A Review of the National Fire Incident Reporting System and the National Fire Protection Association's Upholstered Furniture Fire Statistics

PREPARED FOR

The Fire Prevention Alliance

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Executive summary

This report was prepared for and funded by the Fire Prevention Alliance (FPA), a non-profit 501(c)(3) corporation established in 2002 to promote public fire safety education among segments of the population who are likely to experience a household fire. FPA contributors include trade associations affiliated with the manufacture of home furnishings and suppliers of raw materials and components used for the manufacture of upholstered furniture and mattress sets.

The FPA asked The Brattle Group to assess the reliability of upholstered furniture fire death data reported by the National Fire Incident Reporting System (NFIRS) and the interpretation of these data by the National Fire Protection Association (NFPA). The NFIRS data have served as the primary basis to estimate fire risks and fire-related costs (deaths, injuries, and property losses attributable to upholstered furniture) since 1980.

Specifically, the FPA asked us to evaluate two estimates: 1) the number of deaths attributable to fires where upholstered furniture was identified as the item of first ignition (smolder + small open flame + other ignition sources) and 2) the number of deaths attributable to fires where upholstered furniture was designated as the principal item responsible for fire spread (numerous larger smolder and larger open flame ignition sources). We focus on home structure fires in our analysis.

The NFPA finds that there has been a 67 percent decrease in deaths where upholstered furniture was the item first ignited between 1980 and 2009.[1] But the NFPA also claims that deaths due to upholstered furniture contributing to fire spread should be counted as well. According to the NFPA, including these deaths adds an additional 130 deaths to the average number of deaths attributable to upholstered furniture over the period 2006-2010—27 percent increase over a count based on first ignition alone.[2] This would imply that, while the number of fire deaths is falling, the number of fire deaths due to upholstered furniture has been underreported in the past and that the current risk is higher than generally thought. Deaths per million, a standard risk measure, is 1.36 considering ignition-related deaths and 1.77 when fire spread-related deaths are included.

Since this claim has important implications for fire safety policy, it is an appropriate time to review the reliability of the NFIRS-based fire statistics. We conducted an analysis to address this question and conclude the following:

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[1] NFPA. 2011. *Home Structure Fires that Began with Upholstered Furniture.* NFPA: Quincy, MA.

[2] Hall Jr., John R. 2014. *Estimating Fires When a Product is the Primary Fuel But Not the First Fuel, With an Application to Upholstered Furniture.* NFPA: Quincy, MA.

1. NFIRS-based statistics generated by NFPA and the Consumer Product Safety Commission (CPSC) are subject to substantial uncertainty, making them of limited usefulness for policy making purposes.

2. The high degree of uncertainty is not widely recognized and is not reported in NFIRS, NFPA, or CPSC documents.

3. The number of deaths arising from fires where upholstered furniture is the item first ignited has large confidence intervals. In 2012, for example, there were an estimated 452 deaths with a confidence interval that is wider than the estimate itself: +/- 246. Thus, the actual number of fire deaths could be as low as 206 (452-246) or as high as 698 (452+246).

4. In that same year, there are an additional 73 deaths were upholstered furniture was the item that most contributed to fire spread, with a wide confidence interval of +/-64. Consequently, there could be as few as 9 deaths (73-64) or as many as 137 (73+64) added to total deaths attributable to upholstered furniture.

5. These confidence intervals understate the extent of the uncertainties associated with the NFIRS data for several reasons:
    a. The NFIRS-based values include allocations of both missing and unknown item types because fire department reports are often incomplete. These values represent a large proportion of responses. In 2012, over 30 percent of the item of first ignition responses are missing and about 2 percent are listed as unknown. With respect to the item responsible for fire spread, about 75 percent are missing and about 10 percent are unknown, implying that this variable is only 15 percent complete. Allocating these fires to known sources requires assuming that these fires resemble those whose values were recorded. Because such a significant proportion of the data have unassigned sources, estimates are very sensitive to their inclusion. Performing this allocation more than doubles the estimate of deaths related to upholstered furniture.
    b. An allocation technique designed to overcome these gaps is sensitive to several key assumptions and changes in these assumptions result in notably different estimates. For example, allocation using the national estimates approach—the method commonly employed—results in higher losses and wider confidence intervals than applying regional and metro-area scaling factors to the same unknown data fields.
    c. The accuracy of fire department reporting is unknown. We are unaware of any forensic analysis used to determine the accuracy of the reports. We do not, for example, know the basis used by departments for determining whether a piece of furniture was the item responsible for fire spread; this may be the opinion of a firefighter without the benefit of careful analysis. We do not even know whether missing data reflect that the information is unknown or that the question was simply not answered.

I. Introduction and summary

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The estimated based on the item responsible for fire spread has only recently been proposed as an additional source of upholstered furniture fire-related deaths. Whether this addition actually improves the accuracy of the fire death statistics is unclear, especially in view of the limitations of the NFIRS data. Addressing this question requires a broader and more sophisticated review of the NFIRS data and its applications. This paper is an attempt to accomplish this.

Our analysis of the reliability question leads us to the following basic conclusions:

1. NFIRS-based statistics generated by the NFPA and the Consumer Product Safety Commission (CPSC) are subject to substantial uncertainty, making them of limited usefulness for policy making purposes;

2. The degree of uncertainty is not widely recognized and is not reported in NFIRS, NFPA, or CPSC documents; and

3. The confidence intervals we estimate are large, but still understate the extent of uncertainty associated with the NFIRS data due to data reporting limitations.

We elaborate on these conclusions in the body of this report.

The report is organized in six sections following this introduction. Section II provides a brief background. Section III reviews the allocation approach currently used to account for data gaps in NFIRS, while Section IV provides an alternative method. Section V presents a discussion of

the missing data problem. Section VI discusses how to treat uncertainty in the data and how to calculate confidence intervals. Section VII presents our results and conclusions.

II. Background

NFIRS data have been collected since the 1970s and became a more exhaustive questionnaire beginning in 1999.[3] It has been the primary source of information for researchers and policy makers of the trends and causes of residential fires and fire deaths. The NFPA and the CPSC have both relied on these data to make policy recommendations. Using the NFIRS data, these institutions and the U.S. Fire Administration have noted that residential furniture fires and related deaths have fallen considerably since 1980. According to the NFPA, upholstered furniture fire-related deaths have fallen from 1,360 in 1980 to 450 in 2009.[4] Accounting for population growth, the risk of death from furniture fire has fallen from 8.1 per million to 1.9 per million.[5] These trends are shown in Figure 1.

Despite these trends, the NFPA, the CPSC and the FPA remain concerned about upholstered furniture fires and related deaths. A recent study by John Hall of the NFPA suggest that the number of furniture-related deaths is understated because it refers only to deaths attributed to fires where furniture is the item first ignited.[6] Hall asserts that fires where furniture have been identified as the primary source of fire spread should also be counted. Based on his calculations, this would add 130 deaths to the 480 deaths based on first ignition on average from 2006 through 2010, a 61 percent increase. This would increase the risk level from 1.57 to 1.87 per million on average for the period.

The FPA is concerned that making this addition is problematic due to several important limitations of the NFIRS data. As a result, the proposed addition is not necessarily a step toward

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3 U.S. Fire Administration. 2015. *National Fire Incident Reporting System Complete Reference Guide.*

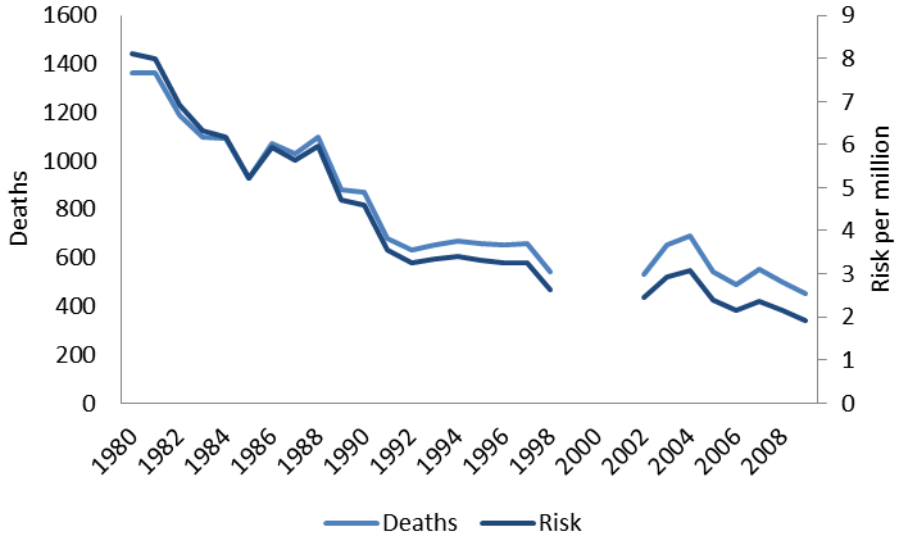
4 Ahrens, Marty. 2011. *Home Structure Fires that Began with Upholstered Furniture.* NFPA: Quincy, MA. Note that the NFPA does not report estimates for 1999-2001.

5 Risk measured by deaths per million is standard practice for government agencies and academic research. See, for example, U.S. Fire Administration. 2015 *Fire Risk in 2011*. Topical Fire Report Series: 15(8). Population data is from US. Bureau of Labor Statistics, *Civilian Noninstitutional Population* [CNP16OV], retrieved from FRED, Federal Reserve Bank of St. Louis.

6 Hall, Jr., John R. 2014. *Estimating Fires When a Product is the Primary Fuel But Not the First Fuel, with an Application of Upholstered Furniture.* NFPA: Quincy, MA.

improving the accuracy of the estimates. Others, including Hall, have recognized these limitations as well.[7]

Figure 1: NFPA estimated furniture fire-related deaths and risk per million



III. The National Estimates Approach

We understand that estimates of the number of fires in the U.S. are traditionally calculated following the National Estimates (NE) approach of Hall and Harwood (1989).[8] In this section, we discuss this approach and its underlying assumptions.

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7 National Fire Protection Association. 2013. *White Paper on Upholstered Furniture Flammability*. NFPA: Quincy, MA, and Moore-Merrell, Lori. 2015. "Fire Data: Quantity and Quality." International Association of Fire Fighters, Flame Retardants Meeting, March 8, 2015.

8 Hall Jr., John R. and Beatrice Harwood. 1989. "The National Estimates Approach to U.S. Fire Statistics." *Fire Technology*. 25(2): 99-113.

A. SUMMARY OF THE NE APPROACH

The steps are:

1. Using the NFIRS data, proportionally allocate fires with unknown or missing sources to each possible source based upon the reported frequency of the source. The reported frequencies are calculated using a cross tabulation of first ignition sources and primary sources of spread.[9]
2. Calculate the total number of fires reported in the NFIRS database.
3. Using the NFPA annual survey of fire departments, calculate the total number of fires in the U.S.[10]
4. Calculate a scaling factor equal to the number of fires implied by the NFPA survey (step 3) divided by the number reported to NFIRS (step 2).
5. Apply the scaling factor (step 4) to the number of fires imputed to have upholstered furniture as the item of first ignition (step 1) and add the number of unconfined fires for which upholstered furniture was not the item of ignition, but was the primary item responsible for spread (also from step 1).

These steps are repeated separately for counts of fires and deaths.

The logic behind the NE approach is:

- Because the NFPA survey includes a (stratified) random sample of fire departments, it can produce an accurate estimate of the total number of fires in the country.[11]
- The NFPA survey asks for fewer details about the fires than are provided to NFIRS.
- The NFIRS fire counts by item can be scaled to a national level by applying the scaling factor calculated using total fire counts from the survey.
- NFIRS reports with missing or unknown values for the items of ignition or spread are similar to those with these values completed.

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[9] The NFPA allocates separately for fires recorded as contained and those that were not contained. Contained fires are assumed not to have a source of spread. They also allocate separately by fire size. We allocate separately for contained and uncontained fires, but not by fire size.

[10] While the NFPA annual survey asks each department how many fires it responded to, the department is not asked for detailed information about those fires, such as the item of ignition or spread.

[11] Of course, even if the departments surveyed are a random sample, the departments that respond are not.

B. Assumptions of the NE approach

For this logic to hold, the following assumptions must be true:

- Departments responding to the NFPA survey are a random sample of U.S. fire departments and accurately report the number of fires that they responded to. This leads to an accurate estimate of the total fires in the country.
- The composition of fires within NFIRS must reflect the typical or average composition of fires in the U.S. This implies an accurate assignment of total fires to particular categories.
- Fires with missing values for the items of ignition or spread must have a similar composition of these items as those for which these values are reported.

Put differently, the average department reporting to NFIRS can respond to more or fewer fires than the average U.S. department; scaling based on the NFPA survey ensures that the total number of fires is accurate. But the average individual fire report in the NFIRS sample must be like the average fire in the U.S. to ensure that the composition of fires is accurately estimated. Furthermore, when these values are missing, these fires must be similar to fires for which these values are recorded.

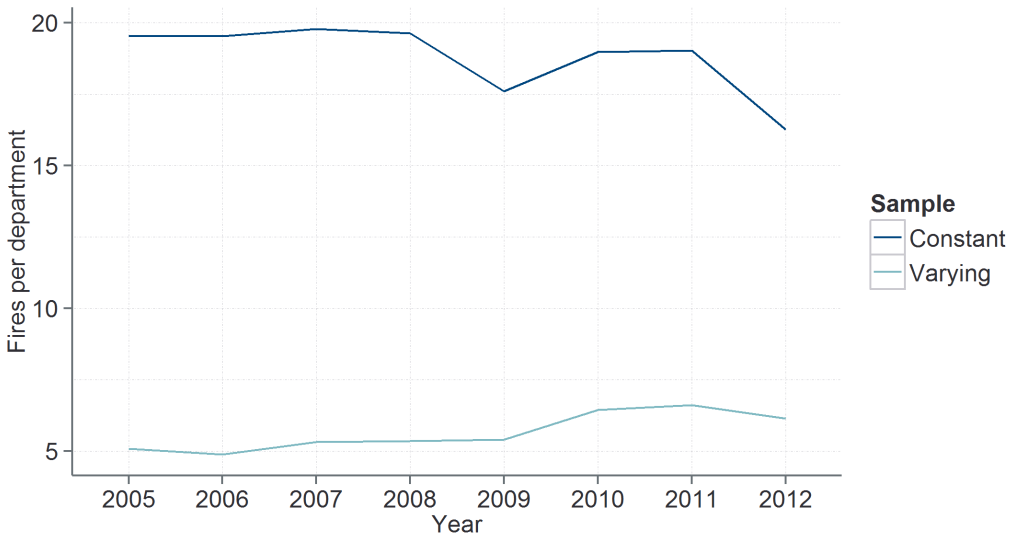
C. Evaluating the representativeness of fires in the NFIRS database

To the second NE assumption, we find that departments in urban areas are overrepresented relative to those in rural areas and some states are overrepresented while others are underrepresented. Furthermore, the extent and degree of these differences change over time. If the proportion of fires of a given type (such as those with upholstered furniture as the item first ignited) differs between urban and rural areas or across states, then they will be disproportionally represented in the NE approach, leading to incorrect estimates of fire counts and trends. Hence, representativeness of the NFPA survey, the departments reporting to NFIRS, and the types of fires with complete information are all required to reach correct policy conclusions.

We consider how the changing composition of NFIRS departments over time influences the fire trends that are estimated using these data. There are 5,668 departments that report at least one fire to NFIRS every year from 2005 to 2012; call this the "constant sample." All other departments are part of the "varying sample." Figure 2 shows the average number of fires per department for these two samples. We see that the departments that tend to consistently report to NFIRS tend to be larger than those that do not.[12]

[12] This is partly a selection effect; smaller departments may not report every year because they do not experience a fire every year.

Figure 2: Average fires per department for a constant sample of NFIRS departments versus all other departments



By the end of the period, the average number of fires per department in the constant sample decreased by about 17%, while it increased by about 20% for the varying sample. Given that the constant sample effectively controls for unobservable factors, the trend experienced by these departments should be pretty reliable (at least for this group). On the other hand, because the departments contained in the varying sample are changing, many other factors could be affecting the observed trend. Taken together, these results suggest that (a) larger departments are more likely to consistently report to NFIRS, possibly inflating total fire estimates (especially when NFIRS counts are scaled by the number of departments, as we do in the next section of this report) and (b) the most reliable indication of fire trends in the NFIRS data indicates that fires have decreased since 2005.

IV. An alternative approach: Scaling by region

In this section, we offer an alternative approach to scaling NFIRS counts to estimates of nationwide fires. We calculate scaling factors using the NFIRS data supplemented with the USFA National Fire Department Census for each combination of states and urban versus rural distinctions.[13]

[13] We use a data set from the National Center for Health Statistics and the U.S. Center for Disease Control that classifies U.S. counties as either urban or rural.

A. SCALING BY REGION

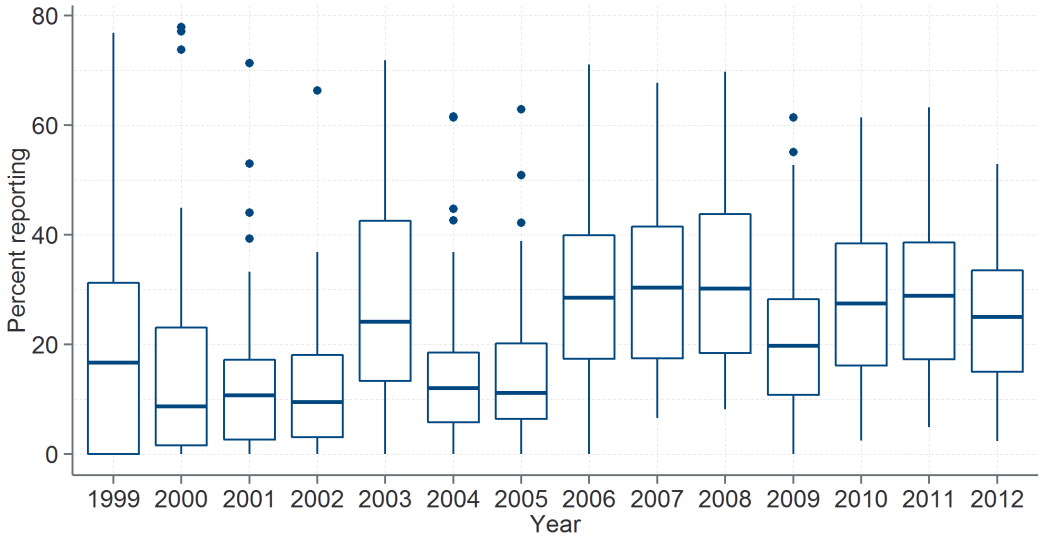
In our approach, we stratify fire departments by state and metro status (such as urban New York State departments), find the average number of fires reported to NFIRS within that area, and scale by the number of departments in the census in that area. Here the assumption is that the average respondent to NFIRS is the same as the average department within a state and metro status pair. We assert that it is more likely that an urban New York State respondent to NFIRS is representative of that area than the average NFIRS respondent is of a typical U.S. department.

This approach is used to scale not only total fires, but also fires by category (such as those in which upholstered furniture was the item first ignited). Hence, if the composition of fires varies by region, our approach takes those differences into account. Region-weighting also takes into account differences in propensities to report to NFIRS across the country. For example, some state fire agencies may encourage local departments to report more than those in other states. Also, larger urban departments may have more resources for filing reports than small rural departments and thus may be more likely to do so. Region weighting is able to take these factors into account, while the NE approach does not.

Figure 3 shows the distribution of the percentage of departments reporting by year across all regions. The figure reveals that the median proportion of reporting departments only begins to exceed 20% in 2006. The results that we present in this report focus on 2005 and later.

Even in this later period, there is tremendous range in this proportion; indeed, in some years, some regions have few to no departments reporting. Hence, if each fire is weighted equally, as in the NE approach, then some regions will be overrepresented (those with a high proportion of departments reporting) and some will be underrepresented (those with a low proportion of reporting departments). Our method ensures that each region contributes to the national total in proportion to their actual size, not in proportion to the number of their departments that report to NFIRS.

Figure 3: Boxplot of NFIRS department reporting percentages by region-year[14]



B. COMPARISON TO THE NE APPROACH

The NE approach requires that the composition of fires in NFIRS be nationally representative, while the region scaling approach requires that NFIRS only be representative in each separate region. This is a weaker assumption: NFIRS can be representative by region, but if those regions are disproportionally represented in NFIRS, NFIRS will not be nationally representative. The NE approach requires that the NFPA survey provide accurate estimates of the total number fires each year, while the region scaling approach requires the USFA census to be comprehensive.[15]

In light of this comparison of assumptions, the region-scaling approach is preferred on NFIRS representativeness grounds. It is preferred entirely if the USFA census contains every U.S. department. The USFA estimates that 88% of departments are registered with the census.[16] The NE approach is preferred if the NFPA survey well represents the typical U.S. department and

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[14] A boxplot shows a distribution of values. Each box indicates the median value by a thick line in the middle of the box. The box is bounded by the 25th and 75th percentiles of the distribution. The "whiskers" extend from the box to the most extreme value unless there are outliers, which are denoted with dots.

[15] For the NFPA survey to accurately estimate total U.S. fires, however, the NFPA must also have a complete census of U.S. fire departments.

[16] If the propensity to be included in the census is the same across regions, then analysis of trends will be accurate, but the total number of fires will be underestimated.

those respondents provide accurate counts of their fires and if the composition of fires is relatively constant across the country.

Our approach allows us to produce national estimates of fire counts using publicly available data that may be more reliable for both total fire counts and counts by category of fire than the NE approach.

V. Handling missing values

There are two types of fires with unassigned sources in the NFIRS data: values that are not completed ("missing") and those where the respondent specifically stated that the value is "unknown." In this section, we reveal how often NFIRS records fall into these categories and discuss the implications for calculating nationwide estimates of fires and deaths.

A. Frequency of unobserved sources

Figure 4 and Figure 5 show the proportions of unassigned fires for first ignition and primary spread items.[17] In the case of first ignition, there are many more unknown classifications than missing classifications. Further, the proportion of unknowns is increasing over time, rather than decreasing, as one might expect if the quality of NFIRS data was improving.

On the other hand, for the item primarily responsible for fire spread, there are many more missing values than unknown values. Notice that about 70% of these values are missing, even in the most recent reporting year. Hence, allocating these values to known sources can have a substantial impact on estimates of nationwide fires and deaths.

[17] Following Hall (2014), we focus on uncontained fires when considering the item responsible for fire spread.

Figure 4: Proportion of raw NFIRS fires with the item of first ignition categorized as missing or unknown

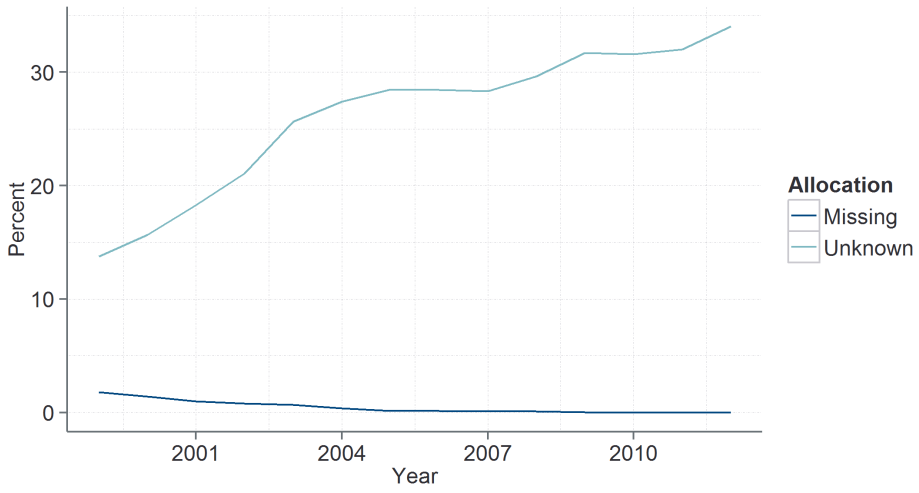
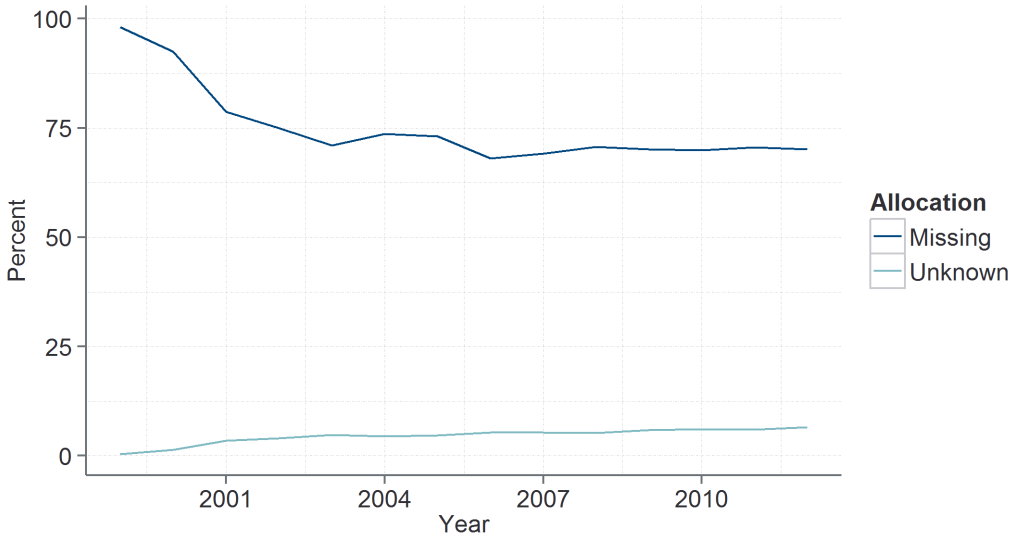


Figure 5: Proportion of raw uncontained NFIRS fires with the item responsible for fire spread categorized as missing or unknown



B. THEORETICAL DISCUSSION

Missing values could reflect either that the recorder skipped the question or that he was unsure of the correct response. In the former case, perhaps it is reasonable to assume that the fires with missing values are similar to those whose values have been completed. In the latter case, missing values are more similar to those recorded as unknown. Without a forensic analysis of the scene of the fire, these unknown fires cannot be accurately categorized.

For both first ignition and for fire spread, the item responsible is imputed when the reported value is either missing entirely or listed as unknown. These are two distinctively different cases, yet the NE approach treats both cases in the same manner.

When the true value is unknown, as opposed to missing, it is unlikely that the true items ignited for these fires are similar to those of fires where the respondent was confident of the item. For example, if a fire was ignited by a transformer, it is likely known to be the source and, contrarily, a fire with an unknown source was unlikely to have been started by a transformer. Hence, a simple proportional allocation of these unknown values is likely inaccurate.

Additionally, the item first ignited may be clearer than the item responsible for spread. For example, in the case of a bedroom fire, it may not be clear whether bedding or clothing, two distinct sources in the NFIRS data, was responsible for furthering the spread of the fire.

Inferences for missing or unknown values must be based upon known values, however. The NFPA assumes that a missing value from any department in the country can be randomly allocated a value from the nationwide distribution of fire types. Our approach is more refined, as it assumes that the missing value be similar to those from a department in the same region. A yet more refined approach would create a statistical model that incorporates many other known features of the fire to predict the unknown values for the fire.

C. IMPLICATIONS FOR RESULTS

Table 2 and Table 3 show a comparison of three allocations. First, we estimate the number of upholstered fires by scaling fires with upholstered furniture as the item first ignited. Second, we allocate missing fires, but not unknown fires, to each source (including to an unknown source). Lastly, we provide an estimate based upon allocating both the missing and unknown values, which is comparable to the approach used by the NFPA and used in the remainder of this report for comparability.

Table 1: Comparison of total fires attributable to upholstered furniture under three allocations (2006-2010 average)

Allocation	First ignition	Item of spread	Total
No allocation	6,560	670	7,230
Allocate missings	6,566	2,262	8,828
Allocate missings and unknowns	9,243	3,503	12,746

Table 2: Comparison of total fire deaths attributable to upholstered furniture under three allocations (2006-2010 average)

Allocation	First ignition	Item of spread	Total
No allocation	211	20	231
Allocate missings	211	56	267
Allocate missings and unknowns	452	102	554

Allocating missing (as opposed to unknown) values has the largest impact on estimates for the item responsible for fire spread, as we would expect upon comparing Figure 4 and Figure 5. Allocating fires whose value is unknown has a large impact on estimates of both first ignition and item of spread. Indeed, allocating these fires more than doubles the estimated number of deaths attributable to upholstered furniture. If these fires of unknown provenance have a different distribution of responsible items than fires with recorded values, then estimates obtained using proportion allocation could be very inaccurate.

VI. Estimating uncertainty and creating confidence intervals

Extrapolating from NFIRS counts of fires related to upholstered furniture to total U.S. fires related to this item requires calculating a scaling factor that inflates NFIRS fire counts to nationwide fire counts and allocating missing (and unknown) items responsible to a known ones.

Theoretically, the scaling factor is a known quantity in our approach: the scaling factor is the number of departments in the region (known exactly from the USFA census) relative to the number of departments reporting to NFIRS (a tabulation of observed departments).[18] In reality, there is an unknown degree of underreporting to the USFA census, which introduces uncertainty. We do not account for this uncertainty in our calculations, however, because we do

[18] This is a simplification. The appropriate denominator to this scaling factor is the number of departments that would report to NFIRS *if they confronted a fire*. Otherwise, the scaling factor would be too high, as the numerator counts departments that may not face a fire in a given year, while the denominator would not. We apply a correction factor assuming that the distribution of fires within a region-year follows a Poisson distribution. The number of departments estimated to experience no fires in a year is generally miniscule and this correction reduces the number of upholstered furniture-related deaths by less than five in a year. This correction introduces uncertainty, as the number of departments without any fires is estimated, rather than known, but we do not consider this source of uncertainty in our estimates.

not have data available to us that would permit us to identify the variation in underreporting that arises across regions.

We focus on the uncertainty arising from allocating fires to specific categories.[19] Begin first with fires assigned to a known item. These fires follow a multinomial distribution. A multinomial distribution can be conceptualized by thinking of a loaded die with the probability of each face arising potentially being different. The multinomial distribution characterizes the chance of observing each side of the die over the course of many throws. Here, the probability of each fire type among those fires with recorded items (*i.e.*, the probability of landing on that face of the die; denoted p_s) is equal to the observed proportion of that type. The variance in the number of recorded fires attributable to this item is

$$Var(N_s) = Np_s(1 - p_s),$$

where N is the number of fires with their items recorded and N_s is the number of fires attributed to item s.

Next, we allocate missing and unknown fire sources to known categories by assuming that the probability that a particular item is responsible for a missing or unknown fire is equal to the proportion of known fires that are attributable to that item. This is equivalent to scaling up the number of fires known to belong to a particular category by the total number of fires in NFIRS relative to the number of fires with their items recorded.[20] This scale factor is squared when calculating the variance of total fires allocated to item s:

$$Var\left(\left(\frac{N+M}{N}\right)N_s\right) = Np_s(1 - p_s)\left(\frac{N+M}{N}\right)^2,$$

where M is the number of fires with missing or unknown sources.

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[19] Because we do not consider uncertainty arising from our scaling factors, we do not estimate error bounds for total U.S. fires, only fires for particular ignition or spread items.

[20] For this calculation, we hold the number of fires with recorded sources and the number of fires with missing sources fixed; in statistical jargon, we are conditioning on these values. In reality, these values are random and thus we are understating the randomness present in the data.

These calculations give the total number of fires in NFIRS that are attributable to item *s*. Suppose that there are D departments in the USFA Census and d departments report to NFIRS.[21] Then, the estimated number of fires attributable to source s is

$$\frac{D}{d}\left(\frac{N+M}{N}\right)N_s$$

and the variance of this estimate is[22]

$$Np_s(1-p_s)\left(\frac{N+M}{N}\right)^2\left(\frac{D}{d}\right)^2.$$

All these calculations occur separately for each region and are aggregated to reach an annual total.[23] The same calculations can also be performed using injuries and deaths.

Ninety-five percent confidence intervals are reported for the counts in this report. These ranges are calculated by adding and subtracting roughly two times the square root of the variance (a quantity known as the standard error) to the estimated number of fires to give the upper and lower bounds of the interval. These confidence intervals are created such that, were we to create 20 of these intervals, we would expect the true value to fall within 19 (*i.e.*, 95%) of them.

It must be emphasized that these intervals are based on the same assumptions that we have discussed in prior sections, notably:

- Departments reporting to NFIRS are similar to others in their regions in terms of number of fires, deaths, and injuries and the items responsible for those fires;
- Fires with missing items responsible have the same distribution of types as those with recorded values within their region;

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[21] Here, d is itself scaled to account for the (small) proportion of departments that do not experience a fire as estimated using a Poisson distribution, but it is assumed to be non-random. See footnote 18 for further discussion.

[22] This discussion outlines the approach for calculating the expected counts and their variance for fires with upholstered furniture as the first item of ignition. For fires where upholstered furniture was the item responsible for spread, this calculation is more complicated. Notably, all fires whose ignition items are recorded to be or are imputed to be upholstered furniture are removed. Careful accounting of the number of known and missing fires is required.

[23] A further complication is that, in 2005 (and in many earlier years), some regions did not have any departments report to NFIRS. In this case, we scale annual totals by the ratio of fires in 2006-2012 estimated to have occurred in these regions relative to the number of fires in regions that did report to NFIRS. As with other scaling factors, this factor is squared in variance calculations.

- Fires with unknown items responsible have the same distribution of types as those with recorded values within their region.

Our estimates of uncertainty do not take these factors into account; indeed, they *cannot* take the uncertainty of these assumptions into account without either data from an additional source or by imposing different assumptions on the NFIRS data. We are unable to ascertain whether our results are over- or underestimates of true counts of fires, injuries, and deaths. Undoubtedly, our estimates of the uncertainty of these estimates, however, are too low as they do not account for the uncertainty in the reliability of the assumptions. Interpretation of our results must be done with these caveats clearly in mind.

VII. Results

In this section, we present detailed results from our scaling and allocation approaches.

A. Total fires and deaths

Figure 6 shows the Brattle and NFPA estimates of total U.S. fires in thousands from 2005 to 2012.[24] There is a general downward trend in both estimates, though the timespan is too short for this effect to be fully evident. The two approaches yield similar estimates of total fires and deaths.

[24] For the NFPA results, see Karter Jr., Michael J. 2014. *Fires Loss in the United States.* NFPA: Quincy, MA.

Figure 6: Brattle and NFPA estimates of total U.S. fires

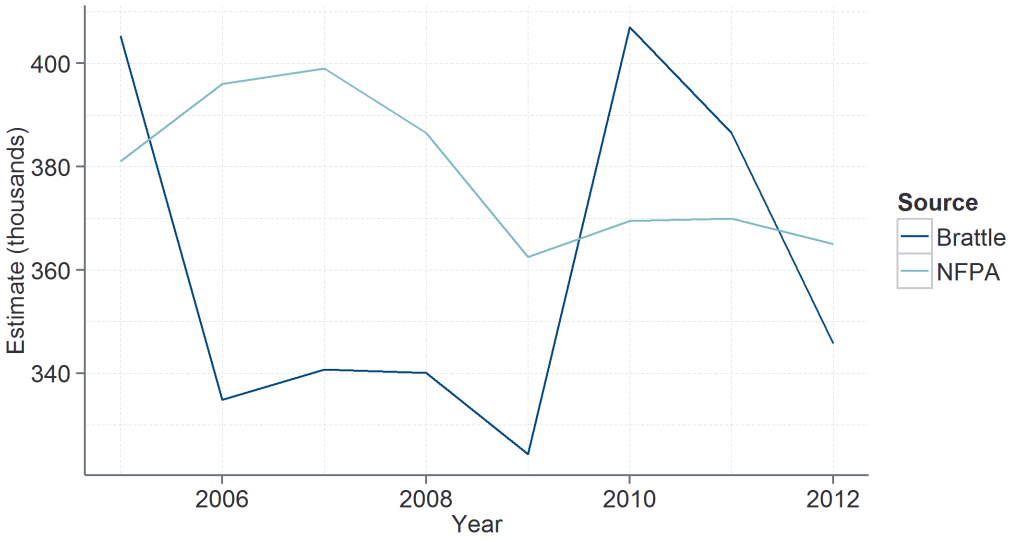
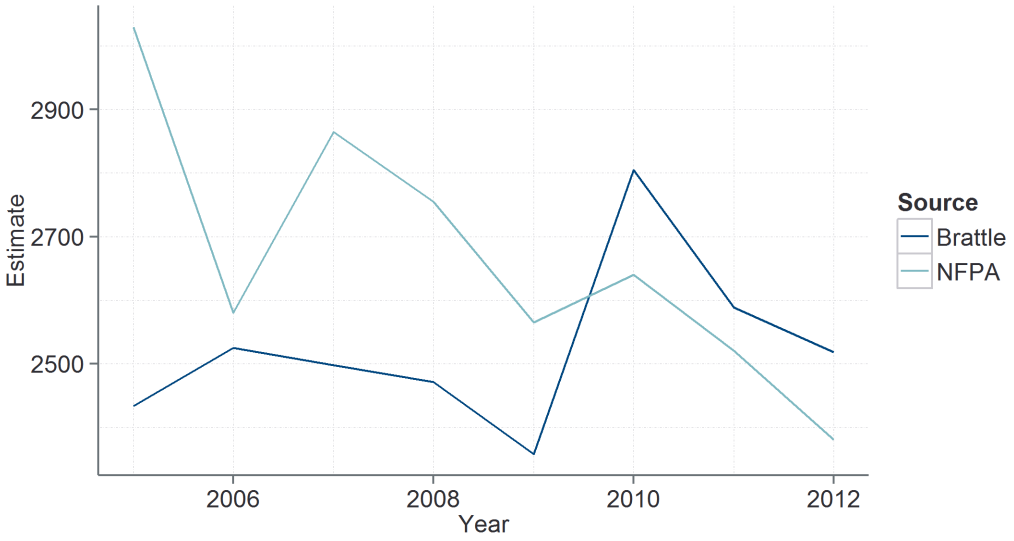


Figure 7: Brattle and NFPA estimates of total U.S. fire deaths



B. FIRES ATTRIBUTABLE TO UPHOLSTERED FURNITURE

Estimates of fire deaths attributable to upholstered furniture as the item of first ignition are shown in Figure 8 along with confidence intervals (depicted as red bars). Notice that the year-to-year changes are overwhelmed by the uncertainty present in these estimates. This result is even more pronounced in Figure 9, which shows the deaths attributable to upholstered furniture as

the item responsible for spread (though not first ignited). Indeed, in this case, the confidence intervals extend to the single digits in 2012.

Figure 8: Estimates of deaths attributable to upholstered furniture as the item of first ignition with 95% confidence intervals

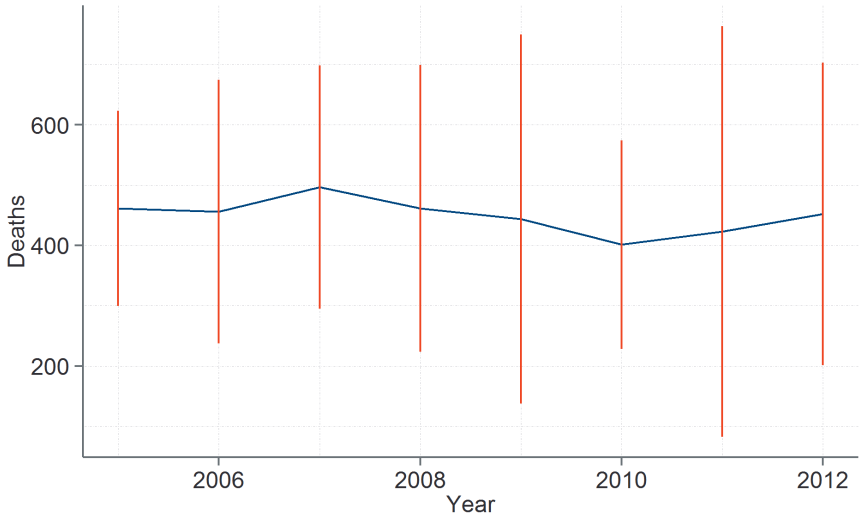
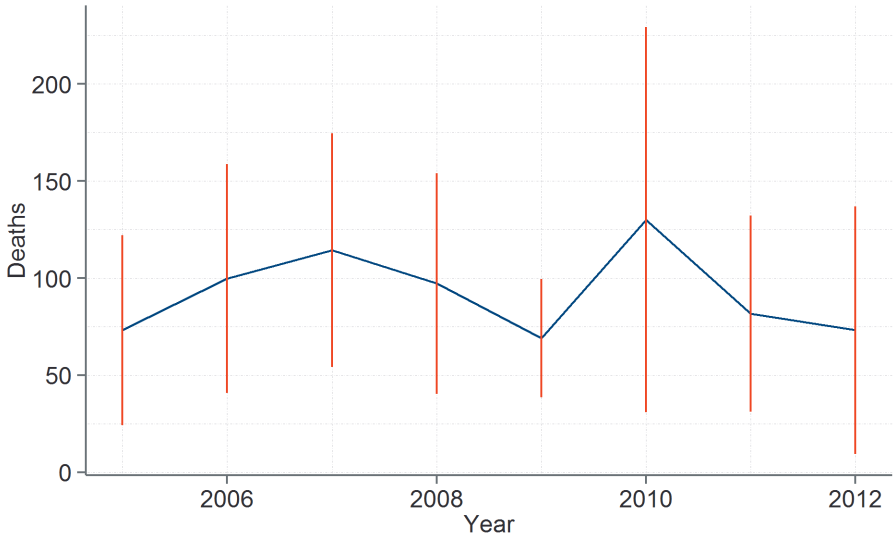


Figure 9: Estimates of deaths attributable to upholstered furniture as the item primarily responsible for fire spread (though not first ignition) with 95% confidence intervals



C. Conclusions

These results show that widely-used fire statistics generated by NFIRS and the NFPA are subject to substantial uncertainty. Because of this uncertainty, these estimates must be used cautiously,

especially for policy making purposes. Impacts of policy changes will be difficult to detect given these bands of uncertainty. Furthermore, secular changes in upholstered furniture-related deaths will also be obscured by this uncertainty. Lastly, as discussed in the introduction, summing deaths attributable to upholstered furniture as either the item first ignited or the item responsible for fire spread may not provide a statistic that is useful for designing a comprehensive fire prevention strategy.

As shown in Table 4, differences in allocation techniques influence the estimates and the confidence intervals.

Table 3: Comparison of estimates of annual fire deaths attributable to upholstered furniture with confidence intervals (2006-2010 average)

	First ignited		Item of spread	
	Estimate	C.I.	Estimate	C.I.
Hall (2014)	480	not provided	130	not provided
Brattle	452	345-558	102	77-128
Difference (%)	6.2%		27.5%	

About The Brattle Group

The Brattle Group, an economic and financial consulting firm, was established in 1990. The firm's 200 employees are located in Cambridge, New York, Washington, D.C., San Francisco, London, Madrid, and Rome. The Brattle Group's principals include several leading academics in economics and finance, including a Nobel Prize winner. Brattle principals and senior staff have broad experience assisting clients worldwide in matters regarding antitrust, intellectual property, environmental, health and safety regulation, energy, securities, telecommunications and valuation. Our experts are regularly called to testify before regulatory agencies, courts, and arbitrations panels.

Dr. Mark P. Berkman, a Brattle principal, is an expert in applied microeconomics. His experience spans the areas of the environment, energy, and natural resources; environmental health and safety; labor and employment; and public finance. He has assisted both public and private clients and provided testimony before state and federal courts, arbitration panels, regulatory bodies, and legislatures.

Prior to joining Brattle he was a co-founder and director at Berkeley Economic Consulting and a vice president at both Charles River Associates and NERA Economic Consulting. He has also held positions at the Congressional Budget Office and the Urban Institute and served as a staff assistant to U.S. Representative Charles Vanik of Ohio. Dr. Berkman earned his PhD from the Wharton School of the University of Pennsylvania in public policy and applied economics. He also holds degrees from Harvard University and George Washington University.

Dr. Charles Gibbons, a Brattle associate, specializes in applying sophisticated econometric and statistical models to legal, regulatory, and policy issues. He has produced analysis for a variety of litigation matters, including models of mortgage delinquencies, forensic analysis of product defects, and local impacts of environmental damages. His work has been used for class certification, liability determination, and damage calculations. He has also developed models for forecasting electricity sales and peak demand for utilities.

Additionally, Dr. Gibbons is a lecturer at the University of California, Berkeley where he last taught a graduate-level course in probability and statistics. He received a Ph.D. in economics and an M.A. in statistics from the University of California, Berkeley. His dissertation proposed new methods in applied econometrics and a theory of competition for online advertising auction platforms. He also holds a bachelor's degree from Cornell University.

Stephen Lagos, a Brattle research assistant, has substantial experience regarding economic and statistical analysis especially where large complex data must be managed. Prior to joining The Brattle Group, Mr. Lagos served as a research assistant at the University of Chicago. He earned a BA in economics from Colorado College.