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Cost shared wildfire risk mitigation in Log Hill Mesa, Colorado: survey evidence on participation and willingness to pay

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Abstract. Wildland–urban interface (WUI) homeowners who do not mitigate the wildfire risk on their properties impose a negative externality on society. To reduce the social costs of wildfire and incentivise homeowners to take action, cost sharing programs seek to reduce the barriers that impede wildfire risk mitigation. Using survey data from a WUI community in western Colorado and a two-stage decision framework, we examine residents' willingness to participate in a cost sharing program for removing vegetation on their properties and the amount they are willing to contribute to the cost of that removal. We find that different factors motivate decisions about participation and about how much to pay. Willingness to participate correlates with both financial and non-monetary considerations, including informational barriers and wildfire risk perceptions, but not with concerns about effectiveness or visual impacts. Residents of properties with higher wildfire risk levels are less likely to participate in the cost sharing than those with lower levels of wildfire risk. We find widespread, positive willingness to pay for vegetation removal, with the amount associated negatively with property size and positively with respondent income. These results can inform the development of cost sharing programs to encourage wildfire risk mitigation on private property.

Additional keywords: contingent valuation, homeowner risk mitigation, non-market valuation, risk perceptions, two-stage decision model, wildland–urban interface.

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Introduction

Recently, wildfires in the western US have increased in frequency and size (Westerling *et al.* 2006; Balshi *et al.* 2009; Litschert *et al.* 2012). Wildfire severity and frequency are expected to continue increasing throughout much of the world (Liu *et al.* 2010), including western Colorado (Litschert *et al.* 2012). Meanwhile, the wildland–urban interface (WUI) is growing faster than the general US population (Radeloff *et al.* 2005; Theobald and Romme 2007). As a result, more people and homes are being exposed to wildfire.

Producing and maintaining 'defensible space' around residential structures, in which combustible material is minimised, helps to reduce wildfire risks to WUI residents and their property (Cohen 2000). Many institutions and agencies offer cost sharing subsidies in an attempt to encourage defensible space on private property (Reams *et al.* 2005; Haines *et al.* 2008; Duerksen *et al.* 2011). However, despite widespread implementation, little empirical evidence supports the effectiveness of such programs in encouraging risk reduction behaviours.

This article addresses this shortcoming by evaluating the efficacy of cost sharing intended to encourage vegetation reduction around the home, using survey data from a western Colorado WUI community. We investigate reported participation and willingness to pay (WTP) for cost sharing for vegetation reduction on private property and how participation and WTP relate to potential barriers to implementing defensible space. We consider potential barriers identified in the literature on wildfire risk mitigation, including resident risk perceptions and self-reported barriers including costs, information and perceived effectiveness of actions. Because these data are paired with parcel level wildfire risk assessments conducted by a wildfire specialist, we can also examine how a resident's parcel-level wildfire risk rating is related to both participation in

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and WTP for the cost sharing program. Results of this study can inform the development and improvement of cost sharing as a tool to encourage wildfire risk mitigation on private property.

The remainder of the article is organised in sections. The first section reviews relevant literature and the second section introduces the analytical model. A third section describes the survey and its results, followed by a section presenting modelling results. The fifth section concludes.

Literature review

A primary means for wildfire risk reduction on private property is the creation and maintenance of defensible space. Fire behaviour modelling, experiments and case studies indicate that '...a home's structural characteristics and its immediate surroundings determine a home's ignition potential in a WUI fire', with defensible space being a key to reducing fire losses in the WUI (Cohen 2000, p. 20; Duerksen *et al.* 2011; CSFS 2012). The difficulty of quantifying wildfire risk (Finney 2005; Thompson and Calkin 2011), let alone estimating the effect of mitigation on wildfire probability or consequences, complicates calculating the expected value of defensible space. However, many post-wildfire investigations have found that defensible space reduced wildfire risks to property (e.g. Abt *et al.* 1987; Bhandary and Muller 2009; Botswick *et al.* 2011; Boulder County 2011; Bracmort 2012).

As a means to reduce the social costs of wildfire, wildfire risk reduction on private property often receives public support. The US Congressional Research Service (CRS) recommends increased support for related programs, including cost sharing assistance to homeowners, as a likely 'cost-saving federal investment' (Bracmort 2012, p. 5) in part because of the large governmental role in funding wildfire suppression and recovery. A recent review found 184 state, county and local programs for wildfire risk mitigation across the US (Haines *et al.* 2008), consisting of such components as general education, demonstration projects, wildfire risk assessments, risk mapping, regulatory programs and direct homeowner assistance in such forms as fuels reduction prescriptions, project cost sharing and debris chipping or disposal. Such programs often emphasise parcel-level mitigation in the form of defensible space or vegetation thinning (Duerksen *et al.* 2011).

Programs also often include cost sharing as a means to incentivise WUI homeowners to mitigate wildfire risks on their properties. Approximately half of the wildfire risk programs found by Haines *et al.* (2008) subsidise fuel treatments at least partially. In 2003, wildfire program managers most often mentioned cost sharing or free treatments when asked their 'most effective program activity for creating defensible space' (Reams *et al.* 2005). However, despite this widespread implementation, empirical research offers limited and mixed support for understanding how, and under what circumstances, cost sharing encourages risk mitigation behaviour. Economic experiments have found that subjects role-playing WUI homeowners increase hypothetical expenditures on risk mitigation activities in the presence of cost sharing, but disaster recovery programs and insurance coverage reduce this increase (McKee *et al.* 2004; Berrens *et al.* 2007). A similar experiment found participants responding to costs when choosing levels of risk protection, but only when given feedback about outcomes in repeat games and not in a simple descriptive choice (Shafran 2011). Simulations of private forest owners show complex effects, such as cost sharing sometimes inducing more fuel reduction than socially desired, landowner behaviour being unaffected by cost sharing in some situations, and risk-adjusted insurance being ineffective when government suppression exists (Amacher *et al.* 2006; Busby *et al.* 2013).

Such results, based on subjects in economic experiments, do not necessarily reflect the wildfire risk decisions of actual WUI residents, which are complex and have been linked to many different considerations (e.g. McFarlane *et al.* 2011; McCaffrey *et al.* 2013). Cost sharing depends on positive homeowner WTP for reducing wildfire risk on private property, and although research has found WTP ranging from \$140 to \$800 per year per respondent for wildfire risk reduction programs on nearby public lands (Loomis *et al.* 2005; Kaval *et al.* 2007; Walker *et al.* 2007), estimates for private lands are mixed. Fried *et al.* (1999) find a median WTP of \$200–500 per year for undertaking a risk reduction action on the respondent's property, whereas Holmes *et al.* (2009) find respondents neutral between fuel reduction on their own property and the status quo (in contrast to a WTP of \$550 per respondent for a 10-year fuel reduction program on public lands). Risk perceptions also play an important role in decisions about mitigation. Although higher perceptions of wildfire risk are often linked to greater willingness for wildfire risk mitigation (e.g. Talberth *et al.* 2006; Martin *et al.* 2009; Brenkert-Smith *et al.* 2012; Champ *et al.* 2013; McNeill *et al.* 2013), research finds that people in WUI communities often underestimate the wildfire risks on their property (Cohn *et al.* 2008; Champ *et al.* 2009; Gordon *et al.* 2010), including the community discussed in this paper (Meldrum *et al.* 2013). Relatedly, providing property-specific information has been found to affect risk perceptions and the willingness to address risk (Donovan *et al.* 2007; Champ *et al.* 2009; Winter *et al.* 2009; Brenkert-Smith *et al.* 2012).

However, understanding risk does not necessarily lead to risk reduction. Many surveys find perceived ineffectiveness to be a barrier to implementing wildfire mitigation measures (Winter *et al.* 2002; Talberth *et al.* 2006; Martin *et al.* 2007; Hall and Slothower 2009; Absher and Vaske 2011; Brenkert-Smith 2011). Finances often constrain the ability to implement mitigation, regardless of interest in such actions (Collins 2008; Winter *et al.* 2009; McFarlane *et al.* 2011; Brenkert-Smith *et al.* 2012; Meldrum *et al.* 2013). Time and physical difficulties also constrain mitigation in some communities (Meldrum *et al.* 2013) but not in others (Brenkert-Smith *et al.* 2012). In decision-making about fuels reduction, residents trade off between the benefits of reduced wildfire risks and such private costs as aesthetic impacts on the landscape (Winter and Fried 2000; Nelson *et al.* 2004; Brenkert *et al.* 2005; Collins 2005; Nelson *et al.* 2005; Talberth *et al.* 2006; Cohn *et al.* 2008; Holmes *et al.* 2009; Schulte and Miller 2010). In summary, many complexities, including resident risk perceptions, self-reported barriers to mitigation and assessed risk levels, might be expected to influence the role of cost sharing in encouraging defensible space.

Two-stage model of participation decision

Here, we investigate the potential influence of such complexities on cost sharing for wildfire risk mitigation on private property in a western Colorado WUI community. We model decisions about participation in cost sharing and the WTP for wildfire risk mitigation as a rational decision in which costs and benefits are weighed. We use Bhat's (1994) model for imputing a continuous variable from grouped data in the presence of substantial item non-response. This model estimates the values underlying respondents' choices from a set of possible WTP values, while accounting for a potentially large proportion of unobserved choices due to 'no' responses. Following Brox *et al.* (2003) and Collins and Rosenberger (2007), we employ this model to jointly estimate a dichotomous choice (i.e. a yes or no question), participation response and the maximum WTP response chosen from a payment card that provides a range of potential cost shares. Our model accounts for the possibility that WTP might relate to willingness to participate, yet the explanatory variables might relate to these two decisions in different ways. This approach combines Winter and Fried's (2001) use of Cragg's (1971) model for estimating a two-stage model of support for collective wildfire protection with Cameron and Huppert's (1989) non-linear maximum likelihood techniques for modelling interval data. This approach is appropriate because it accommodates the two types of information available (i.e. participation and WTP) while avoiding Heckman selection models' problems of the potential endogeneity of selection in the valuation equation (Strazzera *et al.* 2003). In addition, computational complexity, the main reason to not use full information maximum likelihood models such as this (Strazzera *et al.* 2003), is ameliorated by their inclusion in packaged modelling software.

Specifically, we assume respondent i decides whether to participate in the cost sharing program ($D_i = 1$) or not ($D_i = 0$) based on a vector of exogenous variables X_{Di} expected to influence participation (including respondent and property characteristics, measures of current risk and barriers impeding respondents from undertaking risk mitigation), weighted by coefficients β_D, and an idiosyncratic error term ε_{Di}, as described by a standard probit model for a binary outcome:

$$D_i^* = \beta_D' X_{Di} + \varepsilon_{Di}, \begin{cases} D_i = 1 \text{ if } D_i^* > 0 \\ D_i = 0 \text{ if } D_i^* \leq 0 \end{cases}$$

where D_i^* represents respondent i's unobservable propensity to state a willingness to participate in the cost sharing program. Respondent i also decides the (unobserved) level of participation W_i^*,which in our context refers to the true WTP per acre for vegetation reduction through the cost sharing program. This amount is determined by the linear combination of a vector of exogenous variables X_{Wi}, weighted by coefficients β_W, and an idiosyncratic error term ε_{Wi}:

$$W_i^* = \beta_W' X_{Wi} + \varepsilon_{Wi}$$

The 'payment card' responses are analysed as interval data using a maximum likelihood model (Cameron and Huppert 1989) that assumes a respondent circles offer amount a_j from the payment card if W_i^* is between a_j and a_{j+1}. The combined model places no constraint on the relationships among coefficients β_D and β_W, regardless of any similarity between X_D and X_W, but error terms are modelled with a bivariate normal joint distribution with a correlation coefficient of ρ.

We estimate this model with NLOGIT software's 'grouped data with sample selection' command. This estimates the likelihood function shown in appendix A of Collins and Rosenberger (2007) and originally by Bhat (1994). It also uses eqns 5 and 6 in Collins and Rosenberger (2007) to calculate W_i^*, the estimate of the unobservable WTP for wildfire mitigation per acre for respondent i, regardless of whether $D_i = 1$ or $D_i = 0$.

Data from Log Hill Mesa, Colorado

Research setting

We analyse data collected by the West Region Wildfire Council (WRWC) in the Log Hill Mesa Fire Protection District (LHMFPD) of Ouray County, Colorado. LHMFPD covers a 65 square mile (16 800 ha) WUI community with substantial property values at risk of wildfire, including more than 600 primary residential structures (WRWC 2012). Wildfires occur frequently in LHMFPD, with an average of three wildfires reported each year between 1989 and 2010 (WRWC 2012). Modelling of the fire risk by environmental variables predicts a spatially explicit, relative probability of wildfire in the LHMFPD that ranges between 10 and 36%, with a mean probability of 20%, as compared against the probability of wildfire across the entire western US (Parisien *et al.* 2012). Reflecting the district's high probability of wildfire and concentrated social and economic values, WRWC recently developed a community-level Community Wildfire Protection Plan (CWPP) for LHMFPD (WRWC 2012) as a focussed addendum to Ouray County's CWPP, in collaboration with numerous agencies including relevant fire departments, the Colorado State Forest Service and the Montrose Interagency Fire Management Unit.

To further its mission of mitigating the threat of catastrophic wildland fire in six counties in western Colorado, WRWC subsidises vegetation reduction on private property. At the time of data collection, WRWC offered up to 90% of the costs for implementing defensible space through a 90/10 cost-share reimbursement, as well as up to 90/10 cost-share for curbside chipping for removing yard waste. Participation was limited by available funding; 32 properties participated in defensible space cost sharing in either 2011 or 2012 resulting in wildfire risk mitigation on 104 acres (42.1 ha) out of 8538 acres (3455 ha) in total of assessed private property in the LHMFPD. These programs were subsequently adjusted to a maximum 75/25 cost share, but only after all data for this study were collected.

Data sources

We analyse data collected by WRWC as part of the CWPP process. In June 2012, the WRWC mailed a survey and postage-paid return envelope to the current mailing address for all residential properties in the LHMFPD with a structure of at least 800 square feet (74 m^2). Two follow-up mailings were sent to addresses from which responses were not received. Of the 608 surveys initially mailed, 140 were undeliverable and 291 were returned completed by February 2013, for a total response rate of 62% (291 ÷ (608 – 140)). The survey, described in more detail elsewhere (WRWC 2012; Meldrum *et al.* 2013), was developed with standard procedures (Champ 2003) including focus grouping to refine survey content and assurances that participation was voluntary and confidential.

WRWC also conducted a wildfire risk assessment of the same properties, also described by Meldrum *et al.* (2013). Parcels were given an overall wildfire risk rating by a wildfire specialist, based on 10 attributes that address structure survivability during a wildfire event and considerations such as firefighter access and evacuation potential. In addition to a property's aggregated wildfire risk, this assessment provides the defensible space variable, which reports the distance from the house to overgrown, dense or unmaintained vegetation. Ouray County Assessor's Office's publicly available files provided property lot size and house size data. The analysis below focuses on the 217 properties for which the individual variables of all estimated models are available and matched across data sources.

Property and respondent characteristics

The survey population was residents of the LHMFPD. Survey-reported demographics were consistent with US Census Bureau statistics for Loghill Village Census Designated Place (CDP) (a subset of the LHMFPD with 345 housing units in 2010), with the exception that more males (63%) responded than females *v.* an expected near gender balance. Like Loghill Village CDP residents in general, respondents on average were more highly educated than residents in Ouray County, the state of Colorado, or the US, and they were also skewed towards higher income brackets. Nearly half of the respondents were retired (49%), versus 29% employed full-time, 15% part-time and 7% unemployed; this is consistent with Census estimates of 50% not in the labour force, 39% with Social Security income, and 31% with retirement income. Although renters were included in the sampled population, most respondents (94%) owned their residence in LHMFPD. Analysis of the matched datasets found no meaningful difference in overall wildfire risk ratings between survey respondents and non-respondents (Meldrum *et al.* 2013).

Column 1 of Table 1 shows descriptive statistics for those respondents for which all variables included in the model were available (hereafter referred to as 'respondents'), scaled to similar orders of magnitude. The average age is ~62 years old and annual income averages ~\$80 000 (exp(4.39) × 1000). Homes average 2870 square feet (266 m^2), with lot sizes averaging nearly 11 acres (4.5 ha) and ranging up to 160 acres (64.7 ha), with a median of 5 acres (2 ha). All risk rating categories are represented by the respondents, but the majority of properties (67%) are assessed at 'high' overall wildfire risk. Less than 10% of responding properties had more than 150 feet (46 m) of defensible space at the time of the assessment; half of respondents' properties had between 10 and 30 feet (3.0 and 9.1 m) of defensible space. Points, assigned according to the relative level of wildfire risk, convert categorical risk measures into the continuous RiskScore and DefensibleSpace variables. The WRWC had implemented an actual cost sharing program in 2011 and 2012, in which 11 respondents had participated resulting in a total of 31.25 acres (12.6 ha) treated.

Residents' risk perceptions

Respondents rated, on a scale from 0 to 100, their expectations regarding the risks and consequences of wildfire on their properties. The average reported expectation was a 33% chance of a wildfire on one's property in the year of the survey; ~10% stated a 50% or greater chance of this happening (Table 1). In the event of wildfire, respondents expected, on average, their home to be destroyed with 50% probability. The joint probability (JointProb), calculated by multiplying each respondent's two ratings together, shows an average belief of an ~1 in 5 chance that one's home would be destroyed by a wildfire in the year of the survey; ~5% of respondents think this will occur with 50% or greater probability.

Barriers to risk mitigation

The survey included questions about barriers: considerations that keep residents from reducing wildfire risk on their properties. Respondents selected all items they agreed with on the list shown on the bottom panel of Table 1. Financial and physical difficulties were most frequently selected (~40% of respondents each), followed by a lack of information about yard waste removal after vegetation reduction, the time it takes to do the work and the visual impact of the activities (~30% of respondents each). Fewer respondents claimed that the lack of effectiveness of risk reduction actions (17%) or a lack of awareness of risk (8%) kept them from undertaking mitigation.

Because of the similarities among individual items, we construct factor scores for common variation in responses to the barrier questions for further analysis. Table 2 shows factor loading vectors, constructed by maximum likelihood estimation with varimax rotation. Based on the items most strongly loaded upon each factor, we label these BF1: costs (representing primarily financial, physical and time constraints), BF2: information (representing primarily information about vegetation removal and treatment options, as well as risk awareness) and BF3: effectiveness (almost exclusively representing the effectiveness measure). The uniqueness statistics shown in the last column of Table 2 present a measure to which each input variable's variation is not represented in the set of factor scores; higher scores, as for B5_Visual, reflect greater independence from the set of factor scores.

Willingness to participate in and pay for cost sharing for wildfire risk mitigation

Survey respondents replied yes or no to the following question:

> While costs vary, the average cost to a homeowner of having a contractor remove vegetation to reduce wildfire risk is approximately \$1000 per acre. If your property is less than 1 acre, the average cost to reduce risk on the entire property is approximately \$1000. If a grant program paid for a share of the cost of this work on your property, would you participate in the program?

Respondents answering 'yes' were asked to 'Please circle the highest amount that you would be willing to pay per acre to have a contractor remove vegetation.' Payment choices were \$0, \$200, \$400, \$600, \$800 and \$1000, with each possible response also displaying the corresponding amount that the cost sharing grant would provide towards the mitigation on their property (i.e. \$1000 minus the payment choice).

Table 1. Descriptive statistics for model variables, combined and separated by answer to participation question

Table displays means and standard deviations (in parentheses) or percentage of respondents in each category or agreeing with each item, as appropriate. Note: asterisks designate significance of two-tailed *t*-test comparing variable means for Participate = Yes *v.* Participate = No: *, $P < 0.10$; **, $P < 0.05$; ***, $P < 0.01$

	All respondents		Participate = Yes		Participate = No		Significance
n	217		182		35		
Lot size (ha)	4.41	(7.24)	3.97	(5.71)	6.84	(12.42)	**
House size (m^2)	267	(112)	267	(113)	268	(101)	
ln(Income)	4.39	(0.69)	4.38	(0.69)	4.45	(0.66)	
Age (years)	61.9	(11.1)	61.5	(11.1)	63.7	(11.0)	
Gender (1 = female; 0 = male)	0.37	(0.49)	0.38	(0.49)	0.32	(0.47)	
Participated in previous cost sharing programs	5%		6%		0%		
Resident-rated chance of … (mean stated chance shown)							
Wildfire on property this year	33%	(20%)	35%	(20%)	27%	(21%)	**
House destroyed if wildfire on property	49%	(27%)	51%	(26%)	40%	(29%)	**
Wildfire on property AND house destroyed [JointProb]	19%	(18%)	20%	(18%)	13%	(15%)	**
Professional-assessed overall risk rating (percentage in each category shown)							
Low risk	9%		9%		9%		
Moderate risk	12%		13%		9%		
High risk	67%		68%		60%		
Very high risk	10%		8%		17%		
Extreme risk	3%		2%		6%		
RiskScore (mean score shown)	2.22	(0.59)	2.19	(0.57)	2.40	(0.66)	**
Professional-assessed defensible space distance from home (percentage in each category shown)							*
>150 feet (45.7 m) (0 points)	9%		8%		11%		
31–150 feet (9.4–45.7 m) (50 points)	30%		31%		29%		
10–30 feet (3.0–9.1 m) (75 points)	50%		52%		40%		
<10 feet (3.0 m) (100 points)	11%		9%		20%		
'Please tell us if each item listed below is a factor that keeps you from undertaking actions to reduce the wildfire risk on your property.' (percentage agreeing with each statement shown)							
B1_Financial: financial expense or cost	41%		47%		12%		***
B2_Physical: physical difficulty of doing the work	40%		45%		13%		***
B3_RemovalInfo: lack of information about or options for removal of slash or other materials from thinning trees and other vegetation	32%		36%		9%		***
B4_Time: time it takes to do the work	31%		35%		9%		***
B5_Visual: do not want to change the way your property looks	28%		27%		32%		
B6_TreatInfo: lack of specific information on how to reduce wildfire risk on your property	22%		26%		3%		***
B7_Effectiveness: lack of effectiveness of risk reduction actions	17%		18%		10%		
B8_RiskAware: lack of awareness of wildfire risk	8%		8%		3%		

Table 2. Factor loadings and uniqueness values for barrier (top panel) and incentive (bottom panel) factor variables

	BF1: costs	BF2: information	BF3: effectiveness	Uniqueness
B1_Financial	0.64	0.27	0.11	0.50
B2_Physical	0.90	0.06	0.07	0.18
B3_RemovalInfo	0.32	0.64	0.04	0.49
B4_Time	0.57	0.27	0.02	0.60
B5_Visual	0.13	0.15	0.16	0.93
B6_TreatInfo	0.19	0.61	0.14	0.57
B7_Effectiveness	0.03	0.15	0.99	0.01
B8_RiskAware	0.06	0.56	0.13	0.66

Participation descriptive statistics

As Table 1 shows, 182 respondents (84% of 217) responded 'yes' to participating in cost sharing, including all respondents who participated in the actual cost sharing programs of 2011 and 2012. All variables in Table 1 are statistically indistinguishable for actual participants *v.* other respondents at a 10% confidence level. Table 3 presents the percentage of respondents for each maximum WTP category and shows the cumulative percentage at each increasing increment of offered grant funding. Of those respondents saying 'yes' to the participation question, more than half (52%) indicated a WTP more than \$0 per acre but less than \$600 per acre. All WTP categories were represented, meaning some participants (16%) claimed they would participate but not be willing to pay anything (thereby requesting that WRWC pay the full \$1000 per acre) whereas others (8%) claimed they would participate yet be willing to pay up to \$1000 per acre (thereby requesting no grant money).

Table 1 compares descriptive statistics for the groups responding either 'yes' or 'no' for the participation question; the final column depicts whether the difference between groups is statistically significant for each variable. Demographics between the two groups do not statistically differ, except that 'no' respondents have larger lot sizes on average. 'Yes' respondents provided higher average probabilities for all three self-evaluated wildfire risk measures. The professional's measures of overall risk and defensible space distance both differ significantly across groups, with the two highest overall risk categories (Very High Risk and Extreme Risk) and the highest risk category for defensible space (Less than 10 feet) both more prevalent for 'no' respondents than for 'yes' respondents. Responses to B5_Visual, B7_Effectiveness and B8_RiskAware do not differ across groups, but the remainder of responses, which pertain to resources (B1_Financial, B2_Physical and B4_Time) and information (B3_RemovalInfo and B6_TreatInfo), are more commonly noted as barriers to mitigation in the 'yes' group.

Table 3. Cumulative percentage of respondents willing to participate by level of grant funding ($n = 182$)
WTP, willingness to pay

Highest WTP	$1000	$800	$600	$400	$200	$0
Grant amount	$0	$200	$400	$600	$800	$1000
Percentage (yes)	8%	5%	18%	26%	25%	16%
Cumulative (yes)	8%	14%	32%	58%	84%	100%
Cumulative (all)	7%	12%	27%	49%	70%	84%

Modelling results

Further insight comes from the results of estimating the two-stage model, shown in Table 4. For each estimated model, the two sets of parameters shown correspond to β_D for the participation coefficients (from the selection model) and β_W for the WTP coefficients (from the interval model). Consistent with the literature (e.g. Champ *et al.* 2013), we found a strong correlation between gender and risk perceptions (correlation coefficient of 0.35). Faced with potential multicollinearity between gender and JointProb, we exclude the former from the models, although including it does not substantively change results.

We estimate five models to separately evaluate different combinations of perceived (JointProb) and assessed (RiskScore, DefensibleSpace) risks and the perceived barriers. In Models I through IV, a positive, significant estimate of ρ signifies positively correlated errors between the selection and interval models. This implies that unexplained variation that biases respondents towards participation also biases them towards higher WTP. For Model V, ρ is not significant, suggesting that the included variables successfully control for this correlation.

Table 4. Coefficients and standard errors for joint models of participation and willingness to pay (WTP)
Note: coef., coefficient; s.e., standard error; asterisks designate parameter significance: *, $P < 0.10$; **, $P < 0.05$; ***, $P < 0.01$

Model	I		II		III		IV		V	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Participation coefficients (selection model)										
JointProb	1.65***	0.59	–	–	1.99***	0.62	1.59***	0.58	–	–
RiskScore	–	–	−0.36**	0.16	−0.46***	0.17	–	–	–	–
DefensibleSpace	–	–	–	–	–	–	−0.06	0.04	–	–
BF1: costs	–	–	–	–	–	–	–	–	0.50***	0.12
BF2: information	–	–	–	–	–	–	–	–	0.37**	0.17
BF3: effectiveness	–	–	–	–	–	–	–	–	0.10	0.17
B5_Visual	–	–	–	–	–	–	–	–	−0.38	0.29
Lot size	−0.08	0.06	−0.11*	0.06	−0.10	0.06	−0.09	0.06	−0.11	0.07
ln(Income)	−0.08	0.16	−0.14	0.16	−0.19	0.16	−0.14	0.17	−0.08	0.19
Age	−0.05	0.10	−0.06	0.10	−0.05	0.10	−0.09	0.10	0.01	0.14
Constant	1.46	0.96	2.93***	1.06	2.96***	1.14	2.36**	1.06	1.72	1.15
WTP Coefficients (interval model)										
JointProb	2.13	1.38	–	–	2.57*	1.37	2.95*	1.56	–	–
RiskScore	–	–	−0.56	0.45	−0.93**	0.46	–	–	–	–
DefensibleSpace	–	–	–	–	–	–	−0.13	0.11	–	–
BF1: Costs	–	–	–	–	–	–	–	–	−0.26	0.68
BF2: Information	–	–	–	–	–	–	–	–	−0.11	0.49
BF3: Effectiveness	–	–	–	–	–	–	–	–	−0.04	0.26
B5_Visual	–	–	–	–	–	–	–	–	−0.42	0.72
Lot size	−0.67***	0.17	−0.68***	0.16	−0.69***	0.17	−0.71***	0.20	−0.57**	0.24
ln(Income)	1.16***	0.38	1.10***	0.38	1.04***	0.39	1.21***	0.44	1.23***	0.38
Age	0.53**	0.25	0.50**	0.23	0.49*	0.25	0.48	0.29	0.56**	0.24
Constant	−4.08*	2.36	−1.98	2.81	−1.32	2.90	−3.21	3.05	−3.26	2.43
σ	3.37***	0.24	3.26***	0.22	3.39***	0.20	3.69***	0.29	2.87***	0.17
ρ	0.94***	0.12	0.93***	0.10	1.00***	0.11	0.94***	0.13	−0.01	1.61
N	217		217		217		217		217	
LL	−382.14		−383.34		−378.12		−383.31		−372.88	

Across all models, the three general characteristics variables (Lot Size, ln(Income), Age) do not significantly relate to willingness to participate. In contrast, the estimated coefficients on Lot Size and ln(Income) are strongly significant in all five interval models, and the coefficient on Age is positive and significant in all models except model IV. In other words, although incomes and property size do not explain cost sharing participation, respondents with higher incomes are willing to pay more for mitigation (consistent with a sensitivity to the relative marginal utility of money), and those with larger lots are willing to pay less per acre (consistent with a sensitivity to the overall cost of mitigation in addition to the per-acre cost).

None of the remaining coefficients are consistently significant across the five interval models, but many of them are in the selection model. Model I, and similar results for the other perceived risk measures (not shown), demonstrate that respondents who perceive higher risks are more likely to participate in the cost sharing, a result consistent with the literature (e.g. Talberth *et al.* 2006; Martin *et al.* 2009; Brenkert-Smith *et al.* 2012; Champ *et al.* 2013; McNeill *et al.* 2013) in finding a positive association between wildfire risk perception and a willingness to participate in mitigation behaviours. However, Models II and III demonstrate that residents of properties with higher professionally assessed RiskScores are actually less likely to participate in the cost sharing program than those on properties with lower scores, whether or not risk perceptions (JointProb) are controlled for. Because the DefensibleSpace coefficient in the selection model of Model IV is not significant, this assessed-risk result appears to not relate to recent maintenance of defensible space but rather to properties' overall wildfire risks.

Respondents who claim that costs (BF1: costs, which includes time or physical constraints) or informational constraints (BF2: information) limit their defensible space activities are more likely to participate in the cost sharing program (model V). However, willingness to participate is not explained by the barriers of perceived ineffectiveness (BF3: effectiveness) or visual impacts (B5_Visual), suggesting that these concerns are irrelevant to grant participation (and conversely, would not be affected by the cost sharing program). The significance and sign of the coefficients on BF1: costs and BF2: information suggest that respondents would participate in the cost sharing program not only to reduce the costs of mitigation (financial and otherwise) but also because of expected ancillary benefits of participation related to individually relevant information. With a correlation coefficient of -0.11, these two barriers are largely independent of each other, suggesting that it might be efficient to directly supply such information to residents (or to increase efforts to guide residents to such, if it already exists) or to provide two separate programs: one providing targeted information to residents and another bundling such information with cost sharing.

Finally, we use the coefficients shown in Table 4 to construct individual-specific estimates of WTP for all respondents, for which descriptive statistics are presented in Table 5. Joint modelling allows estimation for respondents for whom WTP is unobserved because they answered 'no' to the participation question; we present these estimates separately from those for respondents who answered 'yes' and also show the combined result. The mean estimated WTP for those who said 'yes' is ~ $485 per acre ($1200 per hectare) for all models, which equates to a mean requested amount of grant funding of ~$515 per acre ($1273 per hectare), or an ~50% cost share for average treatment costs of $1000 per acre ($2470 per hectare). In contrast, the mean WTP estimate for respondents answering 'no' to the participation question ranges from $292 to $485, still within overlapping confidence bounds and all positive, suggesting that the majority of respondents who declined to participate in the cost sharing program did so, not because the program did not offer enough money, but because of other considerations.

Table 5. Summary statistics for individual willingness to pay (WTP) per acre estimates (based on Table 4 results)

Model	Group	WTP mean	WTP s.d.	WTP median	*n*	$1000-(mean WTP)
I	Yes	$488	$303	$497	35	$512
	No	$318	$230	$362	182	$682
	All	$460	$299	$490	217	$540
II	Yes	$487	$301	$496	35	$513
	No	$315	$229	$346	182	$685
	All	$459	$297	$492	217	$541
III	Yes	$490	$301	$496	35	$510
	No	$292	$237	$323	182	$708
	All	$458	$300	$488	217	$542
IV	Yes	$487	$313	$497	35	$513
	No	$322	$250	$363	182	$678
	All	$461	$309	$493	217	$539
V	Yes	$480	$309	$497	35	$520
	No	$485	$202	$523	182	$515
	All	$481	$294	$498	217	$519

Discussion

Overall, we estimate the mean WTP for vegetation reduction through a cost sharing program at ~$460 to $480 per acre ($1135 to $1185 per hectare), with approximately half of respondents being willing to participate in a 50% cost-share. Further, 84% of respondents claim a willingness to participate in cost sharing, suggesting that most community members would perform vegetation reduction with cost sharing assistance, if available. Age, lot size and income appear irrelevant to willingness to participate, although people with larger lots and those with less money are not willing to pay as much for mitigation on their properties, so such people might be particularly responsive to larger grants.

The two main considerations estimated to increase the likelihood of cost sharing participation are whether costs or information are perceived as barriers to wildfire risk mitigation, regardless of income levels, and how likely residents think it is that wildfire will affect them personally in the near future. However, residents facing higher assessed wildfire risk are less likely to participate in cost sharing than similar residents on properties with lower risk, implying that such programs might not effectively affect those properties most in need of mitigation without specifically targeting them.

Many residents claim that their mitigation behaviours are limited by a lack of property-specific information about mitigation options, and our results suggest they would participate in cost sharing as an indirect mechanism for accessing such information, where the money provided might be auxiliary to the purpose of gaining that information. For the equally large proportion of residents who are constrained by money or time, the financial resources provided by cost sharing appear to encourage risk mitigation. In contrast, our results suggest that cost sharing subsidisation would not 'buy' willingness to mitigate from people who do not mitigate because they question mitigation's effectiveness or because they want to avoid its visual impacts. In other words, cost sharing should be considered one tool among many for encouraging wildfire risk mitigation among residents of the WUI.

Although these conclusions offer insights for encouraging residents to mitigate wildfire risks on their properties, they are not the final word on the effectiveness of different approaches to that encouragement. Our results demonstrate that direct assistance can help people overcome financial and other barriers impeding risk mitigation, but they also are consistent with previous findings (e.g. McFarlane *et al.* 2011; McCaffrey *et al.* 2013) that non-financial dimensions play important roles in wildfire risk mitigation decisions. This underscores the importance of continued research on this topic. For example, future research could link stated willingness to participate with additional information such as measures of related attitudes or of actual participation in existing programs; such analysis will further investigate the efficiency of subsidisation for encouraging wildfire risk mitigation. Our results suggest value from researching the role of risk tolerance in conjunction with risk perception and risk characterisation. Other research could expand on our findings that opinions about mitigation's effectiveness and its visual impacts do not influence participation; are these findings unique to this particular community? The hazards literature emphasises the role of specific contexts (e.g. community, hazard) and of interactions across property lines in decision-making. Accordingly, future efforts could compare these results to those for different WUI communities facing wildfire risks and for communities facing other hazards, and to results that accommodate spatial spillovers among properties and decision-makers. That said, these results can, and should, inform the development and improvement of programs aimed at increasing homeowner wildfire risk mitigation behaviours.

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