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# Inducing private wildfire risk mitigation: Experimental investigation of measures on adjacent public lands

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**Abstract**
Increasing private wildfire risk mitigation is an important part of the larger forest restoration policy challenge. Data from an economic experiment are used to evaluate the effectiveness of providing fuel reductions on public land adjacent to private land to induce private wildfire risk mitigation. Results show evidence of "crowding out" where public spending can decrease the level of private risk mitigation. Findings also indicate that spending on private mitigation efforts increase when information about individual expenditures are made available and spending on public land fuel reductions are conditional upon a threshold level of private mitigation effort being achieved.

**Keywords**
Wildfire, Public goods, Experimental economics

## Introduction

Responding to increasing wildfire risk is an important policy challenge in the Western U.S. and elsewhere (Donovan and Brown, 2005). Defined as “the area where houses meet or intermingle with undeveloped wildland vegetation,” the wildland–urban interface (WUI) is an area of particular significance (Hammer et al., 2008, p. 5). Land ownership in the WUI commonly follows a mosaic pattern, where the intermixed public and private land make wildfire risk a collective problem. Referred to as the “mitigation paradox” (Steelman, 2007), private landowners and communities frequently fail to undertake sufficient wildfire risk mitigation. The objective of this paper is to use the tools of experimental economics to help design and explore policy packages for confronting the mitigation paradox, and inducing increased private risk mitigation.

Surveys of homeowners indicate that conditions on adjacent properties are an important consideration in mitigation decisions (Brenkert et al., 2005). WUI homeowners recognize the threat of wildfire as a collective problem. Forest management regimes are increasingly accounting for this by providing risk mitigation on publicly owned lands adjacent to privately owned lands (U.S. Congress, 2000, 2009). The effectiveness of these types of policies to induce additional private risk mitigation is unclear and motivates this research.

Data from a computerized laboratory experiment (with 244 participants and 2490 choices) are used to explore the potential response of WUI homeowners to the introduction of policy tools. The experimental design builds on a number of recent studies (McKee et al., 2004; Talberth et al., 2006; Berrens et al., 2007) with the current focus on two potential policies that recognize the prevalent public–private land mosaic in the WUI: (i) a policy where wildfire risk mitigation takes place on surrounding public land; and (ii) a policy where mitigation on surrounding public land takes place only if a threshold number of individuals have undertaken mitigation efforts. The modeling of participants’ mitigation decisions controls for risk aversion, social trust and the provision of information. There are a total of six experiment treatment cells. Two policy treatments are compared against a no action baseline case, and all three settings are then evaluated with and without information on the risk mitigation behavior of other participants being provided.

Results indicate that public land fuels reductions can have the unintended effect of decreasing the amount of private risk mitigation. However, a simulated policy where public land fuel reduction is conditioned upon a threshold level of private risk mitigation while simultaneously providing collective information describing each participant’s mitigation expenditure is shown to not only increase private spending on wildfire risk mitigation but also the likelihood of an individual undertaking such action.

## Background and motivation

The wildfire problem in the Western U.S., and elsewhere, is worsening due to a combination of natural and human factors. The WUI is expanding. During the 1990s, the WUI grew in area by 19% and in number of households by 22%, such that in 2000, the WUI represented 11% of the total land area (715,000 km2) and 38% of all housing units

(44.3 million) for the coterminous US (Hammer et al., 2008). Fuel loads have also grown, as wildfire has been increasingly suppressed in effort to protect homes situated in the WUI (Kovacs, 2001; Donovan and Brown, 2005). Combined with long-term drought and accumulating fuel loads, the expansion of the WUI has significantly increased the risk of high intensity fires (USDA, 2003; Donovan and Brown, 2005; Westerling et al., 2006).

As a result, large wildfires are occurring more often and are burning an expanding area. On USDA Forest Service lands for example, average annual acres burned increased from 285,000 from 1970 to 1986 to 1,000,000 from 1987 to 2002 (Calkin et al., 2005). The pecuniary costs of wildfire are also rising; nominal annual federal appropriations in the US for wildland fire management activities have increased from an average of $1.2 billion from fiscal years 1996–2000 to an average of $2.9 billion during fiscal years 2001–2007 (Nazzaro, 2009). Suppression costs typically account for more than 60% of the annual federal costs of wildfire management activities and are growing as well (US Government Accountability Office, 2007). These rising costs combined with the recognition of wildfire as a natural and beneficial process have lead to growing sentiment that a suppression-centered wildfire policy is unwise (Franklin and Agee, 2003; Berry, 2007; Donovan and Brown, 2007).

Moving away from a costly policy focus on suppression requires the re-introduction of natural fire regimes at a landscape scale (Franklin and Agee, 2003; Donovan and Brown, 2007), while also targeting fuel reduction and risk mitigation efforts to protect at-risk WUI communities (Harbour et al., 2009).

These risk-mitigating efforts include: reducing the volume of fuel in an area, using flame resistant building materials, applying flame retardants, creating strategic breaks in fuel sources, and removing ladder fuels that facilitate the spread of fires into the forest canopy (Murnane, 2006). Because mitigation can potentially reduce the suppression and aesthetic costs associated with wildfire in the WUI a change in priorities, which increases focus on preventative actions, is underway (O'Toole, 2006; USDA, 2006).

Although fuel reduction projects on public lands are an ongoing part of the National Fire Plan (USDA and US Department of Interior, 2000) and Healthy Forest Restoration Act of 2003 (U.S. Congress, 2003), wildfire risk mitigation by government alone is insufficient on three counts. First, a significant amount of forested land (58% in the U.S.) is privately owned (Smith et al., 2004). Second, the scope of wildfire is such that there is simply too much land in need of fuel reductions to be paid for with public funds alone. Recent analyses find that nearly 400 million acres of forestland across the U.S. are characterized as either at a "moderate" or "high" risk of catastrophic fire (Power, 2006). Juxtaposed against these 400 million acres in need of fuel reduction, the federal government has financed projects on less than 3 million acres in recent years (Power, 2006). Third, inefficient levels of wildfire risk mitigation are expected from individuals in the WUI because of the risk externalities associated with fuel treatments (Crowley et al., 2009). Here, risk externalities (sometimes called adjacency externalities) describe the wildfire characteristic of risk being shared across property lines, and that actions taken to mitigate wildfire risk on one property, concurrently reduce the risk of fire in the surrounding area (Konoshima et al., 2008). In this way, wildfire risk mitigation can be thought of as a public good (Busby and Albers, 2010). The behavior of individuals confronting shared wildfire risk is consistent with theoretical predictions; private individuals do not undertake a sufficient level of wildfire risk mitigation (Steelman, 2007). This suggests a potential role for policy to induce WUI homeowners to undertake risk mitigation.

In practice, a varied set of policy responses are being implemented, including subsidizing private spending on fuel treatments,2 enacting legislation that marries insurance availability and premiums to risk mitigating behavior (Wallace, 2005), and providing education about wildfire risk and fuel reductions (Sturtevant and McCaffrey, 2006). This paper focuses on the effectiveness of a specific approach: providing wildfire risk mitigation on public lands that are adjacent to privately owned lands.

A number of collaborative, community-forestry-based management programs have been implemented that fund risk mitigation on public lands, which are adjacent to private lands. One notable example is the ongoing federal Collaborative Forest Restoration Program (CFRP) in New Mexico, and potentially at a broader national level the recently enacted Forest Landscape Restoration Program (FLRP) (U.S. Congress, 2000, 2009). One rationale underlying these programs is that landowners' mitigation decisions are increasingly thought to be influenced by the extent of risk mitigation taking place in the surrounding area (Brenkert et al., 2005; Martin et al., 2007). While evaluation of the effectiveness of collaborative, community forest management programs has begun (American Forests et al., 2005; Prante et al., 2007), the potential of fuel reductions on public lands to generate wildfire risk mitigation on adjacent private lands remains largely unknown.

The issue of how to induce private wildfire risk mitigation is attracting increasing attention from researchers. Two lines of work are particularly relevant here: one set of analyses have addressed the issue with theoretical models and the use of numerical simulation (Amacher et al., 2005, 2006; Lankoande, 2005; Shafran, 2008a; Crowley et al., 2009), and a second set of studies making use of laboratory experiments (McKee et al., 2004; Talberth et al., 2006; Berrens et al., 2007; Shafran, 2008b). Evidence from both lines of research suggests that policy can be effective in inducing private risk mitigation. However, this is tempered by the observation of policy in some instances crowding out private risk mitigation (McKee et al., 2004; Berrens et al., 2007; Crowley et al., 2009). While the overall objective of increasing private spending on wildfire risk mitigation is important, there is also a need to identify policy tools which both ameliorate crowding out, and allow for continued public spending on wildfire risk mitigation.

**Experiment design**

The experiment took place during the fall 2007, spring 2008, and fall 2008 semesters at the University of Alaska, Fairbanks. Prior to administration of the experiment an extensive series of test sessions were conducted. Data from the test sessions were used to refine the presentation of the experiment and parameterize the computing functions supporting the experiment. Once pretesting was complete, undergraduate student were randomly recruited from across the university as subjects. Groups of 12 subjects participated in each session. The experiment was administered using a network of 12 interfaced laptop computers and an independent server. Upon entering the lab, each subject was randomly assigned to a computer workstation in a privacy carrel. Each carrel contained a networked laptop computer, a preamble to the experiment, and a satellite photo showing an example of a home situated in WUI setting. The photo provided a visual context of a WUI type setting for the subject but did not delineate between public and private lands. The preamble detailed the nature of wildfire risk facing WUI homeowners, identified how mitigation efforts reduce the risk of wildfire and wildfire related damages to themselves and their neighbors, and detailed the private financial protections offered by insurance. The preamble also detailed the experiment instructions to the participants and explained that they would be paid in US dollars at the end of the session. To ensure that subjects understood both the experiment context and the instructions the proctor read the preamble aloud as subjects followed along with their hard copies. Once the proctor finished reading the preamble, participants were given an opportunity to ask questions. During a session participants were able to access the experiment instructions and other relevant information directly on the computers by “clicking” on-screen information tabs.

To mirror the relevant features of an environment with intermixed publicly and privately owned land, a circular arrangement of 12 private and four public land parcels was placed at the lower left hand corner of each computer screen. Each of the 12 participants represented a WUI homeowner owning one of the parcels. The arrangement of parcels in the diagram was distinct to each computer; accordingly the experimenter was able to ensure that each participant saw that their parcel was adjacent to a publicly owned parcel. Participants were also aware that the adjoining private parcels were not necessarily owned by the individual in the neighboring carrel. Although no specific cross-parcel effects were modeled, the value of each participant’s parcel was affected by the number of individuals undertaking mitigation and the aggregate level of expenditures. The four parcels of publicly owned land were controlled by the experimenter and were used to simulate the policy tools under evaluation. In rounds where public land mitigation was taking place the color coding of the public parcels changed and a description was placed above the diagram. The diagram was also used to convey the prior round private mitigation expenditures for all participants in treatments where such information was made public.

Each session consisted of two practice rounds and ten live rounds. During the practice rounds subjects were able to familiarize themselves with the computer interface and the nature of the experiment. Once the practice rounds were complete subjects were notified that the following rounds were live and that their decisions would affect their actual payment. To help minimize the potential for end of session strategic behavior participants were not aware of how many rounds were to take place.

Within a session each participant was endowed with a “home asset,” denominated in lab dollars ($lab). An income stream equal to 10% of the “home asset” value was generated in each round. Home asset value and round income information were clearly identified in a text box in the upper left hand corner of the screen. Subjects allocated round income among three goods: (1) A “Mitigation” good which represented expenditures on real world risk mitigating processes such as fuel reductions, (2) an “Insurance” good which approximated real world spending on insurance, and (3) participants were also able to allocate round income to a “Savings” good.

There were two benefits derived from spending on the “Mitigation” good. First, the probability that the session group experienced a wildfire event at the end of a round was reduced. Second, spending on “Mitigation” reduced the magnitude of the loss participants experienced if a wildfire event occurred. As defined, a wildfire event is probabilistic occurrence of wildfire which has the potential to negatively impact the subjects’ home asset. To capture the positive externalities associated with wildfire risk mitigation in real world situations the benefit of a lab dollar spent on the “mitigation” good accrued to not only the individual spending that lab dollar, but to the group as a whole. Thus, the probability of a wildfire event occurring and the severity of that event were reduced for all participants when mitigation was undertaken.

For the “Insurance” good the premium was identical for all participants with one lab dollar resulting in a reimbursement 16 lab dollars to the “home asset” value if a wildfire event occurred. Participants were able to insure up to 90% of the “home asset” value of the current round. Insurance purchases reduced the exposure of the individual subject and did not extend to other participants. Finally, insurance was only good for the current round.

Finally, a subject’s spending on “Savings” did not impact wildfire behavior in the experiment. Saved funds could not be used in following rounds; instead accrued funds were tracked and included in the calculation of the final payment for participating in the experiment. The “Savings” amount was also displayed in the upper left hand corner of the screen. The behavior of interest is how participants distributed the income earned in each round among “Mitigation,” “Insurance,” and “Savings” as experimental treatments were introduced.

In order to simplify how participants input their expenditure decisions two sets of “drag and scroll” “sliders” were placed on the right hand side of the screen. The first set of “sliders” was used to input the subject’s spending allocations on the three goods. The second set of “sliders” could be used by participants to evaluate the impact of their spending decision on the wildfire event probability and “home asset” value under assumed levels of group mitigation efforts and total expenditures. Subjects drag scrollbars representing the number of participants undertaking risk mitigation and the level of mitigation undertaken by the group, respectively. As participants change their estimate of what the group will do, the estimated probability of a wildfire event and potential losses presented at the bottom right corner of the screen were updated. The advantage of using sliders is that the complicated process of wildfire risk mitigation could be simplified and presented in a comprehensible way. Once all subjects had submitted their spending allocation, a random draw to determine whether the group experienced a wildfire event took place. To simplify, it was assumed that, in the case of a wildfire event, the entire landscape burned. Consequently, each participant's home asset decreased in value and, subsequently, reduced their income stream in future rounds. For any individual subject, the actual decline in home asset value was a function of the risk reduction activities they and other participants chose to pursue.

Wildfire events in the experiment were designed to follow the properties of wildfire in the WUI. Risk mitigation has the potential to reduce the severity of a fire by reducing the amount of available fuel to burn (Kovacs, 2001). Fuel reductions can also reduce wildfire severity by inhibiting the spread into the forest canopy where fuel is abundant (USDA, 2003). Homeowner's risk exposure is thought to be determined not only by the conditions on their property, but also by the conditions of the surrounding landscape (Finney, 2006; Scott, 2006). Further, because wildfire risk is shared, the effectiveness of risk mitigation also depends upon the conditions on surrounding lands (Shafran, 2008a). Though weather and topography cannot be altered by mitigation, reducing fuel loads provides homeowners a way to offset the impacts that wildfire may have on their property (van Wagtendonk, 1996; Finney, 2001).

Wildfire risk is complex. In real world applications, the efficacy of risk mitigating behaviors to reduce risk exposure varies as local geographies change. To simplify this complexity the probability of a wildfire event is modeled as a function of the sum of all participants spending on "Mitigation" in the round, the number of participants' engaging in mitigation, and the number of rounds that have elapsed since the previous wildfire event (this simulates fuel accumulation in the absence of wildfire). The relationship between mitigation actions and the wildfire event probability is given by Eq. (1):

$$\pi = 0.4 + (RE * 0.01) - \left( \frac{N/48}{1 + 60e^{-GMIT/6000}} \right) \quad \textbf{(1)}$$

where _ is the probability of a wildfire event occurring, RE is the rounds elapsed since the last wildfire event, N is the number of participants mitigating, and GMIT is the sum of all participants spending on "Mitigation" in the round. While this function is a simplification, the key components of wildfire risk and mitigation impacts are present. The effectiveness of mitigation efforts depends not only upon the level of expenditures (GMIT) but also the number of individuals participating. The function assumes a nonlinear relationship between "Mitigation" and wildfire risk, where the total benefit of mitigation dollars increase at a diminishing rate. With respect to RE, accumulated fuel loads are assumed to increase the probability of a wildfire event. If a wildfire event took place in a preceding round, RE was set to a value of zero, and the accumulation process started over.

Given the level of complexity, participants do not directly observe Eq. (1). Instead, subjects could see how much each lab dollar spent on mitigation reduced risk exposure using the "sliders." The severity of a wildfire event is measured by the loss in value of a participant's home asset. The loss of home asset value is a function of the sum of all participants' spending on "mitigation" in the round and the number of participants engaging in mitigation. If a wildfire event takes place in a round, the loss (severity) was determined by Eq. (2):

$$LOSS = 0.71 - \left( \frac{N/24}{1 + 36e^{-GMIT/3600}} \right) \quad (2)$$

LOSS is the proportion of a participant's home asset value that is lost due to the wildfire event, N is the number of participants mitigating, and GMIT is the sum of all participants spending on "Mitigation" in the round. Based on (2) the effectiveness of GMIT increases as the number of individuals mitigating (N) grows. As before, participants use the sliders to form estimates of how spending on "Mitigation" and the number of participants undertaking mitigation will reduce the severity of a potential loss.

The home asset value on a round by round basis is a function of the severity of a wildfire event and the participant's insurance expenditures (Eq. (3)):

$$V_{r+1} = V_r - (V_r * LOSS + INS_i * 16) \quad (3)$$

where Vr + 1 is the value of a participant's home asset in the next round (r + 1), Vr is the value of a participant's home asset in the current round (r), LOSS is the proportion of a participant's home asset value that is lost due to the wildfire as determined by (2), and INSi is the number of $LAB the participant spent on the good "Insurance" in the round, which is then multiplied by the reimbursement to the home asset value. Recall that the LOSS value, as defined in (2), is a function of both the sum of mitigation expenditures (GMIT) made by other participants and the number (N) of participants undertaking mitigation actions. Thus, the home asset value of a participant is determined by the subject's actions and the mitigation behaviors of other participants.

A factorial experimental design is used; refer to Table 2 for a summary of the treatments. Noted in the previous section, we are interested in how the introduction of the simulated policy of fuel treatments taking place on adjacent public land influences participant behavior. Such a policy is simulated in the experiment by manipulating Eqs. (1) and (2). For treatments where mitigation has taken place on publicly owned land, N is increased by 4 to reflect simulated treatments on 4 parcels of public land and GMIT by $LAB 60,000 to simulate $LAB 15,000 of "Mitigation" spending on each of these 4 parcels. Additionally, we examine the influence of making participant spending decisions publicly known. In sessions implemented "With Information," participants could use the circular diagram to view the mitigation spending of others in the previous round; this is in contrast to sessions implemented "Without Information" where the circular diagram only showed the parcels and the participant's mitigation spending.

Once all of the rounds were complete the participants lab earning were converted to US dollars and displayed on screen. There were four components to participant earnings for the experiment: (1) the sum of a participant's spending on "Savings" for each round, (2) the participant's earnings from a risk elicitation task, (3) 50% of the participant's asset value at the conclusion of the experiment, (4) and a "show up" payment of five dollars.

On average, the experiment lasted 1 h and 15 min and subjects were paid $31.87 for their participation.

**Data analysis**

In all 22 sessions involving 244 subjects were completed, generating 2490 decisions for analysis. Given that there are multiple observations from each subject, panel estimation techniques were used. The econometric analysis assumes that participant behavior with respect to decisions over spending on wildfire risk mitigation in the experiment can be characterized by the following model:

**(4)**
$$\text{Spending} = f(X_{Treatment}, X_{Non\text{-}Treatment\text{-}Characteristics}, X_{Attitudinal\text{-}Description}, X_{Demographics})$$

where XTreatment is a vector of variables describing the experiment treatment invoked (e.g., public lands fuels reduction undertaken), XNon-Treatment-Characteristics is a vector of variables that control for differences in sessions or rounds not attributed to changes in experiment treatments, XAttitudinal-Description is a vector of variables characterizing participants' responses to a set of questions regarding risk and trust, and XDemographics is a vector of demographic variables.

Success for wildfire policy can be defined in several ways. As a result, the econometric approach uses several models. One possible policy goal is to increase the level of wildfire risk mitigation that WUI homeowners undertake. Proponents of this goal argue that because WUI homeowners accrue much of the benefit of wildfire risk mitigation, policy should focus on shifting more of the corresponding financial burden of providing these treatments to these individuals (O'Toole, 2006; USDA, 2006). The variable MIT is defined as the number of lab dollars a participant allocates to the good "Mitigation" in a round and is used as the dependent variable in the first of the estimated models. The spending of participant ion MIT is modeled as follows:

**(5)**
$$\text{MIT}_i = \alpha + \beta_1 X_{Treatment} + \beta_2 X_{Demographics} + \beta_3 X_{Attitudinal\text{-}Description} + \beta_4 X_{Non\text{-}Treatment\text{-}Characteristics} + e_i$$

where ˛ represents an intercept term, ˇ represents the estimable coefficients corresponding to the vectors of explanatory variables, and ei is an error term. Another perspective is that the policy objective should be more general, and that alongside increasing mitigation spending should be the goal of increasing private spending on insurance. Insurance has obvious benefits at an individual level and public benefits insofar as homeowners with adequate insurance coverage from private markets are less likely to require public assistance in the event of a disaster. The variables INSURANCE and TOTAL are created to reflect this possible goal. INSURANCE is the number of lab dollars a participant allocates to the good "Insurance" in a round and TOTAL is defined as the sum of INSURANCE and MIT within a round. The spending of participant i on TOTAL is modeled with Eq. (6):

**(6)** $$\text{TOTAL}_i = \alpha + \beta_1 X_{Treatment} + \beta_2 X_{Demographics} + \beta_3 X_{Attitudinal\text{-}Description} + \beta_4 X_{Non\text{-}Treatment\text{-}Characteristics} + e_i$$

where again ˛ represents an intercept term, ˇ represents the estimable coefficients corresponding to the vectors of explanatory variables, and ei is an error term.

Finally, increasing the number of homeowners that undertake mitigation is an additional potential policy goal. The variable MITDV is created to evaluate this objective. MITDV is a dummy variable coded as 1 where a participant undertakes some mitigation and 0 otherwise. Defining X as the groups of variables introduced above in XTreatment, XDemographics, XAttitudinal-Description, and XNon-Treatment Session Characteristics, and ˚as the standard normal cumulative distribution,9 the decision of whether to allocate any lab dollars to "Mitigation" is analyzed with random effects probit modeling (7):

**(7)** $$Pr(\text{MITDV}_i = 1 \,|X) = \Phi(X\beta)$$

For each model, multiple observations are taken from the same session. A concern is that the error terms for such observations are not independent. As a result, random effects modeling is used to analyze the data for each of the three models presented here.

By using three models that differ in dependent variables but are similar in the sets of regressors included in the specifications presented here, a framework is constructed to examine the impact of potential policy tools on a varied set of possible objectives.

Table 1 presents a list of the variables used in the modeling and descriptive statistics. The vector XTreatment is made up of a set of dummy variables that distinguish the sessions by the policy regime implemented. Table 2 provides descriptions of the treatments implemented in the experiment. Both of the policy tools are implemented in the experiment in two ways: once "with information" where participants have access to a map on the screen that provides a description of all participants' mitigation spending in the previous round, and one "without information," where participants' mitigation spending decisions are kept private.

Used for comparison against treatments where explicit policy tools are implemented, two variables designate the baseline case where no policy is invoked. BASEWO and BASEW are dummy variables coded as 1 where no policy tool is implemented (without and with information, respectively), and 0 otherwise.

The variable PL TREATED WO and PL TREATED W are dummy variables coded as 1 for sessions where the experimenter has simulated mitigation taking place on the public land (without and with information, respectively) and 0 otherwise.11 Fuel treatments on public land have in some instances been conditional on the commitment exhibited to the problem on surrounding private lands (Prante et al., 2007). An example is the community collaboration requirements of cost-share programs for treating public lands in the federal Collaborative Forest Restoration Program (CFRP) in New Mexico (Prante et al., 2007). The variables POSSIBLE PLT WO and POSSIBLE PLT W are created to analyze the effectiveness of making fuel treatment on public land contingent upon a threshold of private participation. The dummy variables POSSIBLE PLT WO and POSSIBLE PLT W are coded as 1 for treatments where the public land in the experiment is treated only if six or more participants undertake mitigation in the previous round (without and with information, respectively).

Transitioning to the control variables, the vector XNon-Treatment-Characteristics is a set of variables that distinguish session or round characteristics. The variable ROUND INC is defined as the number of lab dollars a participant receives at the outset of each round to allocate between "mitigation," "insurance," and "savings." The variable WEALTH is defined as the sum of a participant's "savings" through the current completed round. Within a session, the time elapsed since a wildfire occurred varies by round and has the potential to influence behavior. The variable FIREPREV is a dummy variable coded as 1 if a fire occurred in the previous round, 0 otherwise. The final two variables included in this category measure the level of interaction a participant exhibits with the software. DIAGRAM is a dummy variable coded as 1 where a participant decided to view a map that provided a more detailed description of the allocation decisions of others than is presented, and 0 otherwise. The variable SLIDER is a dummy

**Table 1 Variable descriptions and summary statistics (N = 2490).**

| Variable | Description | Mean (SD) |
|---|---|---|
| MIT | The number of lab dollars ($LAB) a participant spends on the good "Mitigation" in a round | 2463.11 (2697.71) |
| INSURANCE | The number of lab dollars ($LAB) a participant spends on the good "Insurance" in a round | 2486.87 (2332.82) |
| TOTAL | Sum of the number of lab dollars a participant spends on total risk reduction for both goods "Mitigation" and "Insurance" in a round | 4949.98 (3970.35) |
| MITDV | Dummy variable coded as 1 if a participant spends at least 1 lab dollar on the good "Mitigation" in a round, 0 otherwise | 0.86 (0.34) |
| BASE_WO | Dummy variable coded as 1 for sessions where no policy tool is implemented and subjects are not provided information describing the spending of their fellow participants, 0 otherwise | 0.19 (0.39) |
| BASE_W | Dummy variable coded as 1 for sessions where no policy tool is implemented and subjects are provided information describing the spending of their fellow participants, 0 otherwise | 0.19 (0.39) |
| PL_TREATED_WO | Dummy variable coded as 1 for sessions where the public land has been treated and subjects are not provided information describing the spending of their fellow participants, 0 otherwise | 0.12 (0.33) |
| PL_TREATED_W | Dummy variable coded as 1 for sessions where the public land has been treated and subjects are provided information describing the spending of their fellow participants, 0 otherwise | 0.17 (0.38) |
| POSSIBLE_PLT_WO | Dummy variable coded as 1 for sessions where contingent public land is invoked and subjects are not provided information describing the spending of their fellow participants, 0 otherwise | 0.18 (0.38) |
| POSSIBLE_PLT_W | Dummy variable coded as 1 for sessions where contingent public land is invoked and subjects are provided information describing the spending of their fellow participants, 0 otherwise | 0.14 (0.35) |
| ROUND_INC | The number of lab dollars a participant receives at the outset of the round | 13,248.81 (2683.99) |
| WEALTH | Sum of a participant's "Savings" from each completed round | 48,281.91 (33,490.30) |
| FIREPREV | Dummy variable coded as 1 if a fire occurred in the previous round, 0 otherwise | 0.19 (0.39) |

| | | |
|---|---|---|
| DIAGRAM | Dummy variable coded as 1 if during the experiment the participant clicked on the diagram providing more in depth information regarding the spending pattern of the group in the previous round, 0 otherwise | 0.24 (0.43) |
| SLIDER | Dummy variable coded as 1 if during the experiment the participant adjusted the slider that shows how the level of group spending changes the impact of the good "Mitigation," 0 otherwise | 0.77 (0.42) |
| RISKAV | Dummy variable coded as 1 for participant's whose choices in the risk aversion elicitation task indicate risk averse preferences, 0 otherwise | 0.66 (0.47) |
| TRUST | Dummy variable coded as 1 for participants who when asked the question "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?" selected the response "Most people can be trusted," 0 otherwise | 0.31 (0.46) |
| NTRUST | Dummy variable coded as 1 for participants who when asked the question "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?" selected the response "You can't be too careful," 0 otherwise | 0.36 (0.48) |
| T_INDEX | A constructed trust index from responses to the GSS "Trust Question." T_INDEX = TRUST-NTRUST | −0.05 (0.81) |
| FEMALE | Dummy variable coded as 1 if a participant is female, 0 otherwise | 0.40 (0.49) |
| AGE | Age of a participant | 22.27 (5.23) |
| EDUCATION | Number of years of schooling a participant has completed | 14.20 (2.45) |
| ANNUAL_INC | A participant's annual household income ($) | 32,409.64 (21,900.39) |
| HOMEOWNER | Dummy variable coded as 1 if a participant is a homeowner, 0 otherwise | 0.15 (0.35) |
| DEMOCRAT | Dummy variable coded 1 if a participant's political party is Democrat, 0 otherwise. | 0.19 (0.39) |
| REPUBLICAN | Dummy variable coded 1 if a participant's political party is Republican, 0 otherwise | 0.27 (0.44) |
| OTHERPARTY | Dummy variable coded 1 if a participant does not identify their political party as Democrat or Republican, 0 otherwise | 0.55 (0.50) |

**Table 2 Treatment table.**

| Treatment name | Land treatment policy tool | Description | Information describing the spending of other participants provided | Variable designation | Number of sessions |
|---|---|---|---|---|---|
| T1 | None | Baseline, without information: No land treatment policy tool is invoked | No | BASE_WO | 4 |
| T2 | None | Baseline, with information: No land treatment policy tool is invoked | Yes | BASE_W | 4 |
| T3 | Public land is treated | For each of the four parcels of public land, 15,000 lab dollars are added to the sum of all participants spending on "Mitigation" in the round | No | PL_TREATED_WO | 3 |
| T4 | Public land is treated | For each of the four parcels of public land, 15,000 lab dollars are added to the sum of all participants spending on "Mitigation" in the round | Yes | PL_TREATED_W | 4 |
| T5 | Public land treated contingent on participation | If at least 6 participants spent at least 1 lab dollar on "Mitigation" in the previous round, then for each of the four parcels of public land, 15,000 lab dollars are added to the sum of all participants spending on "Mitigation" in the round | No | POSSIBLE_PLT_WO | 4 |
| T6 | Public land treated contingent on participation | If at least 6 participants spent at least 1 lab dollar on "Mitigation" in the previous round, then for each of the four parcels of public land, 15,000 lab dollars are added to the sum of all participants spending on "Mitigation" in the round | Yes | POSSIBLE_PLT_W | 3 |

coded as 1 if a participant adjusted the slider corresponding to group “mitigation” to evaluate how the probability and severity of wildfire change with group spending on “mitigation” and 0 otherwise.

The vector XAttitudinal-Description is made up of variables that capture differences in participant responses to a set of questions after the experiment. Because participants are asked to make decisions that impact probabilities of an uncertain payoff, it is especially important to control for risk preferences. To this end, subjects participated in a widely used risk preference elicitation task (Holt and Laury, 2002). In this task, each made a series of choices between two payoff options, one providing a lower payoff with certainty and the other providing either a higher payoff or nothing at varying probabilities. The behavior of interest is at the point where the probability of getting the higher payoff increases such that a participant switches from preferring the sure payoff to the gamble. Using observed choices in this task as a measure of risk preferences, a dummy variable was constructed to sort participants by risk aversion. RISKAV is a dummy variable coded as 1 if a participant displayed risk-averse preferences in the risk elicitation task, and 0 otherwise. Results from this elicitation task are revealed after the wildfire experiment.

In addition to controlling for risk preferences, XAttitudinal-Description also includes a variable that controls for participants’ beliefs regarding social capital. The General Social Survey (GSS) is an extensive survey with the objective of collecting data to monitor and characterize trends in American culture. While the GSS has been used in addressing a variety of social science questions, it is increasingly being used in economics analyses involving collective action (Karlan, 2005). An index created from responses to a question from the GSS is used here as a proxy for social capital. The question put to participants was the GSS trust question, “Generally speaking, would you say that most people can be trusted or that you can’t be too careful in dealing with people?”15 Participants select one of six responses to the question that best describes their beliefs. A set of dummy variables has been created here to correspond with these responses. The variable TRUST is a dummy coded as 1 where a participant selects the option most consistent with well developed social capital (“Most people can be trusted”). The dummy variable NTRUST is coded as 1 where a participant selects the response most consistent with a lack of social capital (“You can’t be too careful”). These two variables are summed to construct a trust index. The variable T INDEX is defined as TRUST-NTRUST, so that the variable takes the value of a 1 for trusting participants, −1 for non-trusting participants, and 0 if the participant selected any of the other possible responses to the trust question (“It Depends,” “Don’t Know,” “No Answer,” or “Not Applicable”).

The vector XDemographics includes a set of control variables. Participants report demographic information at the conclusion of the experiment. FEMALE is a dummy coded as 1 if a participant identifies themselves as female, 0 otherwise. AGE is the age in years of the participant. The variable EDUCATION is the number of years of formal education. Not to be confused with their income earned in the experiment, the variable ANNUAL INC is defined as a participant’s annual income. HOMEOWNER is a dummy coded as 1 where a participant owns their home, 0 otherwise. XDemographics includes dummy variables that control for political party affiliation. DEMOCRAT and REPUBLICAN are dummy variables coded as 1 for membership in the identified party and 0 otherwise, and OTHERPARTY is a dummy coded as 1 for participants that do not identify their political party as Democrat or Republican, and 0 otherwise.

A summary of statistical hypotheses is presented in Table 3 and a summary of the results of these hypotheses is presented in Table 5. The expectation is that simulated policies of wildfire risk mitigation on public land will increase risk-mitigating behavior in the experiment for each of the three measure of success introduced previously (the level of spending on mitigation, the level of total protective spending, and the probability that a participant engages in mitigation). Additionally, a final hypothesis of the relationship between social capital (as measured by trust) and mitigation is presented. As with the expectations for the simulated policies, it is posited that social capital and mitigation expenditures are positively related. Each hypothesis is tested against a null hypothesis of no statistically significant influence relative to the baseline treatments.

**Table 3 Hypotheses.**

| Hypothesis | Description |
|---|---|
| H1: $\beta_{PL\_TREATED\_WO} > 0$ | Fuel reductions on public lands induce increased mitigation when implemented without making participant decisions known to the group |
| H2: $\beta_{PL\_TREATED\_W} > 0$ | Fuel reductions on public land induce increased mitigation when implemented in combination with making participant decisions known to the group |
| H3: $\beta_{POSSIBLE\_PLT\_WO} > 0$ | Fuel reductions on public land that are conditional on a threshold level of private mitigation induce increased mitigation when implemented without making participant decisions known to the group |
| H4: $\beta_{POSSIBLE\_PLT\_W} > 0$ | Fuel reductions on public land that are conditional on a threshold level of private mitigation induce increased mitigation when implemented in combination with making participant decisions known to the group. |
| H5: $\beta_{T\_INDEX} > 0$ | Participants with higher levels of trust will spend on mitigation and are more likely to engage in mitigation spending |

## Econometric results

Estimation results are presented in Table 4 and are organized according to the dependent variable analyzed. Results for MITDV are presented as Models 1A and 1B, for MIT, Models 2A and 2B, and for TOTAL, Models 3A and 3B. Trimmed and an extended specifications are presented for each of the three dependent variables used. Additional specifications were also evaluated, with results qualitatively consistent with the modeling presented here (available upon request). A Hausman test is used to evaluate the random effects modeling. For the extended specification using the dependent variable MIT (Model 2B), the chi-squared test statistic is −34.44, indicating that the estimated coefficients in the random effects model are statistically similar to the coefficients from a fixed effects model (known to produce consistent estimates).

For Models 1A and 1B, the results are mixed. The estimated coefficients for the variables PL TREATED WO and POSSIBLE PLT WO are positive but statistically significant for only one specification. This implies that when fuel reductions are simulated on publicly owned parcels and participant spending is kept private, subjects are not more likely to undertake risk mitigation than in the baseline session. Similarly, the statistically insignificant coefficients for BASE W indicate that making subject spending public did not, by itself, increase the probability of mitigation. However, simulating fuel reductions on publicly owned parcels is effective when participant spending is made public. The estimated coefficients for PL TREATED W and POSSIBLE PLT W are positive and statistically significant in 3 of 4 specifications presented. The results suggest that the likelihood of a subject engaging in risk mitigation increases when public fuel reductions were made in conjunction with information about mitigation efforts of other participants being provided. The estimated coefficient for T INDEX is not statistically significant for this set of models.

The marginal effects presented in brackets in Table 4 show the change in probability of undertaking risk mitigation as the variable of interest changes from 0 to 1. Marginal effects for this model are calculated as:

**(8)**
$$ME = \beta \hat{P}(1 - \hat{P})$$

The marginal effects for PL TREATED WO and PL TREATED W in the extended specification are relatively large, 0.06 and 0.11 respectively.

Of the control variables, the estimated coefficients for WEALTH and AGE are negative and statistically significant, suggesting that participants that have allocated more to “Savings” in previous rounds are older and less likely to undertake risk mitigation. The estimated coefficient for FEMALE is positive and significant indicating that female participants are more likely to undertake mitigation than the base case (males). The coefficients for the remaining control variables are not statistically significant.

As with the results discussed above, the impact of simulated fuel reductions on the level of participant spending is influenced by whether participants had information describing one another’s spending. Shown in Models 2A and 2B, the negative and significant coefficients for PL TREATED WO and POSSIBLE PLT WO (negative but not significant in the trimmed specification) suggest that spending

**Table 4 Random effects regression results (N = 2490).**

| | Model | | | | | |
|---|---|---|---|---|---|---|
| | 1A | 1B | 2A | 2B | 3A | 3B |
| | Dependent variable: MITDV | | Dependent variable: MIT | | Dependent variable: TOTAL | |
| BASE_W | −0.16 (−0.88) [−0.03] | −0.20 (−0.97) [−0.04] | −888.71 (−1.72)* | −1158.49 (−6.67)*** | −994.26 (−1.22) | −1092.53 (−4.73)*** |
| PL_TREATED_WO | 0.25 (1.18) [0.04] | 0.39 (1.74)* [0.06] | −946.68 (−1.68)* | −579.01 (−3.12)*** | −1997.14 (−2.26)** | −1558.30 (−6.32)*** |
| PL_TREATED_W | 0.76 (3.68)*** [0.11] | 0.89 (3.86)** [0.11] | −419.58 (−0.81) | −242.17 (−1.27) | −1167.22 (−1.43) | −822.38 (−3.22)*** |
| POSSIBLE_PLT_WO | 0.29 (1.48) [0.05] | 0.33 (1.62) [0.05] | −265.66 (−0.51) | −359.51 (−2.10)*** | −461.10 (−0.57) | −382.23 (−1.69)* |
| POSSIBLE_PLT_W | 0.35 (1.64)* [0.06] | 0.26 (1.14) [0.04] | 1027.11 (1.84)* | 412.56 (2.13)** | 1246.90 (1.42) | 715.68 (2.77)*** |
| ROUND_INC | – | 1.69e−5 (1.00) [0.00] | – | 0.05 (2.23)** | – | 0.15 (4.86)*** |
| WEALTH | – | −8.54e−6 (−7.15)*** [−0.00] | – | −0.04 (−25.87)** | – | −0.06 (−30.57)*** |
| FIREPREV | – | 0.01 (0.07) [0.00] | – | 38.40 (0.29) | – | 542.54 (2.91)*** |
| DIAGRAM | – | 0.04 (−0.40) [−0.01] | – | 362.09 (2.86)*** | – | 476.66 (2.66)*** |
| SLIDER | – | 0.43 (5.59)*** [0.09] | – | 366.14 (3.36)*** | – | 198.88 (1.29) |
| RISKAV | – | −0.06 (−0.77) [−0.01] | – | −541.73 (−5.56)*** | – | −452.02 (−3.30)*** |
| T_INDEX | – | 0.05 (1.09) [0.01] | – | 161.56 (2.76)*** | – | 388.86 (4.71)*** |
| FEMALE | – | 0.51 (6.27)*** [0.08] | – | −218.98 (−2.28)** | – | −387.66 (−2.87)*** |
| AGE | – | −0.03 (−4.36)*** [−0.01] | – | −58.98 (−5.85)*** | – | 2.08 (0.15) |
| EDUCATION | – | 0.10 (6.26)*** [0.02] | – | 11.36 (0.55) | – | −77.14 (−2.65)*** |
| HOMEOWNER | – | 0.16 (1.30) [0.03] | – | 494.34 (3.49)*** | – | 37.77 (0.34) |
| ANNUAL_INC | – | −2.55e−6 (−1.45) [−0.00] | – | −1.20e−3 (−0.53) | – | −2.64e−3 (−0.83) |
| REPUBLICAN | – | 0.10 (0.11) [0.00] | – | 334.40 (2.96)*** | – | 326.14 (2.05)** |
| DEMOCRAT | – | −0.13 (−1.30) [−0.02] | – | 122.49 (0.99) | – | 242.41 (1.39) |
| CONSTANT | 0.94 (7.14)*** | 0.17 (0.45) | 2710.33 (7.39)*** | 5020.51 (10.30)** | 5477.50 (9.51)*** | 7514.90 (11.01)*** |
| Log Likelihood | −943.72 | −842.83 | – | – | – | – |
| Wald Chi squared | – | – | 15.51*** | 1154.53 | 14.66 | 1505.66*** |

**Table 5 Summary of hypotheses. The influence of the policy tool on the dependent variable is listed in each cell.**

| Hypothesis | Model | | | | | |
|---|---|---|---|---|---|---|
| | 1A | 1B | 2A | 2B | 3A | 3B |
| | Dependent variable: MITDV | | Dependent variable: MIT | | Dependent variable: TOTAL | |
| $\beta_{PL\_TREATED\_WO} > 0$ | Insignificant | Positive* | Negative* | Negative*** | Negative** | Negative*** |
| $\beta_{PL\_TREATED\_W} > 0$ | Positive*** | Positive** | Insignificant | Insignificant | Insignificant | Negative*** |
| $\beta_{POSSIBLE\_PLT\_WO} > 0$ | Insignificant | Insignificant | Insignificant | Negative*** | Insignificant | Negative* |
| $\beta_{POSSIBLE\_PLT\_IW} > 0$ | Positive* | Insignificant | Positive* | Positive** | Insignificant | Positive*** |
| $\beta_{T\_INDEX} > 0$ | Not applicable | Insignificant | Not Applicable | Positive*** | Not Applicable | Positive*** |

on fuel reductions on publicly owned parcels is replacing private spending. As observed elsewhere (McKee et al., 2004; Berrens et al., 2007), subjects in these sessions spent less on risk mitigation than their counterparts in baseline sessions. Significantly though, providing information about the mitigation expenditures of other group participants ameliorates the crowding out. The estimated coefficients for PL TREATED W are not statistically significant. It appears that the addition of information about participant mitigation expenditures mutes the negative influence observed in the PL TREATED WO sessions. Further, the estimated coefficients for POSSIBLE PLT W are positive and statistically significant. The behavior observed here suggests that a policy of making fuel reductions on publicly owned parcels contingent on private spending can successfully induce private risk mitigation when information about the mitigation efforts of other individuals is made available. There is a positive and statistically significant coefficient for T INDEX, indicating that participants that are more trusting spend more on risk mitigation than their counterparts.

Of the control variables included in Models 2A and 2B, the estimated coefficients for WEALTH, RISKAV, AGE, and FEMALE are negative and significant. The estimated coefficients for DIAGRAM, SLIDER, T INDEX, HOMEOWNER, and REPUBLICAN are positive and significant. The coefficients for the remaining control variables are not statistically significant for this set of models.

Simulated fuel reductions on publicly owned parcels did influence mitigation total protective spending (TOTAL).18 In Models 3A and 3B, estimated coefficients for PL TREATED WO and POSSIBLE PLT WO are negative and statistically significant in 3 of 4 models. This finding indicates that the policy tool has reduced private spending. As evidenced by the positive and significant estimate on POSSIBLE PLT W, crowding out is offset when information about participant mitigation expenditures is provided in conjunction with fuel reductions on public parcels. As before, the negative and significant coefficient for BASE W suggests that it is the combination of fuel reductions and the provision of mitigation information, rather than fuel reduction or information alone, which generates increased mitigation spending. Participants that are more trusting spend higher amounts on mitigation and insurance in sum as shown by the significant positive coefficient for T INDEX.

Of the control variables in Model 3B, the estimated coefficients for ROUND INC, FIREPREV, DIAGRAM, T INDEX, and REPUBLICAN are positive and statistically significant. The estimated coefficients for WEALTH, RISKAV, FEMALE, and EDUCATION are negative and significant. The coefficients for all other variables are not statistically distinct from zero in these models.

**Discussion and conclusions**

The objective of this paper is to analyze the effectiveness of providing fuel reduction on adjacent publicly owned lands at increasing private spending on wildfire risk mitigation. Using the observed decisions of participants as a policy guidepost, several observations stand out.

The results suggest that policy tools intending to induce WUI homeowners to engage in risk mitigation have the potential to reduce private spending. This effect is identified both for treatments that simulate risk mitigation taking place on public lands irrespective of private behavior and for treatments that offer risk mitigation on public lands conditional upon a sufficient number of individuals undertaking private risk mitigation. In this light, particular care should be taken in policy design to avoid the crowding out of private spending on risk mitigation.

Importantly, the estimated models reveal a specific antidote for this unintended effect: disseminating particular information on the behavior of others sharing the same risk externality. Behavior in the experiment is influenced by both simulated fuel reductions on public land and the provision of information. Robust across multiple models and specifications, we find that when implemented alongside a policy of fuel reductions on public lands, providing participants with information describing each other's mitigation decisions dampens the degree to which private spending is reduced. In addition, when this information is provided along with a policy of contingent fuel reduction on public lands, participants increase their spending on wildfire risk mitigation. Similar impacts in different experimental settings have been found elsewhere. Shang and Croson (2009) found that social information increased voluntary contributions to a public radio station. Like Shang and Croson (2009), our explanations as to why this occurs are speculative and the subject for future research.

Because programs like New Mexico's federal Collaborative Forest Restoration Program (CFRP) [and by inference the newly initiated, national-level Forest Landscape Restoration Program (FLRP)] are costly to implement relative to standard fuels reduction efforts, whether they generate spillover mitigation on adjacent private lands is an important consideration. That is, attempting to develop social capital by adding collaboration and community-capacity building requirements to fuels reduction projects (or funding opportunities) increases project costs, but may generate important spillover benefits. Shepherd et al. (2009) provide recent evidence that relative to other National Fire Plan fuels reduction projects, CFRP projects in New Mexico exhibit significantly improved social equity effects by better targeting poor communities, with no identifiable loss in risk targeting. This supports the potential of such programs to induce increased private mitigation. However, given that participants in the experiment increase mitigation spending only when information is provided in conjunction with providing fuel reductions on public lands that are conditional on private participation, we find both that both aspects of the policy prescription are important.

Providing fuel treatments on publicly owned lands has a disparate influence on seemingly similar measures of mitigating behavior. This can be observed in the results from sessions where fuel reductions took place without information about private mitigation efforts being provided (PL TREATED WO). Here, the policy tool increases the probability that a participant will undertake some mitigation but decreases the level of spending on mitigation. It is therefore possible to increase the number individuals engaging in wildfire risk mitigation (e.g., possibly through a demonstration effect) while at the same time decreasing the total level of mitigation (e.g., a possible crowding out effect). Given the spatial complexities of wildfire risk, it is not obvious whether the negative impact of decreased aggregate expenditures outweighs the positive impact of more people mitigating. Results suggest that policymakers may have to prioritize among policy objectives, weighing the potential gains associated with more individuals undertaking wildfire risk mitigation with costs associated with a reduction in the total level of risk mitigation that takes place.

Finally, the importance of information dissemination in observed mitigation decisions underscores the idea that social factors are critical in analyzing the “Mitigation Paradox.” It has been suggested that developing social capital in forest communities is a worthwhile goal of policy, insofar as increased social capital can lead to increased levels of participation and/or private spending on wildfire risk mitigation. Again, this idea appears to be at least part of the motivation behind community forestry-based cost-share programs (e.g., CFRP and FLRP). The observed behavior here that higher levels of trust are a positive determinant of mitigation spending suggests that developing social capital is a worthwhile endeavor for policy.

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