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Cigarette Fires Involving Upholstered Furniture in Residences: The Role that Smokers, Smoker Behavior, and Fire Standard Compliant Cigarettes Play

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Abstract

Residential structure fires pose a significant risk to life and property. A major source of these fires is the ignition of upholstered furniture by cigarettes. It has long been established that cigarettes and other lighted tobacco products could ignite upholstered furniture and were a leading cause of fire deaths in residences. In recent years, states have adopted fire standard compliant cigarettes ('FSC cigarettes') that are made with a wrapping paper that contains regularly spaced bands, which increases the likelihood of self-extinguishment. This paper measures the effectiveness of FSC cigarettes on the number of residential fires involving upholstered furniture, and the resulting fatalities, injuries, and extent of flame spread, while accounting for the under-reporting of fire incidents. In total, four models were estimated using fire department data from 2002 to 2011. The results provide evidence that FSC cigarettes, on average, reduced the number of residential fires by 45 %, reduced fatalities by 23 %, and extent of flame spread by 27 % in 2011. No effect on injuries was found. Within each state, effectiveness is moderated by the number of smokers and their consumption patterns. In general, FSC cigarettes are more effective in places with a large smoking population who engage in heavier smoking. There is a very limited effect on the lightest of smokers, suggesting behavioral differences between heavy and light smokers that influence fire risk.

Keywords

fire safe cigarettes; reduced ignition propensity cigarettes; prevention; statistics; loss; damage

1. INTRODUCTION

In 2010, 80 % of all structure fires were residential fires and many of these fires involved upholstered furniture, which can contribute significantly to the ignition and/or growth of a fire. Ahrens [1] estimates that upholstered furniture was the first item ignited in an annual 7040 residential fires between 2005 and 2009. In addition, Hall [2] using data from 2006 to 2010, estimates another 2223 fires involved upholstered furniture, but as the item contributing most to flame spread. Thomas and Butry [3] similarly, estimate that there were between 7400 and 13 000 residential fires in 2010 where upholstered furniture was either the first item ignited or contributed significantly to flame spread. One of the major sources of

the ignition of upholstered furniture fires are cigarettes. Ahrens [1] estimates that 28 % of home upholstered furniture fires were ignited by smoking materials and they account for 58 % of the home upholstered furniture fire deaths. In recent years there has been interest in reducing the fire risk that both furniture and cigarettes pose to residential property and occupants.

It has long been established that cigarettes and other lighted tobacco products could ignite upholstered furniture and were a leading cause of fire deaths in residences. As early as 1929, there were calls for self-extinguishing cigarettes; however, it wasn't until the 1970s that a grassroots campaign was started and in the 1980s and 1990s federal and state legislative efforts were underway. In recent years, fire standard compliant (FSC) cigarettes have been adopted, which are made with a wrapping paper that contains regularly spaced bands.¹ At a band, the air flow to the burning tobacco is reduced, and (some of the time) the cigarette goes out. Starting in 2004, New York became the first state to require FSC cigarettes. By 2012, all 50 states, and the District of Columbia, had such a requirement [4]. The NFPA reports that fatalities due to smoking material fires dropped by 30 % from 2003 to 2011 [5].

Between 1980 and 2011, fires caused from smoking materials were down 73 %, according to municipal fire department data [5]. Meanwhile, based on data from the National Cancer Institute [6], cigarette smoking by adults has fallen steadily from a rate of 33 % in 1980 to 19 % in 2011 (or 42 %). Based on data from the Federation of Tax Administrators [7], state tax-paid cigarette sales fell 51 % over this period. Therefore, while FSC cigarettes have decreased fire ignitions, it is likely that the decline in cigarette smokers partially explains the fall in smoking-caused fires as well. In 2011, smoking caused wildfires were only 10 % of their 1980 level. Butry et al. [8] examined reasons for this decline and showed that the decline in the number of adult cigarette smokers and the advent of FSC cigarettes were both statistically linked to the number of smoking-caused wildfires, and at the same time, not correlated with the number of other human-caused wildfires. However, the ignition scenarios are quite different between a wildland ignition and residential upholstered furniture (e.g., geometries of item, air access conditions). The behavior of smokers has also changed. King et al. [9] report the percentage of smokefree homes increased from 9.6 %, in 1992 and 1993, to 46.1 %, in 2010 and 2011, in homes with at least one adult smokers. In homes without adult smokers, they found the percentage increased from 56.7 % to 91.4 %. The NFPA [10] reports a shift in the areas of origin of home fires started by smoking materials from bedroom and living room, family room or den, kitchen, and bathroom to outdoor areas, such as exterior balcony, open porch, courtyard, terrace, patio, and trash and rubbish area, from the period of 1980 to 1984 to the period of 2007 to 2011.

This paper examines the impact that fire standard compliant cigarettes have had on residential fires involving upholstered furniture while controlling for the number of smokers and their cigarette consumption, as well as linear time effects from unobserved factors. It measures the effect FSC cigarettes had on the count of residential fire incidents involving upholstered furniture, the count of related fatalities, and the count of related injuries, and the extent of flame spread (a proxy for property damage).² Data from fire departments reporting

¹These cigarettes are also known as 'fire-safe cigarettes' and 'fire standard compliant cigarettes.'

to the National Fire Incident Reporting System (NFIRS) are aggregated at the state level for the years 2002 through 2011.

The results show that the measured impact of FSC cigarettes varies across time and space, and are sensitive to the under-reporting of fire incidents. A key finding is the number of smokers and their relative cigarette consumption are correlated with other (unobserved) factors that affect the measured effectiveness of FSC on the rate of fires and fatalities, and extent of flame spread. For instance, while controlling for the number of smokers and cigarettes consumed, the states with the lightest smokers demonstrated little measured benefit from FSC use, unlike states with heavy smokers. This suggests factors relevant to fire incidents—e.g., related to reporting or related to conditions that influence fire growth—may differ in residences with light versus heavy smokers.

2. BACKGROUND

A number of other studies have examined the impact of FSC cigarettes, each coming to qualitatively similar, but numerically different conclusions. Some of these studies examined the fire death rate while others studied the incidents of fire and deaths. Four primary methods have been used: trend analysis, ordinary and generalized least squares regression, univariate analysis, and Poisson regression.

Hall [5] reports deaths from fires involving smoking materials fell 41 % after New York State required FSC—43 average deaths per year (2000 to 2002) to 25 (2006 to 2008). A study of the US state of New York and the Canadian provinces of Alberta and Ontario indicated that the implementation of FSC cigarettes did not result in the predicted decrease of smoking material related fires and deaths [11]. This study, however, has several challenges in that it focused on only three areas and utilizes trend analysis, which does not provide the insight that econometric analysis provides. Changes in population, smoking habits, and number of smokers among other things make it difficult to observe the impact of FSC using trend analysis of only three areas. Also, one of the areas, New York, has a prevalent smuggling problem where large amounts of cigarettes are brought into the state illegally and sold to the public. Depending on where these cigarettes originated from, they may or may not be compliant with the requirement for FSC cigarettes. (In the US, after 2011, when all states required compliance, the effect of smuggled cigarettes should disappear.) The other areas may also have a smuggling problem, as there is evidence of large scale smuggling in Canada where some executives have gone to prison for such activities [12–13].

In addition to the study using trend analysis, a doctoral dissertation at the University of Tennessee utilized a generalized least squares model with fixed effects to examine death rate data from 2005 through 2012 for all US states [14]. The findings from this study indicate that the FSC policy was an effective strategy by the states to reduce both home fire deaths and damage. It estimates that the smoking-related fire death rate was reduced by 0.11 per

²In NFIRS, extent of flame spread is recorded for non-confined fires as either: (1) confined to room of origin, (2) confined to floor of origin, (3) confined to building of origin, or (4) beyond building of origin.

million in population, which would equate to a reduction of approximately 11 %. Fire incidents were reduced by 0.30 per million in population, which would equate to a reduction of approximately 12 %. This work, however, did not find that injuries declined due to the implementation of FSC policies. Folz and Shults [15] also examined rate of residential smoking related fire deaths. Using Ordinary Least Squares along with Random Effects Generalized Least Squares regression, the paper concluded that the FSC cigarettes reduced the state residential fire mortality rate by 0.23 per million, which would equate to a 22 % reduction.

Alpert et al. [16] examined FSC requirements in Massachusetts and concluded that there was a 28 % reduction in the odds of cigarette- versus noncigarette-caused fires, but no statistical reduction in the odds of those fires that resulted in one or more fatalities. (The latter analysis was based on a smaller sample size. They considered the number of fatal fires, but not number of fatalities.) Alpert et al. [16] performed a univariate analysis of the “relationship between cigarette versus noncigarette heat source and each of the candidate fixed effects variables by using contingency tables and the Fisher’s exact test.” The Fisher’s exact test is a statistical significance test used in the analysis of contingency tables, which are frequency distribution tables often used in survey research. Yau and Marshall [17] conducted a study on the impact of FSC cigarettes and found that they resulted in a 19 % reduction in residential fire mortality rates, after controlling for demographics. Yau and Marshall [17] examined state level annual data using a Poisson regression. Butry et al [8] analyzed the impact on wildfires using a zero-inflated negative binomial regression model. Butry et al [8] found that FSC cigarettes reduced wildfire starts by 23 %, an unintended benefit of a technology aimed at reducing fire fatalities in residences. In a study of FSC cigarettes in Sweden, Bonander et al. [18] found no statistical evidence of an effect on the number smoking-related residential fires or fatal fires. They examined monthly data from 1999 to 2013 (FSC were required in Sweden in 2011) and found a pronounced seasonal pattern—peaking during winter months—in the number of fires and fatal fires, including those that involved smoking-material.

3. DATA

Our analysis examines residential fire incidents involving upholstered furniture by state between 2002 and 2011 in the National Fire Incident Reporting System (NFIRS).³ NFIRS is a product of the National Fire Data Center, an entity of the U.S. Fire Administration (USFA), which is authorized to gather, analyze, and standardize fire information and data through the Federal Fire Prevention and Control Act of 1974. Approximately 1 million fires are reported to NFIRS each year by over 22 000 fire departments. NFIRS is the world’s largest, national database of fire incident information; however, fire department participation in NFIRS is voluntary. Consequently, not all fire departments participate, making the incident data a partial, and potentially non-random, census. Therefore, zero inflated modeling methods were selected to account for this issue.

³For purposes of this analysis, residential fires included all NFIRS incidents with a property use codes beginning with a ‘4’ (residential) and an incident type code 111 (building fire, excluding confined fires).

Data obtained from NFIRS include the number of cigarette-ignited residential fire incidents that involved upholstered furniture [FIRES] based on the item first ignited, along with the number of reported civilian (non-fire service) fatalities [FATALITIES] and injuries [INJURIES] from these fires, and the extent of flame spread.⁴ Flame spread, an ordinal variable as reported by NFIRS, was weighted to produce a single flame spread index [SPREAD].⁵ Incidents were selected by the combination of incident type (structure fire), property use (residential), heat source (cigarette), and item first ignited (upholstered furniture). In addition, data were obtained from NFIRS describing the number of cigarette-ignited outdoor fires [OUTSIDE] and the number of residential fires that did not involve upholstered furniture [NONRUF]. A fire department reporting variable was created based on the count of departments that reported at least one fire to NFIRS during a given month summed for all months over the year [REPORTING]. The data was aggregated by state by year.

The average cigarettes consumed per day per smoker and percent of adults that smoke was obtained from the Census Bureau and the National Cancer Institute [6]. These data were interpolated for state-year combinations that were missing. These data were coupled with population estimates from the Census Bureau to produce the number of cigarette packs smoked [PACKS] in ten-millions and the number of adult smokers [SMOKERS] in millions. PACKS equals daily cigarette consumption multiplied by the number of smokers, by state and year. SMOKERS equals the percent of adult smokers multiplied by the population, by state and year. The year that FSC cigarettes were required by state law [FSC] was taken from the NFPA [4].

Descriptive statistics providing the mean, standard deviation, minimum and maximum values of the four dependent variables (FIRES, FATALITIES, INJURIES, SPREAD) and the three base regressors (FSC, PACKS, SMOKERS) and three regressors explaining the zero-inflation process (NONRUF, REPORTING, OUTSIDE) are shown in Table 1.

4. METHODS

Four models were estimated to measure the annual effect of fire standard compliant (FSC) cigarettes in each state on (1) the count of fires involving residential upholstered furniture (RUF) [FIRES], (2) the count of fire-related civilian (occupant) fatalities from RUF fires [FATALITIES], (3) the count of fire-related civilian injuries from RUF fires [INJURIES], and (4) the total extent of flame spread resulting from RUF fires [SPREAD].

Statistical models that are used to investigate data representing counts of items assume some proportion of counts will be zero—e.g., there were no fatalities. In some instances, count data include ‘too many zeros,’ meaning the observed number of counts of zero exceed the proportion assumed by a standard count model. This process of ‘zero-inflation’ can occur when there is a second process involved—e.g., fatalities occurred but they were not reported

⁴Flame spread is reported as either: confined to object of origin, confined to room of origin, confined to floor of origin, confined to building of origin, or beyond building of origin.

⁵A weighted average was used to aggregate each count into a single metric. The weighting weighted confined to object of origin as zero up to beyond building of origin as four.

by the fire department. Count models accounting for zero-inflation were used for models (1) through (3). Standard linear regression (Ordinary Least Squares [OLS] regression), was used to model the extend of flame spread (model 4), as it is not measured as a count variable. Model 4 is based on only a subset of observations, those state/year combinations that reported a positive number of RUF fires. The technical details describing final model specification are presented below.

Two count models were employed: a zero-inflated Poisson (ZIP) regression and a zero-inflated negative binomial (ZINB) regression. Each count variable was first estimated as a ZINB and evaluated whether the ZIP specification explained more variation via a likelihood ratio test [16]. The difference being that the negative binomial specification allows for count of the dependent variable to be over-dispersed (i.e., greater variation in the count than that generated by a true Poisson process), unlike the Poisson that assumes an equal mean and variance. (The Poisson model will produce biased standard errors if the mean and variance of the count variable are unequal, and overstate the significance of the model parameters.) In addition, each zero-inflation model was evaluated versus the null hypothesis of no zero-inflation via the Vuong test [19]. The ZINB, ZIP, and OLS regressions used the same set of base regressors: a dummy variable indicating the presence or absence of the FSC requirement in each state/year combination [FSC]; the number of adult smokers (in millions) [SMOKERS]; the number of smoked cigarettes [PACKS], a linear variable accounting for time trends [TREND], and each of their interactions. While other factors affect the rate and consequence of fires ignited by smoking materials, there were not suspected to be correlated with the introduction or effectiveness of FSC in each state, and were excluded from the modeling for parsimony. The zero-inflation regressions used a second set of covariates to account for the inflation process. Those variables included: the number of non-RUF involved residential fires (i.e., those with a reported item first ignited other than upholstered furniture) [NONRUF]; the number of fire identified as having occurred outdoors [OUTSIDE]; and a metric to account for fire incident reporting behavior by fire departments [REPORTING]. All variables varied by state/year combinations, except TREND, which varies only temporally.

The model specifications are as follows.

4.1 Zero-Inflated Negative Binominal

The ZINB model maximizes the following log-likelihood function with respect to the parameters θ , γ , β :

$$\ln L_j = \sum_{i=1}^N (1 - s_{ji}) \ln \left[F(\mathbf{z}_i, \gamma_j) + \{1 - F(\mathbf{z}_i, \gamma_j)\} \left(1 + \theta_j^{-1} e^{\beta_j' \mathbf{x}_i} \right)^{-\theta_j} \right] \\ + s_{ji} \left[\ln \{1 - F(\mathbf{z}_i, \gamma_j)\} + \ln \Gamma(\theta_j + y_{ji}) - \ln \Gamma(y_{ji} + 1) - \ln \Gamma(\theta_j) - \theta_j \ln \left(1 + \theta_j^{-1} e^{\beta_j' \mathbf{x}_i} \right) - y_{ji} \ln \left\{ 1 + \theta_j e^{-\beta_j' \mathbf{x}_i} \right\} \right]$$

where y_j is the count of dependent variable j ; i indexes the observations (state/year combinations); θ is a shape parameter; s is a binary variable indicating the state (=0 if dependent variable j is never reported [state 1]; =1 otherwise); $e^{\beta_j' \mathbf{x}_i}$, which is the conditional

mean number of occurrence of dependent variable j per period, and is a function of covariates $\mathbf{x}$ (SMOKERS, PACKS, TREND, and their interactions) and parameters β , and where Γ denotes the Gamma distribution.

We assume, as is standard with the ZINB model, that the probability of state 1 can be estimated as a function of covariates $\mathbf{z}$ ('zero inflation factors,' NONRUF, OUTSIDE, REPORTING) and parameters γ , such that $\Pr(s_{ji} = 0) = F(\mathbf{z}_i, \gamma_j)$. In this analysis, the probability of state 1 is estimated using the logit specification, so that

$$F(\mathbf{z}_i, \gamma_j) = (1 + e^{\gamma_j' \mathbf{z}_i})^{-1}.$$

4.2 Zero-Inflated Poisson

The ZIP model maximizes the following log-likelihood function with respect to the parameters δ and η :

$$\ln L_j = \sum_{i=1}^N (1 - s_{ji}) \left[F(z_i \delta_{ji}) + \{1 - F(z_i \delta_{ji})\} e^{-\hat{\lambda}_{ji}} \right] + s_{ji} \left[\ln \{1 - F(z_i \delta_{ji})\} - \hat{\lambda}_{ji} + x_i \eta_j y_{ji} - \ln(y_{ji}!) \right]$$

where $\hat{\lambda}_{ji} = e^{\eta_j' \mathbf{x}_i}$, which is the conditional mean number of occurrence of dependent variable j per period, and is a function of covariates $\mathbf{x}$ and parameters η . We assume, as is standard with the ZIP model, that the probability of state 1 can be estimated as a function of covariates $\mathbf{z}$ and parameters δ , such that $\Pr(s_{ji} = 0) = F(\mathbf{z}_i, \delta_j)$. In this analysis, the probability

of state 1 is estimated using the logit specification, so that $F(\mathbf{z}_i, \delta_j) = (1 + e^{\delta_j' \mathbf{z}_i})^{-1}$.

4.3 Ordinary Least Squares

The OLS model fits a linear-in-parameters function:

$$y_{ji} = \tau_j' \mathbf{x}_i$$

where τ are the parameters. The OLS model was used to fit the total extent of flame spread (SPREAD). It bears mentioning that the flame spread model is different from the models for fires, fatalities, and injuries in that it is focused on fires that have transitioned to flaming combustion, whereas the other models will be evaluating the effect of FSC cigarettes on a mix of fires with smoldering and flaming combustion.

5. RESULTS

5.1 Count of RUF Fires

Table 2 provides the estimated coefficients and significances of the RUF fire model, generated by estimating the count of RUF fires as a zero-inflated negative binomial function. Not shown is that the model is significant, based on a likelihood ratio test with a chi-square statistic of 383.1 and 15 degrees of freedom ($p < 0.01$). In addition, a likelihood ratio test of the null hypothesis that the shape parameter is zero, which would indicate

support for a Poisson specification rather than the negative binomial, is rejected with a chi-square statistic of 511.0 and 1 degree of freedom ($p < 0.01$). Finally, and also not shown, is a Vuong test of the null hypothesis of no zero-inflation, which is rejected with a z-score of 3.0 ($p < 0.01$). Thirty observations did not report any RUF fires.

In the main model—the portion that explains the count process—four interactions terms are significant to 10 % level: (FSC $\times$ PACKS), (PACKS $\times$ SMOKERS), (FSC $\times$ SMOKERS), and (FSC $\times$ PACKS $\times$ TREND). The former two are negatively correlated with FIRES, while the latter two are positively correlated. The number of smokers, their cigarette consumption, the FSC requirement, and a linear trend explain the variation (across states and over time) in the count of cigarette ignited upholstered furniture fires.

In the Discussion section we will untangle the meaning of these (as with the other models below) results. In the zero-inflation model, only NONRUF is (negatively) correlated with the probability of zero FIRES.

5.2 Count of RUF Fire-Related Fatalities

Table 3 provides the estimated coefficients and significances of the RUF fire-related fatalities model, generated by estimating the count of RUF fire-related fatalities as a zero-inflated Poisson function. Not shown is that the model is significant, based on a likelihood ratio test with a chi-square statistic of 46.4 and 15 degrees of freedom ($p < 0.01$). In addition, a likelihood ratio test of the null hypothesis that the shape parameter is zero, which would indicate support for a Poisson specification rather than the negative binomial, is not rejected with a chi-square statistic of 2.3 and 1 degree of freedom ($p = 0.06$). Thus, the ZIP model is (marginally) preferred. A Vuong test of the null hypothesis of no zero-inflation is rejected with a z-score of 4.1 ($p < 0.01$). Three-hundred and six observations did not report any RUF fire-related fatalities.

In the main model three interactions are significant to 10 % level: (FSC $\times$ TREND), (SMOKERS $\times$ TREND), and (PACKS $\times$ TREND). The first two terms are negatively correlated with FIRES, while the third interaction is positively correlated. In the zero-inflated model, all three variables are correlated with the probability of no FATALITIES, with OUTSIDE being positively correlated and NONRUF and REPORTING being negatively correlated.

While this model is significant, as are several regressors, it demonstrated a poor job of producing marginal effects (the subject of the Discussion section) consistent with the results. For example, while the interaction of (FSC $\times$ TREND) is negative, indicating FIRES fell over time in states with FSC restrictions, the marginal effects were noisy (large errors) and produced a positive marginal effect—i.e., that FSC increased FIRES. Instead, a parsimonious model was fit, which included only those regressors with a significance of 15 % or less. The results are shown in Table 4. The parsimonious model improved the consistency of the predictions, but weakened the correlation between FSC and FIRES (FSC $\times$ TREND is significant at the 11 % level). The full model is preferred in terms of inference, while the parsimonious model is preferred for prediction.

5.3 Count of RUF Fire-Related Injuries

Table 5 provides the estimated coefficients and significances of the RUF fire-related injury model, generated by estimating the count of RUF fire-related injuries as a zero-inflated negative binomial function. Not shown is that the model is significant, based on a likelihood ratio test with a chi-square statistic of 87.4 and 15 degrees of freedom ($p < 0.01$). In addition, a likelihood ratio test of the null hypothesis that the shape parameter is zero, is rejected with a chi-square statistic of 60.5 and 1 degree of freedom ($p < 0.01$). The Vuong test of the null hypothesis of no zero-inflation is rejected with a z-score of 4.9 ($p < 0.01$). Two-hundred and thirty-four observations did not report any RUF fire-related injuries.

The main model produced no significant terms. Only NONRUF in the inflation model was significant, and negatively correlated with the probability of no INJURIES. Several parsimonious versions of the INJURIES model were explored, but none produced any meaningful results (analysis not shown). Thus, the analyses provide little evidence that FSC, SMOKERS, or PACKS affect the occurrence of injuries from RUF fires.

5.4 Extent of Flame Spread

Table 6 provides the estimated coefficients and significances of the model of total extent of flame spread resulting from RUF fires, generated by estimating the total extent of flame spread as a linear-in-parameters function. Not shown is that the model is significant, based on a F-test with a F-statistic of 41.3 and 15 and 442 degrees of freedom ($p < 0.01$). The adjusted R^2 is 0.57, meaning the covariates explain 57 % of the variation in flame spread across states and over time. The model was estimated conditioned on there being reported RUF fires; therefore, 458 of the 488 total possible observations were included.

In the model, PACKS, $(FSC \times SMOKERS)$, $(FSC \times PACKS \times TREND)$, and $(PACKS \times SMOKERS \times TREND)$ are positively correlated with the total extent of flame spread, while $(FSC \times PACKS)$, SMOKERS, and $(FSC \times SMOKERS \times TREND)$ are negatively correlated. Thus, there is evidence that the number of smokers, their cigarette consumption, the FSC requirement, and a linear trend explain the variation (across states and over time) in flame spread.

6. DISCUSSION

In general, the models described above provide evidence that fire standard compliant cigarettes affect the number of reported residential fires involving upholstered furniture, as well as the occurrence of related reported fatalities and reported extent of property damage (flame spread). Somewhat surprising is the lack of correlation between injuries and FSC compliance. The lack of significance could be due to poor model specification or inadequate data. This would be consistent with the notion that the factors that generate injuries are sufficiently different from those that result in death. We leave this hypothesis for future research. The remainder of this section focuses on the implications of the model results of the FIRES, FATALITIES, and SPREAD models.

While the zero-inflation modeling approach addresses a statistical issue resulting from non-reporting, underreporting is not addressed. The findings below are specific to reported

residential fire incidents with a known heat source being a cigarette and item first ignited being upholstered furniture. If underreporting of these types of fire incidents exists, and if the count of the underreported incidents is correlated with those that are reported, the statistical findings below are biased downward. An implication of this would be the effectiveness of fire standard compliant cigarette is actually larger than shown.

6.1 Marginal and Discrete Effects

The estimated average marginal effects are shown in Table 7. For this study, marginal effects are estimated as the expected change in the number of fires, fatalities, injuries, and flame spread from a small (marginal) change in the number of cigarette packs smoked (PACKS), number of smokers (SMOKERS), time trend (TREND), and the presence of fire standard compliant cigarettes (FSC). Table 7 presents the 16 marginal effects and their statistical significances. Each estimated marginal effects holds the other variables constant. The marginal effects are calculated over the entire sample, meaning the values shown are averages (across states and over years), and they are presented in per state/year terms. (Individual state and year effects are presented below.) For example, the marginal effect of the number of cigarette packs consumed (PACKS) on fires is 0.1597, which means, on average, we expect the number of home fires involving upholstered furniture to increase in a year by 0.1597 in a state for every additional million cigarette packs smoked in that state for that year. (Based on the average number of fires of 8.83, shown in Table 1, this would equate to a 2 % increase.)

As shown in Table 7, it is estimated that the presence of fire standard compliant potential cigarettes reduced the number of RUF fires by 3.2 per state/year, on average for the U.S. over the study period. This equates to a 32 % (90 % CI: 56 % to 7 %) reduction—the result of moving from 10.1 to 6.9 fires per state/year on average (results not shown). The reduction on fatalities (−0.11 from Table 7) equates to a 16 % (90 % CI: 31 % to <1 %) reduction (0.73 to 0.62 fatalities per state/year; results not shown). Finally, the reduction in extent of flame spread due to FSC is −6.9 (from Table 7), which implies a 55 % (90 % CI: 87 % to 22 %) reduction in total flame spread (12.6 to 5.6; results not shown). The total for the U.S., on average each year, equates to a reduction in fires by 160 and fatalities by 5.5.

In addition, based on the marginal effects presented in Table 7, we see smoking consumption is positively related with the number of fires, fatalities, and extent of flame spread, as expected. The number of smokers is negatively correlated with fatalities and flame spread. Because the marginal effects are holding the other variables constant, a change in the number of smokers has to do with the smoking behavior of the average smoker. The negative correlation implies that when the smoking population is comprised of lighter smokers the resulting fires are generally less deadly and less damaging. The linear trend variable is positively correlated with the number of fires, fatalities, and flame spread, suggesting all else equal, RUF fire risks are increasing in time.

Marginal effects are useful to show how small changes in model variables affect outcomes; however, larger changes can also be modeled. We evaluated how discrete changes in the number of smokers and their cigarette consumption compared to presence of fire standard compliant cigarettes. Specifically, we compared the impact of fire standard compliant

cigarettes with changes in the numbers of smokers and numbers of cigarettes consumed over (148) state-year combinations when cigarette compliance was required. This was done by comparing predicted values from two runs of each model (fires, fatalities, flame spread). The first run predicted the outcomes (fires, fatalities, or flame spread) based on the observed data. The second run produced counterfactual outcomes for comparison. In the case of fire compliant cigarettes, the counterfactual was if there was no requirement. For smokers and packs consumed, the counterfactual was if there was no change in the number of smokers and packs consumed from the year previous to the cigarette requirement. (In reality, the number of smokers and packs consumed fell over the study period marked with a cigarette requirement. For the counterfactual, smokers and packs consumed were held constant and did not decline.)

The fire standard compliant cigarette requirement was estimated to reduce the number of RUF fires by 542, fatalities by 26, and total flame spread by 510 units. By comparison, the decline in smokers and cigarette consumption was estimated to reduce, on net, the number of RUF fires by 10, fatalities by 22, and total flame spread by 199 units. For smokers and packs consumed the results are net-results because the declines in smokers and packs consumed can partial offset, because their relative declines are not proportional. While overall declines in smokers and packs consumed would be assumed as having a positive impact on the number of fires, our findings suggest that smokers' smoking rates (packs consumed per smoker) matter. This means, within a state, fire risks differ depending on the type of smoker found there—i.e., lighter and heavier smokers have different fire risks per cigarette consumed. (More on this below.) That the results predict a reduction in 10 fires, but 22 fatalities do not necessarily imply that those 10 avoided fires were responsible for the 22 avoided fatalities. Rather the shifting distribution of relative smoking consumption rates per smoker meant the model would predict some areas to have more fires while others less, so on-net there were 10 fewer fires and of those fires that did occur, they were less damaging on average.

6.2 Trend Effects

In the fire, fatalities, and flame spread models, there are significant interactions between FSC and TREND. This implies marginal effects vary over time. Figures 1 through 3 provide greater insight into the implication of changes over time. Note that the marginal effects shown in the figures can be either compared against zero or against other measured marginal effects. Comparing a marginal effect against zero determines whether the effect is statistically significant. Comparing marginal effects—in this case, across time—determines whether the size of the effects is different, for instance, indicating whether the effect trends over time.

Figure 1 plots the estimated average marginal effect of FSC on the number of RUF fires over time, starting when the first state adopted a FSC regulation in 2004. The plot shows that as more and more states adopted FSC cigarettes, the average effect of FSC on the number of resulting fires, increased (became more negative). This could be a statistical issue of the effect being better detected with more data. It could also be the result of a lag between the

date of compliance and the sale of remaining non-compliant stock. Finally, it is also consistent with an increasing over time proportion of smuggled compliant cigarettes.

Figure 2 shows the estimated average marginal effect of FSC on the number fatalities over time. Similar to the pattern with fires, the average marginal effect is becoming negative over time. However, while suggestive, the evidence is statistically weak. Most of the marginal effects shown are significant only at the 11 % level. (The full model produce slightly higher significances – 9 %). Difficulties in modeling fatalities (and perhaps injuries) exist due to their limited occurrence in the dataset—63 % of the observations did not report any fatalities.

Figure 3 plots the estimated average marginal effect of FSC on the total extent of flame spread over time. Unlike Figures 1 and 2, Figure 3 demonstrates a rather stable, but slightly decreasing (less negative), effect over time.

For 2011, it is estimated that the presence of fire standard compliant cigarettes reduced the number of RUF fires by 7.5 per state (375 in total). This equates to a 45 % (90 % CI: 88 % to 3 % reduction in fires) reduction (16.6 to 9.1) in fires per state/year on average. The reduction on fatalities (–0.30) equates to a 23 % (90 % CI: 48 % to 1 % reduction in fatalities) reduction (1.3 to 1.0 fatalities per state), or 15 avoided fatalities for the Nation. Note, Hall (2012) finds that 24 % of fatal victims of home fires involving smoking materials were not the smoker, so the reductions in fatalities accrue to both smokers and the non-smoking occupants. Finally, the reduction in extent of flame spread due to FSC is –5.1, which implies a 27 % (90 % CI: 44 % to 10 % reduction in total flame spread) reduction in total flame spread (19.1 to 14.0).

6.3 Smokers and Cigarette Consumption

Smokers experience similar fire risks on a per-pack consumed basis across cigarette consumption levels. Table 8 provides the average number of fires, fatalities, injuries, and extent of flame spread, and associated standard error and 90 % confidence interval, per ten million packs consumed, by each cigarette consumption quartile, and only for those state/year combinations without a FSC requirement. Smoking rates were calculated by dividing cigarette packs smoked by the number of smokers in each state/year combination. Quartiles from lowest to highest were constructed and labeled, ‘Lightest,’ ‘Lighter,’ ‘Heavier,’ and ‘Heaviest.’ Table 8 shows that within risk categories (e.g., fires/packs), the means are not statistically different indicating the baseline fire risks are about the same, per cigarette smoked, regardless of consumption habits.

However, the results suggest effect of smokers and their consumption of FSC cigarettes affect fires, fatalities, and flame spread in nonlinear ways. Figures 4 through 6 depict the differences in cigarette consumption and size of the smoker population on the average marginal effects of FSC. Within each consumption quartile, the state/year combinations with the smallest and largest smoking populations were selected, along with their smoking consumption, and used as inputs into the fire, fatalities, and flame spread models to estimate the average marginal effects of FSC at each smoker population and consumption level. The figures show how the estimated effectiveness of FSC within a state depends on the number

of smokers and how much they smoke (per person). Variations in the estimated effectiveness suggests that factors relevant to fire incidents—e.g., related to reporting or related to conditions that influence fire growth—may be different across states due to the type of smokers found there.

Figure 4 shows when a smoker population is small the level of FSC cigarette consumption does not affect the occurrence of RUF fires. However, for a state with a large smoker population, FSC consumption reduces the number of fires (compared to the non-FSC condition), but only in areas with ‘Lighter’ to ‘Heaviest’ smokers.

Figure 5 indicates that FSC cigarettes have a life-safety effect in states with a small number of smokers, regardless of smoking consumption—and it should be noted this is the only instance where we find evidence of FSC affecting the fire risks associated with the lightest of smokers. However, for in states with a large number of smokers, FSC appear to reduce fatalities in places, but only with the ‘Heaviest’ smokers.

Figure 6 demonstrates a similar pattern to Figure 4, mainly that FSC cigarettes appear to affect the total extent of flame spread, but only in states with high smoking populations who smoke at the ‘Lighter’ level or higher.

Together, these findings suggest fire standard compliant cigarettes do not limit ‘random’ fires. Rather, the effect of FSC cigarettes is modulated by smoker consumption, the concentration of smokers available, and unobserved factors evolving over time. It is likely that the number of smokers and their relative cigarette consumption are correlated with other (unobserved) factors that affect the measured effectiveness of FSC on the rate of fires and fatalities, and extent of flame spread.

6.4 National Patterns

Due to differences in the number of smokers and their cigarette consumption, the effect of low-ignition potential cigarettes varies across states—and years too, as shown above. Figures 7 through 9 map the estimated percent reduction in RUF fires for 2011 (Figure 7), the estimated ratio of avoided RUF fire-related fatalities to RUF fires in 2011 (Figure 8), and the estimated percent reduction in the total extent of flame spread from RUF fires. (The quantity-groupings shown generally align to quartiles.)

Note that fatalities are shown as the ratio between fatalities avoided and number of fires rather than the percent reduction in fatalities, like the other measures. This was due to the fact that the specification and model functional form produce a constant percent reduction across states (25 % reduction), even though the marginal effects (number of fatalities avoided) are not constant. The ratio represents the change in the rate of fatalities per fire, holding the number of fires constant.

Looking across figures, the pattern of percent reduction in fires (Figure 7) generally tracks with the pattern of the percent reduction in flame spread (Figure 9), at least in those states with the greatest reductions. Most states are estimated to have at least a double-digit percent reduction in fires, where many more states are estimated to have singled-digit percent reduction in flame spread.

The pattern of fatality avoidance rates is a bit different than injuries and fire incidence. For instance, Florida, a state with high estimated percent reduction in fires and flame spread, also shows a high fatality avoidance rate. However, the estimated fatality avoidance rate for Texas is in the bottom fourth, unlike the percent reduction in fires and flame spread, which are in the top fourth. Virginia and Kentucky show the opposite pattern.

7. CONCLUSION

Residential structure fires pose a significant risk to life and property. A major source of these fire incidents is the ignition of upholstered furniture by cigarettes. This paper examines the impact that fire standard compliant cigarettes have had on residential fires involving upholstered furniture using three modeling techniques: Poisson model, negative binomial model, and ordinary least squares model. Four models were estimated to measure the annual effect of fire standard compliant cigarettes in each state on (1) the count of fires involving residential upholstered furniture, (2) the count of fire-related civilian (occupant) fatalities from RUF fires, (3) the count of fire-related civilian injuries from RUF fires, and (4) the total extent of flame spread resulting from RUF fires. Count models accounting for zero-inflation were used for models (1) through (3). Ordinary least squares (OLS) was used to model (4), and only on the subset of observations reporting a positive number of RUF fires. These models provide evidence that fire standard compliant cigarettes, on average, reduced the number and impact of residential fires. For 2011, the number of cigarette-ignited residential fires involving upholstered furniture were reduced by 45 %, fatalities reduced by 23 %, and the extent of flame spread reduced by 27 %. The findings are generally supportive of previous literature suggesting reductions in the number of fires from FSC use of 12 % to 28 %, reductions in fatalities of 11 % to 41 % (although one study found no correlation with the number of fatal fires), and no statistical correlation between fire injuries and FSC use.

The measured effectiveness of fire standard compliant cigarettes is influenced by the number and behavior of smokers. In general, FSC cigarettes are more effective in places with a large smoking population who engage in heavier smoking. The exception to this is with regards to fatalities, where places with smaller smoking populations can benefit irrespective to smoking consumption. It is only in places with smaller smoker populations that the lightest smokers seem to benefit from FSC, and only in terms of a reduction in fatalities, as the number of fires and extent of flame spread (a proxy for property damage) appear unresponsive.

Differences in the behavior of smokers, along with the disproportional reductions in fires to fatalities and extent of flame spread, demonstrate a non-randomness in the types of fires affected by FSC cigarettes. This can be due to severity of the fire or the presence of occupants, or factors related to their condition. Opportunities exist for new technologies, which can better counter the ignitions from light smokers, to reduce the fire risks from cigarettes. The analysis does not account for changes in the flammability of upholstered furniture over the study period, other than those that may have occurred linearly over time. However, no new regulations occurred over this period. The average life span of upholstered furniture is estimated to be 15 to 17 years [20], so the mix of furniture found in U.S. greatly varies with respect to age.

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Figure 1.
Estimated average marginal effects, and 90 % confidence interval, of FSC cigarettes on the number of RUF fires caused by cigarettes from 2004 to 2011.

Figure 2. Estimated average marginal effects, and 90 % confidence interval, of FSC cigarettes on the number of RUF fire-related fatalities caused by cigarettes from 2004 to 2011.

Figure 3. Estimated average marginal effects, and 90 % confidence interval, of FSC cigarettes on the total extent of flame spread of RUF fires caused by cigarettes from 2004 to 2011.

Figure 4.

Estimated average marginal effects, and 90 % confidence intervals, of FSC cigarettes on the number of RUF fires caused by cigarettes, differentiated by groupings of the number of smokers and their average cigarette consumption. The four cigarette consumption categories correspond to the quartiles of smoking rates (cigarette packs smoked divided by smokers).

Figure 5.

Estimated average marginal effects, and 90 % confidence intervals, of FSC cigarettes on the number of RUF fire-related fatalities caused by cigarettes, differentiated by groupings of the number of smokers and their average cigarette consumption. The four cigarette consumption categories correspond to the quartiles of smoking rates (cigarette packs smoked divided by smokers).

Figure 6.

Estimated average marginal effects, and 90 % confidence intervals, of FSC cigarettes on the total extent of flame spread of RUF fires caused by cigarettes, differentiated by groupings of the number of smokers and their average cigarette consumption. The four cigarette consumption categories correspond to the quartiles of smoking rates (cigarette packs smoked divided by smokers).

Figure 7.
Estimated percent reduction in RUF fires (due to FSC) in 2011. (Gray denotes no data.)

Figure 8.
Estimated ratio of avoided RUF fire-related fatalities (due to FSC) to RUF fires in 2011.
(Gray denotes no data.)

Figure 9.
Estimated percent reduction in the total extent of flame spread from RUF fires (due to FSC) in 2011. (Gray denotes no data.)

Table 1

Descriptive statistics of the variables used in the modeling, including the number of observations (Obs.), their mean, standard deviation (Std. Dev.), and minimum (Min.) and maximum (Max.) values.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
FIRES	488	8.83	9.17	0.0	54.0
FATALITIES	488	0.68	1.17	0.0	8.0
INJURIES	488	1.44	2.29	0.0	22.0
FSC	488	0.30	0.46	0.0	1.0
PACKS	488	32.61	28.54	3.3	132.9
SMOKERS	488	1.07	0.98	0.1	5.1
TREND	488	5.43	2.87	1.0	10.0
SPREAD *	458	11.48	12.64	0.0	73.0
Confined to Object *	458	2.32	3.13	0.0	20.0
Confined to Room *	458	3.11	3.38	0.0	20.0
Confined to Floor *	458	0.86	1.34	0.0	7.0
Confined to Building *	458	1.90	2.43	0.0	16.0
Beyond Building *	458	0.23	0.58	0.0	4.0
NONRUF	488	64.69	67.52	0.0	431.0
REPORTING	488	31.77	25.89	0.0	119.4
OUTSIDE	488	32.61	43.26	0.0	327.0

* Only 458 observations reported a positive number of fires.

Table 2

Output of the zero-inflated negative binominal model for the count of RUF fires, including the estimated model coefficients (Coeff.), and their corresponding standard error (Std. Err.), z value (standard deviations from the mean), and probability ($P>|z|$) of equaling zero.

Variable	Coeff.	Std. Err.	z	$P> z $
<i>Main Model</i>				
Intercept	0.9114	0.2127	4.28	<0.01
FSC	-0.4650	1.0307	-0.45	0.65
PACKS	0.0369	0.0251	1.47	0.14
FSC × PACKS	-0.1650	0.0817	-2.02	0.04
SMOKERS	0.2665	0.9445	0.28	0.78
FSC × SMOKERS	6.0600	3.2007	1.89	0.06
PACKS × SMOKERS	-0.0090	0.0025	-3.57	<0.01
FSC × PACKS × SMOKERS	-0.0129	0.0154	-0.83	0.40
TREND	0.0085	0.0464	0.18	0.85
FSC × TREND	0.0007	0.1249	0.01	1.00
PACKS × TREND	-0.0005	0.0059	-0.08	0.93
FSC × PACKS × TREND	0.0180	0.0107	1.68	0.09
SMOKERS × TREND	-0.0061	0.2152	-0.03	0.98
FSC × SMOKERS × TREND	-0.5919	0.4067	-1.46	0.15
PACKS × SMOKERS × TREND	0.0008	0.0006	1.37	0.17
FSC × PACKS × SMOKERS × TREND	0.0005	0.0018	0.28	0.78
<i>Zero-Inflation Model</i>				
Intercept	2.5715	1.0295	2.50	0.01
NONRUF	-1.0029	0.3754	-2.67	0.01
REPORTING	0.0344	0.1533	0.22	0.82
OUTSIDE	-0.1245	0.3209	-0.39	0.70

Table 3

Output of the zero-inflated Poisson model for the count of RUF fire-related fatalities, including the estimated model coefficients (Coeff.), and their corresponding standard error (Std. Err.), z value (standard deviations from the mean), and probability ($P>|z|$) of equaling zero.

Variable	Coeff.	Std. Err.	z	$P> z $
<i>Main Model</i>				
Intercept	-0.5217	0.5875	-0.89	0.38
FSC	2.4970	1.8128	1.38	0.17
PACKS	-0.0260	0.0583	-0.45	0.66
FSC × PACKS	-0.0272	0.1626	-0.17	0.87
SMOKERS	1.5194	2.1761	0.70	0.49
FSC × SMOKERS	-0.5469	5.9447	-0.09	0.93
PACKS × SMOKERS	-0.0046	0.0056	-0.81	0.42
FSC × PACKS × SMOKERS	0.0044	0.0259	0.17	0.86
TREND	0.1231	0.1124	1.10	0.27
FSC × TREND	-0.4267	0.2402	-1.78	0.08
PACKS × TREND	0.0283	0.0125	2.26	0.02
FSC × PACKS × TRND	-0.0175	0.0216	-0.81	0.42
SMOKERS × TREND	-1.0343	0.4570	-2.26	0.02
FSC × SMOKERS × TREND	0.8835	0.7815	1.13	0.26
PACKS × SMOKERS × TREND	0.0015	0.0011	1.33	0.18
FSC × PACKS × SMOKERS × TREND	-0.0021	0.0031	-0.68	0.50
<i>Zero-Inflation Model</i>				
Intercept	1.8960	0.3455	5.49	<0.01
NONRUF	-0.0367	0.0107	-3.44	<0.01
REPORTING	-0.0224	0.0113	-1.99	0.05
OUTSIDE	0.0161	0.0071	2.26	0.02

Table 4

Output of the parsimonious version of the zero-inflated negative binominal model for the count of RUF fire-related fatalities, including the estimated model coefficients (Coeff.), and their corresponding standard error (Std. Err.), z value (standard deviations from the mean), and probability ($P>|z|$) of equaling zero.

Variable	Coeff.	Std. Err.	z	$P> z $
<i>Main Model</i>				
Intercept	0.0447	0.1151	0.39	0.70
FSC $\times$ TREND	-0.0293	0.0181	-1.62	0.11
PACKS $\times$ TREND	0.0094	0.0025	3.84	<0.01
SMOKERS $\times$ TREND	-0.2462	0.0717	-3.44	<0.01
<i>Zero-Inflation Model</i>				
Intercept	1.9632	0.3184	6.17	<0.01
NONRUF	-0.0339	0.0097	-3.51	<0.01
REPORTING	-0.0240	0.0106	-2.27	0.02
OUTSIDE	0.0151	0.0068	2.22	0.03

Table 5

Output of the zero-inflated negative binominal model for the count of RUF fire-related injuries, including the estimated model coefficients (Coeff.), and their corresponding standard error (Std. Err.), z value (standard deviations from the mean), and probability ($P>|z|$) of equaling zero.

Variable	Coeff.	Std. Err.	z	$P> z $
<i>Main Model</i>				
Intercept	-0.4322	0.4769	-0.91	0.37
FSC	1.5593	1.7262	0.90	0.37
PACKS	-0.0260	0.0535	-0.49	0.63
FSC × PACKS	0.1379	0.1393	0.99	0.32
SMOKERS	1.8386	1.9601	0.94	0.35
FSC × SMOKERS	-6.0375	5.2653	-1.15	0.25
PACKS × SMOKERS	-0.0057	0.0051	-1.11	0.27
FSC × PACKS × SMOKERS	0.0179	0.0248	0.72	0.47
TREND	0.0094	0.1013	0.09	0.93
FSC × TREND	-0.2059	0.2170	-0.95	0.34
PACKS × TREND	0.0107	0.0115	0.94	0.35
FSC × PACKS × TRND	-0.0227	0.0185	-1.23	0.22
SMOKERS × TREND	-0.3617	0.4095	-0.88	0.38
FSC × SMOKERS × TREND	0.9583	0.6786	1.41	0.16
PACKS × SMOKERS × TREND	0.0007	0.0011	0.64	0.53
FSC × PACKS × SMOKERS × TREND	-0.0030	0.0030	-1.01	0.31
<i>Zero-Inflation Model</i>				
Intercept	2.4243	0.6844	3.54	<0.01
NONRUF	-0.1563	0.0627	-2.49	0.01
REPORTING	-0.0080	0.0266	-0.30	0.76
OUTSIDE	0.0262	0.0557	0.47	0.64

Table 6

Output of the ordinary least squares model for total extent of flame spread, including the estimated model coefficients (Coeff.), and their corresponding standard error (Std. Err.), z value (standard deviations from the mean), and probability ($P>|z|$) of equaling zero.

Variable	Coeff.	Std. Err.	z	$P> z $
<i>Main Model</i>				
Intercept	1.6899	2.3679	0.71	0.48
FSC	2.3023	11.0257	0.21	0.84
PACKS	0.8623	0.2984	2.89	<0.01
FSC × PACKS	-3.8993	1.1709	-3.33	<0.01
SMOKERS	-21.1867	11.5263	-1.84	0.07
FSC × SMOKERS	106.1664	43.0094	2.47	0.01
PACKS × SMOKERS	-0.0302	0.0335	-0.90	0.37
FSC × PACKS × SMOKERS	0.0849	0.1922	0.44	0.66
TREND	0.1849	0.5273	0.35	0.73
FSC × TREND	-0.4373	1.3514	-0.32	0.75
PACKS × TREND	-0.0479	0.0743	-0.64	0.52
FSC × PACKS × TREND	0.4178	0.1492	2.80	0.01
SMOKERS × TREND	1.3860	2.7098	0.51	0.61
FSC × SMOKERS × TREND	-10.8416	5.3936	-2.01	0.05
PACKS × SMOKERS × TREND	0.0191	0.0074	2.58	0.01
FSC × PACKS × SMOKERS × TREND	-0.0235	0.0227	-1.04	0.30

Table 7

Estimated average marginal effects (ME), and their significances (P; probability of ME equaling zero), of a change in the count of fires, fatalities, injuries, and total extent of flame spread resulting from a change in the covariates.[/]

	Fires		Fatalities		Injuries		Flame Spread	
	ME	P	ME	P	ME	P	ME	P
FSC	-3.2065	0.04	-0.1146	0.10	0.5332	0.72	-6.9333	<0.01
PACKS	0.1597	0.05	0.0363	<0.01	0.0163	0.47	0.5568	<0.01
SMOKERS	1.2046	0.60	-0.9495	<0.01	0.3304	0.63	-8.6011	0.03
TREND	0.3697	0.06	0.0421	<0.01	0.0581	0.29	1.0856	<0.01

[/] All changes are the result in a small (marginal) change in the covariate, except for FSC, which corresponds to a discrete change from 0 to 1 in the FSC variable.

Table 8

The mean rate of fires, fatalities, injuries, and flame spread per ten million cigarette packs consumed by quartile (lightest, lighter, heavier, heaviest) of the average cigarette consumption per smoker over state/year combinations with no FSC requirement, and the associated standard error, lower 90 % confidence interval (CI), and upper 90 % confidence interval.

Consumption	Mean	Std. Err.	Lower 90 % CI	Upper 90 % CI
FIRES/PACKS				
Lightest	0.3389	0.0313	0.2868	0.3909
Lighter	0.3241	0.0254	0.2818	0.3664
Heavier	0.3024	0.0229	0.2643	0.3405
Heaviest	0.2697	0.0193	0.2375	0.3018
FATALITIES/PACKS				
Lightest	0.0316	0.0098	0.0153	0.0479
Lighter	0.0404	0.0119	0.0207	0.0602
Heavier	0.0235	0.0055	0.0144	0.0326
Heaviest	0.0199	0.0032	0.0145	0.0253
INJURIES/PACKS				
Lightest	0.0627	0.0103	0.0455	0.0799
Lighter	0.0586	0.0096	0.0428	0.0745
Heavier	0.0382	0.0060	0.0281	0.0482
Heaviest	0.0376	0.0079	0.0245	0.0508
SPREAD/PACKS				
Lightest	0.3878	0.0429	0.3164	0.4592
Lighter	0.3713	0.0339	0.3150	0.4276
Heavier	0.3695	0.0280	0.3230	0.4160
Heaviest	0.3226	0.0261	0.2792	0.3660