influenced by local business capacity to participate in federal NRM. We focus specifically on county-level private sector capacity and hypothesize that more contract expenditures will be awarded locally on fires that occur in counties where more local businesses are performing federal NRM activities prior to a fire. In addition, we ask whether

contracting patterns vary during large wildfire events by location factors such as local economic specialization and geographic context (e.g., geographic region, isolation from metropolitan areas, and the local proportion of federal lands). To focus on these effects, we control for characteristics of large wildfire suppression events, including total suppression costs and the proportion of costs expended on contract resources. In light of the federal policy goals embodied in the Cohesive Strategy and the relationships between fire suppression and NRM contracting on federal lands, we discuss policy, economic, and community implications for local business and workforce development and future fire preparedness and response.

Methods

Data, Sampling, and Measures

Large Wildfire Suppression Contracting

We defined large wildfire suppression events as those where the Forest Service was the lead protection agency and suppression costs for the Forest Service exceeded $1 million. In contrast to an area criterion, the suppression cost definition of large wildfires focuses our research on those wildfires where suppression is more likely to engage contracted resources. The National Interagency Fire Management Integrated Database (NFMID) reported 346 such large wildfires between federal fiscal years 2004 and 2008 in the ten western states of the United States. To minimize Forest Service administrative time to requisition our data, we examined a sample of these large wildfires. We selected a stratified random sample of 135 large wildfires to analyze suppression expenditures for local capture (Figure 1). Our stratification involved three categories: metropolitan and non-metropolitan counties, Forest Service administrative regions (covering the northern Rockies; southern Rockies; California; and the Pacific Northwest), and the cost of the fire using two levels: between than $1 and $5 million, and more than $5 million (the median suppression cost in our large wildfire pool). The stratification improved the spatial distribution of the sample across the western United States as well as in urban and rural counties (a disproportionate number of large wildfires during our study period occurred in metropolitan counties in California), while also providing a broader range of suppression costs than was likely to occur under a simple random sample.

Forest Service suppression expense transaction records for each wildfire in the sample were obtained from the Foundation Financial Information System (FFIS). Each transaction record was coded with a unique job code for the fire to which the expense was attributed. Contracted expenses were attributed with the name of the vendor, the vendor's registered business location zip code, and a four-digit Budget Object Code (BOC) that identified the type of expense. There were over 1.3 million transactions recorded for the 135 fires.

Local Capture of Suppression Expenses

Based on FFIS data, we calculated local capture of service contracts related to fire suppression. We defined "local capture" for each fire as the ratio between the net value of private contracting (transactions classified as BOC 2540 [Contractual Services–Other], which included most wildfire suppression contracts) that was awarded to local vendors and the net value of all private contracting associated with each fire. We defined vendors as local if their registered business address was located in the same county as the fire. We attributed each wildfire to the county in which the fire's ignition point was located.

Local Contracting Capacity

To estimate local capacity to perform contracted NRM work, we chose a single measure—the number of vendors in each county receiving contracts for NRM work. We constructed the local capacity measure from contracting records obtained from the Federal Procurement Data System (FPDS), which includes most records associated with federal contract obligations. FPDS categorizes contracts by a product-service code (PSC) that identifies the type of work associated with the contract. We included contract actions specific to NRM on public lands (Moseley and Toth 2004, Moseley

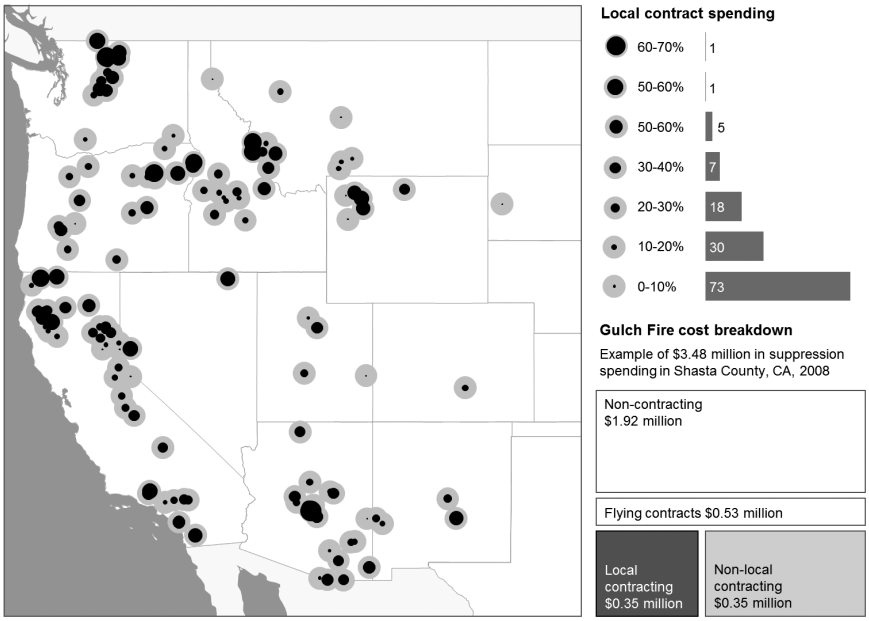

Figure 1. Sample fires and percentage of local wildfire contract capture in the western US.

and Reyes 2008) using 35 PSCs that fell into the following aggregate categories: NRM (PSC category F), building construction (PSC category Y), and structure repair (PSC category Z). We included contract actions that were awarded by the Forest Service and four Department of Interior agencies (Bureau of Indian Affairs, Bureau of Land Management, Fish and Wildlife Service, and National Park Service) for work performed in the 11 western states between 1999 (five years previous the first fire in our sample) and 2008 (the end of our study period). A total of 208,710 contract actions met these criteria. Other potential measures of capacity, such as the total dollar value of contracts, were highly correlated ($r > 0.50$) with the number of vendors. The number of vendors has the value of roughly representing the value of contracting due to the high correlation and describing the general structure of the local contractor market (many or few local businesses).

Other Location Factors

We assessed several other location-based factors for their influence on wildfire contracting patterns. We used USDA Economic Research Service (ERS) county-level data to characterize the level of urbanization and types of economic specialization in each county in our sample (USDA Economic Research Service 2004, 2008). Economic specializations are based on wages and employment, and include farming, mining, manufacturing, services, and government specializations. Counties that do not meet the criteria for those specializations are described as unspecialized. We combined farming, manufacturing, and mining specializations into a single group since few wildfires occurred in each of these types of counties. In addition, for urbanization, we used three categories: metropolitan counties (i.e., counties with greater than 500,000 inhabitants); non-metropolitan counties adjacent to metropolitan counties; and isolated non-metropolitan counties. Although these measures had not been used in prior research on forestry services contracting, prior research suggested that counties that were neither isolated nor urbanized would have more success in capturing contracts (e.g., Moseley and Shankle 2001). Our final location descriptor was the proportion of the county in federal ownership, based on the assumption that counties with more public lands would tend to have a greater economic connection to those public lands and therefore be better positioned to capture wildfire expenditures.

Fire-Related Variables

We captured several attributes related to each fire and its administrative and suppression cost context. We coded each fire according to its location in the six administrative regions of the Forest Service in the contiguous western United States to examine whether regional differences in contracting may exist. We also included the total suppression costs and the proportion of contracted suppression costs for each fire as measures of the fire suppression effort. The total suppression cost indicates the resources needed for a given fire, anticipating that more costly fires would involve a lower proportion of local resources (Davis et al. 2014, Nielsen-Pincus et al. 2014). The proportion of contracted resources in a suppression event may indicate the extent to which the suppression effort outstrips federal, state, and local resources, or may suggest a relative lack of private sector resources available for dispatch because resources either are limited or are already deployed.

Data Analysis

We used a fractional logit model to evaluate the relationship between the local capture of suppression contract awards and local business capacity (number of contractors) as well as other location- and fire-specific factors: economic specialization, level of isolation, proportion of public ownership, forest service region, total suppression costs, and the proportion of contract suppression costs. Fractional dependent variables have several distinct properties: values are continuous (not binary), values are bound within zero and one, and, typically, variance is linked to the mean, which can lead to heteroscedasticity and poor model estimates for both coefficients and their standard errors. Papke and Wooldridge (1996) showed that it is possible to account for these properties with a generalized linear model (GLM) by using a logit link with a quasi-binomial distribution and reporting robust standard errors. To implement the fractional regression model, we used the "frm" package in R (Ramalho 2015), which employs a quasi-likelihood maximization function and does not make any distributional assumptions.

Fractional regression models the mean of the dependent variable y conditional on covariates x. In our model, the conditional mean model for local capture is assumed to be $E(lc_i \mid x_i) = G(\beta, x_i)$, where lc_i is the proportion of locally captured suppression dollars for fire i; β are parameters to be estimated and x_i are explanatory variables (as listed in Table 1). As a logit model, effects are non-linear and vary in magnitude across the range of independent variable values.

Two additional model specifications were considered: (1) whether the model should be specified as zero-inflated; and (2) how to account for repeated observations of fires originating within the same county. An unusually large number of values occurring at the limits of a fractional response variable can indicate a separate process driving those observations and is commonly addressed by considering a two-part zero-inflated model (Ramalho et al. 2011). For the first consideration, we concluded that the number of zero observations found was not particularly inflated (i.e., our sample included less than 10% of fires that had zero local capture), and as a result, we decided against building a two-part zero-inflated model. For the second consideration, we examined the number of repeated observations. Large wildfires were found in 74 counties, and over the study period only 15 counties experienced large fires in multiple years. Although these patterns suggest that a repeated measures specification may be appropriate to understanding local capture, treating the sample as paneled data was problematic since the sample was extremely unbalanced. Instead, we included a fixed effect for the year of the fire as a first approximation of variability that may be associated with differences in contracting patterns over time.

Results

Wildfire Suppression Spending

Wildfire suppression expenditures for our sample of 135 large wildfires totaled $1.23 billion and varied between $1 million and $86 million per fire (Table 1). Over half of expenses resulted from the top 18 most costly fires. Approximate two-fifths of total suppression costs ($469 million, 38%) were contracted to the private sector, although this varied widely by fire from 5% to 90%. Of contracted expenditures, on average 13% were captured locally—that is, awarded to vendors in the county where the fire occurred. Local contracting also varied substantially by fire, from a low of 0% to a high of 63%. Less than 10% of sampled fires (n=12) had zero local capture (Figure 2).

Table 1. Frequency (and proportion) of categories of local capture of suppression contracts, number of vendors, economic specialization, Forest Service region, proximity to urban area, and total suppression cost.

	Wildfires (proportion)
Dependent variable:	
Local capture of fire suppression contracting (y)	
mean	13%
range	0% – 63%
Independent variables	
Number of NRM local contractors (prior to fire)	
mean	38
range	2 – 155
County economic specializations	
Unspecialized	58 (43%)
Farming, mining, manufacturing	28 (20%)
Government	30 (22%)
Service	19 (14%)
County isolation levels	
Isolated non-metropolitan	49 (36%)
Adjacent to metropolitan	46 (34%)
Metropolitan	40 (30%)
Percent of county in federal ownership (%)	
Mean	67%
Range	0% – 97%
Administrative region of the Forest Service	
Region 1: Northern region	13 (10%)
Region 2: Rocky Mountain region	7 (5%)
Region 3: Southwest region	23 (17%)
Region 4: Intermountain region	21 (16%)
Region 5: Pacific Southwest region	39 (29%)
Region 6: Pacific Northwest region	32 (24%)
Total Forest Service suppression costs (millions)	
Mean	$8.8
Range	$1.0 – $86.0
Suppression cost privately contracted (%)	
Mean	32%
Range	5% – 90%
Fiscal year of fire	
2004	19 (14%)
2005	17 (13%)
2006	31 (23%)
2007	33 (24%)
2008	35 (26%)

The average number of NRM businesses contracted in the five years prior to each wildfire ranged from a low of 2 to high of 155, with an average of 38. The vast majority of counties had fewer than 50 vendors, and half had fewer than 25. The number of vendors was highest in metro counties (mean = 49), followed by isolated rural counties (*not* adjacent to a metro county; mean = 28), and rural counties adjacent to metro areas (mean = 21).

Large wildfires occurred in a variety of different types of counties. Fifty-eight fires (43%) were found in counties with non-specialized economies. Of those wildfires occurring in counties with more specialized economies, 30 fires (22%) were in government-dependent counties, 19 fires (14%) in service-dependent counties, and the remainder in counties specialized in mining, manufacturing, or farming (n = 28, 20%). Wildfires in the sample were evenly distributed among metropolitan counties (30%), counties adjacent to metropolitan counties (34%), and isolated non-metropolitan counties (36%). The number of large wildfire suppression events increased from 19 in 2004 to 35 in 2008.

Predictors of Local Capture

The local capture model performed well (R^2 = 0.42). Residuals were normally distributed (Shapiro-Wilk normality test, W=0.97, p=0.19). Given the bounded nature of the data and the range of local capture observed between 0 and 0.63, we were not surprised to find significant heteroscedasticity (Breusch-Pagan test, BP=43.806, p<0.001), which we account for by reporting robust standard errors.

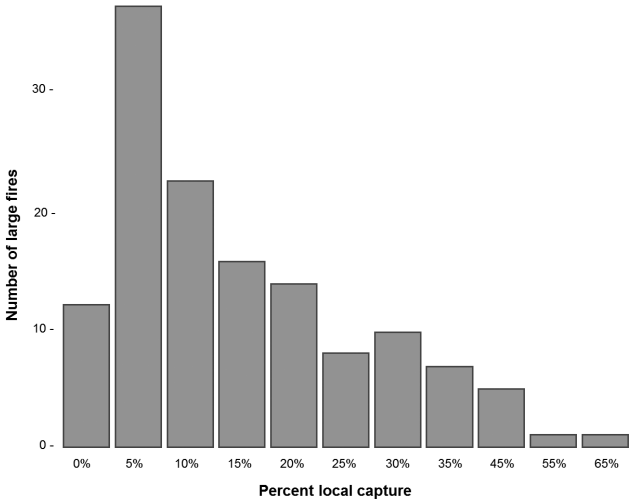

Figure 2. Histogram of the proportion of contracts awarded to local vendors during 135 large wildfire events in the western US.

Several location factors had significant influence over local capture (Table 2). Local capture was higher when large wildfires occurred in counties that had more NRM vendors. On average, every additional local NRM vendor prior to a wildfire resulted in a 0.2% increase in local capture (95% CI = 0.12% – 0.24%, p<0.001). As the fractional logit model is non-linear, the marginal effect of NRM vendors on local capture increased as the number of vendors increased, but at a decreasing rate. All else equal, an additional vendor in a county with 10 vendors resulted in a 0.2% increase in local capture while the additional vendor in a county with 100 vendors resulted in just greater than a 0.4% increase in local capture.

Local capture also depended on the context of the local economy. Economic specializations tended to reduce the proportion of contract spending that local vendors captured during wildfire suppression events. The effect was strongest in counties dependent on farming, mining, or manufacturing, which captured 9% fewer dollars compared to non-specialized counties (95% CI = –15.36% – –3.12%, p=0.002). Wildfires that occurred in counties dependent on government employment also captured 5% fewer contract suppression dollars (95% CI: = –10.42% – 0.52%, p=0.074) compared to wildfires that occurred in non-specialized counties. Service-based economies did not differ from non-specialized counties. Local capture also differed in some rural counties relative to the metropolitan counterparts. Large wildfires occurring in isolated rural counties (i.e., *not* adjacent to a metropolitan county) actually captured 4% more contracting dollars compared to metro counties (95% CI = –0.36% – 9.44%, p=0.068). We also note, however, that we found that a greater portion of wildfires with zero local capture in rural counties and the most observations of zero local capture in isolated rural counties, suggesting greater uncertainty in more isolated contexts. Fire contracting patterns were not influenced by the percent of federally managed lands in the fire's locale.

Table 2. Fractional logit regression model parameters predicting local capture of wildfire suppression contracting. Robust standard errors (RSE) and average marginal effects (AME) are reported.

Dependent variable	Estimate	RSE	p		AME†
Intercept	–2.116	0.578	<0.001	***	
Number of NRM local businesses	0.017	0.003	<0.001	***	0.002
Economy specialization (reference = non-specialized)					
Farming, mining, or manufacturing	–0.898	0.294	0.002	***	–0.092
Government	–0.481	0.269	0.074	*	–0.050
Service	–0.175	0.301	0.560		
County isolation (reference = metro county)					
Isolated non-metropolitan	0.441	0.241	0.068	*	0.045
Adjacent to metropolitan	0.328	0.257	0.201		
Percent of county in federal ownership (%)	–0.370	0.480	0.440		
Forest Service region (reference = Region 1)					
Region 2	0.326	0.500	0.514		
Region 3	0.260	0.355	0.463		
Region 4	0.016	0.410	0.968		
Region 5	0.005	0.331	0.989		
Region 6	–0.052	0.387	0.894		
Fire suppression cost ($ million)	–0.001	0.006	0.892		
Suppression cost privately contracted (%)	–1.435	0.711	0.044	**	–0.015
Fiscal year (reference = 2004)					
2005	0.074	0.317	0.816		
2006	–0.196	0.290	0.499		
2007	0.174	0.294	0.553		
2008	–0.029	0.299	0.923		
Model parameters					
N	135				
Shapiro-Wilk normality test	0.982		0.177		
Breusch-Pagan heteroscedasticity test	50.063		<0.001	***	
Pseudo R-squared	0.419				

*p<0.10, **p<0.05, ***p<0.01

†AMEs are reported for those variables with significance at the alpha=0.10 level or less. For NRM local businesses, AME is estimated per additional business. AME for nominal variables is estimated as the marginal effect for that variable relative to the reference category. AME for the proportion of suppression costs that are privately contracted are estimated per 10% increase in proportion of contracted expenses.

Local capture of suppression contracting was independent of the total suppression costs of the fire and the national forest administrative region where the fire occurred. In contrast, local capture decreased as a greater percentage of suppression expenditures on a given wildfire were allocated to privately contracted services. Specifically, for every 10% increase in the portion of contracting, the average decrease in local capture was about 1.5% of total suppression costs (95% CI = –0.03% – –2.92%, p = 0.044).

Discussion

Local Contracting Increased Where NRM Capacity was Higher

Previous research during the same time period as our study has shown that economic impacts of wildfires on communities are significantly influenced by contracting patterns during a suppression event (Nielsen-Pincus et al. 2013). In the present study, we found that contracting patterns during large wildfires sampled between 2004 and 2008 were correlated with local NRM business capacity, as well as other location and fire factors. Our model demonstrated a significant relationship between the number of local NRM firms contracted by the federal land management agencies prior to a large wildfire and the proportion of contracted work awarded locally during wildfire suppression events. Moseley and Toth (2004) reported similar findings in their study of economic opportunities for fire hazard mitigation work funded by the National Fire Plan; the authors explain that local contract awards were driven by local experience with previous contract awards and the extent to which contractors had the experience required for specific types of fuels work. Our results also show that the marginal effect of local business capacity on local capture of suppression contracts increased non-linearly. The finding suggests that although local economies with little existing capacity for federal contracting may have a steep road to climb, they have relatively more to benefit from economic development when compared to those places with robust concentrations of economic capacity.

Our findings may point to an indicator of community efforts to becoming more adapted to wildfire—the number of local firms with federal NRM contracting experience. Indicators of community business capacity can help strategically target specific communities for business development assistance. This type of assistance, in turn, may improve community resilience to wildfire and increase local capacity for NRM needed to maintain resilient landscapes. Using a similar framework, Aguilar (2009) identified counties in the US South that would be well suited for development assistance in the wood products industry, and similar methods may identify areas well suited for further investment in business capacity oriented toward developing fire-adapted communities. Efforts to implement the Cohesive Strategy could consider existing local capacity in order to deliberately engage actors already involved in federal NRM-related work and to fill gaps in wildfire management capacity. Additionally, existing NRM related businesses may not be experienced in federal contracting, suggesting that contractor training may be an important strategy for some communities to increase local business capacity to participate in federal NRM activities and become more fire-adapted. Moseley and Toth (2004) discuss the importance of training to help contractors accurately bid on NRM activities in rural isolated counties. Considering existing economic development conditions as part of Cohesive Strategy

implementation could help apply the lessons from our research and build on recommendations from economic geography. For example, in his study of regional economic performance, Porter (2003) concluded that economic development should focus on improving regional performance in industries where "a meaningful position" (p. 571) already exists locally. Targeted identification of existing integrated workforce and firm capabilities can help build on existing efforts by communities to become fire-adapted while simultaneously furthering both business and workforce development goals (CS-CW 2011, Huber-Stearns, Moseley, and Goulette 2016).

Moseley and Toth (2004) highlighted the link between firm participation in wildfire hazard mitigation and non-fire-related NRM activities. Our findings suggest that the conventional wisdom about the link between firm participation in wildfire suppression and non-fire NRM activities also holds true (Huber-Stearns et al. 2016), especially in communities where preexisting business capacity was sufficient. Counties with a robust NRM contracting economy saw greater participation from local contractors in fire management and response, as measured by suppression contracting patterns. Although our findings help confirm Davis et al.'s (2014) observation that participation in emergency wildfire response may be limited in communities where natural resource business capacity has dwindled, they may also suggest a nuance. The development of new businesses with federal contracting capacity may be an opportunity to initiate a process of asset building that leads to an upward spiral (Emery and Flora 2006)—new NRM businesses foster capacity to engage in projects to improve landscape resilience to wildfire while also indicating community adaptation to wildfire through increased capacity to participate in wildfire management.

Social and Economic Dynamics Affected Patterns in Local Capture

Local capture of suppression contracts was also constrained or enhanced by local social and economic context. Contracting patterns were mediated by factors such as county economic specialization and the level of isolation from metropolitan areas. Similar to findings from research on wildfire hazard mitigation (Moseley and Toth 2004), we found that local vendors were more likely to receive contract awards on fires that occurred in counties with less specialized economies than fires occurring in counties with more specialized economies. While industry specialization may initially seem like it could facilitate economic performance, Porter (2003) notes that from a regional perspective, industry diversity can lead to higher regional economic performance. In addition, fires that occurred in isolated rural counties tended to result in a higher percentage of locally awarded contracts, which is similar to the findings of Nielsen-Pincus et al. (2014) that smaller-population counties that experience wildfires tend to experience relatively more job growth. Nonetheless, we found that local contracting patterns in isolated rural counties were also more variable, as evidenced by the greater likelihood of zero local capture in isolated rural counties compared to other counties. Such uncertainty may contribute to a vicious cycle of the loss of economic and social assets in some isolated rural places (Emery and Flora 2006). Further explanation is needed of the unique factors associated with the experience of individual locations, like the case study work explored by Mosely and Toth (2004) and Davis et al. (2014) in several isolated rural communities.

Additional Factors Contributing to Variation in Local Capture

While NRM contracting capacity clearly impacted local capture of suppression contracts, our model explained less than half of the variation in local capture. Given the lack of previous research in this field, we can only speculate about other potential causes. Contracting patterns were mediated by fire-specific factors like the proportion of suppression spending allocated to privately contracted resources. Wildfire suppression contracting is likely to vary with the timing and location of other fires and the availability of agency and contracted crews. Further, agencies typically dispatch private contractors to fires on public land only after exhausting resources available internally or through interagency agreements (Lyon et al. 2017). When private contractors are dispatched, local vendors may be unavailable or already be engaged in suppression of another fire. Local capture also varies because of the demand for specific types of work needed on a given suppression effort. Research on national forest contracting has shown that contracts requiring heavy equipment are more likely to be awarded to local contractors than labor-intensive work (Moseley and Shankle 2001, Moseley and Toth 2004). In the Pacific Northwest, this has meant that that some local public land-based communities have benefited economically as the Forest Service has shifted from labor- to equipment-intensive contract work (Moseley and Reyes 2008). Given the need for heavy equipment in wildfire suppression, the shift may contribute to the relationship between fire suppression contracting and local NRM capacity.

NRM vendors engaged in fire mitigation, including both prescribed fire and mechanical fuel treatments, may be particularly well suited to participating in suppression efforts and may provide specific evidence of addressing Cohesive Strategy goals. Prescribed fire and mechanical treatments are important tools for achieving Cohesive Strategy goals (North et al. 2015), but vary in their use due to costs and concerns about liability among other challenges (Haines and Cleaves 1999, Yoder et al. 2004, Rummer 2008, Stephens et al. 2012). These constraints have implications for where, how, and what kinds of NRM work are applied on any given national forest, and therefore what types of NRM contracting national forests may offer (and local contractors may bid on). Nonetheless, prescribed fire and mechanical mitigation efforts may be important not only for their effects on future fire behavior, but also for the implication that having local businesses engaged in fire mitigation activities may help create more resilient landscapes and help communities be more adapted when wildfires do occur.

Although our analysis demonstrated a relationship between existing NRM capacity and local capture during wildfire suppression, there are several limitations created as part of our research design that should be addressed in future research. First, we attributed local capture to the scale of the county. However, our results may be masking important inter- and intra-county dynamics, especially where tension exists among local communities within or between counties or where a single town or city dominates the population or economic distribution of a county, masking the effects on smaller communities (Carroll et al. 2005, 2011). A spatial model may directly address these concerns, but we did not pursue this route as multiple authors have noted that spatial proxies may adequately account for spatial variation (McMillen 2003, Aguilar 2009). Second, we were not able to distinguish transactions between the different types of contracts that are issued

(e.g., national contracts versus regional contracts made preseason). Reliance on national contracts appears to be increasing (NWCG 2012, NIFC 2015), and could have important implications on local capture of fire suppression-related work, and thus how local communities prepare for, participate in, and recover from wildfire events. National contracts represent a centralization of wildfire response capacity and may limit the capacity of many communities to engage during incident response by changing the economic geography of the market for wildfire management services. Further research could also help illuminate the extent to which contracting and related dispatch practices are making local communities more or less resilient to wildfire, while also addressing the drivers of wildfire suppression contractors' location decisions. To move toward achieving Cohesive Strategy goals, managers and policymakers may want to balance the centralization tendencies occurring in NRM and wildfire policy with Porter's (2003) suggestion that improved regional economic performance can be fostered by decentralized economic policy.

Conclusion and Implications

In light of growing threats of wildfires to communities, policymakers and local leaders are increasingly interested in how community capacity can improve preparation and recovery to wildfire (Jakes et al. 2007). The Cohesive Strategy strongly promotes fire-adapted communities and resilient landscapes, and fire managers play a key role in how communities are engaged in all stages of fire management, including preparedness, fuel reduction, fire suppression, and post-fire recovery. Community participation in all stages of wildfire management depends on having and maintaining local business capacity to contract with the federal government. With intensifying fire, there is an amplified need to understand how local communities and their available workforces and businesses can prepare for, respond to, and recover from wildfires. As we have demonstrated, local NRM business capacity may be an important indicator of fire-adapted communities and engagement in management to improve landscape resilience.

This study provides evidence of linkages between a local business engagement in federal NRM and local participation in fire suppression efforts. These capacities appear to be reinforcing at the local scale, even if some businesses do not participate in both kinds of activities. However, because of the lack of historical analysis of these two markets, we do not know whether or how much these relationships have changed over time, although conventional wisdom would suggest that the relationship between these two markets has become more complex as private wildfire response has become more professionalized and nationalized. Nonetheless, sustaining local business capacity to contribute to NRM continues to be an important tactic for accomplishing the goals envisioned by the National Cohesive Wildland Fire Management Strategy.

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