Endogenous Risk Perception and Wildfire Risk Mitigating Behavior

Hari Katuwal[1]

Tarleton State University

katuwal@tarleton.edu

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[1] Corresponding author. Tel.: +254768-9907. *E-mail address:* katuwal@tarleton.edu (Hari Katuwal)

Abstract

Wildfire research suggests that the likelihood of wildfire related damages in wildland-urban interface can be significantly reduced by creating defensible space in the areas around a home or other structure. Despite the potential benefits, many homeowners do not adopt mitigation measures and are exposed to wildfire risks. Mitigating behavior models are used to examine the factors that influence household's mitigating action. Research suggests that risk perception and mitigating behavior are jointly determined and direct estimation would produce biased and misleading estimates. However, wildfire mitigating behavior models often employ risk perception as one of the explanatory variables without appropriately addressing the potential endogeneity of the perceived risk. In this paper, we use bivariate probit model to jointly estimate risk perception and mitigating behavior to examine the effect of risk perception on the likelihood that a household takes mitigation actions to reduce potential wildfire risk. Results suggest that the risk perception is one of the important determinants of wildfire risk mitigation behavior. Additionally, result also indicates that the effect of risk perception is significantly affected by the presence of endogeneity. We find evidence suggesting that the effect of risk perception is underestimated because of endogeneity. These results suggest that risk perception endogeneity should be properly addressed when estimating effect of risk perception on mitigation activities.

Keywords: risk perception, home ignition zone, mitigation behavior, risk management, wildfire

JEL Classification: D81, Q23, Q54

1 Introduction

Each year wildfires burn millions of acres, and cause loss of life and property and forced evacuation in the wildland-urban interface (WUI) in the western United States. Wildfire research suggests that the likelihood of wildfire related damages in WUI can be significantly reduced by creating defensible space in the areas around a home or other structure (Cohen, 2000). Despite the potential benefits of defensible space in Home Ignition Zone (HIZ[1]), many homeowners in wildfire prone areas do not adopt risk mitigation measures and are exposed to wildfire risks. In this paper, we identify and examine the factors that influence mitigating behaviors adopted by homeowners living in the WUI using a survey data from Flathead County in northwestern Montana. More specifically, we examine the effect of risk perceptions on mitigation behavior.

Mitigating behavior models are used to examine the factors that influence household's mitigating actions to reduce risk from poor environmental quality and natural hazards such as flood and wildfires (Lloyd-Smith et al., 2018). Natural hazards mitigation behavior literature suggests that risk perception is one of the important determinants of mitigation behavior (Brenkert-Smith et al., 2012; Champ et al., 2013). While some studies have demonstrated that wildfire risk mitigation behavior increases with higher risk perception (Hall and Slothower, 2009; McFarlane et al., 2011; Brenkert-Smith et al., 2012; Fischer et al., 2014), others have indicated that risk perceptions do not have positive effect on mitigation behavior (Collins, 2008; Champ et al., 2013). For instance, in one of the mitigation behavior studies, author found that the reported fire hazard perception and the number of mitigation actions were not significantly associated

[1] Home itself and everything around the home up-to 200 feet that determines home ignition potential is known as the HIZ

(Collins, 2008). In another similar study, Brenkert-Smith et al. (2012) found that greater risk perception was positively associated with higher level of mitigation actions to reduce wildfire risk. Using survey data from Alberta Canada, McFarlane et al. (2011) concluded that the risk perception significantly influences mitigation behavior (McFarlane et al., 2011). More recently, the relationship between perceived wildfire risk and risk mitigating behavior were simultaneously estimated by Champ et al. (2013). The authors concluded that perceived risk and wildfire risk mitigations behavior are jointly determined. As summarized by Champ et al. (2013), some studies suggest that there is a positive relationship between perceived risk and risk-mitigating behavior, whereas other studies suggest no association between risk perception and risk-mitigating actions. In spite of the fact that there are several studies on wildfire risk perception and mitigation behavior, the relationship between risk perception and mitigation behavior remains uncertain, and is still unclear and controversial. Moreover, research also suggests that risk perception and mitigating behavior are jointly determined and direct estimation without properly addressing endogeneity would produce biased and misleading estimates of the risk perception effect (Champ et al., 2013). However, an examination of current wildfire literature indicates that wildfire mitigating behavior models often employ risk perception as one of the explanatory variables without appropriately addressing the potential endogeneity of the perceived risk. Thus, while risk perceptions may be used as one of the explanatory variables, it raises potential issue of endogeneity.

In this paper, we jointly estimate risk perception and mitigation behavior to examine the effect of risk perception on the likelihood that a household takes mitigation actions to reduce potential wildfire risk. We develop a mitigation behavior model of risk-mitigation actions and demonstrate how endogeneity associated with risk perceptions may be addressed using

instrumental variable. We use bivariate probit model to jointly estimate risk perception and mitigating behavior.

Results suggest that the risk perception is one of the important determinants of wildfire mitigation behavior. We find evidence suggesting that the effect of risk perception is underestimated because of endogeneity. A better understanding of these determinants will enable planners and fire managers to more effectively promote and engage homeowners to take mitigation actions in the WUI to reduce wildfire damages and wildfire management costs.

2 Methods

Risk perception is commonly included as one of the explanatory variables to examine mitigation action in mitigation behavior models. However, one potential issue that could arise because of the use of risk perception is endogeneity bias. As noted previously, there might be two sources of potential endogeneity of risk perceptions; simultaneity and omitted variable bias. It is possible that homeowners with high-risk perception may be more likely to take mitigation actions; these mitigation actions may in turn affect the risk perceptions. Additionally, there may be several unobserved factors affecting mitigation actions and those factors may be correlated with risk perception leading to omitted variable bias. In this study, we jointly estimate risk perception and mitigating behavior using bivariate probit model to address the potential endogeneity issue.

A latent-index model of the dependent variable provides a basis for empirical analysis:

(1) $Y_i^* = \beta R_i + \gamma X_i + \mu_i,$

(2) $Y_i = \begin{cases} 1 \; if \; Y_i^* > 0 \\ 0 \; if \; Y_i^* \leq 0 \end{cases}.$

where Y_i^* is an unobserved dependent variable index of the likelihood of undertaking mitigation action by homeowner i. The latent variable Y_i^* drives the observed outcome i.e. mitigation action. We observe mitigation action for each homeowner as Y_i (where $Y_i = 1$ indicates mitigation actin in at least one HIZ and $Y_i = 0$ indicates no action). R_i indicates risk perceptions, X_i is a vector of exogenous explanatory variables, and μ_i is a zero-mean random error. β is the parameter to be estimated and captures the effect of risk perception, all else equal.

The parameters in equation (1) could be estimated directly using naïve probit model if risk perceptions were exogenous. Because of potential endogeneity, direct estimation of equation (1) without properly addressing potential endogeneity would yield biased and misleading estimates. To identify and estimate unbiased effects of risk perception, we need to identify an instrumental variable that would affect risk perception directly but is not directly associated with mitigation action. That is, we need to find a variable Z such that,

(3) $R_i^* = \delta Z_i + \theta X_i + \varepsilon_i$,

(4) $R_i = \begin{cases} 1 \; if \; R_i^* > 0 \\ 0 \; if \; R_i^* \leq 0 \end{cases}$,

(5) $E[Z_i \mu_i] = 0, \; E[Z_i \varepsilon_{i_i}] = 0.$

For estimation purposes, the primary challenge is to specify a valid identification strategy for R_i that satisfies equation (5).

Creation of defensible space around property by thinning vegetation and reducing combustible materials in HIZ significantly increases the chances that the property survives in the event of wildfire (Cohen 2000). Accordingly, we use mitigation action in HIZ as our dependent variable for this study. Respondents were asked if they have performed any of the mitigation actions described in three different zones (Zone 1, Zone 2, and Zone 3) of the HIZ around their residence since moving in. Mitigation action is considered complete within a zone only if all actions listed

for that specific zone were performed by the respondents. A categorical mitigation behavior variable was created from respondents' reported action in different zones of HIZ; mitigation action variable (*mitigation*) is 1 if all mitigation actions were performed in at least one of three HIZs, 0 otherwise.

The risk perception index was created from respondents answers to multiple questions in the survey dealing with respondent's concern about likelihood that wildfire would burn respondent's private land, burn respondent's property, destroy respondent's home, or damage respondent's home in Flathead County. All the individual likelihood scales (0 - 100) were summed to create the risk index. The risk index was then divided into two categories (e.g. *lowrisk* and *highrisk*) based on 50th percentile of the index to create categorical variables such that *highrisk* is 1 if respondent risk index lies in the high-risk category i.e. risk index is more than 50th percentile, otherwise zero.

One of the challenges of estimating recursive bivariate model is identification of a valid instrumental variable that is significant determinant of treatment variable but does not directly influence outcome variable. A valid instrument for this study needs to have a causal effect on the risk perception but should not directly influence mitigation action. We use homeowners risk perception associated with the place respondents used to live in before their current property as our instrumental variable.

In addition to risk perception, mitigating behavior is expected to be influenced by several other sociodemographic, attitudinal, experiential and community related variables. We use several sociodemographic, experiential and community related variables to capture effect of these variables on mitigation actions.

3 Survey and Data

The data for this study comes from a survey that was conducted in 2011 to understand risk perception, mitigation activities, and homeowners' preferences toward wildland fire management programs in Flathead County, located in northwest Montana, USA. All the households selected for the survey are WUI communities that are prone to wildfire risk and majority of the respondents have experienced wildfire. Questionnaires were mailed in early October 2011 to the 1889 households, 1155 questionnaires were returned; resulting a response rate of 61 percent. The survey also collected host of demographic and socioeconomic information in addition to mitigation actions undertaken by respondents.

4 Results

Definitions and descriptive statistics of the variables used in the analysis are presented in Table 1. Average education level of the respondents is 15 years. Average annual reported income of households is USD 83,250.

[Table 1 about here]

Several indices were created from the respondents' answers to experience, attitude and risk perceptions questions from the survey. Respondents' answers to experiential questions such as discomfort from wildfire smoke, road closure, property damage, evacuation, injury in the Flathead County were used to create experience index (*experience*). The majority of the respondents have some kind of experience with wildfires. Participants who did not undertake any of the mitigation actions were asked about the reasons behind not undertaking any of the mitigation actions to assess the important constraints towards mitigation behavior. The variables

noteffective, *notresponsible*, *cost*, *physical*, *aesthetic* and *dkn* capture important reasons selected by respondents for not having undertaken mitigation action in any zone of the HIZ. The survey did not collect specific information about respondents' knowledge of wildfire and wildfire risk. However, respondents were asked about the source and frequency of information they sought on wildfire. Almost half (45%) of the respondents had sought information at least once (*seekinfo*) about risk associated with wildfire. Several questions related to community program, community participation and discussion about wildfire with community members were included in the survey to assess the role of community participation towards mitigation behavior. Three variables (*cprogram, cparticipation, cdiscuss)* were defined to capture the effect of social interaction on wildfire risk mitigation behavior.

Respondents were also asked about their concerns. The risk perception index was created from respondents answer to questions in the survey dealing with respondent's concern about likelihood that wildfire would burn respondent's private land, burn respondent's property, destroy respondent's home, or damage respondent's home in Flathead County. All the individual likelihood scales (0 - 100) were summed to create the risk index. The risk index was then divided into two categories (e.g. *lowrisk* and *highrisk*) based on 50th percentile of the index to create categorical variables such that *highrisk* is one if respondent risk index lies in the high-risk category i.e. risk index is more than 50th percentile, otherwise zero.

We estimated naïve probit and bivariate probit models in order to analyze how mitigation actions are related to risk perception and other explanatory variables. Mitigation action is a binary variable that takes the value of one if the homeowner had completed all actions in at least one of three HIZs, and zero otherwise. A binary choice model (*mitigation* = 1 if homeowners undertook mitigation action in at least one of three HIZs, and 0 otherwise) is used to estimate the

relationship between explanatory variables and mitigation behavior. Naïve probit and bivariate probit model results are presented in Table 2. Model 1 in column 1 treats risk perception as exogenous variables and column 2 presents results from the bivariate probit model that seeks to reduce the potential endogeneity bias. We use wildfire risk perception associated with the area respondents used to live before current property as our main instrument.

[Table 2 about here]

Results from the naïve probit and bivariate models are consistent. The sign and significance of the variables in both the probit and the bivariate probit models are quite similar. Results reveal a number of important determinants of mitigation behavior. Our results suggest that socioeconomic and demographic factors are not the most important determinants of mitigation behavior. Experience appears to be significant and negatively associated with mitigation actions in at least one zone of HIZ. Homeowners' attitudes towards effectiveness of mitigation actions appear to be important determinants of the mitigation behavior. For example, the coefficient of *noteffective* is negative and significant. This implies that the respondents who think the mitigation action may not be effective are less likely to undertake any mitigation action.

Results indicate that only having community program in the neighborhood is not enough in terms of motivating respondents to take mitigation action. However, results suggest that talking about wildfire with neighbors influenced respondents to take steps to reduce wildfire risk in at least one zone of the HIZ. Results show that mitigation behavior is positively associated with information seeking behavior of the respondents. This finding implies that increased knowledge or information seeking behavior stimulates mitigation behavior.

The positive coefficients of *highrisk* in both probit and bivariate probit models suggest that homeowners, who think the wildfire risk is higher and are more concerned about the risk, are more likely to undertake mitigation actions in at least one of the three different zones of HIZ. More specifically, our bivariate model results indicate that the effect is highly significant and stronger when endogeneity issue is addressed. The naïve probit model, without controlling for the endogeneity, underestimated the effect of risk perception on the mitigating behavior. This result is consistent with the result from previous studies that suggest heightened risk perception is associated with increased mitigation behavior.

5 Discussion and Conclusion

The main objective of the present study was to examine the effect of risk perception on mitigation behavior to reduce wildfire risk. Bivariate probit model results suggest that risk perception is endogenous, and risk perception and wildfire mitigating action are jointly determined. Additionally, result also suggests that the effect of risk perception is significantly affected by the presence of endogeneity. We find evidence suggesting that the effect of risk perception is underestimated because of endogeneity. Effects of risk perception become significant and stronger when endogeneity is corrected. These findings suggest that proper caution should be taken and that risk perception endogeneity should be properly addressed when estimating effect of risk perception on mitigation activities. It is, however, important to note that the focus of this study was mitigating action undertaken in at least one of the three HIZs, and result should be interpreted accordingly. Further analysis is required to examine the relationship between risk perception and mitigating behavior in three HIZs and other relevant mitigation actions.

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Table 1: Descriptive Statistics and Definition of the Variables

Variables	Definition	Mean	Sd	Max	Min
income	Annual income of the household ($ 000 based on midpoint of pre-coded income intervals reported by households)	83.25	56.93	200	5
edu	Education level of the respondents in years	15	2.79	21	5
age50	Dummy variable for age of the respondent (=1 if older than 50 years, else 0)	0.81	0.39	1	0
male	Dummy variable for gender of the respondent (=1 if male, else 0)	0.6	0.49	1	0
residency15	Dummy variable for number of years respondent has lived in the Flathead County (=1 if more than 15 years, else 0)	0.5	0.5	1	0
fulltime	Dummy variable for residency in Flathead County (=1 if fulltime, else 0)	0.76	0.43	1	0
experience	Constructed index of wildfire experience based on experiences with smoke, road closure, property, damage, evacuation, personnel witness and injury in the Flathead County.[1]	1.15	1.13	5	0
noteffective	Dummy variable for effectiveness created from a question asked of respondent's primary reason for not conducting the mitigation action (=1 if respondent indicated that the action will not reduce wildfire risk, else 0)	0.2	0.4	1	0
cost	Dummy variable for cost constraint created from a question asked of respondent's primary reason for not conducting the mitigation action (=1 if respondent indicated that the mitigation action is too costly, else 0)	0.11	0.31	1	0
lackoftime	Dummy variable for time constraint created from a question asked of respondent's primary reason for not conducting the mitigation action (=1 if respondent indicated that the mitigation action , take too much time, else 0)	0.05	0.22	1	0

aesthetic	Dummy variable for aesthetic constraint created from a question asked of respondent's primary reason for not conducting the mitigation action (=1 if respondent indicated that the mitigation action would detract the appearance of the property, else 0)	0.18	0.39	1	0
physical	Dummy variable for physical work created from a question asked of respondent's primary reason for not conducting the mitigation action (=1 if respondents indicated that the he/she is not able to work physically, else 0)	0.1	0.3	1	0
dkn	Dummy variable for lack of knowledge created from a question asked of respondent's primary reason for not conducting the mitigation action (=1 if respondent indicated that he/she is not sure what needs to be done, else 0)	0.11	0.32	1	0
seekinfo	Dummy variable for wildfire information seeking behavior (=1 if sought at least once, else 0)	0.45	0.5	1	0
cprogram	Dummy variable for presence of wildfire programs such as programs aimed at reducing, wildfire risk, efforts to obtain grants for forest thinning or other wildfire mitigations, a committee dedicated to wildfire planning in the community (=1 if present, else 0)	0.1	0.3	1	0
cparticipation	Dummy variable for community participation based on respondent's involvement such as attending or organizing a wildfire information event, contributing comments to a wildfire mitigation plan, participating in a community fuel reduction program, serving on a local or community wildfire committee and helping develop a community evacuation or shelter plan (=1 if participated in community program, else 0)	0.15	0.36	1	0
cdiscuss	Dummy variable for discussion with neighbors based on how often respondents discuss about wildfire risk with neighbors (=1 if discussed at least once, else 0)	0.38	0.49	1	0
highrisk	Dummy variable for wildfire risk perception	0.2	0.4	1	0

(=1 if high risk, else 0)[2]

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[1]Respondents answers to experience questions such as discomfort from wildfire smoke, road closure, property damage, evacuation, injury in the Flathead County were used to create experience index.

[2]The risk perception index was created from respondents answer to questions in the survey dealing with respondent's concern about likelihood that wildfire would burn respondent's private land, burn respondent's property, destroy respondent's home, or damage respondent's home in Flathead County. All the individual likelihood scales (0- 100) were summed to create the risk index. The risk index was then divided into two categories (e.g. lowrisk and highrisk) based on 50th percentile of the index to create categorical variables such that highrisk is 1 if respondent risk index lies in the high risk category i.e. risk index is more than 50th percentile, otherwise zero.

Table 2: Naive and Bivariate Probit Model Results for Mitigation Behavior

Variables	Model 1		Model 2	
(Intercept)	-0.2744		-0.7425	**
	(0.3196)		(0.3367)	
income	-0.0012		-6e-04	
	(9e-04)		(9e-04)	
edu	-0.009		-0.0077	
	(0.0186)		(0.0175)	
age50	0.1332		0.1549	
	(0.1212)		(0.1131)	
male	0.3325	***	0.3234	***
	(0.0977)		(0.0949)	
residency15	0.1209		0.0888	
	(0.0988)		(0.0946)	
fulltime	0.0364		0.075	
	(0.1191)		(0.1123)	
experience	-0.1055	**	-0.0941	**
	(0.0425)		(0.0412)	
noteffective	-0.1055	***	-0.357	**
	(0.1152)		(0.1556)	
cost	-0.1587		-0.175	
	(0.173)		(0.1616)	
lackoftime	-0.3161		-0.3141	
	(0.2074)		(0.197)	
aesthetic	0.1411		0.1284	
	(0.1198)		(0.1128)	
physical	0.1825		0.1972	
	(0.17)		(0.1578)	
dkn	0.0039		-0.0935	
	(0.1422)		(0.1392)	

cprogram	-0.0403		-0.0283	
	(0.1677)		(0.156)	
cparticipation	0.1184		0.0404	
	(0.141)		(0.1357)	
cdiscuss	0.5146	***	0.3186	**
	(0.1006)		(0.1502)	
seekinfo	0.7187	***	0.4886	***
	(0.0999)		(0.1728)	
highrisk	0.1689	*	1.2135	***
	(0.0936)		(0.3922)	
N	880		880	
AIC	1056.71		2258.02	
BIC	1147.52		2444.43	

Significance codes: *** 0.01 ** 0.05 * 0.1
Numbers in parentheses indicate standard errors
The dependent variable "*mitigation"* is equal to one if homeowners undertook mitigation action in at least one zone of three zones in Home Ignition Zones.