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The social costs of homeowner decisions in fire-prone communities: Information, insurance, and amenities

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ABSTRACT

In this article, we consider wildfire risk management decisions using a dynamic stochastic model of homeowner interaction in a setting where spatial externalities arise. Our central objective is to apply observations from the social science literature about homeowner preferences to this economic externality problem and determine how assumptions about insurance, information and starting fuel loads affect outcomes and the effectiveness of policy. Three new features of our approach are, first, to assess fuel treatment behavior under potential misinformation scenarios, second, to allow for heterogeneous starting fuel loads across ownerships, and, finally, to evaluate the effectiveness of insurance and direct regulation at improving outcomes. Among other results, we find that risk-adjusted insurance may not create incentives for fuel treatment when government suppression exists, and in games with heterogeneous starting fuel loads, the social costs from misinformation can persist over a greater range of fire probability and damage function parameter values. These results suggest that, even as information about wildfire improves, the social costs inherent in private decisions will be more persistent than previously thought on landscapes where fuel stock differs across ownerships.

1. Introduction

In recent years, the extent and severity of wildfires in the western U.S. have become an important policy issue (Dombeck et al., 2004; National Interagency Fire Center, 2011). Annual wildfire suppression often exceeds $1 billion, and this suppression has left large amounts of hazardous forest fuels on U.S. landscapes putting communities at risk. Given budget-constrained governments, the fuel reduction decisions individual landowners make in the wildland–urban interface (WUI) are critical, yet these measures are costly and as a result many landowners fail to mitigate risk.

Because wildfire moves across landscapes and ownership boundaries, forest fuel conditions on an individual property affect wildfire damage on both the individual property and neighboring properties. Positive spatial externalities (i.e., benefits to adjacent landowners) created by removing hazardous forest fuels have been documented (Hann and Strohm, 2003) and found significant for large wildfires (Finney, 2001; Gill and Bradstock, 1998). Fuel reduction undertaken on an individual property limits the accumulation of forest fuels and decreases the risk of fire damage on neighboring properties. Recognizing these spatial links, many landowners living in the WUI consider the state of neighboring forests when making decisions about investment in fuel treatment (Brenkert-Smith et al., 2005; Monroe and Nelson, 2004). The pattern of fuel treatment on the landscape, therefore, depends on the pattern of landowner risk mitigating decisions across the landscape and how these decisions interact.

The relatively few economic studies of risk-mitigating decisions in the context of spatial externalities with multiple landowners include Butry and Donovan (2008), Shafran (2008) and Busby et al. (2012).[3] Butry and Donovan (2008) develop a simulation model to evaluate several landscape-level fuel treatment strategies and illustrate the benefits from collective action, but do not examine landowner interaction. Busby et al. (2012) and Shafran (2008) develop game theoretic models that allow for strategic interaction between landowners.

Through the use of written survey and interview data, social science research has recently explored a variety of reasons landowners fail to undertake fuel reduction. These include misinformation about wildfire risk (Talberth et al., 2006), a reliance on and an overly optimistic belief in the ability of government suppression to protect private property (Fried et al., 1999; Gardner et al., 1987; McCaffrey, 2006), or that insurance will always be available to compensate landowners for wildfire damages (Brenkert-Smith et al., 2005). Brenkert-Smith et al. (2005) also note that availability of insurance is an important factor in that landowners view losses as less costly when they are insured, which

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[3] Crowley et al. (2009) use a Faustmann model to examine similar spatial externalities among adjacent forest landowners, but insurance and home structures are not considered.

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begs the question of how the possibility of insurance drops (loss of access to landowner insurance) might affect behavior. Reluctance to remove hazardous fuel may also be due to positive amenity values that vegetation provides to landowners (Brenkert-Smith et al., 2005; Talberth et al., 2006). Collectively, these studies show that landowner incentives for fuel treatment depend in complex ways on the information landowners have, the presence of public agency fire suppression, amenity values and the availability of insurance.

The focus on wildfire education programs in many fire-prone communities also reflects the need, highlighted in the social science research, to improve landowner information about wildfire and the benefits of risk-mitigating fuel treatments. State, federal and community education programs focus primarily on fire behavior, vegetation management, and raising awareness about fire danger (e.g., Bitterroot Community Wildfire Protection Plan, 2010; Colorado Springs Fire Department, 2011; Sunriver Owners Association, 2010). In addition, numerous studies have pointed to the need to improve information about wildfire and risk management (e.g., Bowman et al., 2008; Jarrett et al., 2009). To better understand the impact of misinformation on the fuel treatment decision and social costs, we examine cases where landowners have misinformation about the probability of fire, fire damage and the spatial externalities associated with fuel management decisions. Identifying the sources of misinformation with the greatest social costs will improve the ability of land management agencies and communities to design effective education programs.

Similar to Busby et al. (2012) and Shafran (2008), our purpose is to examine the fuel treatment decision between adjacent landowners where spatial externalities are present, but our work goes beyond existing literature to include investigating the role of insurance and the possibility that landowners are misinformed about wildfire risk. We also build upon the recent insights from social science research and specify a dynamic economic model of the fuel treatment decision that incorporates key spatial features of the wildfire risk management problem and allows an exploration of the social inefficiencies associated with misinformation, government suppression, and insurance programs. We use our model to, first, assess fuel treatment behavior and associated social costs for landowners with misinformation about wildfire, and, second, to examine outcomes when landowners make fuel treatment decisions over time on a landscape that begins initially with unequal fuel loads across ownerships. This is a departure from related Faustmann-based studies that assume that starting fuels are equal or zero (e.g., Crowley et al., 2009). Relaxing this assumption permits study of the strategic interaction between landowners in a more realistic setting, given that individual ownerships are managed independently. Finally, we evaluate the effectiveness of insurance, where the cost of coverage depends on landowners' fuel management decisions, and we consider fuel treatment cost-sharing and fuel stock regulation as a means for reducing social costs. A better understanding of the fuel treatment decision in the cases we examine will improve the ability of policy-makers and public land managers to craft more effective public policies, leading to better protected and informed WUI communities.

The remainder of this paper is organized as follows. First, we outline a stochastic dynamic game theoretic model that captures features of spatial externalities, strategic behavior, misinformation, and insurance for two adjacent properties in a fire-prone area. In Section 2, we describe the simulation approach used to solve this model for various types of imperfect information and spatial externalities inherent in the problem. Sections 3 and 4 describe the results from the fuel treatment game and policy applications, respectively. Finally, in Section 5, we offer a discussion of the results, concluding remarks, and policy recommendations.

2. Model of a Fire-Prone Community

We begin by examining the strategic incentives for two adjacent landowners (labeled by subscripts k and j) living in the fire-prone WUI. Initially, we assume that each landowner values amenities generated by forest vegetation, is aware of the positive relationship between forest fuels and wildfire damage, and knows the probability of fire in each time period. Both landowners begin with insurance, but if fire damage is costly it can reduce landowner access to insurance in future time periods.

In what follows, we describe the model using landowner k as the primary landowner and j as the adjacent landowner, although the same general specification holds also for landowner j. The spatial features of the model are driven by the landscape pattern of forest fuel. When a fire occurs, it may damage homes, reduce landscape amenities by consuming vegetation, and lead to insurance drops. The severity of wildfire impacts increases when there is more fuel on the landscape. The presence of fire suppression can reduce wildfire damage but is costly. The sequence of events described by the model is outlined in Table 1.

2.1. Fuels, Fire, and Suppression

In every time period, each landowner's choice is whether to undertake fuel treatment on their property or to let forest vegetation grow. By removing flammable vegetation, fuel treatment reduces damage to the landowner's property structure if a wildfire occurs. For example, the state of fuel loading for landowner k at time t is given by Z_t^k, and this fuel load changes over time according to:

$$Z_t^k = \gamma\left(Z_{t-1}^k - M_{t-1}^k\right) \tag{1}$$

where M_{t-1}^k is the amount of fuel removed by landowner k at time $t-1$ and γ is a community fuel growth rate that does not vary over landowners k and j. Later in the simulation, we discuss a simplified index for M_t^k that represents Eq. (1) and is more tractable in the dynamic programming solution process. With this in mind, the convex cost of fuel treatment paid by landowner k is a function of fuel removed on property k at time t:$C_M(M_t^k)$, such that $C'_M\left(M_t^k\right) > 0$ and $C''_M\left(M_t^k\right) < 0$. For the simulation, we separate $C_M(M_t^k)$ into fixed and variable components.

Both landowners take the probability of a fire occurring on their property as independent of the fuel stock on the landscape, as in Amacher et al. (2005) and Amacher et al. (2006). Fire can arrive each year in the community with a probability at time t equal to:

$$p(t) = pf_t, \forall t. \tag{2}$$

When a fire occurs, both landowner parcels are assumed to burn, but fire damage and fuel consumption on each individual property depend on the fuel present on each landowner's property and the adjacent property, and as in Amacher et al. (2005, 2006), and Busby et al. (2012).

We assume a government agency (noted as 'Government' in what follows) expends effort to suppress fires in the time period that fire arrives. As in Crowley et al. (2009) and Busby et al. (2012), Government acts as a follower by observing a fire at time t, and then choosing

Table 1
Sequence of events in each time period.

1. Landowners k, j choose fuel treatment.
2. Insurance premium for current period is calculated, according to post-treatment fuel stock.
3. Fire occurs or does not occur.
4. Government chooses level of fire suppression.
5. Landowners k, j realize payoffs (losses from fire).
6. Insurance drops, if any, are made.
7. Fuel stock grows.