# The Role of Insurance in Reducing the Frequency and Severity of Fire Losses

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## Executive Summary

Fires, whether in urban areas, the wildland–urban interface (WUI) or on undeveloped land, create significant losses in Canada. The risk associated with fire varies across urbanization, land use, fire services, vegetation, weather, and other factors. From mega–cities to suburban neighbourhoods to remote communities, the risk associated with fire and the response to fire events differs substantially. The underlying risk is also evolving due to both shifting populations and climate change. To better understand fire risk, the Canadian Association of Fire Chiefs, the Council of Canadian Fire Marshals and Fire Commissioners, the Canadian Safety and Security Program, and Public Safety Canada, with the assistance of Statistics Canada, launched a program in 2015 to collect and standardize fire information statistics from across the country. The National Fire Information Database (NFID) program was created to gather and unify over a decade of fire related information from across the entire country to create Canada's first national system of fire statistics. The overarching goal of this collaboration is to create a database to enable researchers to gain a greater understanding of the nature and extent of fire incidents across the country.

Because of the significant economic and human costs arising from fire losses, many researchers worldwide have examined drivers of both structural (urban) fires and wildfires. We build upon this research by considering the role of insurance in reducing the frequency and severity of fire losses. Here we exploit that insurers i) have a clear financial interest in preventing and reducing fire losses; ii) are the natural disseminators of information concerning fire risk assessment, mitigation and property protection, and iii) play an essential role in providing indemnity for recovery after a fire loss.

Historically, insurers have a tradition of promoting urban fire safety, including the creation of fire brigades and enhanced building codes. Until recently, urban fires were the number one cause of insured residential property losses in Canada. Although the threat of urban fire has decreased over time, climate change, the health and management of boreal forests, and the increase in the population living in the WUI have led to an increase in the frequency and severity of wildfire. The changing nature of the risk of wildland fires indicates a significant increase in exposure for insurers. In order to address this changing exposure, insurers need to i) improve the quality and provision of information to property owners about the drivers of fire which in turn will lead to more effective mitigation, ii) improve the accuracy of fire insurance pricing and iii) improve the provisions of insurance coverage to reflect that recovery after a catastrophic loss such as a wildfire is different from recovery after an isolated fire.

In the appendix, we present an economic framework underpinning the complementary roles of insurers and government in reducing human and economic loss. We focus on the nature of the coordination between insurance companies and government in loss reduction, and the real possibility of maximizing the economic welfare of all parties through such coordination. By examining the property owner's choice of insurance coverage, the extent to which the owner was incented to invest in mitigation, and the resultant risk associated with fire loss, our goal is to provide the basis of a thorough analysis of the fundamental economic aspects of fire risk which could serve as a foundation for both public policy and private decision–making. This discussion is theoretical in nature as we note the lack of any empirical measure of the efficiency in insurance coverage and mitigation of fire loss.

Unfortunately, due to limitations with the data, we are not able to fully analyze the risk factors impacting the frequency and severity of fire loss. Although six provinces plus the Canadian Armed Forces reported data at some level, our analysis was limited to Ontario, Alberta and British Columbia. These three provinces had the most complete data (by year and by variables included). However, even for variables that are available for these provinces, a large number of observations were coded as “unknown,” “unclassified”, or “other”. A key issue is that NFID data are coded at the census subdivision (CSD) level[•]. This does not allow us to disaggregate across different neighbourhoods in urban centres. As a result, we are unable to address fire risk for at-risk populations – elderly, children, the physically infirmed, new Canadians – or at-risk places – high-crime neighbourhoods, neighbourhoods with large transient populations.

We did analyze the NFID fire loss data using ordinary least squares regression across two dimensions: frequency and severity of fire loss. We defined frequency of loss as reported fire loss incidents per year per CSD normalized either by dwelling count per CSD or population per CSD. Severity of fire loss, which could only be calculated for British Columbia and Alberta, was measured by the dollar value of loss divided by the value-at-risk (the total value of building and contents in British Columbia and the value of the building only in Alberta). The dollar value of loss was estimated by the fire service that responded to the event, but the source of the value-at-risk was either an insurance company or the fire service / investigator’s office.

Due to data limitations, our explanatory variables for the frequency analysis were socioeconomic and demographic data collected at the CSD level, and our explanatory variables for the severity analysis included characteristics about the building (including occupancy, construction, building height, built fire detection and protection features), cause of fire (if known) as well as socioeconomic and demographic data.

Despite the lack of granularity in the data and our concerns about data quality, our results are consistent with previous research: the likelihood of a fire incidence is greater in economically challenged communities with higher unemployment and less education (see, for example, Canadian Mortgage and Housing Corporation (CMHC) 2004; and Jennings, 2013). We also find that the incidence of fire is greater in First Nations communities (when frequency is measured based on number of dwellings). CMHC (2004) indicate that one reason why First Nations communities have greater fire losses is that many of these communities are isolated.

Our results for the severity regressions are less robust, in part; we suspect, due to missing, unknown and unclassified observations. In both British Columbia and Alberta, residential

[•] A CSD, according to Statistics Canada, is a municipality or an area that is deemed to be equivalent to a municipality for statistical reporting purposes. According to Statistics Canada (2017), in 2011, approximately 800 CSDs in Canada had less than 100 residents, whereas the largest three CSDs (Toronto, Montreal and Calgary) all had populations exceeding 1 million residents.

properties have less severe fires than all other property types and the severity of fire damage is more for properties with no manual fire protection and properties located in CSDs with lower education levels. There is also some evidence that losses are less severe for properties with more resistant construction. In British Columbia, the presence of fire service is associated with lower fire severity.

If the fire database is to inform public policy, then it is clearly necessary to improve the quality and granularity of the data. Our biggest concern with the dataset is the lack of geographic granularity for the urban CSDs. An examination of fire risk for at-risk places and at-risk populations requires that data be collected at the neighbourhood level (e.g., forward sortation area, the first three digits of the postal code). Better training of fire departments is required to improve the quality of data collected by fire service. We also suggest engaging the insurance industry to collect data on the value-at-risk and the size of loss metrics, as insurance companies have the best data for measuring these variables.

## Introduction

Fires, whether in urban areas, the wildland–urban interface (WUI) or on undeveloped land, create significant economic losses in Canada. As such, they are a major concern for both the property/casualty insurance industry and government policymakers. Such fires result in a substantial loss of private and public property and often the loss of human life. According to the most recent available data from the Council of Canadian Fire Marshals and Fire Commissioners (CCFMC), a total of 42,753 fires resulted in 226 deaths and $1,551,657,179.00 in direct property damage across Canada in 2007, (Wijayasinghe, 2011) net of public expenditures of the evacuation of threatened populations, ex post recovery assistance and investment in infrastructure for fire prevention and suppression.

Because of the significant economic and human costs arising from fire loss, many researchers have examined drivers of both structural (urban) fires and wildfires. Jennings (2013) provides a conceptual model of urban fire risk in which the main drivers include the physical environment, dwelling characteristics, weather conditions, neighbourhood characteristics and individual and group behavior.

The drivers of wildfire are quite different. Growth in the population living in the WUI, climate change, and wildland fire management impact the likelihood and severity of wildfires. Over the past decade wildfires have caused 700 million dollars of insured losses in Slave Lake (2011) and 3.6 billion dollars of insured losses in Fort McMurray (2016). Natural Resources Canada (2017) reports that wildfire suppression costs annually range from 500 million to 1 billion dollars.

The NFID was established as a pilot project with the objective of gathering ten years of information on fire incidents and fire losses from across Canada to develop and maintain a national database of statistical information on fire incidents, losses and casualties. The database is intended to be a census of fire loss incidents and to be used as a centralized national system for the collection of fire statistics.

We build upon previous research by considering the role of insurance in reducing the frequency and severity of fire losses. Historically, the insurance industry has played an important role in encouraging loss prevention and supporting loss control research. Insurers have a tradition of promoting urban fire safety, including the creation of fire brigades and enhanced building codes. This arises out of their direct financial interest in reducing the frequency and severity of perils that cause injuries, death, property damage and other losses. Given their interest, insurers have long engaged in proactive risk prevention and reduction of fire losses.

Our proposed research plan first focused on understanding the underlying risk factors that affect the frequency and severity of fire risk for residential and small commercial properties, and how these factors vary geographically (e.g., inner city, suburban, WUI, remote communities). Our interest was specifically on residential and small commercial properties because their owners are at risk due to the significant likelihood of being under-informed about fire risk and about cost–

effective mitigation activities.[1] We believed our research would assist the insurance industry in three distinct ways: first, by improving the accuracy of property insurance pricing by better matching the risk to the cost of coverage based on our analysis of how fire risk varies across urbanization, land use, fire services, vegetation, weather, and other factors; second, by improving coverage offered by insurers, recognizing that the cost of recovery after a catastrophic fire event in which a whole community is impacted is different than the cost of recovery after an isolated fire, and finally, by facilitating more accurate information provided to property owners, including information on premium discounts based on loss mitigation, so that they would be motivated to prevent and mitigate fire losses ex ante.

However; due to significant data limitations, we were not able to fully analyze the risk factors impacting the frequency and severity of fire loss. Because of inconsistencies in the data collection between provinces, and occurrences in which data were incomplete, erroneous or unavailable, we could only analyze the frequency of fire incidents for British Columbia, Alberta and Ontario, and we could only examine the severity of incidents for British Columbia and Alberta. A key issue is that NFID data are coded at the census subdivision (CSD) level, which does not allow us to disaggregate across different neighbourhoods in urban centres. Unfortunately, because of the lack of granularity in the NFID data, we could not accurately address our original research question – how do drivers of fire risk vary across populations based on demographics such as income, education, age, employment, immigration status, languages spoken and crime rate. Moreover, we were also unable to fully address how the frequency and severity of fire losses vary geographically across inner cities, urban and suburban communities.

Using the limiting data that was provided, our analysis included running three separate ordinary least squares (OLS) regression models to examine the impact of demographic variables on the frequency of fire. We measured frequency in two different ways: the number of fire incidents per 1000 dwellings (within a CSD) and the number of incidents per 100,000 population. Consistent with previous literature, when we measured frequency with respect to the number of dwellings, we found that fire risk was higher in First Nations communities, and in CSDs with higher levels of unemployment and lower income. When frequency was measured with respect to population, we found that CSDs with a higher median age had a higher likelihood of fire incidence. Finally, we developed a regression model that allowed for interactions between First Nations communities and our demographic variables of interest. Interaction effects were significant in British Columbia only: First Nations communities with a lower median age, higher percentage of male population and higher percentage of married couples had higher fire risk. One explanation is that there could be more overcrowding in these communities – a greater percentage of married individuals implies more children and hence more crowded households.

[1] These property owners are typically sold a package insurance product such as the comprehensive homeowners' policy that may or may not actually meet their needs. As a result, they are likely to face insurance coverage gaps, unlike large commercial businesses that are more sophisticated insurance buyers.

It was difficult to draw any credible conclusions from our fire loss severity analysis due to the NFID data limitations. First, we were only able to analyze severity in two provinces: Alberta and British Columbia. Second, our severity analysis, similar to the frequency analysis, was undertaken at the CSD level. Because of this, we were unable to capture the necessary socioeconomic and demographic characteristics within urban neighbourhoods that are known to impact the severity of loss. Third, many observations of categorical independent variables in our analyses were reported as not available, unclassified or unknown. Recognizing these data limitations, our main severity analysis results across the two provinces, nonetheless, suggested that the type of construction and a building's designed use (i.e., residential) were significantly related to the severity of damages. In addition, a building with no manual fire protection was associated with increased fire severity as was a building located in a CSD where there is a lower level of education across the population.

There are several opportunities to improve the robustness of the database. For example, weather information and other demographic variables previously shown to impact either the frequency or severity of fire could be added. Adding weather variables (e.g., temperature, some measure of recent precipitation, and wind speed at time of fire) would add valuable information, recognizing that these data may be cumbersome to collect. As mentioned, our biggest concern with the data set is the lack of geographic granularity for the urban CSDs. An examination of fire risk for at-risk places and at-risk populations requires that data be collected at the neighbourhood level. This could be achieved by providing the postal code of the location of the incident, or, at the very least, the postal code of the first responding fire station.

We recognize that data are collected at the municipal level. One suggestion would be to first improve training in jurisdictions which already have robust reporting structures, with the caveat that fire data need to be collected over a mix of communities in order to understand how fire impacts urban, suburban and rural communities.

This report includes an extensive appendix examining the fundamental economic issues surrounding insurance mitigation and fire risk. In this appendix, we provide an economic framework underpinning the complementary roles of insurers and government in reducing human and economic loss. We note that in the presence of insurance, individual property owners and communities as a whole have less of an incentive to undertake mitigation activities unless the insurance contract requires and / or rewards property owners for these activities.

We focus on the nature of the coordination between insurance companies and government in loss reduction and the real possibility of maximizing the economic welfare of all parties through such coordination. For example, governments can use subsidies to encourage mitigation activities. Governments and insurers also have a role in educating property owners about fire risk, with the caveat that property owners have to find the information credible. By examining the property owner's choice of insurance coverage, the extent to which the owner was incented to invest in mitigation, and the resultant risk of fire loss, our goal was to provide the basis of a thorough analysis of the fundamental economic aspects of fire risk which could serve as a foundation for both public policy and private decision–making.

Finally, we also initially considered the role of the mortgage lender, as the vast majority of both commercial and residential properties are leveraged. Because of this, most property owners have less incentive to invest in both mitigation and insurance than mortgage lenders desire. This is why a virtually universal covenant in Canadian residential and commercial mortgages is that the property owner must invest in some minimal amount of mitigation against fire risk and that he purchase enough insurance coverage on fire damage to cover at least the amount of the debt used to finance the property purchase at the time of mortgage origination.

Unfortunately, this discussion on incentives, information and the trade–off between insurance and mitigation is currently theoretical in nature due to the lack of any empirical measure of the efficiency in insurance coverage and mitigation for fire losses.

The outline of this report is as follows. We first examine the role of insurance with respect to fire losses. (We expand upon this discussion in the Appendix.) This is followed by a discussion of the data, data limitations and suggestions for data improvement. We next present our statistical model, results and implications on the drivers of fire frequency, followed by a similar layout for the drivers of fire severity. We highlight our findings again in the conclusion, paying particular attention to the need for better data to inform future public policy.

## Role of Insurance in Reducing Fire Losses

As noted in the introduction, insurers have a long history of working to reduce both the frequency and severity of fire losses. The necessary link between fire safety and insurance was established after the London Fire of 1666, which led to the creation of the first fire insurance company. At that time it became evident that in order to provide insurance, insurers needed to know that the property was protected. This recognition that losses from fires can be prevented through proper fire safety measures, as well as through education and the application of scientific knowledge, continues to be one of the main principles of how insurers do business. Over time insurers have continued to participate in and support initiatives aimed at reducing injuries, loss of life and property damage from fire and other hazards.

As an industry, insurance is invested in wildfire loss reduction through the Institute for Catastrophic Loss Reduction (ICLR). The insurance industry, along with the ICLR, provides comprehensive disaster loss prevention advice.[2] Due to their relationship with both residential and small business property owners, insurers can serve a valuable role as the primary source of risk assessment, loss mitigation and property protection information. *Ex post*, insurers also play a critical role as they provide indemnity for covered losses, which is an essential component of the financial resources available after a fire.

[2] For more detailed information regarding the ICLR, see iclr.org.

Until recently, fires were the number one cause of insured residential property losses in Canada. The likelihood of urban/structural fires has decreased over time due to efforts on the part of multiple stakeholders, including the insurance industry, to mitigate the risk. Recently, water damage has taken over in terms of the most common cause of insured losses, yet there are growing concerns regarding the severity of insured fire losses, particularly wildfires. Evidence indicates the probability of wildfires is increasing due to climate change and property values at risk are also increasing due to development and increasing activity in the WUI (Cross, 2001). Other factors that are impacting the potential for more frequent and more severe wildland fires include the health of the boreal forest, insect infestations, and wildland fire management that has not kept up over time (Kovacs, 2008).

As noted above, the risk from urban structural fires has been reduced over time. However, research has shown that there are clear inequalities in terms of how this risk is distributed across different populations. Certain sectors in Canada experience a disproportionately high number of fire incidents, including First Nations communities (Garis et al., 2016). For example, the First Nations per capita fire incidence rate is 2.4 times the per capita rate for the rest of Canada. The death rate is 10.4 times greater; the fire injury rate is 2.5 times greater; and the fire damage per unit is 2.1 times greater (Canadian Mortgage and Housing Corporation (CMHC), 2004). As well, poverty and poor housing quality have consistently been identified as being associated with greater incidence of fires in residential buildings. A review by Jennings (2013) concludes that fire incidence varies systematically according to social and economic characteristics of residents, and secondarily by housing and neighborhood conditions. These at-risk populations are generally the least able to afford losses from fire and also are less likely to have insurance or invest in mitigation, increasing their vulnerability.

One segment of the population that is often uninsured is renters. However, even if these individuals are uninsured, the owner of the rented building typically has insurance on the building, leaving a role for insurance to play in providing fire safety information and incenting risk reduction. Nonetheless, a significant obstacle is ensuring that populations that face the greatest risk of having a fire in their home, including the elderly and residents of low socio–economic areas, are educated about basic fire safety. Hence, there may be a role for local government in reducing fire risk by targeting fire safety education at those at risk. Clare et al. (2012) reviewed best practices from other countries on residential fire safety and concluded that "targeted home visits have produced promising results examining a range of outcome measures, from reduction in rates of fires and fire-related casualty through to increased presence of working smoke alarms when residences were audited" (Clare et al. 2012, p.123).

Over time insurers' participation in managing urban fire risk has contributed to safer communities, fewer fatalities and reduced property damage. Yet, the threat of wildland fire has created a new challenge for the industry. To effectively address this risk, insurers will need to improve risk assessment, make better use of data, design and price coverages for wildland fire, and work with other stakeholders. Below we address the unique challenges that wildland fires create and the role that insurance can play in reducing the risk.

The changing nature of the risk of wildland fires indicates a significant increase in exposure for insurers. In order to address this changing exposure, improvements in risk assessment and modeling are necessary. More accurate risk assessment will allow insurers to harness their potential in helping to reduce fire risk and build more resilient communities through:

- Providing information to property owners about the risk and how to mitigate the risk ;
- Providing insurance coverage that is appropriate for the risk and sends the right signals (setting price, limits, deductibles, other terms and conditions in order to provide incentives that encourage better risk management by property owners);
- Managing claims *ex post* in a way that helps to reduce the risk in the future (i.e. rebuilding in a more fire resilient manner);
- "Promoting improved land use practices and adequate resources for wildfire management." (Kovacs, 2001, p. 6), and
- Working with other stakeholders, particularly government, to ensure a consistent and effective approach to wildfire risk management.

## RISK ASSESSMENT

The combined effect of more Canadian communities at risk as the WUI continues to expand and the expected increase in fire activity across Canada as a result of climate change implies that insurers face a new reality in terms of assessing fire risk. These changes require insurers to reassess their wildland fire exposures. Better data and improved modeling tools for risk assessment (e.g. satellite maps that measure fuel density and topographical maps showing slope, elevation and severe weather frequency) allow insurers to analyze differences in risk exposure across locations that can lead to better informed pricing decisions and other elements of coverage. This requires insurers to improve their use of data, exploiting geographically refined data to more precisely estimate land parcel risk (Kahn, Casey and Jones, 2017). The use of more fine-grained data allows insurers to engage in more accurate risk assessment, which will enable better decision-making on the part of insurers, policyholders and communities. Insurance pricing and other policy terms and conditions can provide clear risk signals and reward risk reduction efforts. Properties that are exposed to different levels of risk should be priced accordingly. Models that allow insurers to better understand the risk will also provide information to assist in making decisions about the appropriateness of deductibles, limits and replacement value.

Such detailed and accurate risk assessment will also provide information regarding essential loss prevention and property protection strategies. If policyholders and other decision makers are not well informed and do not recognize the growing risk of fire loss, this is likely to lead to dangerous decisions regarding the location and maintenance of buildings. By combining price signals with relevant risk and mitigation information to policyholders, insurers can play an important role in reducing fire risk. The FireSmart program, endorsed by the insurance industry, is one example of an initiative that seeks to educate property owners and communities about specific actions that they can take to best manage their exposure to wildland fire. The FireSmart Home Development Guide provides recommendations on elements that significantly reduce the wildfire risk a home faces, such as roofing material and design; siding and vents; gutters and eaves, decks; fencing, and landscaping.[3] By being proactive in providing this information, insurers can help policyholders to better understand their role in reducing fire risk. In addition, insurers are also able to better promote property management through premium discounts, surcharges, and other policy conditions.[4]

Previous experience demonstrates that insurance savings alone are typically not sufficient to incent property owners to engage in loss mitigation. However, changes in behavior are likely to occur if properties are deemed to be at such high risk due to the increase in the frequency and severity of fire losses that insurers simply reduce or stop providing coverage in certain vulnerable regions until communities and property owners adopt sufficient loss mitigation practices.

## INSURANCE COVERAGE CONSIDERATIONS

The Fort McMurray wildfire (2016) resulted in the largest insured loss in Canada's history (estimated $3.6 billion). The entire city (90,000 people) was evacuated for over a month, more than 2500 structures were destroyed and thousands of homes and businesses were damaged. Prior to the Fort McMurray fire, two previous wildfires served as wake–up calls to the insurance industry, property owners and other stakeholders regarding the challenges and consequences of these events. In 2003, over 2500 fires swept through the interior of British Columbia, destroying 334 homes and killing 3 firefighters, resulting in insured losses of $200 million. In May 2011, wildfires moved through Slave Lake, Alberta, destroying more than 700 homes and causing over $700 million in insured losses. This was the second costliest insurance disaster in Canadian history at that time.

The experience from these fires uncovered a number of challenges and opportunities for insurers. These events highlighted important differences between risk exposure for urban and suburban fires compared to fires in the WUI and remote communities. Standardized insurance coverages and amounts that provided adequate coverage for losses in more populated, urban areas were not necessarily sufficient for fire losses in more remote communities; in particular, if the fire resulted in large scale damage. For example:

1. When an entire city is evacuated and if the fire does extensive damage, the time it takes for residents to return to their homes (even if they were not damaged) can easily extend beyond 2 weeks, the typical coverage period for mass evacuation. Firefighters and others must first ensure it is safe for residents to return, and services and infrastructure must first be restored and repaired.

2. After many buildings are destroyed, there is a long line up for building permits, which can add to the time needed for reconstruction.

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[3] For further information see www.firesmartcanada.ca/resources–library/firesmart–begins–at–home–home–development–guide

[4] Surcharges could be applied for wildfire–vulnerable homes that do not install approved roofing materials, fail to clear the area around their home and/or are not accessible to firefighting services (ISO, 1998).

3. Remote communities do not have the building capacity to rebuild hundreds of homes in a short period of time, as the local construction industry simply does not have the capacity to meet the demand.

4. Transporting labourers and materials to the site becomes costlier and difficult when the community is remotely located. As well, costs are higher due to insufficient accommodations for workers and insurance adjusters, and getting enough trades people is also a challenge.

5. Due to a spike in construction activity, demand surge leads to higher costs for materials.

6. Northern, remote communities (e.g., Fort McMurray) pose additional challenges due to severe winters that curtail the building season. Moreover, access to the region is generally limited (e.g., served by a small airport and/or a single highway) which reduces the ability to quickly transport materials and resources.

7. Other cost increases must also be factored into rebuilding. For example, changes to the National Energy Code (effective November 1, 2016) are likely to result in higher insulation costs, while a new tariff by Canada Border Services Agency on drywall materials entering Western Canada from the U.S. could result in a cost increase of 276 percent. (Van Bakel, 2017)

All of these factors contribute to a greater likelihood that policyholders in remote communities will incur costs that are not covered and that rebuilding costs will exceed policy limits, resulting in policyholders being underinsured. Other factors also cause underinsurance, such as errors in the valuation of the property and the failure of homeowners to report renovations and upgrades to their insurer.

A related problem that became evident after both the Slave Lake and the Fort McMurray wildfires was policyholders' lack of understanding of their insurance coverage. This created several challenges for insurers, including "neighbouritis," where insureds demanded that their insurers provide the same calibre of treatment received by their neighbours, even if their policies did not provide the same coverage. After the Fort McMurray fire, insurers were generally flexible about paying claims that were outside the coverage stated in the policy. For example, when establishing the cause of loss and determining whether it was smoke–related damage or normal dust accumulation, most insurers gave residents the benefit of the doubt that it was smoke damage, which triggered broader policy coverages that were not available for mass evacuation circumstances only. As well, insurers were lenient regarding proof of loss in instances when everything was destroyed.[5] Finally, even though policies typically provide only 2 weeks of coverage

[5] Proof of loss may be difficult or impossible to establish as relevant records may be destroyed, as happened in the Slave Lake fire when the town hall, which housed all municipal property records, was destroyed (Mariga, 2011).

for mass evacuation, after the Fort McMurray fire most insurers were flexible, recognizing the uniqueness of the situation (Van Bakel, 2017).

Although such flexibility contributes to a more positive reputation for insurers, it negatively affects their financial results if insurers fail to price for those extra loss and loss related expenses. Insurers should evaluate these special coverage requirements that arise from wildland fires in order to ensure that their policyholders are offered the appropriate coverage, and that insurers are charging a price that reflects the level of risk as well as the scope of the coverage.

## IMPROVING RESILIENCE

The effects of climate change on the frequency and severity of natural disasters has brought attention to the much more significant role insurance can play in disaster risk management and improving the resilience of communities. While the role of insurance as an important risk financing tool that helps communities recover after a loss is well established, recent attention has been focused on the broader role insurers can play in helping communities better protect themselves, reduce avoidable loss and build resilience to cope with the increasing threat.

The insurance industry's role in disaster risk management is increasingly being reflected in global insurance industry initiatives, principles and statements. For example, consider the Global Insurance Industry statement, "Building climate and disaster–resilient communities and economies: How the insurance industry and governments can work together more effectively". This statement emphasizes how, by working in partnership with all stakeholders, insurers can assist in assessing hazards, prioritizing the areas of greatest risk, and promoting and investing in cost–effective loss mitigation. Here we discuss a number of initiatives that are essential in creating more resilient communities.

1. Investment in disaster risk reduction reduces economic, social and environmental losses; creates safer and more resilient communities and economies; reduces the amount of public and private funds spent on disaster relief and recovery, enabling better investment; and improves access to affordable insurance, helping communities to recover better after a loss. (UNEP Finance Initiative, 2014). In their role as institutional investors (globally, the insurance industry has nearly USD 27 trillion in assets under management), insurers are beginning to invest in more resilient infrastructure, climate adaptive technologies, and steering investment away from industries that contribute to climate change, such as coal. The size of the insurance industry's investment portfolio offers the potential for positively impacting the long–term resilience of communities.

2. After a loss, as part of the claim settlement process, insurers can work with property owners to ensure rebuilding decisions are forward looking and help reduce vulnerability to fire, for example, by using FireSmart building materials. There is some evidence that in Fort McMurray many homes that have been rebuilt have been put back exactly as there were (e.g. with vinyl siding), without considering the potential for reducing the risk. Policies often stipulate rebuilding must be with materials "of like kind and quality," and coverage is limited to return damaged structures back to pre–disaster condition, with no additional

assistance for mitigation measures. This is clearly a faulty approach. When structures are rebuilt after a major loss, there is a valuable opportunity to reduce the risk of future fire loss (e.g., new metal roofs) and other risks, such as heavy snow loads. In addition, policies typically require that rebuilding occur on the same location or an adjacent site; yet insurers should consider whether such restrictions places the property at risk for future damage (and in some instances it may not even be possible to rebuild on the same site).

Beyond rebuilding damaged structures, the period of time after a disaster tends to focus public and political attention on the disaster, its impact and possible solutions. This is a prime time opportunity for implementing mitigation. Disasters can effectively reveal vulnerabilities that have developed within a system and can trigger improved disaster management. Hence, insurers can work with communities to use the post–disaster period to prioritize and implement mitigation strategies. (Sandink, 2009; p. 17)

3. Insurers working with communities, governments and other stakeholders to improve decision making regarding loss prevention and resilience.

   Insurers can work with local government to promote better land–use planning and encourage adequate resources for wildfire management. Hazard risk needs to be a more important consideration in community planning efforts to avoid putting property and lives in harm's way. It is poor decisions that results in natural hazards becoming natural disasters (Mileti, 1999). By sharing its knowledge and expertise with city planners, the insurance industry can help reduce vulnerability to natural hazards by promoting better land use planning (Kovacs, 2001).

   As emphasized by the Global Insurance Industry statement "Building Climate and Disaster Resilient Communities," collaborative action between governments and the insurance industry will help to improve disaster prevention. Long-term partnerships, including public-private-partnerships, are key to improving the situation of people at risk and building more resilient communities.

   *"Public authorities and insurers have a common interest in managing climate risks and risk reduction. This provides the basis for partnership in forging climate and disaster-resilient development pathways. The global insurance industry is uniquely placed in our economies as a market mechanism for risk sharing as the management of risks is its core business. Governmental authorities and agencies provide the frameworks within which insurers manage their risk exposures. Furthermore, regulatory frameworks, incentives and public- private collaboration are critical to providing vulnerable communities, […], access to risk management services and risk transfer products offered by insurers. A mutually dependent relationship between governments, society and the insurance industry is therefore obvious.*

   *By working with other affected stakeholders, insurers can help to facilitate the building of climate and disaster-resilient communities as well as resilient economies. This can be done effectively and efficiently by focusing action along the insurance risk management value chain, risk identification and analysis, risk prevention and reduction and risk transfer, to foster* *collaborative action to co-ordinate the management of weather-related risks and build risk prevention and reduction capabilities."* (UNEP Finance Initiative, 2013)

4. As previously discussed, insurers are active participants in education and outreach programs aimed at helping the public to better understand actions they can take to reduce fire risk. After a fire and particularly when a property owner has experienced a loss, she may be more aware of the risk and more willing to adopt mitigation measures (Burton et al., 1993). This presents another opportunity for insurers to utilize their risk assessment expertise to educate the public and help communities / local government make better decisions. In the past, efforts were largely focused on urban areas, but improved data techniques mean that it is possible to target messages to specific audiences, and provide more clear advice on how to reduce the risk of wildfire damage (Kovacs, 2001).

   In providing information to policyholders on how to mitigate wildland fire risk, messaging needs to be coordinated with similar outreach efforts by governmental agencies and local NGOs. Information on how to mitigate fire risk is typically based on the concept of the home ignition zone and creating defensible space; however, if these messages are not tailored to the local community or coordinated with related outreach efforts, property owners may receive conflicting messages, leaving them unsure of what to do (Galbraith, 2017).

These initiatives show that the insurance industry has an important role to play in reducing the frequency and severity of fire losses and helping to build more resilient communities. One of the necessary elements of doing this effectively is having credible, accurate data and being able to understand the drivers of fire losses. In subsequent sections, we discuss our intended objectives in using the NFID data to explore how insurance can play a more significant role.

## Data and Data Limitations

In this section, we first outline the structure of the database, and data available on each province. Our goal is to capture variables related to both the frequency and severity of fire risk in Canada. We highlight our concerns with data quality and how this limits our ability to undertake an analysis of at-risk populations and at-risk places across Canada.

The NFID program was created to gather and unify over a decade of information from across the entire country to create Canada's first national system of fire statistics. Robust, high quality data are necessary to create and implement sound public policy. As noted by Maxim, Garis and Plecas (2013, p 3.), "*Good decision making […] needs to be informed by evidence, research and sound information*." The collection and standardization of fire statistics allow researchers to analyze the drivers of fire losses, the impact of fire services in reducing both the frequency and severity of losses, and the impact of human behaviour on fire losses.

Specifically, with this database, we had hoped to gain an understanding of the underlying risk factors that affect the frequency and severity of fire risk for residential (and small commercial) properties, and how these factors vary geographically (e.g., inner city, suburban, WUI, remote communities). Our focus on residential and small commercial properties was intentional as we believed that the owners / occupants of these properties had the greatest likelihood of being under informed about fire risk and about cost–effective mitigation activities. We had two key populations of interest: properties in the WUI at-risk of wildfire losses and properties in high risk / marginalized neighbourhoods.

As reported by Statistics Canada (2016), the NFID is structured to contain information on:

i. fire incident characteristics (e.g., date, time, location);
ii. property characteristics (e.g., type of property and use, type of construction, age of building);
iii. fire protection features (e.g., use of sprinklers, alarms);
iv. circumstances contributing to the outbreak of fire (e.g., igniting object, fuel or energy associated with igniting object);
v. factors related to the origin and spread of fire (e.g., area of origin, flame and smoke spread areas);
vi. fire loss details (e.g., extent of fire and damage, dollar amount of loss);
vii. discovery of fire and actions taken (e.g., how fire was initially detected, transmission of alarm to fire department, performance of extinguishing equipment and smoke alarm device, occupants in dwelling at time of fire);
viii. fire casualties (e.g., age and sex of victim, nature of casualties [i.e., extent of injury, death], cause of failure to escape);
ix. other existing socio–economic variables from Statistics Canada (e.g., average income data, employment rates, crime rates, etc., by selected geography); and
x. other data elements not mentioned above, which may be collected only by selected fire services.

The data were made available by the NFID in Spring 2017. Our aim was to use the data to better understand factors impacting frequency and severity of fires, as well as geographic differences. Unfortunately, there are multiple shortcomings with the data, which limited our ability to carry out the original research project. Data are collected at the provincial level, and there is little consistency across provinces in which data were collected. Only six provinces report data, and although we have data on the number of incidents in each province per year, not all provinces report the month of the incident. Below, in Table 1, is a brief snapshot of the number of fire incidents reported by each province in addition to the Canadian Armed Forces.

**TABLE 1 – NUMBER OF REPORTED INCENDIARY INCIDENTS BY JURISDICTION 2005 – 2015***

| | New Brunswick | Ontario | Manitoba | Saskatch–ewan | Alberta | British Columbia | Canadian Armed Forces |
|---|---|---|---|---|---|---|---|
| **Total Incidents** | 19,602 | 235,955 | 54,492 | 9940 | 61,707 | 81,399 | 3834 |
| **Min. Annual No. Incidents (year)** | 1431 (2009) | 18,725 (2014) | 3420 (2015) | 2399 (2014) | 4989 (2009) | 6593 (2014) | 237 (2005) |
| **Max. Annual No. Incidents (year)** | 2232 (2007) | 28,790 (2005) | 6090 (2006) | 2644 (2012) | 7424 (2011) | 8720 (2009) | 466 (2009) |

* Ontario data available until 2014 only.

Our initial analysis is limited to Ontario, Alberta and British Columbia. These three provinces have the most complete data (by year and by variables included). Even for variables that were to be available for these provinces, a large number of observations are coded as “unknown,” “unclassified”, or “other”. We next provide a brief summary of some of the data issues.

To appropriately measure frequency, the number of incidents needs to be normalized with respect to some metric that captures the number of items or population at risk. Since our study focuses on residential fires, possible candidates include the population or the number of private dwellings for each reporting location.[6] This greatly restricted the number of observations in Alberta, as property type (i.e., residential versus non-residential) was not recorded for 47.9 percent of observations.

To appropriately measure fire severity, it is necessary to record both the value of the entire property at-risk, as well as the value of the actual property destroyed by the fire event. Thus, either of two metrics are necessary for the latter value: the total dollar value of loss and/or the percentage of the property destroyed by fire. As can be seen in Table 2, the value of the property was never collected in Ontario, and the total dollar of loss was available in about one–half of Ontario properties. Property value data were somewhat more complete in British Columbia and Alberta; however the size of loss variables accounting for contents was only available in British Columbia. There are additional concerns with the accuracy of these data. The dollar loss variables were provided by the fire service that responded to the incident. According to Statistics Canada, the origin of the value-at-risk variables is less clear. In some cases in British Columbia, the information may be provided by insurers, and for the remaining observations in British Columbia and for all observations in Alberta, the values-at-risk were estimated by the fire service / investigator’s office.

[6] The reporting area used by the NFID is census subdivision (CSD). We provide a discussion on page 13 on issues using CSD as the reporting area.

**TABLE 2 – PERCENTAGES OF MISSING OBSERVATIONS FOR SEVERITY METRICS BY JURISDICTION**

| Variable | Definition | British Columbia | Alberta | Ontario |
|---|---|---|---|---|
| **risk vala** | Value-at-risk – building/vehicle value | 31.99 | 15.91 | 100 |
| **risk valb** | Value-at-risk – Contents | 0.81 | 56.84 | 100 |
| **risk valc** | Value-at-risk – total | 43.60 | 100 | 100 |
| **dollossa** | Dollar of Loss – Building/Vehicle | 48.73 | 10.24 | 99.70 |
| **dollossb** | Dollar of Loss – Contents | 75.99 | 100 | 99.74 |
| **dollossc** | Dollar of Loss – Total Property and Contents | 34.83 | 100 | 55.93 |

Insurance companies have the best methods and data for measuring both the value-at-risk and the size of loss. Municipal records may not accurately reflect the value of the property at risk, and do not capture the value of contents at risk. Insurers, because they pay the actual claims, record the ultimate dollar value of loss for both the property and contents. For some fire events, insurers may also capture other economic losses associated with the event such as the cost of evacuation, temporary housing costs for residential properties and business interruption losses for commercial properties. This helps measure the true cost associated with a fire loss. If data cannot be collected from insurers, then municipal tax records may provide a next best estimate of building value-at-risk amounts.

The availability of data elements across the three jurisdictions delineated the variables that could be used to model both frequency and severity of fire losses. This resulted in the exclusion of many key variables, including response time of first vehicle, distance between fire station and location of incident, number and type of emergency vehicles responding, and number of occupants in the building. In general, the database contains more variables that influence the severity of fire losses than influence the frequency of fire losses. In particular, as will be discussed in the section on Fire Frequency, only demographic data were used to model the likelihood of fire. However, consistent with our observations in Table 2, many values were coded as unknown or missing. For data collected specifically for the NFID project, we provide the percentage of missing, unclassified or unknown data by jurisdiction in Table 3.

**TABLE 3 –PERCENTAGES OF MISSING DATA IN NFID EXPLANATORY VARIABLES BY JURISDICTION**

| Variable | Definition | Type of Variable | British Columbia | Alberta | Ontario |
|---|---|---|---|---|---|
| **genconst** | General construction | Categorical variable with 8 classes; 3 were NA, unclassified or unknown | 65.44 | 59.78 | Not collected |
| **height** [a] | Actual height in stories | Numerical | 3.9 | 13.07 | 62.58 |
| **manprot** | Manual fire protection facilities | Categorical variable with 7 classes; 2 were unclassified or cannot be determined | 49.63 | 51.06 | 99.78 |

| Variable | Definition | Type of Variable | British Columbia | Alberta | Ontario |
|---|---|---|---|---|---|
| **sprinpro** | Sprinkler protection | Categorical variable with 10 classes; 2 were unclassified or cannot be determined | 64.76 | 63.88 | 84.25 |
| **fixedsys** | Fixed system other than sprinklers | Categorical variable with 8 classes; 2 were unclassified or cannot be determined | Not collected | 60.3 | 100 |
| **autodet** | Automatic fire detection system | Categorical variable with 10 classes; 3 were NA, unknown or not reported or cannot be determined | 76.66 | 63.2 | 89.21 |
| **firedet** | Fire detection devices | Categorical variable with 13 classes; 1 was cannot be determined | Not collected | 18.04 | 75.82 |
| **outprot** | Outside fire protection | Categorical variable with 9 classes; 2 were unclassified or cannot be determined | 0 | 19.56 | Not collected |
| **service** | Fire service | Categorical variable with 20 classes; 2 were unclassified or cannot be determined | 1.25 | 12.37 | Not collected |
| **actomgrp** | Act or omission group | Categorical variable with 10 classes; 2 were miscellaneous NA, unclassified or cannot be determined | 30.4 | 29.19 | 44.8 |
| **detect** | Initial detection | Categorical variable with 12 classes; 3 were NA, unclassified or cannot be determined | 62.31 | 11.86 | 80.91 |
| **action** | Action taken | Categorical variable with 9 classes; 3 were NA, unclassified or cannot be determined | 9.13 | 36.72 | 39 |

[a] Percentage missing is percentage in which height is recorded as zero storeys.

In order to capture demographic data, the fire losses were matched with Statistics Canada data. Jennings (2013) reviews the literature on urban fire risk and its relationship to social and economic characteristics. Previous research has found a consistent relationship between fire risk, poverty and quality of housing. Poorer neighbourhoods are more likely to be overcrowded and have substandard housing and abandoned buildings. Families with limited income are less likely to invest in and maintain safety equipment (e.g., functioning smoke detectors).

The CMHC (2004) found similar results. The Indigenous death rate from fire was approximately four times the Canadian average, although the fire incidence rate was lower. Fire death rates were also higher for the elderly, those living in rural communities, those living in crowded dwellings and dwellings in need of repair. The inclusion of demographic data enable researchers to address the fire risk of at-risk populations – elderly, children, the physically infirmed, new Canadians – and at-risk places – high–crime neighbourhoods, neighbourhoods with large transient populations, which are of interest to the Canadian Association of Fire Chiefs and Fire Marshalls (CAFCFM).

Currently, NFID data are coded at the CSD level. A CSD, according to Statistics Canada, is a municipality or an area that is deemed to be equivalent to a municipality for statistical reporting purposes. There are (in 2011) 5253 CSDs in Canada, but the number of CSDs per province varies greatly: Quebec has 1285 CSDs, followed by Saskatchewan with 959, and British Columbia with 743. The number of CSDs does not appear to relate to the population of the province.[7] Because of this, it is important to standardize any frequency metric by a measure of population or building density. We used the number of dwellings per CSD as collected in the 2006 and 2011 Canadian census. However, because of missing or incorrect observations, the inclusion of these demographic data further reduces the sample size. This information is collected for 2006 and 2011, and we used linear interpolation and extrapolation to create values for the remaining years in the data set. The percentages of available observations for the three jurisdictions are given in Table 4.

**TABLE 4 – PERCENTAGES OF VALID OBSERVATIONS (NOT MISSING OR ZERO) FOR SOCIOECONOMIC AND DEMOGRAPHIC VARIABLES BY JURISDICTION**

| Source | Variables | British Columbia | Alberta | Ontario |
|---|---|---|---|---|
| **2006 Census** | Single dwelling counts, after tax income, employment rates, educational attainment | 91.55 to 91.85 | 95.5 to 96.16 | 89.4 |
| **2011 Census** | Single dwelling counts | 92.9 | 91.85 | 87.2 |
| **2011 National Household Survey** | After tax income, employment rates, educational attainment | 90.87 to 92.9 | 90.91 to 91.85 | 86.98 to 87.2 |
| **NFID** | Property crime rate | 94.73 | 96.7 | 89.35 |

The collection of data at the CSD level, however, creates a larger issue. In order to address the risks to these populations, data need to be collected at a much finer level than CSD for urban communities. For example, Toronto is a single CSD, as are Vancouver, Calgary and Edmonton. Without more geographic refinement, such as forward sortation area (FSA, the first three digits of the postal code), the characteristics relevant to the location of the loss cannot be determined. We strongly urge the CAFCFM to disaggregate the data by FSA for urban centres. Census data are available from Statistics Canada at this level. This would then allow researchers to address issues relating to at-risk populations and at-risk places within urban centres. Unfortunately, because of the lack of granularity in the data, we cannot accurately address our original question: how do

[7] According to the Statistics Canada (2017), in 2011, approximately 800 CSDs in Canada had less than 100 residents, whereas the largest three CSDs (Toronto, Montreal and Calgary) all had populations exceeding 1 million residents.

drivers of fire risk vary across populations based on socioeconomic and demographic characteristics such as income, education, age, employment, immigration status, languages spoken and crime rate. Furthermore, we cannot address how the frequency and severity of fire losses vary geographically across inner cities, urban and suburban communities.

Alternatively, if it is not possible to disaggregate the data by FSA for urban centres, a higher level of granularity could be achieved if the location of the (initial) responding fire station was added to the database. Then it would be possible to use the location of each fire station as a proxy for the location of the fire incident.

Other missing demographic data that would be useful to our research include the number of individuals in the household (overcrowding is correlated with increased frequency and severity of fire loss), percentage of household smokers, percentage of household that does not speak either official Canadian language, household sources of heating and amounts spent on home repairs within a region. Unfortunately, some of these data are not easily available at the FSA level. But these data are available through microdata in surveys such as the Survey of Household Spending (SHS) or the Canadian Health Measures Survey from regional data centres including the Prairie Regional Research Data Centre (https://crdcn.org/prairie–regional–rdc) at University of Calgary and the South–Western Ontario Research Data Centre (https://crdcn.org/south–western–ontario–rdc–swo–rdc) at University of Waterloo. The SHS asks questions concerning the amounts spent on improvement, maintenance and repairs of principal residences and amounts spent on heating oil, propane, wood and other fuel. The Canadian Health Measures survey collects data on smoking and alcohol usage and census data contains information on languages spoken.[8]

Weather information is also absent from the current database, but it could be incorporated by matching each CSD with the closest Environment and Climate Change Canada (ECCC) weather station. Wind can determine the directions and speed of the spread of fire, if any; relative humidity impacts the moisture content of potential fuels and hence both the severity and likelihood of fires. Temperature impacts fire directly through humidity and wind formation; however, it also impacts human behaviour, which may increase the likelihood of fire (e.g., the use of wood burning stoves in the winter). Depending on the weather station, data are available on hourly, daily and / or monthly frequency. On a daily basis, data collected include minimum, maximum and mean temperature and the number of heating and cooling degree days (on a daily basis it is the number of degrees Celsius that the mean temperature is below or above 18C, respectively), total rain, snow and precipitation, amount of snow on the ground, and direction and speed of maximum wind gusts. Hourly observations include temperature, dew point temperature, relative speed and humidity, wind direction and speed, visibility, pressure, humidex, wind chill and occurrence of weather and obstructions to vision, which are namely different precipitation events. (A full list is available at: http://climate.weather.gc.ca/glossary_e.html#weather) On a monthly basis, data collected include the minimum, maximum and average monthly temperature, the monthly snowfall and amount of snow on the ground at the end of the month, the monthly precipitation and the number of days with

[8] Ducic and Ghezzo (1980) found that the number of alcohol users in a household was significantly higher in households that had reported a serious fire loss.

precipitation of at least 1 mm, and the number of heating and cooling degree days. A combination of the different frequencies would be necessary – hourly wind, daily temperature, and precipitation data on both daily and monthly basis – to accurately capture their impact.

## Fire Frequency: Data, Methodology and Results

We analyzed the NFID fire loss data across two dimensions: frequency and severity. We first present our frequency fire loss analysis and in the next section detail the severity fire loss analysis.

Due to the significant data limitations discussed earlier, our frequency fire loss analysis was limited to three provinces: Alberta, British Columbia, and Ontario. The data for Alberta and British Columbia span the years 2005 to 2015 while the data for Ontario span the years 2005 to 2014. In the following two sub–sections, for each dimension of analysis, we describe and summarize the relevant data, introduce econometric regression models and discuss the results of these models.

### FREQUENCY FIRE LOSS DATA

Given the complexities in determining what constitutes an individual incident of fire loss and the challenges presented with the NFID data, we constructed two different measures of fire loss frequency to utilize in our analysis. The first measure restricts reported fire loss incidents to residential types of dwellings and standardizes these counts to a per year, per 1000 dwellings basis. The second measure also restricts reported fire loss incidents to residential types of dwellings but standardizes the counts to a per year, per 100,000 population basis. Both these measures are reported at the CSD level and both were used as dependent variables in our econometric regression models, which we introduce later in this sub–section.

To better understand how fire loss frequency varies across populations, we extracted various demographic variables from Statistics Canada census data at the CSD level. These demographic variables included the following: First Nations CSD identifier, population density, median income, unemployment rate, education level, property crime rate, median age, gender composition and marital status. Because actual census data was only available for the years 2006 and 2011, we linearly interpolated annual variables for non-census years between 2006 and 2011 and linearly extrapolated annual variables for non-census years outside of 2006 and 2011. These demographic variables were used as independent variables in our econometric regression models. Table 5 describes all of our frequency analysis variables.

**TABLE 5 – VARIABLES FOR FREQUENCY ANALYSIS**

| Variable | Description |
|---|---|
| **Dependent Variables** | |
| **Fire loss per 1K dwellings** | Residential type of fire loss incident count per year per 1,000 dwellings. |
| **Fire loss per 100K population** | Residential type of fire loss incident count per year per 100,000 population. |

| Variable | Description |
|---|---|
| **Independent Variables** | |
| **First Nations** | Based on criteria established by Aboriginal Affairs and Northern Development Canada (AANDC; formerly Indian and Northern Affairs Canada [INAC]), six CSDs types are identified as "First Nations" based on the legal definition of communities affiliated with First Nations or Indian bands. The six CSDs types include: Indian reserve (IRI), Indian settlement (S–É), Indian government district (IGD), *Terres réservées aux Cris* (TC), *Terres réservées aux Naskapis* (TK) and Nisga'a land (NL). |
| **Population density** | Population/Land area in square meters for each CSD. |
| **Median income** | Median income for each CSD. |
| **Unemployment rate (%)** | Unemployment rate for each CSD. |
| **Low education level (%)** | Percentage population aged 25 years and older without a certificate, diploma or degree for each CSD. |
| **Property crime rate** | Property crime rate per 100,000 population for each CSD. Property crimes, as defined by the Uniform Crime Reporting Survey, involve unlawful acts to gain property, but do not involve the use or threat of violence against the person. They include offences such as break and enter, theft, and mischief, among others. |
| **Median age** | Median age for each CSD. |
| **Percent male** | Percentage of males in the total population for each CSD. |
| **Percent married** | Percentage of persons who are legally married and not separated or in common–law in the total population 15 years or older for each CSD. |

Panels A, B and C of Table 6 present summary statistics (mean, standard deviation, minimum and maximum) and correlation coefficients for our frequency analysis variables (those described in Table 5) for CSD's in Alberta, British Columbia and Ontario, respectively. The statistics are based on 1386 CSD–year observations for Alberta (from 2005 to 2015), 1492 CSD–year observations for British Columbia (from 2005 to 2015) and 2694 CSD–year observations for Ontario (from 2005 to 2014).

These numbers of observations are significantly smaller than the initial total number of fire loss incidents reported in the NFID (and reported in Table 1) for the following reasons:

- We removed incidents where the number of dwellings was recorded as negative by Statistics Canada.
- We removed observations where Statistics Canada reported unreasonable variable values including a median income less than zero, an unemployment rate less than zero, an education rate less than zero or a property crime rate less than zero.
- We removed observations where we were unable to match the CSD in the NFID data with any CSD in the list provided by Statistics Canada.

- Because of our focus on individuals, we removed observations that were not categorized as residential type incidents in the NFID data.

From Table 6, we observe some interesting comparisons across these three provinces. The residential fire incident rate per year (as measured by the 'Fire loss per 1K dwellings' variable) was on average highest in Alberta (2.63 percent) followed by Ontario (1.88 percent) and then British Columbia (1.64 percent). There were more First Nations CSDs in Alberta and British Columbia than in Ontario. The average population density in British Columbia (527.91) was higher than in Alberta (345.77) and almost twice as high as in Ontario (272.44). Alberta had the highest average median income (50,338.31 CAD) followed by Ontario (48,665.24 CAD) and British Columbia (44,579.58 CAD). The mean unemployment rate was lowest in Alberta (6.00 percent) and highest in British Columbia (8.23 percent). Alberta had the highest mean percentage of those 25 or older without a certificate, diploma or degree (27.83 percent), followed by Ontario (23.70 percent) and then British Columbia (20.21 percent). The mean property crime rate was far lower in Ontario (2834.12) than in Alberta (6142.24) or British Columbia (5183.69). Alberta reported the youngest median age by six to seven years. Half the population in all three provinces was male and over sixty percent of the population in all three provinces was married.

Within each province, most correlation coefficients were significant and in the direction one would expect across the two variables of interest (e.g., unemployment rate and low education level were significantly positively correlated).

**TABLE 6 – SUMMARY STATISTICS FOR FREQUENCY REGRESSIONS**

| Variable | Mean | Standard Dev. | Min–imum | Maximum | Correlation Coefficient | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fire loss per 1K dwellings | First Nations | Pop'n Density | Median Income | Unem–ployment Rate (%) | Low Edu–cation Level (%) | Property Crime Rate | Median Age | Percent Male | Percent Married |
| **Fire loss per 1K dwellings** | 2.63 | 4.63 | 0.08 | 131.43 | 1.00 | | | | | | | | | |
| **First Nations** | 0.05 | 0.21 | 0 | 1.00 | 0.23*** | 1.00 | | | | | | | | |
| **Population density** | 345.77 | 345.57 | 0.07 | 1,722.20 | −0.12*** | −0.21*** | 1.00 | | | | | | | |
| **Median income** | 50,338.3 | 16,744.9 | 0 | 141,135.6 | −0.07* | −0.27*** | 0.06* | 1.00 | | | | | | |
| **Unemploy–ment rate (%)** | 6.00 | 4.91 | 0 | 44.72 | 0.23*** | 0.76*** | −0.15*** | −0.37*** | 1.00 | | | | | |
| **Low education level (%)** | 27.83 | 12.25 | 1.84 | 88.84 | 0.24*** | 0.69*** | −0.34*** | −0.19*** | 0.58*** | 1.00 | | | | |
| **Property crime rate** | 6,142.2 | 7,244.9 | 474.9 | 133,502.8 | 0.07** | 0.44*** | −0.07* | −0.11*** | 0.39*** | 0.33*** | 1.00 | | | |
| **Median age** | 37.38 | 6.33 | 15.00 | 58.40 | −0.05 | −0.57*** | −0.11*** | 0.08** | −0.42*** | −0.40*** | −0.37*** | 1.00 | | |
| **Percent male** | 50 | 2 | 45 | 56 | 0.01 | 0.03 | −0.39*** | 0.07** | −0.01 | 0.00 | 0.01 | −0.17*** | 1.00 | |
| **Percent married** | 62 | 6 | 34 | 75 | −0.12*** | −0.56*** | −0.17*** | 0.26*** | −0.51*** | −0.41*** | −0.41*** | 0.36*** | 0.35*** | 1.00 |

**PANEL A: ALBERTA (1386 OBSERVATIONS)**

Using the two–tailed t–test of Pearson's correlation coefficient for 1386 CSD–year observations, we test the significance of the relationships between the sets of variables. The correlation measures the strength of the relationship, with larger absolute values implying a stronger relationship. The t–test tests the likelihood that the given correlation coefficient will be observed if there is indeed no relationship between the two variables. Thus the smaller the p value, the more significant the relationship. Only one correlation coefficient – First Nations and Unemployment Rate – is large enough that it could cause instability in the model. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

| Variable | Mean | Standard Deviation | Minimum | Maximum | Correlation Coefficient | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fire loss per 1K dwellings | First Nations | Pop'n Density | Median Income | Unemployment Rate (%) | Low Education Level (%) | Property Crime Rate | Median Age | Percent Male | Percent Married |
| **Fire loss per 1K dwellings** | 1.64 | 1.73 | 0.07 | 23.26 | 1.00 | | | | | | | | | |
| **First Nations** | 0.05 | 0.23 | 0 | 1.00 | 0.23*** | 1.00 | | | | | | | | |
| **Population density** | 527.91 | 894.15 | 0 | 5,417.23 | −0.06* | 0.04 | 1.00 | | | | | | | |
| **Median income** | 44,579.6 | 15,210.3 | 0 | 145,476.0 | −0.09*** | −0.19*** | −0.01 | 1.00 | | | | | | |
| **Unemployment rate (%)** | 8.23 | 4.51 | 0 | 61.24 | 0.29*** | 0.40*** | −0.08** | −0.36*** | 1.00 | | | | | |
| **Low education level (%)** | 20.21 | 7.56 percent | 3.14 | 56.64 | 0.39*** | 0.24*** | −0.26*** | 0.03 | 0.36*** | 1.00 | | | | |
| **Property crime rate** | 5,183.7 | 2,610.5 | 1,113.9 | 18,810.3 | 0.14*** | 0.05 | 0.15*** | 0.10*** | 0.03 | 0.25*** | 1.00 | | | |
| **Median age** | 44.77 | 6.65 | 28.86 | 72.20 | −0.13*** | 0.05* | −0.08** | −0.21*** | −0.03 | −0.17*** | −0.31*** | 1.00 | | |
| **Percent male** | 50 | 24 | 14 | 974 [a] | −0.03 | −0.01 | −0.05 | 0.05 | 0.00 | 0.03 | 0.00 | −0.05 | 1.00 | |
| **Percent married** | 61 | 6 | 40 | 75 | −0.12*** | −0.24*** | −0.57*** | 0.23*** | −0.22*** | 0.01 | −0.42*** | 0.29*** | 0.06* | 1.00 |

**PANEL B: BRITISH COLUMBIA (1492 OBSERVATIONS)**

[a] Clearly this value is coding error. In discussion with the project lead at Statistics Canada, we were told that, at the request of NFID, the data were not cleaned before being released to researchers. All numerical variables in our regressions were winsorized at the 1 percent and 99 percent for each province.

Using the two–tailed t–test of Pearson's correlation coefficient for 1386 CSD–year observations, we test the significance of the relationships between the sets of variables. The correlation measures the strength of the relationship, with larger absolute values implying a stronger relationship. The t–test tests the likelihood that the given correlation coefficient will be observed if there is indeed no relationship between the two variables. Thus the smaller the p value, the more significant the relationship. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

| Variable | Mean | Standard Deviation | Min–imum | Maximum | Correlation Coefficient | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fire loss per 1K dwellings | First Nations | Pop'n Density | Median Income | Unem–ployment Rate (%) | Low Edu–cation Level (%) | Property Crime Rate | Median Age | Percent Male | Percent Married |
| **Fire loss per 1K dwellings** | 1.88 | 1.69 | 0.10 | 17.54 | 1.00 | | | | | | | | | |
| **First Nations** | 0.00 | 0.06 | 0 | 1.00 | 0.10*** | 1.00 | | | | | | | | |
| **Population density** | 272.44 | 506.82 | 0 | 4,255.72 | –0.14*** | –0.03 | 1.00 | | | | | | | |
| **Median income** | 48,655.2 | 13,333.0 | 0 | 95,403.6 | –0.08*** | –0.09*** | 0.03 | 1.00 | | | | | | |
| **Unemploy–ment rate (%)** | 7.40 | 3.77 | 0 | 79.70 | 0.21*** | 0.23*** | 0.06** | –0.32*** | 1.00 | | | | | |
| **Low education level (%)** | 23.70 | 7.26 | 6.96 | 80.24 | 0.31*** | 0.13*** | –0.17*** | –0.08*** | 0.17*** | 1.00 | | | | |
| **Property crime rate** | 2,834.1 | 1,283.2 | 263.6 | 18,506.5 | 0.09*** | 0.15*** | 0.19*** | 0.10*** | 0.13*** | 0.27*** | 1.00 | | | |
| **Median age** | 43.72 | 4.82 | 17.24 | 60.58 | 0.06** | –0.12*** | –0.28*** | –0.40*** | 0.28*** | –0.11*** | –0.05* | 1.00 | | |
| **Percent male** | 0.50 | 0.02 | 0.33 | 0.64 | 0.11*** | 0.02 | –0.45*** | 0.07*** | 0.05* | 0.13*** | –0.32*** | –0.05** | 1.00 | |
| **Percent married** | 0.63 | 0.05 | 0.41 | 0.78 | 0.05** | –0.20*** | –0.55*** | 0.22*** | –0.23*** | –0.04* | –0.43*** | 0.10*** | 0.63*** | 1.00 |

**PANEL C: ONTARIO (2694 OBSERVATIONS)**

*Using the two–tailed t–test of Pearson's correlation coefficient for 1386 CSD–year observations, we test the significance of the relationships between the sets of variables. The correlation measures the strength of the relationship, with larger absolute values implying a stronger relationship. The t–test tests the likelihood that the given correlation coefficient will be observed if there is indeed no relationship between the two variables. Thus the smaller the p value, the more significant the relationship.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

### FREQUENCY FIRE LOSS METHODOLOGY AND RESULTS

To better understand the correlation of each variable with our main fire loss frequency measure variables, while taking into account the other variables, we designed three econometric regression models to which we applied data from Alberta, British Columbia and Ontario. The following three ordinary least squares (OLS) regression models were used:

(1) $\text{Fire loss per 1K dwellings}_{jt} = \alpha + \beta_1 \times \text{First Nations}_{jt} + \beta_2 \times \text{Population density}_{jt} + \beta_3 \times \text{Median income}_{jt} + \beta_4 \times \text{Unemployment rate}_{jt} + \beta_5 \times \text{Low education level}_{jt} + \beta_6 \times \text{Property crime rate}_{jt} + \beta_7 \times \text{Median age}_{jt} + \beta_8 \times \text{Percent male}_{jt} + \beta_9 \times \text{Percent married}_{jt} + \varepsilon_{jt}$

(2) $\text{Fire loss per 100K population}_{jt} = \alpha + \beta_1 \times \text{First Nations}_{jt} + \beta_2 \times \text{Population density}_{jt} + \beta_3 \times \text{Median income}_{jt} + \beta_4 \times \text{Unemployment rate}_{jt} + \beta_5 \times \text{Low education level}_{jt} + \beta_6 \times \text{Property crime rate}_{jt} + \beta_7 \times \text{Median age}_{jt} + \beta_8 \times \text{Percent male}_{jt} + \beta_9 \times \text{Percent married}_{jt} + \varepsilon_{jt}$

(3) $\text{Fire loss per 1K dwellings}_{jt} = \alpha + \beta_1 \times \text{First Nations}_{jt} + \beta_2 \times \text{Population density}_{jt} + \beta_3 \times \text{Median income}_{jt} + \beta_4 \times \text{Unemployment rate}_{jt} + \beta_5 \times \text{Low education level}_{jt} + \beta_6 \times \text{Property crime rate}_{jt} + \beta_7 \times \text{Median age}_{jt} + \beta_8 \times \text{Percent male}_{jt} + \beta_9 \times \text{Percent married}_{jt} + \text{First Nations}_{jt} \times (\beta_{10} \times \text{Population density}_{jt} + \beta_{11} \times \text{Median income}_{jt} + \beta_{12} \times \text{Unemployment rate}_{jt} + \beta_{13} \times \text{Low education level}_{jt} + \beta_{14} \times \text{Property crime rate}_{jt} + \beta_{15} \times \text{Median age}_{jt} + \beta_{16} \times \text{Percent male}_{jt} + \beta_{17} \times \text{Percent married}_{jt}) + \varepsilon_{jt}$

where $j$ and $t$ denote the CSD and year, respectively. Model (1) utilized ‘Fire loss per 1K dwellings’ as the dependent variable. Model (2) utilized ‘Fire loss per 100K population’ as the dependent variable. Model (3) again utilized ‘Fire loss per 1K dwellings’ as the dependent variable but in this specification, the First Nations variable was interacted with all the other demographic variables. All numerical variables in the regression are Winsorized at the 1 percent and 99 percent level for each province.[9] In Model (3), all variables were mean–centered before creating the interaction terms except for the First Nations identifier variable.

Table 7, Table 8 and Table 9 report the OLS regression results of Models (1), (2) and (3) respectively, where each model was applied to data from each of the three provinces. Table 7 shows some consistent results across Alberta, British Columbia and Ontario. Specifically, the coefficients of the First Nations variable, the Unemployment rate variable and the Low education level variable are all significant and positive. This implies a positive association between each of these independent variables and the frequency of fire loss incidents per 1K dwellings in all three provinces. In Alberta, there is a significant positive correlation between Median age and the

[9] Winsorizing replaces the top and bottom 1 percent of numeric values (extreme values) with the 99 percent and 1 percent percentile numeric value respectively. Winsorizing removes the impact of extreme values that could otherwise unduly impact regression results.

dependent variable. In British Columbia, this same correlation is significant and negative. In British Columbia, there is also a significant negative association between Median income and the frequency of fire loss incidents per 1K dwellings. In Ontario, several other independent variables have significant coefficients. The coefficient on Population density is significant and negative while the coefficients on Property crime rate and Percent married are significant and positive, implying that CSDs with higher crime rates have a lower frequency of fire (contrary to the literature), and CSDs with a higher proportion of married couples have a higher frequency of fire.

When we changed the dependent variable to Fire loss per 100K population (Model (2)), we observe in Table 8, for the most part, similar results for Alberta, British Columbia and Ontario. The most notable exception was the loss of significance in the First Nations variable for Alberta and British Columbia. In Ontario, Median age and Percent male became significant and positive. In British Columbia, the coefficients of Population density, Property crime rate and Percent married also became significant.

Finally, Table 9 shows our results when the First Nations variable was interacted with all the other demographic variables and we used Fire loss per 1K dwellings as the dependent variable (Model (3)). Here we see less consistency across Alberta, British Columbia and Ontario. In fact, only the coefficient of Low education level is significant and positive in all three provinces. The coefficients for Population density are surprisingly negative and significant in British Columbia and Ontario. The coefficients for Unemployment rate are significant and positive in Alberta and Ontario, implying that an increase in unemployment is associated with an increase in fire loss frequency. In Alberta and Ontario, the coefficients of Property crime rate are significant but are opposite in signs. This occurs again with Percent married in British Columbia and Ontario.

Most of the significant First Nations interaction coefficients occur in British Columbia. Specifically, we see positive relationships on Population density, Low education level, Percent male and Percent married while we see negative relationships on Median income (also true for Alberta) and Median age. The likelihood of fire is greater in First Nations communities where there is a higher male population, a greater percentage of the population is married, and the community has a lower median age. One explanation is that there could be more overcrowding in these communities, if a greater percentage of married individuals also imply more children and hence more crowded households. Collecting data on household size would help to answer this question.

**TABLE 7 – OLS REGRESSION ON FIRE LOSS 1K DWELLINGS**

| Independent Variable | Model (1) | | |
|---|---|---|---|
| | Alberta | British Columbia | Ontario |
| **First Nations** | 2.56(1.14)* | 0.73(0.20)*** | 1.22(0.54)* |
| **Population density** | −0.00(0.00) | −0.00(0.00) | −0.00(0.00) |
| **Median income** | 0.00(0.00) | −0.00(0.00) | −0.00(0.00) |
| **Unemployment rate** | 0.12(0.04)** | 0.04(0.01)*** | 0.08(0.01)*** |
| **Low education level** | 0.06(0.01)*** | 0.07(0.01)*** | 0.06(0.00)*** |
| **Property crime rate** | −0.00(0.00) | 0.00(0.00) | 0.00(0.00)* |

| Independent Variable | Model (1) | | |
|---|---|---|---|
| | Alberta | British Columbia | Ontario |
| **Median age** | 0.09(0.03)*** | –0.02(0.01)** | 0.00(0.01) |
| **Percent male** | 5.42(8.14) | –0.24(0.17) | –0.84(2.82) |
| **Percent married** | –0.22(2.68) | –1.22(0.99) | 4.03(1.03)*** |
| **Constant** | –5.95(4.55) | 1.73(0.68)* | –2.42(1.34) |
| **$R^2$** | 0.084 | 0.196 | 0.138 |
| **Adjusted $R^2$** | 0.078 | 0.191 | 0.135 |
| **Observations** | 1386 | 1492 | 2694 |

All probabilities are two–tailed tests. * p≤0.05; **; p≤0.01; ***p≤0.001.
Standard errors are reported in parentheses.

**TABLE 8 – OLS REGRESSION ON FIRE LOSS PER 100K POPULATION**

| Independent Variable | Model (2) | | |
|---|---|---|---|
| | **Alberta** | **British Columbia** | **Ontario** |
| **First Nations** | 20.67(52.22) | 13.51(9.40) | 49.14(27.62) |
| **Population density** | 0.00(0.02) | –0.01(0.00)* | 0.01(0.00) |
| **Median income** | 0.00(0.00) | –0.00(0.00)* | –0.00(0.00) |
| **Unemployment rate** | 5.03(1.82)** | 0.47(0.52) | 3.68(0.49)*** |
| **Low education level** | 2.41(0.67)*** | 3.10(0.30)*** | 3.28(0.24)*** |
| **Property crime rate** | –0.00(0.00) | 0.00(0.00) | 0.01(0.00)*** |
| **Median age** | 6.03(1.22)*** | 0.34(0.32) | 4.78(0.42)*** |
| **Percent male** | 386.84(373.59) | –0.61(7.76) | 606.68(143.14)*** |
| **Percent married** | –54.92(123.14) | –100.11(46.19)* | 249.67(52.30)*** |
| **Constant** | –394.15(209.00) | 65.57(31.73)* | –695.31(67.93)*** |
| **$R^2$** | 0.048 | 0.140 | 0.229 |
| **Adjusted $R^2$** | 0.042 | 0.135 | 0.226 |
| **Observations** | 1386 | 1492 | 2694 |

All probabilities are two–tailed tests. * p≤0.05, **; p≤0.01;, ***p≤0.001.
Standard errors are reported in parentheses.

**TABLE 9 – OLS REGRESSION WITH INTERACTION EFFECTS ON FIRE LOSS PER 1K DWELLINGS**

| Independent Variable | Model (3) | | |
|---|---|---|---|
| | **Alberta** | **British Columbia** | **Ontario** |
| **First Nations** | –10.04(16.13) | 1.61(0.37)*** | –14.19(13.26) |
| **Population density** | –0.00(0.00) | –0.00(0.00)* | –0.00(0.00) |
| **Median income** | 0.00(0.00) | –0.00(0.00)* | –0.00(0.00) |
| **Unemployment rate** | 0.14(0.05)** | 0.01(0.01) | 0.08(0.01)*** |
| **Low education level** | 0.06(0.02)*** | 0.07(0.01)*** | 0.06(0.00)*** |

| Independent Variable | Model (3) | | |
|---|---|---|---|
| | Alberta | British Columbia | Ontario |
| **Property crime rate** | –0.00(0.00) | 0.00(0.00) | 0.00(0.00)** |
| **Median age** | 0.09(0.03)** | –0.01(0.01) | 0.00(0.01) |
| **Percent male** | 8.69(8.51) | –0.24(0.16) | 0.51(2.83) |
| **Percent married** | –1.50(2.85) | –2.17(1.03)* | 4.40(1.03)*** |
| **First Nations × Population density** | –0.02(0.04) | 0.00(0.00)*** | –0.15(0.26) |
| **First Nations × Median income** | –0.00(0.00)** | –0.00(0.00) | 0.00(0.00) |
| **First Nations × Unemployment rate** | –0.02(0.10) | 0.01(0.02) | 1.26(2.18) |
| **First Nations × Low education level** | –0.08(0.06) | 0.04(0.02) | –0.53(1.34) |
| **First Nations × Property crime rate** | 0.00(0.00) | –0.00(0.00) | –0.00(0.00) |
| **First Nations × Median age** | –0.30(0.21) | –0.10(0.03)** | 1.68(2.07) |
| **First Nations × Percent male** | 9.72(35.83) | 55.63(12.27)*** | –273.49(503.75) |
| **First Nations × Percent married** | 5.66(12.53) | 21.38(3.79)*** | –45.17(243.43) |
| **Constant** | 2.50(0.13)*** | 1.58(0.04)*** | 1.88(0.03)*** |
| **$R^2$** | 0.094 | 0.268 | 0.148 |
| **Adjusted $R^2$** | 0.083 | 0.260 | 0.142 |
| **Observations** | 1386 | 1492 | 2694 |

All probabilities are two–tailed tests. * p≤0.05; ** p≤0.01; ***p≤0.001.
Standard errors are reported in parentheses.

Despite the lack of granularity in the data, and our concerns about data quality, our results are consistent with previous research: the likelihood of a fire incidence is greater in communities with higher unemployment and less education (see, for example, CMHC, 2004; and Jennings, 2013). We also find that the incidence of fire is greater in First Nations communities (when frequency is measured based on number of dwellings). CMHC (2004) indicate that one reason why First Nations communities have greater fire losses is that many of these communities are isolated. We did examine whether rural (versus urban) CSDs had greater fire risks, but this variable was not significant in our frequency regressions.

## Fire Severity: Data, Methodology and Results

Since we had no data on the value of the property in Ontario, our severity fire loss analysis was limited to two provinces, Alberta and British Colombia. We estimated the severity of an individual incident of fire loss by constructing two slightly different metrics due to data availability – one for the province of Alberta and one for British Columbia. The measure used for Alberta is a ratio of the estimated dollar amount of damage to a building caused by fire relative to the estimated cash value of the building or its value-at-risk (VAR). We labeled this variable: Dollar loss/VAR (building). The measure used for British Columbia is a ratio of the estimated dollar amount of total damage caused by fire relative to the estimated cash value of the property including its contents or its value-at-risk (VAR). We labeled this variable: Dollar loss/VAR (total). Both of these metrics were reported at the CSD level and each was used as a dependent variable in our econometric regression model, which we introduce later in this section.

### SEVERITY FIRE LOSS DATA

To better understand how fire loss severity varies across structures, communities and populations, we extracted building characteristics and fire loss prevention variables from the NFID data. We also extracted several demographic variables from Statistics Canada census data, again at the CSD level. The building and fire loss prevention variables included the following: occupancy type, construction type, building height, manual fire protection, sprinkler protection, fire detection, outdoor fire protection, fire service, cause of fire, initial detection and action taken after detection. These variables were either binary or had several classes within them as they tended to be more descriptive rather than quantitative. For example, the categorical variable *genconst* (general construction as related to property classification) had 8 different classes: 1 = combustible construction – open wood joist; 2 = protected combustible construction – wood protected by plaster; 3 = heavy timber construction; 4 = non–combustible construction – exposed steel; 5 = protected non–combustible construction – protected steel or concrete; 8 = general construction – not applicable, 9 = general construction – unclassified; and 0 = general construction unknown. The classes 8, 9 and 0 are represented by the indicator variable *other construction*. This indicator variable is not included in the regressions, and as such becomes the baseline against which all other construction is measured.

The demographic variables included the following: First Nations CSD identifier, Urban location, Median income, and Education level. These demographic variables were at the CSD level. Similar to our frequency analysis, because actual census data was only available for the years 2006 and 2011, we linearly interpolated annual variables for non-census years between 2006 and 2011 and linearly extrapolated annual variables for non-census years outside of 2006 and 2011. These building characteristics, fire loss prevention and demographic variables were used as independent variables in our econometric regression model. Table 10 describes all of our severity analysis variables in greater detail. Following from our discussion on data limitations earlier, it is important to reiterate that missing / or unclassified observations for indicator variables are coded as zero.

**TABLE 10 – VARIABLES FOR SEVERITY ANALYSIS**

| Variable | Description |
|---|---|
| **Dependent Variables** | |
| **Dollar loss/VAR (building)** | Dollar amount of estimate of the building damage caused by the fire divided by the estimated cash value of the building. Used for Alberta. |
| **Dollar loss/VAR (total)** | Dollar amount of estimate of the total damage caused by the fire divided by the estimated cash value of the property including its contents. Used for British Columbia. |
| **Independent Variables** | |
| **First Nations** | Based on criteria established by Aboriginal Affairs and Northern Development Canada (AANDC; formerly Indian and Northern Affairs Canada [INAC]), six CSDs types are identified as "First Nations" based on the legal definition of communities affiliated with First Nations or Indian bands. The six CSDs types include: Indian reserve (IRI), Indian settlement (S–É), Indian government district (IGD), *Terres réservées aux Cris* (TC), *Terres réservées aux Naskapis* (TK) and Nisga'a land (NL). |
| **Urban** | Indicator variable = 1 if CSD was categorized as a city, town or municipality; 0 otherwise. |
| **Residential occupancy** | Indicator variable = 1 if major occupancy of the building is residential; 0 otherwise. |
| **Residential property** | Indicator variable = 1 if the type of use made of the area within a building, structure or other facility where the fire occurred is residential use; 0 otherwise. |
| **Wood construction** | Indicator variable = 1 if the type of construction is open wood joist; 0 otherwise. |
| **Wood plaster construction** | Indicator variable = 1 if the type of construction is wood protected by plaster; 0 otherwise. |
| **Heavy timber construction** | Indicator variable = 1 if the type of construction is heavy timber; 0 otherwise. |
| **Exposed steel construction** | Indicator variable = 1 if the type of construction is exposed steel; 0 otherwise. |
| **Steel concrete construction** | Indicator variable = 1 if the type of construction is protected steel or concrete; 0 otherwise. |
| **Other construction** | Indicator variable = 1 if the type of construction is not wood, wood plaster, heavy timber, exposed steel or steel concrete; 0 otherwise. |
| **Height** | Actual height of the building as number of storeys. |
| **Extinguisher standpipe manual fire protection** | Indicator variable = 1 if manual fire protection facilities exist as extinguishers and/or standpipe system; 0 otherwise. |
| **No manual fire protection** | Indicator variable = 1 if no manual fire protection exists; 0 otherwise. |
| **Other manual fire protection** | Indicator variable = 1 if manual fire protection is not extinguishers and/or standpipe system; 0 otherwise. |
| **Complete** | Indicator variable = 1 if complete sprinkler protection system exists; 0 |

| Variable | Description |
|---|---|
| **sprinkler protection** | otherwise. |
| **Partial sprinkler protection** | Indicator variable = 1 if partial sprinkler protection system exists; 0 otherwise. |
| **No sprinkler protection** | Indicator variable = 1 if no sprinkler protection exists; 0 otherwise. |
| **Other sprinkler protection** | Indicator variable = 1 if sprinkler protection system is not complete or partial; 0 otherwise. |
| **Alarm fixed system** | Indicator variable = 1 if fixed system exists as supervision or alarm; 0 otherwise. |
| **No fixed system** | Indicator variable = 1 if no fixed system of any kind exists; 0 otherwise. |
| **Miscellaneous fixed system** | Indicator variable = 1 if miscellaneous fixed system exists, such as dry chemical system or special hazard system; 0 otherwise. |
| **Other fixed system** | Indicator variable = 1 if fixed system is not alarm, miscellaneous or none; 0 otherwise. |
| **No automatic fire detection** | Indicator variable = 1 if no automatic detection system exists; 0 otherwise. |
| **Automatic alarm fire detection** | Indicator variable = 1 if alarm of any sorts exists; 0 otherwise. |
| **Other automatic fire detection** | Indicator variable = 1 if automatic fire detection system is not alarm or none; 0 otherwise. |
| **Fire detection device** | Indicator variable = 1 if any sort of specialty detectors exist; 0 otherwise. |
| **No fire detection device** | Indicator variable = 1 if no specialty detector exists; 0 otherwise. |
| **Fire detection device unknown** | Indicator variable = 1 if the fire detection device is unknown; 0 otherwise. |
| **Outside fire protection hydrant or fire department** | Indicator variable = 1 if fire hydrant and/or fire department exists as outside fire protection; 0 otherwise. |
| **Outside fire protection only fire department** | Indicator variable = 1 if only fire department exists as outside fire protection; 0 otherwise. |
| **Other outside fire protection** | Indicator variable = 1 if outside fire protection is not fire hydrant or fire department; 0 otherwise. |
| **Fire service** | Indicator variable = 1 if structural fire response and/or pre–hospital emergency care exist; 0 otherwise. |
| **No fire service** | Indicator variable = 1 if no fire service function of any sort exists; 0 otherwise. |
| **Other fire service** | Indicator variable = 1 if fire service function exists outside of structural fire response and/or pre–hospital emergency care; 0 otherwise. |
| **Act or omission** | Indicator variable = 1 if fire is incendiary fire; 0 otherwise. |

| Variable | Description |
|---|---|
| incendiary | |
| Act or omission misuse | Indicator variable = 1 if fire is caused by human misuse or omission of any kind; 0 otherwise. |
| Act or omission failure | Indicator variable = 1 if fire is caused by breakdown or deficiency of any machineries, electricity or construction; 0 otherwise. |
| Act or omission other | Indicator variable = 1 if fire is not incendiary, is not caused by human misuse or omission of any kind, or is not caused by breakdown or deficiency of any machineries, electricity or construction; 0 otherwise. |
| Detect system | Indicator variable = 1 if fire is detected by any sort of system; 0 otherwise. |
| Detect human | Indicator variable = 1 if fire is detected by human detection of any sort; 0 otherwise. |
| Detect none | Indicator variable = 1 if fire is not detected by any means; 0 otherwise. |
| Detect other | Indicator variable = 1 if fire is not detected by system or human means; 0 otherwise. |
| Action extinguished | Indicator variable = 1 if fire is extinguished by any means; 0 otherwise. |
| Action none | Indicator variable = 1 if fire is not extinguished by any means; 0 otherwise. |
| Action other | Indicator variable = 1 if some other action is taken on the fire; 0 otherwise. |
| Median income | Median income for each CSD. |
| Low education level | Percentage population aged 25 years and older without a certificate, diploma or degree for each CSD. |

Panels A and B of Table 11 display summary statistics (mean, standard deviation, median, minimum and maximum) for our severity analysis variables (those described in Table 10) in Alberta and British Columbia, respectively. These summary statistics are based on 44,931 fire loss observations in Alberta and 35,695 observations in British Columbia; both spanning 2005 to 2015. Again, the number of observations is smaller than the initial total number of fire loss observations reported in the NFID for similar reasons discussed in the prior frequency loss analysis.

From Table 11, we observe some interesting comparisons across Alberta and British Columbia. The average severity of an individual incident of fire loss in Alberta (as measured by Dollar loss/VAR (building)) was 0.71 while the median such loss was 0.57. In British Columbia, the average severity of an individual incident of fire loss (as measured by Dollar loss/VAR (total)) was 0.47 while the median such loss was 0.18. In both provinces, over 75 percent of fire incidents occurred in urban areas while over 40 percent of such incidents occurred in residential properties or in residential areas of buildings. The most common distinct type of building construction was wood plaster. The median number of storeys across the buildings in both provinces was three.

For loss control, 35 percent (52 percent) of buildings in Alberta (British Columbia) had no manual fire protection (e.g., extinguishers and/or standpipe system), and 37 percent (44 percent) of buildings in Alberta (British Columbia) had no sprinkler protection. Also, 33 percent (36 percent) of buildings in Alberta (British Columbia) had no automatic fire detection (e.g., fire alarm). Alberta reported about a 50 percent higher rate of outside fire protection (e.g., fire hydrant and/or fire department exists) relative to British Columbia. Both provinces reported over 95 percent of the incidents involved some type of fire service response. Finally, in Alberta, 43 percent of buildings had no fixed system while only 13 percent had no fire detection device (these variables were not reported in British Columbia).

Other reported fire incident related variables included the cause of the fire, the initial detection of the fire and extinguishment of the fire. In Alberta (British Columbia), 21 percent (23 percent) of the fire incidents were incendiary, 30 percent (32 percent) were caused by human error and 25 percent (17 percent) were caused by system failure (e.g., breakdown or deficiency of machinery, electricity or construction). In Alberta (British Columbia), 88 percent (43 percent) of the fires were detected by humans while 7 percent (9 percent) were detected by a system. Finally, 67 percent (87 percent) of the fires in Alberta (British Columbia) were extinguished by any means.

Consistent with our frequency analysis data, Alberta reported a higher average median income of 53,803.86 CAD compared to 45,798.28 CAD in British Columbia. Alberta also reported a slightly higher mean percentage of those 25 or older without a certificate, diploma or degree (20.30), compared to British Columbia (18.26).

**TABLE 11 – SUMMARY STATISTICS**

**PANEL A: ALBERTA (44,931 OBSERVATIONS)**

| Variable | Mean | Std. Dev | Median | Min | Max |
|---|---|---|---|---|---|
| **Dollar loss/VAR (building)** | 0.71 | 3.64 | 0.57 | 0.00 | 500.00 |
| **First Nations** | 0.01 | 0.08 | 0 | 0.00 | 1.00 |
| **Urban** | 0.77 | 0.42 | 1 | 0.00 | 1.00 |
| **Residential occupancy** | 0.42 | 0.49 | 0 | 0.00 | 1.00 |
| **Residential property** | 0.40 | 0.49 | 0 | 0.00 | 1.00 |
| **Wood construction** | 0.15 | 0.36 | 0 | 0.00 | 1.00 |
| **Wood plaster construction** | 0.24 | 0.43 | 0 | 0.00 | 1.00 |
| **Heavy timber construction** | 0.01 | 0.08 | 0 | 0.00 | 1.00 |
| **Exposed steel construction** | 0.02 | 0.14 | 0 | 0.00 | 1.00 |
| **Steel & concrete construction** | 0.03 | 0.18 | 0 | 0.00 | 1.00 |
| **Other construction** | 0.55 | 0.50 | 1 | 0.00 | 1.00 |
| **Height** | 4.69 | 13.13 | 3 | 0.00 | 2000 |
| **Extinguisher standpipe manual fire protection** | 0.20 | 0.40 | 0 | 0.00 | 1.00 |
| **No manual fire protection** | 0.35 | 0.48 | 0 | 0.00 | 1.00 |
| **Other manual fire protection** | 0.45 | 0.50 | 0 | 0.00 | 1.00 |
| **Complete sprinkler protection** | 0.02 | 0.16 | 0 | 0.00 | 1.00 |
| **Partial sprinkler protection** | 0.01 | 0.08 | 0 | 0.00 | 1.00 |
| **No sprinkler protection** | 0.37 | 0.48 | 0 | 0.00 | 1.00 |
| **Other sprinkler protection** | 0.60 | 0.49 | 1 | 0.00 | 1.00 |
| **Alarm fixed system** | 0.02 | 0.15 | 0 | 0.00 | 1.00 |
| **No Fixed System** | 0.43 | 0.49 | 0 | 0.00 | 1.00 |

| Variable | Mean | Std. Dev | Median | Min | Max |
|---|---|---|---|---|---|
| Miscellaneous fixed system | 0.00 | 0.07 | 0 | 0.00 | 1.00 |
| Other fixed system | 0.55 | 0.50 | 1 | 0.00 | 1.00 |
| No automatic fire detection | 0.33 | 0.47 | 0 | 0.00 | 1.00 |
| Automatic alarm fire detection | 0.09 | 0.28 | 0 | 0.00 | 1.00 |
| Other automatic fire detection | 0.58 | 0.49 | 1 | 0.00 | 1.00 |
| Fire detection device | 0.24 | 0.43 | 0 | 0.00 | 1.00 |
| No fire detection device | 0.13 | 0.34 | 0 | 0.00 | 1.00 |
| Fire detection device unknown | 0.63 | 0.48 | 1 | 0.00 | 1.00 |
| Outside fire protection hydrant or fire department | 0.71 | 0.45 | 1 | 0.00 | 1.00 |
| Outside fire protection only fire department | 0.18 | 0.39 | 0 | 0.00 | 1.00 |
| Other outside fire protection | 0.06 | 0.24 | 0 | 0.00 | 1.00 |
| Fire service | 0.95 | 0.23 | 1 | 0.00 | 1.00 |
| No fire service | 0.01 | 0.11 | 0 | 0.00 | 1.00 |
| Other fire service | 0.04 | 0.20 | 0 | 0.00 | 1.00 |
| Act or omission incendiary | 0.21 | 0.41 | 0 | 0.00 | 1.00 |
| Act or omission misuse | 0.30 | 0.46 | 0 | 0.00 | 1.00 |
| Act or omission failure | 0.25 | 0.43 | 0 | 0.00 | 1.00 |
| Act or omission other | 0.25 | 0.43 | 0 | 0.00 | 1.00 |
| Detect system | 0.07 | 0.26 | 0 | 0.00 | 1.00 |
| Detect human | 0.88 | 0.32 | 1 | 0.00 | 1.00 |
| Detect none | 0.01 | 0.09 | 0 | 0.00 | 1.00 |
| Detect other | 0.04 | 0.19 | 0 | 0.00 | 1.00 |
| Action extinguished | 0.67 | 0.47 | 1 | 0.00 | 1.00 |
| Action none | 0.04 | 0.19 | 0 | 0.00 | 1.00 |
| Action other | 0.29 | 0.45 | 0 | 0.00 | 1.00 |
| Median income | 53,803.9 | 14,175.8 | 54,018 | 0.00 | 141,135.6 |
| Low education level | 20.30 | 7.24 | 18.62 | 1.84 | 90.56 |

PANEL B: BRITISH COLUMBIA (35,695 OBSERVATIONS)

| Variable | Mean | Std. Dev | Median | Min | Max |
|---|---|---|---|---|---|
| Dollar loss/VAR (total) | 0.47 | 2.09 | 0.18 | 0.00 | 241.51 |
| First Nations | 0.00 | 0.07 | 0 | 0.00 | 1.00 |
| Urban | 0.80 | 0.40 | 1 | 0.00 | 1.00 |
| Residential occupancy | 0.41 | 0.49 | 0 | 0.00 | 1.00 |
| Residential property | 0.42 | 0.49 | 0 | 0.00 | 1.00 |
| Wood construction | 0.09 | 0.29 | 0 | 0.00 | 1.00 |
| Wood plaster construction | 0.34 | 0.48 | 0 | 0.00 | 1.00 |
| Heavy timber construction | 0.01 | 0.08 | 0 | 0.00 | 1.00 |
| Exposed steel construction | 0.02 | 0.14 | 0 | 0.00 | 1.00 |
| Steel & concrete construction | 0.02 | 0.15 | 0 | 0.00 | 1.00 |
| Other construction | 0.51 | 0.50 | 1 | 0.00 | 1.00 |
| Height | 4.57 | 3.16 | 3 | 0.00 | 50.00 |

| Variable | Mean | Std. Dev | Median | Min | Max |
|---|---|---|---|---|---|
| **Extinguisher standpipe manual fire protection** | 0.22 | 0.41 | 0 | 0.00 | 1.00 |
| **No manual fire protection** | 0.52 | 0.50 | 1 | 0.00 | 1.00 |
| **Other manual fire protection** | 0.26 | 0.44 | 0 | 0.00 | 1.00 |
| **Complete sprinkler protection** | 0.06 | 0.23 | 0 | 0.00 | 1.00 |
| **Partial sprinkler protection** | 0.01 | 0.12 | 0 | 0.00 | 1.00 |
| **No sprinkler protection** | 0.44 | 0.50 | 0 | 0.00 | 1.00 |
| **Other sprinkler protection** | 0.49 | 0.50 | 0 | 0.00 | 1.00 |
| **No automatic fire detection** | 0.36 | 0.48 | 0 | 0.00 | 1.00 |
| **Automatic alarm fire detection** [a] | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| **Fire detection device unknown** | 0.64 | 0.48 | 1 | 0.00 | 1.00 |
| **Outside fire protection hydrant or fire department** | 0.47 | 0.50 | 0 | 0.00 | 1.00 |
| **Outside fire protection only fire department** | 0.05 | 0.23 | 0 | 0.00 | 1.00 |
| **Other outside fire protection** [b] | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| **Fire service** | 0.96 | 0.20 | 1 | 0.00 | 1.00 |
| **No fire service** | 0.00 | 0.05 | 0 | 0.00 | 1.00 |
| **Other fire service** | 0.00 | 0.02 | 0 | 0.00 | 1.00 |
| **Act or omission incendiary** | 0.23 | 0.42 | 0 | 0.00 | 1.00 |
| **Act or omission misuse** | 0.32 | 0.47 | 0 | 0.00 | 1.00 |
| **Act or omission failure** | 0.17 | 0.38 | 0 | 0.00 | 1.00 |
| **Act or omission other** | 0.28 | 0.45 | 0 | 0.00 | 1.00 |
| **Detect system** | 0.09 | 0.29 | 0 | 0.00 | 1.00 |
| **Detect human** | 0.43 | 0.49 | 0 | 0.00 | 1.00 |
| **Detect none** | 0.00 | 0.05 | 0 | 0.00 | 1.00 |
| **Detect other** | 0.48 | 0.50 | 0 | 0.00 | 1.00 |
| **Action extinguished** | 0.87 | 0.34 | 1 | 0.00 | 1.00 |
| **Action none** | 0.06 | 0.25 | 0 | 0.00 | 1.00 |
| **Action other** | 0.05 | 0.22 | 0 | 0.00 | 1.00 |
| **Median income** | 45,798.3 | 11,867.1 | 45,942.4 | 0.00 | 145,476 |
| **Low education level** | 18.26 | 4.99 | 18.16 | 3.14 | 56.64 |

[a] In the raw data, all observations in BC are categorized as either "no automatic fire detection system", or "cannot be determined" and "not applicable".
[b] In the raw data, no observation in BC is categorized as "unknown", "not applicable", or "cannot be determined".

## SEVERITY FIRE LOSS METHODOLOGY AND RESULTS

We again use OLS to estimate the following model for severity, where severity is measured as the dollar value of loss/value-at-risk (building value) for Alberta, and dollar value of loss/value-at-risk (total value) for British Columbia:

(4a) $Dollar\ loss/VAR_{ijt} = \alpha + \beta_1 \times First\ Nations_{jt} + \beta_2 \times Urban_{ijt} + \beta_3 \times Residential\ occupancy_{it} + \beta_4 \times Residential\ property_{it} + \boldsymbol{\beta}_5 \times Construction_{it} + \beta_6 \times Height_{it} + \boldsymbol{\beta}_7 \times Manual\ fire\ protection_{it} + \boldsymbol{\beta}_8 \times Sprinkler\ protection_{it} + \boldsymbol{\beta}_9 \times Fixed\ system_{it} + \boldsymbol{\beta}_{10} \times Automatic\ fire$

*detection system*$_{it}$ + $\boldsymbol{\beta}_{11}$ × *Fire detection device*$_{it}$ + $\boldsymbol{\beta}_{12}$ × *Outside fire protection*$_{it}$ + $\boldsymbol{\beta}_{13}$ × *Fire service*$_{it}$ + $\boldsymbol{\beta}_{14}$ × *Act or omission*$_{it}$ + $\boldsymbol{\beta}_{15}$ × *Initial detection*$_{it}$ + $\boldsymbol{\beta}_{16}$ × *Action taken*$_{it}$ + $\beta_{17}$ × *Median income*$_{jt}$ + $\beta_{18}$ × *Low education level*$_{jt}$ + $\nu_i$

(4b) *Dollar value of loss/VAR*$_{ijt}$ = $\alpha$ + $\beta_1$ × *First Nations*$_{jt}$ + $\beta_2$ × *Urban*$_{ijt}$ + $\beta_3$ × *Residential occupancy*$_{it}$ + $\beta_4$ × *Residential property*$_{it}$ + $\boldsymbol{\beta}_5$ × *Construction*$_{it}$ + $\beta_6$ × *Height*$_{it}$ + $\boldsymbol{\beta}_7$ × *Manual fire protection*$_{it}$ + $\boldsymbol{\beta}_8$ × *Sprinkler protection*$_{it}$ + $\boldsymbol{\beta}_{10}$ × *Automatic fire detection system*$_{it}$ + $\boldsymbol{\beta}_{11}$ × *Fire detection device*$_{it}$ + $\boldsymbol{\beta}_{12}$ × *Outside fire protection*$_{it}$ + $\boldsymbol{\beta}_{13}$ × *Fire service*$_{it}$ + $\boldsymbol{\beta}_{14}$ × *Act or omission*$_{it}$ + $\boldsymbol{\beta}_{15}$ × *Initial detection*$_{it}$ + $\boldsymbol{\beta}_{16}$ × *Action taken*$_{it}$ + $\beta_{17}$ × *Median income*$_{jt}$ + $\beta_{18}$ × *Low education level*$_{jt}$ + $\nu_i$

where *i, j, t* denotes incident *i*, CSD *j,* and year *t*.

Each categorical variable is separated into several indicator variables with each indicator representing one class in the categorical variable. For example, *Construction*$_{it}$ is a matrix of five indicator variables: *wood construction, wood plaster construction, heavy timber construction, exposed steel construction,* and *steel & concrete construction*, and $\boldsymbol{\beta}_5$ is the corresponding vector of five coefficients. Recall that *other construction* is the default and, as such, not included as an explanatory variable. All numerical variables in the regression are Winsorized at the 1 percent and 99 percent level for each province. We estimate median income and education level at the CSD level. See Table 10 for descriptions of each variable.

Results for the OLS for Model (4a) (Alberta) and Model (4b) (British Columbia) are given in Table 12.

**TABLE 12 – OLS REGRESSION ON VALUE OF LOSS / VAR**

| Independent Variable | Model (4a) Alberta | Model (4b) British Columbia |
|---|---|---|
| **First Nations** | −0.34(0.25) | −0.07(0.17) |
| **Urban** | −0.12(0.05)* | −0.03(0.03) |
| **Residential occupancy** | −0.11(0.08) | −0.05(0.06) |
| **Residential property** | −0.18(0.08)* | −0.12(0.05)* |
| **Wood construction** | −0.01(0.07) | −0.17(0.06)** |
| **Wood plaster construction** | −0.15(0.07)* | −0.22(0.05)*** |
| **Heavy timber construction** | −0.03(0.23) | −0.21(0.15) |
| **Exposed steel construction** | −0.13(0.14) | −0.35(0.10)*** |
| **Steel & concrete construction** | −0.24(0.11)* | −0.34(0.09)*** |
| **Height** | 0.00(0.00) | 0.01(0.01) |
| **Extinguisher standpipe manual fire protection** | −0.10(0.06) | 0.11(0.04)* |
| **No manual fire protection** | 0.11(0.05)* | 0.23(0.03)*** |
| **Complete sprinkler protection** | −0.02(0.14) | −0.06(0.08) |

| Independent Variable | Model (4a) Alberta | Model (4b) British Columbia |
|---|---|---|
| Partial sprinkler protection | −0.00(0.22) | −0.07(0.11) |
| No sprinkler protection | 0.17(0.07)* | −0.01(0.08) |
| Alarm fixed system | −0.04(0.15) | Omitted [a] |
| No fixed system | −0.11(0.09) | Omitted [a] |
| Miscellaneous fixed system | −0.13(0.26) | Omitted [a] |
| No automatic fire detection | 0.04(0.08) | 0.11(0.04) |
| Automatic alarm fire detection | −0.03(0.11) | Omitted [a] |
| Fire detection device | −0.12(0.07) | Omitted [a] |
| No fire detection device | 0.06(0.08) | Omitted [a] |
| Outside fire protection hydrant or fire department | −0.14(0.07) | −0.11(0.10) |
| Outside fire protection only fire department | 0.30(0.08)*** | −0.03(0.11) |
| Fire service | 0.09(0.11) | −0.37(0.10)*** |
| No fire service | −0.07(0.18) | 0.09(0.24) |
| Act or omission incendiary | 0.03(0.05) | −0.04(0.03) |
| Act or omission misuse | 0.02(0.05) | −0.21(0.03)*** |
| Act or omission failure | −0.02(0.05) | −0.18(0.03)*** |
| Detect system | −0.08(0.12) | 0.01(0.03) |
| Detect human | −0.02(0.10) | 0.07(0.08) |
| Detect none | −0.04(0.21) | −0.03(0.23) |
| Action extinguished | −0.07(0.04) | 0.11(0.07) |
| Action none | −0.31(0.10)*** | −0.04(0.08) |
| Median income | −0.00(0.00) | 0.00(0.00) |
| Low education level | 0.01(0.00)* | 0.01(0.00)** |
| Constant | 0.96(0.14)*** | 0.67(0.10)*** |
| $R^2$ | 0.010 | 0.017 |
| Adjusted $R^2$ | 0.009 | 0.017 |
| Observations | 44,931 | 35,695 |

All probabilities are two–tailed tests. * p≤0.05; ** p≤0.01; ***p≤0.001.
Standard errors are reported in parentheses.
[a] Items are omitted due to data availability.

Unlike the prior frequency results, this table shows relatively few consistent results between Alberta and British Columbia. Specifically, only the coefficients of the residential property variable, the wood plaster construction variable and the steel concrete construction variable are significant and negative. This implies a negative association between each of these independent variables and the severity of fire incidents in both provinces. The negative coefficient on residential property suggests that severity, in terms of the property destroyed, is less for households than for businesses. Insurance companies provide variables on size of loss in some cases. We suspect that there are many small household fires whose total dollar value of loss are such that the loss is not reported to the insurance company.[10]

Also, only the coefficients of the no manual fire protection variable and the low education level variable are significant and positive, which implies a positive association between each of these independent variables and the severity of fire incidents. These are not surprising results – if there is no manual fire protection, then the fire spreads until the fire department arrives, resulting in greater severity. Lower education levels are associated with greater poverty. Although most research (for example, Jennings, 2003 and Gunther, 1981) look at the relationship between fire incidence and poverty, it is not unreasonable to expect that the severity (as a proportion of total value) is also higher.

In Alberta, there is a strong significant positive (negative) correlation between outside fire protection only fire department (action none) and the dependent variable. This suggests fire severity increases when outside fire protection is limited to only fire departments and fire severity decreases when fire is not extinguished by any means. In British Columbia, there is a strong significant negative association between the wood construction variable, the exposed steel construction variable, the fire service variable, the act or omission misuse variable and the act or omission failure variable and the fire severity dependent variable.

Due to the lack of granularity in the data, our severity analysis, at best, reinforces several intuitive relationships between factors surrounding fires and the severity of fire incidences. Specifically, we observed that in Alberta and British Columbia, the severity of fire damage was less for residential properties than for business properties. Furthermore, the severity of fire damage was more for properties with no manual fire protection and properties located in CSDs with lower education levels. To further validate our results, we would need to have all data provided at a more local level (i.e., more details of the individual fire incidences).

## Discussion and Conclusion

Fire causes substantial economic and human losses each year in Canada. Although the threat of catastrophic urban fires has largely been eradicated, the threat of wildland fire losses is increasing due to climate change, wildfire management practices, the health of the boreal forest as well as increasing activity and property values at risk in the WUI. As well, at the individual level, at-risk populations including the elderly, First Nations, and socioeconomically disadvantaged persons face greater risk of fire than the rest of the population.

[10] This observation is based on discussions with a retired fire captain from the Toronto Fire Department and his experience of residential versus industrial fires.

The most effective measures to minimize the exposure to risk from fire are insurance and mitigation (Kunreuther, 2001; UNEP, 2013). Property insurance allows residents and property owners affected by fire to cover potential losses, enhancing recovery after loss. As well, the terms of coverage can be used to encourage mitigation, influencing both the frequency and severity of fire losses. To further encourage mitigation, government regulations and subsidies to invest in direct measures to mitigate fire risk are an effective mechanism to reduce potential fire losses in Canada. As the risk of wildland fires increases, such regulations and subsidies at the community level will become more important.

As demonstrated in the Appendix, while neither the industry nor the government could create the incentives required for efficient risk exposure by acting in isolation, the *simultaneous* provision by government of a subsidy compensating the property owner for the benefits his neighbors freely receive from his investment in mitigation and the incorporation by insurance companies of an appropriate rate of discount in premiums commensurate in magnitude with those mitigation expenditures could induce property owners to voluntarily purchase those amounts of mitigation and insurance that result in an exposure to fire risk that conveys the greatest possible economic benefit on both an individual and collective basis.

Our proposed research was directed at studying the underlying risk factors that affect the frequency and severity of fire risk for residential and small commercial properties, and how these factors vary geographically. We hoped the analysis would be useful to the insurance industry in improving the accuracy of pricing, improving the coverage offered, and in facilitating more accurate information provided to property owners, including information on premium discounts that would encourage loss mitigation.

As previously noted, because of data limitations, we were not able to undertake these analyses at the level of detail that we had wished. Data were only collected for 6 provinces (and the Armed Forces) but only British Columbia, Alberta and Ontario had enough data with which to undertake any analysis. Weather information and some demographic variables previously shown to impact either the frequency or severity of fire were not available. Adding weather variables (temperature, some measure of recent precipitation, and wind speed at time of fire) would add valuable information, but these data may be cumbersome to collect. Our biggest concern with the data set is the lack of geographic granularity for the urban CSDs. An examination of fire risk for at-risk places and at-risk populations requires that data be collected at the neighbourhood level (e.g., forward sortation area).

If this database is to be used to inform future public policy, then it is necessary to improve the quality of the data. We recognize that data are collected at the municipal level. One suggestion would be to first improve training in jurisdictions which already have robust reporting structures, with the caveat that fire data need to be collected over a mix of communities in order to understand how fire impacts urban, suburban and rural communities.

Despite the data shortcomings, we conducted three separate ordinary least squares (OLS) regression models to examine the impact of demographic variables on the frequency of fire and a separate OLS regression to examine the impact of fire–related variables on fire loss severity. Based on the number of dwellings, we found that fire frequency is higher in First Nations communities, and in CSDs with higher levels of unemployment and lower income. Based on population, we found that CSDs with a higher median age have a higher likelihood of fire incidents. On the severity dimension of our analysis, we found that construction, design use of a building, the presence of manual fire protection, and the education level of the local community were all associated with damage severity.

These findings are consistent with the literature which also finds that the likelihood of a fire incidence is greater in First Nations communities and economically challenged communities. Although our focus was on the role of insurance in reducing the frequency and severity of fire, those most susceptible to fire losses are also the least likely to purchase insurance. This suggests that there may be a role for local government to play in reducing fire risk by targeting these populations.

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# Appendix: Insurance Mitigation and Fire Risk: Fundamental Economic Issues for Public Policy

## INTRODUCTION

Widespread fires, whether in urban areas, the WUI or on undeveloped land, are the costliest type of disaster in Canada. As such, they are a significant concern for both the property insurance industry and government policymakers. Such fires result in a substantial loss of private and public property and often the loss of life. According to the most recent available data from the Council of Canadian Fire Marshals and Fire Commissioners, a total of 42,753 fires resulted in 226 deaths and $1,551,657,179 in direct property damage across Canada in 2007 (Wijayasinghe, 2011), net of public expenditures of the evacuation of threatened populations, ex post recovery assistance and investment in infrastructure for fire prevention and suppression. These losses will invariably increase over the next decades as climate change accelerates.

Insurance and mitigation are the most effective measures to minimize the exposure to risk from fire (Kunreuther (2001), UNEP (2013)). Coverage available from private insurance companies allows residents and property owners in at-risk areas to hedge potential losses. The terms of this coverage also exert significant influence on both the frequency and severity of these fires through the provision of incentives to policyholders to reduce their exposure to fire risk. Government regulations and subsidies, at the federal, regional, and local levels, to invest in direct measures to mitigate fire risk are a second and equally significant influence on potential losses from fires in urban and rural communities across Canada.

Actions by the insurance industry and the government simultaneously affect the economic efficiency of the insurance market and, consequently, the extent to which fire risk can be reduced through private insurance coverage and by investment in mitigation. They also affect the opportunities different individuals have to participate in that market in accordance with the preferences of society. While considerable academic and public–sector research on the costs and efficacy of mitigation is available, much less research has been devoted to the role of insurance in managing fire risk and almost none to the crucial issue of coordinating industry and public–sector actions in this task.

In this Appendix, we consider the respective roles of private insurance companies and government in reducing human and economic loss from the occurrence of widespread fires in both urban and rural communities. We focus, in contrast to much of the existing literature, on the role of insurance in this regard and, most importantly, on the nature of the coordination between insurance companies and government in loss reduction and the real possibility of maximizing the economic welfare of all parties through such coordination. Our goal is to provide the basis of a thorough analysis of the fundamental economic aspects of fire risk to serve as a foundation for both public policy and private decision–making.

We proceed by first identifying the nature and origins of the two fundamental economic inefficiencies that respectively apply to the markets for insurance and mitigation in the section titled “The Markets for Insurance and Mitigation.” We describe the economic relations between insurance and mitigation, a fundamental but often overlooked topic in managing fire risk. We subsequently use our insights to identify the respective measures that insurance companies and government can use to address these market inefficiencies and the effects these measures can have on economic welfare. Most importantly, we find that, while neither private insurers nor government can optimally manage risk in isolation, a particular type of coordination between private insurers and government does have the capacity to induce the socially–optimal level of both insurance coverage and mitigation by at-risk individuals.

We also consider, in the section “The Role for Private and Public Initiatives in Education and Information Provision”, the ability of both industry and government to influence individual choices of exposure to fire risk through the provision of information and education about such risk to property owners. We discuss the most significant economic reason why the extent of this influence is limited and describe the circumstances under which industry or government has a relative advantage in persuading individuals to reduce their risk exposure through such provision. In the section “Three Fundamental Issues Crucial for Public and Private Policy”, we subsequently describe, for the first time in research on fire risk, the implications of debt–financing properties for the risk – reduction decisions of property owners, the resulting implications for observed levels of insurance and mitigation, and the need for coordination between not only the insurance industry and government, but also mortgage lenders, in creating risk –reduction incentives for the owners of such properties. The section “The Interaction between Insurance and Mortgage Markets” follows by analyzing the three fundamental issues arising from the joint presence of insurance and mitigation, each of which is crucial to the incentives of industry, government and individual property owners with respect to mitigation. The document concludes with selected normative recommendations for both the insurance industry and government.

## THE MARKETS FOR INSURANCE AND MITIGATION

### *Insurance Market Efficiency*

Property insurance is a financial instrument that allows an individual to limit loss to the value of his equity interest in a property from the occurrence of an adverse event such as a fire. Mitigation refers to that individual’s investment in non–financial means to similarly manage the risk of this loss. Under ideal circumstances, the representative insurance market will provide coverage in a volume and at a price that allows the individual to obtain his desired degree of exposure to risk. This market is termed *“efficient”* if the means by which coverage is traded between property owners (“individuals”) and insurance companies (“insurers”) cannot be changed in a manner in which the welfare of both parties is increased.[11] These same circumstances also offer the individual

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[11] In contrast, in an “inefficient” market, the institutional arrangement governing the exchange of a good or service **can** be changed, through government policy or through private innovation in the means by which information about prices is distributed to buyers and sellers, in such a manner that some parties gain more from trading in this market and no other party is disadvantaged. The net effect of such a change is, in essence, to create more wealth to market participants as a whole without increasing the resources expended by any

property owner the opportunity to directly reduce his expected losses by investing, prior to the occurrence of a fire, in various types of mitigation to lower his probability of loss to a similar degree.

If the individual is limited in his participation in a sufficient number of financial markets, he will use insurance to hedge his exposure to the risk of such loss and/or mitigation to reduce the probability he will incur any given amount of loss. The extent to which he regards insurance and mitigation as substitutes or complements in managing his risk exposure depends on both his preferences and characteristics of the market for each. This question of whether insurance and mitigation are alternative or complementary means the individual's decision on how to manage his risk exposure is, consequently, an essential aspect of an overall public–private policy of reducing such risk to the individual and to his community.[12]

Actual markets, including those for insurance coverage and for mitigation, rarely exhibit these ideal circumstances. Owing to external factors, transactions in insurance and mitigation are normally limited in the combined benefit each can deliver to buyers and sellers. The extent of insurance coverage is most often limited by the cost to each of these parties of acquiring relevant information about the other. The extent of mitigation in an at-risk community is constrained by the insufficient ability of each individual residing in that community to receive the full value of his investment in mitigation. A third factor exacerbating these respective inefficiencies is the degree to which unintentional effects of regulation and other public policies adversely affect the incentives of these parties to fully manage their risk.[13]

Inadequate information available to each party about his counterparty in the insurance market precludes his efficient evaluation of risk. This inability to accurately evaluate risk, which results in direct and indirect losses to both parties in the insurance transaction, can arise in three distinct circumstances.

The first occurs when an individual's demand for coverage is limited by his knowledge about the solvency risk posed by any particular insurer. The individual will incur some cost for coverage which is promised by an insurer but not delivered if the insurer becomes financially insolvent. Since

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party in buying or selling in this market. Governments most often attempt to implement such changes through taxes, subsidies and regulation. One significant example of private innovation enhancing market efficiency is statistical credit–scoring.

[12] Economists refer to two goods as "substitutes" in the case that individuals perceive them as alternatives and as "complements" when individuals perceive that the two goods should be used together. The respective prices and quantities purchased of each of these goods move inversely if they are substitutes and together if complements.

[13] Regulating the maximum value an insurer can charge for coverage in a competitive market, for example, does not lower the price of coverage to all those wishing to insure but instead simply limits the amount of coverage available for various risks. Such a situation results in losses to both insurance companies and to those individuals unable to procure any amount of the limited coverage available, leaving both groups worse off, relative to a situation in which insurers were free to adjust their premium to the actual amount of risk they cover.

shareholders in the insurer (assuming it is not a mutual insurance company) benefit from increases in the risk displayed by the firm's portfolio of assets and liabilities, the limited information available to potential clients creates an opportunity for moral hazard on the part of the firm, leading to its holding a greater degree of risk than expected. The government imposition of capital regulations and mandatory disclosures on the industry are, on both a theoretical and practical basis, insufficient to remedy this inefficiency.[14]

Occurrence of the second and third circumstances precludes the ability of the insurer to correctly price coverage on each individual such that the price reflects the actual degree of risk posed. Such mispricing, which leads to a loss to both parties in the insurance transaction, results from the insurer facing a prohibitive cost of fully discerning the true degree of the individual's risk. This inefficiency in pricing coverage to individual members of a group who, to the insurer, appear to pose the same degree of risk arises in either a situation in which those individuals have similar attitudes toward risk but are exposed to different and unobservable degrees of risk – a situation known as "adverse selection" – or a situation in which individuals are exposed to the same degree of risk but differ in their unobservable preferences toward risk, which economists term "advantageous selection."[15] If the insurer can only measure the average risk across this group, it prices coverage on this basis, resulting in excessive loss by inducing individuals posing higher risk to be represented in larger proportions than low–risk individuals.

Whenever a selection problem occurs, the insurer will face actual losses greater than that expected loss on which he has based his common premium to individuals in such a group. Increasing premiums in response to higher losses reduces demand for coverage, but in these circumstances also increases the average degree of risk of those individuals still willing to purchase coverage: the increased premium discourages low–risk members but individuals with high risk will still find the higher premium attractive enough to purchase. This diminishes the gains to both sides of the market with successive increases in premiums ultimately reducing coverage to clients and lowering returns to the insurer. If sufficiently strong, these selection effects can even lead to rationing in the form of denial of coverage and the maximum combined loss to both parties.

The adoption by insurers of innovative methods to improve the accuracy of measuring risk is a private–sector means of enhancing market efficiency. Statistical innovations in risk measurement have, in fact, significantly reduced the inability of insurers to accurately price insurance on individuals. The perceived difficulties of implementing these methods, however, have constrained the extent to which it can ultimately reduce selection effects.

Three related difficulties are particularly prominent in the property–insurance industry. First, insurers have invested extensively in inductive means of measuring risk directly from historical

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[14] For example, Kupiec and Nickerson (2006) show that, in practice, capital regulations can also be an independent source of market inefficiency, preventing insurers from offering an optimal level of coverage by requiring them to hold capital at a level that does not take into account the contingent nature of insurance.

[15] The seminal papers on these two types of market selection are, respectively, Stiglitz and Weiss (1981) and to de Meza and Webb (2001).

loss data. While extrapolating from data, the insurer's exposure to risk from providing coverage is subject to potentially large biases. Individual firms within the industry are rationally reluctant to abandon their investment in inductive estimation unless they are certain that competing insurers will also do so.[16] This disincentive to invest in more sophisticated methods of risk measurement, common to all insurance firms competing to sell coverage, subsequently compounds the collective difficulty insurers have to adopt a more sophisticated industry–wide method to estimate any given insurer's exposure to fire risk through his sales of coverage.[17] The complete absence of a common, industry–wide model to measure risk exposure precludes consistent risk –pricing among competing insurers and results in the reduced ability of consumers to easily compare policies from different insurers and the establishment of a uniform unit price of coverage in the market.[18]

The primary means insurers use to offset adverse selection is to offer policies that contain incentives for the property owner to reduce fire risk. The most common covenant used is the provision of insurance discounts to policyholders for investing in observable mitigation measures.[19] Beyond any actual reduction in risk, discounting is used to 'screen' individual property owners by their actual but unobservable degree of risk. Since the discount is more likely to induce mitigation on the part of 'lower–risk ' property owners and less likely to do so for their 'high–risk ' counterparts, the insurer can at least partially infer an individual's true risk by the extent of his investment in mitigation. Discounting on this basis is a means of more efficiently pricing insurance to each individual.

Although there are several difficulties with the way in which Canadian insurers have incorporated rate discounts into practice, contracts of this type can result in more efficient coverage levels. When property owners do invest in a certain amount of mitigation, in fact, the efficient level of coverage can be attained. This will occur, as a result of uncompensated benefits to others created by individual mitigation, only if the rate discount is implemented with the simultaneous presence of a particular type of public subsidy to individual property owners. We turn to describing this uncompensated benefit or 'spill–over' effect below.

***"Spillover" Effects: the Disincentive for Individual Mitigation***

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[16] The situation in which the benefit to any given firm of investing in new technology depends in part on the decisions of his rivals to also invest is known to economists as a game of "strategic complements." See the survey by Monaco and Saberwal (2014) for further details. It should be noted that one especially significant source of bias in industry data arises from the effects of publicly funded recovery aid and subsidization of some types of mitigation and fire suppression, including municipal fire departments.

[17] Such models do exist for other types of natural disasters, however, including floods, wind damage and earthquakes. See Murmane (2006).

[18] See Murmane (2006).

[19] Industry spokesmen commonly argue that 'denial of coverage' is a second means of offsetting selection inefficiencies and acts as a complement to premium discounting in providing mitigation incentives to property owners (Wells (2006)). In reality, denial of coverage or the 'rationing' of coverage is the result of adverse selection rather than a means of curing it, and inevitably results in a loss to both the insurer and the insured, as first shown by Stiglitz and Weiss (1981).

A risk–averse property owner would be expected to invest in mitigation to an extent which, in combination with his insurance coverage, reduces his exposure to fire risk to the exact degree he prefers. When markets are competitive, this optimal level of coverage for the individual is also optimal for the community/economy as a whole.

Unfortunately, virtually every means of mitigation reduces fire risk not only to the individual property owner but to all other property owners in his vicinity. The absence of any practical means by which that individual can charge his neighbors for this benefit implies that he is incurring costs for which he receives less than full value and as a result he will inevitably invest in less mitigation than otherwise. Since each individual property owner is in this position, the aggregate level of mitigation in a community will also be lower. This is what is popularly referred to as the “spillover” effect of mitigation.[20]

The spillover effect not only reduces the extent of private mitigation in a community, it also precludes individuals from taking full advantage of the rate discount offered by property insurers. This results in a higher than optimal cost of insurance to the property owner, a lower purchase of coverage and a higher than efficient exposure to fire risk by the residents in any given community.

The spillover effect arises from the technology of mitigation rather than being caused by the markets for mitigation and insurance. Nonetheless, it has the ultimate effect of making those markets ‘inefficient,’ in the sense that market forces alone cannot induce individuals to optimally reduce their exposure to fire risk. Neither property owners nor insurers have the ability to offset this adverse influence.

***A Solution through Private–Public Coordination?***

When a market displays such inefficiency, government often has, in theory, a capacity to enhance market efficiency through such channels as regulation, specification of property rights or taxes and subsidies. While these measures cannot eliminate externalities such as the spillover effect, they can ideally affect the incentives of market participants in a way that results in the market displaying so–called ‘second–best’ efficiency. [21]

Economic theory suggests that the most effective means a government can use to reduce the ‘spillover’ effect and encourage individual investment in mitigation is to provide a net subsidy to individual property owners. The amount of subsidy received by each resident in a given community would be calibrated to fully compensate him for the private subsidy he provides to his neighbors through his investment in mitigation.

The presence of insurance as an alternative means of managing property risk implies that this subsidy will affect, and be affected by, the incentives offered in property insurance contracts. The

[20] Economists would refer to this same effect as a ‘positive externality.’

[21] Such government policies are beneficial in regard to market efficiency, but it should be noted that their implementation can lower the overall costs to society of attaining its standard of economic equity via a socially preferred distribution of wealth among its members.

insurer's decision on the rate at which it will discount insurance depends directly on the extent to which the cost of a given level of mitigation is reduced by the public subsidy. Analogously, the value of the subsidy inducing optimal mitigation will depend directly on the cost of insurance coverage.

The most important questions for both private and public policy regarding fire risk are these: Can either a public subsidy or an incentive–based insurance contract induce individual property owners to voluntarily choose the socially optimal exposure to fire risk? If not, can the combination of a public subsidy and an incentive–based insurance contract do so? If the answer to either of these questions is yes, then either or both such instruments could be deployed to induce property owners to select a privately and socially optimal exposure to fire risk. This would accomplish the primary goal of both insurance companies and government policymakers: the attainment by each community of the efficient level of fire risk exposure and the elimination of any excess exposure to such risk.

Theoretical economic research offers a definite answer to these two questions. While neither a public subsidy nor an incentive–based private insurance contract can accomplish this goal in isolation, the introduction of a suitably calibrated combination of these two instruments can do so![22] Specifically, under certain broad assumptions, there is a unique pair of subsidy values and rates of discount that can jointly induce property owners to purchase those amounts of insurance and mitigation that reduce their individual exposure to risk, and consequently that of the community, to the private and social optimum (conditional on the presence of the externality). The existence of this ideal pair is proof that the two essential sources of insurance market inefficiency can be successfully addressed through public–private coordination of rates and subsidies and a privately and socially optimal exposure to fire risk is possible – the goal of public and private fire risk policy.

This is one of the most significant findings in the economics of fire risk and is the fundamental argument for the need for coordination between the insurance industry and government in reducing fire risk. While such an optimal combination of policies would lead to efficiency, implementing this combination in practice comes with several practical difficulties. Two such difficulties are obvious. The first is the current lack of such coordination. A second difficulty is in determining these respective values for subsidy and discount. The value of externalities is notoriously difficult, if not impossible, to measure. The current technology in risk underwriting, in any financial market, is extremely costly and currently inadequate to generate a sufficiently accurate estimate of individual risk.

Coordination between the insurance industry and government is a particularly complex problem. Each institution may well have incentives, arising from other activities, which prevent sufficient coordination. The government, for example, would need to refrain from other policies leading to distortions in insurance pricing, including regulating insurance rates and providing recovery aid to individual property owners and the community as a whole. Even in the absence of these incentives,

[22] The original paper demonstrating this in the specific case of fire risk is Lankoande, Yoder and Wandschneider (2006).

the degree to which each party believes the other will actually implement the respective optimal discounts and subsidies may be insufficient to allow their actual implementation, even if those values were known.

A third difficulty arises from the behavior of individual property owners. These individuals must react to the chosen subsidy and discounts in a rational, consistent and predictable manner, and also regard as certain the respective 'goodwill' intentions of government and insurer. Each property owner must choose his investment in mitigation without attempting to strategically influence the analogous decisions of his neighbors. Each property owner in any given community must have sufficient wealth to purchase insurance while simultaneously purchasing other necessities. In addition, the countervailing incentives provided by mortgage contracts and other sources almost surely imply that private mitigation expenditures will not be a "fully–revealing" signal. Consequently, incentive–based insurance contracts will not fully screen property owners differing in risk or risk preferences.

Solving these difficulties is, in theory, quite possible. The current absence of solutions, however, is of paramount importance to the social goal of fire risk reduction, since the implementation of either a suboptimal subsidy or rate discount could actually exacerbate the inefficiencies in the insurance and mitigation markets relative to their initial state and result in a loss of both private and social economic welfare.[23]

## THE ROLE FOR PRIVATE AND PUBLIC INITIATIVES IN EDUCATION AND INFORMATION PROVISION

The insurance industry and government are both engaged in efforts to influence property owners in making effective and rational economic decisions in regard to property risk. One initiative is the provision of public education concerning the nature of risk and insurance, the role of mitigation in the reduction of property risk, and the respective roles of private insurers and the government in making available the means by which property owners can achieve their desired exposure to risk. A second initiative is the dissemination of accurate and timely information about current hazard conditions affecting that exposure.

The fundamental rationale for initiatives in public education can be found in one of the most basic concept in economics: comparative advantage. Risk specialists in both the private and public sectors have invested significant wealth, time and effort in acquiring their education and technical skills, and many have years of experience in risk, insurance and mitigation issues as well. One might expect individuals specializing in other fields, including property owners, to have less expertise in these subjects, where unequivocal proof of the pervasiveness of this difference lies in the costs of acquiring field–specific expertise: someone who has invested considerable resources in the fields of risk and insurance would not have rationally done so if this investment did not earn a positive return on the differential knowledge he possesses relative to non–specialists. There will be,

[23] Lipsey and Lancaster (1956) offer the seminal definition and discussion of 'second–best efficiency and the effects of suboptimal economic policy.

consequently, substantial benefits to property owners and other members of the public from the availability of such education which will have a high likelihood of improving the decisions of these individuals when considering the extent of fire risk to their property and other assets, and choosing their expenditures on insurance coverage and mitigation.

Precisely the same justification exists for insurers and/or government agencies to disseminate information about current levels of risk and impending changes in the risk posed to individuals by fire risk, whether in urban areas or in the WUI. Massive scale economies exist for specialization in providing hazard information.

Although the net benefits of both activities are undoubtedly positive, there are two factors that may diminish the total value of those benefits in regard to improving individual decision–making. The first involves the incentives of the insurance industry to provide education and information with the intention of reducing risk and the credibility with which this education and information is regarded by the public when the strategic incentives of insurance firms are common knowledge. The same consideration also applies to the provision of these by government, since the public sector bears a significant proportion of the total liability for fire loss. The second factor involves coordination between the respective providers of education and hazard information.

***Incentives and Credibility***

While property owners and residents of any given community benefit from more information about fire risk and its management, regardless of the source, they will also undoubtedly be aware of the incentives of insurers and of government to bias or exaggerate loss and risk management information in order to reduce the simultaneous liabilities of these two institutions by persuading individuals to undertake excessive risk reduction expenditures. The consequence of this awareness of moral hazard on the part of information and education providers is that whichever institution, the insurance industry or government, is perceived to have the weakest motive to encourage individuals to over–invest in either insurance or mitigation will be the more credible, and hence effective, provider. This is an especially important consideration when individuals are aware of the financial burden of subsidizing mitigation and providing post–fire aid to their community.

When we consider the incentives of insurers to provide objective education and information about fire risk and the benefits of mitigation, as well as insurance coverage, in controlling such risk, two related questions must be answered: First, what is the insurance industry's incentive to provide such education and information? And second, should they do so, what is the industry's incentive to provide unbiased information about mitigation benefits in addition to those from insurance coverage? Answers to these questions touch upon both the fundamental economic relation between mitigation and insurance and on the relation between the average insurer's financial return from assuming more risk through additional sales of coverage and the cost of doing so.

The incentive of the insurance industry to incur the costs of providing the public with either objective or biased information and education concerning fire risk depends on whether the industry believes property owners will increase their demand for insurance if they receive such information, conditional on the public's awareness of the industry's potential incentive to enhance such demand through the presentation of biased information. The extent of the industry's effort and scope in providing such education and information in this circumstance, consequently, comes down to the marginal benefit to insurers from increased demand from such education less the marginal costs of providing such education. In turn, if the return, net of costs, is known by the public to significantly increase with the provision of information by industry, the public will regard this information as less credible. The equilibrium extent of information supplied by the industry will depend on both of these factors.

An analogous consideration also applies to the government provision of fire risk information. Since government also shares in the liability of fire loss, which it can only finance through some form of tax revenue, it too has to consider whether, at the margin, additional expenditures on education carry a social benefit in terms of their effect on private risk management, as compared to alternative public projects that these expenditures could finance. An additional source of moral hazard with the government provision of information, which is absent from the industry's decision, is whether the incumbent government has political as well as economic incentives affecting the extent of this provision, as well as its degree of potential bias.[24]

### *Strategic Aspects of the Public Provision of Education and Information Regarding Fire Risk*

If either industry or government finds their respective private or social return to disseminating fire risk information to the public is increased by so doing, the subsequent issue becomes the potential incentive of either party to provide biased information in an attempt to manipulate the public's expenditures on insurance and/or mitigation for their own benefit and the extent of such bias. Since rational owners of at-risk properties will undoubtedly perceive the possibility of moral hazard on the parts of both the industry and government, the question of bias reduces, in a practical context, to the question of how either industry or government could effectively provide property owners and residents of at-risk communities the greatest extent of useful education or information, conditional on the fact that their public credibility is inevitably limited.

Economic theory has a qualitative answer to this question when there is only one source of education and information about fire risk. A party with the known opportunity for moral hazard in the dissemination of biased information will be most credible to a counterparty only if it provides information with limited precision.[25] This relationship between precision and credibility exists because a rational and informed individual knows that the marginal benefit of providing information, in the absence of moral hazard, increases more rapidly than its marginal cost. The sacrifice of a sufficiently large amount of these benefits, relative to the cost of providing any given level of information, is a signal to the individual that the information being provided has limited or no bias relative to the more precise information that the provider would have supplied if it was trying to maximize its opportunity for moral hazard. This means, in the current context, that,

[24] Using American data from a variety of natural disasters, Husted and Nickerson (2014) provide empirical evidence concerning the strength of this political incentive on the part of government.

[25] Crawford and Sobel (1982) offer the original proof of this result.

whether industry or government is providing the public with information about fire risk, that information is most beneficial to the community as a whole when it is relatively basic and general rather than more sophisticated or detailed.

The situation is more complex when two different parties offer such information and each such party has an incentive to exploit the possibility of moral hazard through bias in the information it offers. When both industry and government provide education and information about fire risk but have different preferences toward which instrument – insurance or mitigation – individuals use to manage their risk, they will inflict an externality on each other, leading to excessive costs relative to public benefits.

While economists have yet to ascertain the degree and socially–optimal extent of bias in the case of two different providers of information, two unequivocal assertions can be safely made. First, whether the externality inflicted on each party is positive or negative depends entirely on the fundamental question of whether insurance and mitigation are economic substitutes or complements.[26] If they are substitutes, the extent and accuracy of the information provided by industry (government) will adversely affect the usefulness of information provided by government (industry.) Alternatively, if they are complements, then the extent and accuracy of the information provided by one of these parties will increase the usefulness, to both parties, of the information provided by the other. These two possibilities will respectively lead to deficient or excessive amounts of education and information provided to the public, along with correspondingly lower or greater expenditures on their provision relative to the economically efficient level. Second, when both industry and government engage in such provision, the net benefits received by the public will be maximized by the elimination of this externality through close coordination of effort between industry and government.

## THREE FUNDAMENTAL ISSUES CRUCIAL FOR PUBLIC AND PRIVATE POLICY

Three underlying economic issues are crucial in any discussion about the behavior of insurance firms and the design of public policy by government. Research is ongoing in the first two while the third is yet to be fully explored by economists. These issues are:

1. Do insurers really have an incentive to reduce property risk?
2. Are insurance and mitigation substitutes or complements?
3. What is the "efficient" level of risk from the respective perspectives of the representative property owner and the community (or society) as a whole?

### *Do Insurers Really Have an Incentive to Reduce Risk?*

Virtually be definition, insurance firms do not always possess an incentive to encourage mitigation or otherwise engage in activities, other than selling insurance, which result in a reduction of the risk to property or other assets, independent of the level of extant risk. If, for example, that level of

[26] This is the topic of the Section "Three Fundamental Issues Crucial for Public and Private Policy".

risk was close to zero, additional private expenditures on mitigation that further reduced risk would ultimately eliminate any role for insurance. There is, however, a range in both the frequency and severity of property risks, including that of fire, for which insurers may have an incentive to engage in these activities.

Conditional on insurance demand, the extent of this range is determined by a number of factors, including the financial capacity of the insurer, the presence of a reinsurance market, the availability of a derivatives market to hedge risk, and the behavior of the firm's shareholders and it management. Basic financial economics suggests that at least for privately owned insurance companies and in situations where the insurance company can effectively hedge or transfer risk, the extent of this range depends primarily on the incentives of the insurer's shareholders.

Assuming the risk underwritten is diversifiable, even shareholders who are averse to risk would prefer more risk in the returns to an insurance company's shares, while the insurer's managers would prefer less risk. This is because shareholders have limited liability with respect to the risk the insurer's shares embody: shareholders receive all the gain from an increase in the insurer's share price but, should a fall in share value bankrupt the insurer, bear only the loss of their investment rather than both that loss and repayment to the creditors of the insurer. This asymmetry implies, as shown by Rothschild and Stiglitz (1970), that an increase in the risk covered by the insurer raises the expected return on their investment. Under the traditional assumption that shareholders have access to a sufficient number of independent financial markets, they can eliminate firm–specific or "unsystematic" risk from their investment portfolios through holding a diversified financial portfolio. Even risk averse shareholders, consequently, do not care about the risk posed by their ownership of any one firm, such as an insurance company, but do value the additional returns they receive as the risk associated with ownership of that insurer increases.

Both firm management and the firm's creditors, in contrast, prefer lower risk to the insurer's share value since, in general, they receive none of the gains from increases in share value but do bear a direct loss from the firm's insolvency.[27] The risk that an insurer cannot cover its liabilities and therefore becomes insolvent translates to risk to management through the loss of their salaries and to risk to creditors through the loss of their debt interests in the insurer.

In circumstances where shareholders can fully diversify, consequently, the insurance firm will act to reduce the risk generated by their coverage only in two cases. The first is when the cost of funds supplied by creditors to that firm is highly sensitive to the firm's exposure to property risk. The

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[27] The limited liability inherent in owning shares of the insurance firm immediately implies that creditors prefer less risk in that firm's coverage. Compared to shareholders, corporate managers tend to be relatively risk–averse because their remuneration does not fully vary with the risk of the firm's coverage. In addition, managers cannot generally diversify their labor "investment" so as to eliminate firm–specific risk. Managers therefore tend to prefer the firm to sell "safer" coverage. This situation becomes more complex when 'profit–sharing' or other incentive–based remuneration to mangers exists. In this case, the interests of managers become more closely aligned with those of the shareholders. The firm's creditors, however, remain opposed to additional risk and will raise the cost of funds to the firm, perhaps substantially, as the risk of the firm's insolvency increases.

second is when shareholders are not fully aware of the actions of management, and by taking advantage of this opportunity for moral hazard, management can indulge its preferences at the expense of the shareholders.

The immediate question is then how frequently shareholders or either creditors or management are the primary influence on the risk inherent in the firm's existing coverage. Empirical studies of this question generally offer ambivalent results, but apart from considerations of the cost of funds or moral hazard on the part of management, theory describes a number of situations in which the interests of shareholders are either subordinate or shareholders will rationally refrain from inducing the firm to sell riskier coverage. These include the particularly plausible circumstances in which shareholders have only incomplete access to capital markets and, consequently, an inability to diversify the aggregate risk in their own financial portfolios; or in the presence of corporate taxes which bound the extent to which shareholders receive gains from higher share prices.

***Are Insurance and Mitigation Substitutes or Complements?***

A closely related and equally important question is whether insurance and mitigation are economic substitutes or complements. If they are substitutes, then the returns to providing insurance coverage will almost surely diminish as individuals invest more heavily in mitigation. If, on the other hand, they are complements, then sales of coverage will increase with such investment.

Theoretical research on the economics of risk invariably concludes that, in general, insurance and risk reducing protective measures such as investment in mitigation are substitutes (Ehrlich and Becker (1972), Rothschild and Stiglitz (1976), Arnott and Stiglitz (1988)). This conclusion, which applies across a variety of underlying assumptions, arises from the fact that the cost of insurance will discourage individuals from investing in loss reduction measures unless they receive a sufficiently large reward from such investment through a reduction in their premiums. Owing to adverse selection or moral hazard, however, insurers are unable to accurately price coverage on the basis of a given individual's risk and, consequently, cannot reward individuals who invest in mitigation by a suitable discount in their premiums.

The incentive for individuals to reduce their risk through costly mitigation is compromised by moral hazard, since the inability of insurers' to closely monitor the actions of those individuals who already have some coverage implies that these individuals have the countervailing incentive to reduce, rather than increase, any potential expenditure on mitigation. Since insurers recognize this moral hazard incentive, they cannot receive the full benefit of discounting premiums and will therefore not offer such discounts. In this case, consequently, insurance and mitigation will act as substitutes.

Insurers' willingness to discount could also be limited by selection issues. If the insurer cannot appropriately price risk on an individual basis owing to its inability to distinguish between higher and lower risk individuals in a given pool of applicants, then an insurer knows that it is mainly individuals with higher risk who demand insurance. Once again they will not receive the full benefit from a lower premium and will again not offer any such premium reduction.

The conclusion that insurance and mitigation are substitutes, however, does not follow in some reasonably realistic scenarios. The scenario of most interest to us is precisely the same one in which a simultaneous public subsidy for the spillover effects of individual mitigation and a corresponding premium discount by insurers are simultaneously provided. In this case, using an observable degree of investment in reduction as a so–called "screening device" would persuade insurers to offer premium discounts commensurate with the individual's investment. Since the individual is fully compensated for the benefits he would otherwise provide freely to his neighbors, that individual would have a direct incentive to purchase more insurance and further reduce his exposure to fire risk. Implementing this ideal pair of policies, as discussed above, depends upon the insurer being able to fully verify an individual's investment in mitigation, the ability of government to accurately measure the economic value of the spillover benefit created by that individual's investment, and coordination between the insurance industry and government in selecting the appropriate values for the respective subsidy and discount.[28] These are significant but not impossible difficulties to overcome.[29]

Empirical studies of the economic relation between insurance and mitigation reach, unfortunately, equivocal conclusions. Moreover, no empirical studies exist for the case of fire risk. Born and Viscusi (2006) and Wouter–Botzen, Kunreuther and Wood (2017) show that insurance and mitigation act as complements for some types of disasters, when no viable means of damage suppression exists, unlike the case of fire. Siegelman (2004), as another example, argues that the incidence of adverse selection in health insurance markets is negligible and, consequently does not pose an impediment to full risk pricing of coverage. Einav et al. (2013), however, provide significant empirical evidence of moral hazard in those same markets.

### *What is the "Efficient" Level of Risk?*

A government presence in markets for natural disasters is almost invariably justified in economic research by reference to a benchmark "efficient" level of expenditures on insurance coverage and/or mitigation by property owners and other residents of at-risk communities. While economic efficiency is a condition clearly and rigorously defined in economic theory, an empirical measurement of a benchmark value of efficiency in regard to these expenditures, as well as for private and community risk exposure to fire and other natural disasters is both all but impossible to estimate and such an empirical benchmark is altogether absent in research on fire and other such disasters.

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[28] The efficacy of this private–public coordination would require, however, the elimination of public subsidies to various means of fire suppression and, even more importantly, a government commitment to refrain from providing any tax–financed recovery aid to fire victims after the occurrence of a fire. See Snider, Daugherty and Wood (2006) for an explanation of the former situation and Lewis and Nickerson (1989) for one for the latter.

[29] A second scenario involves situations in which certain psychological traits in their decision–making induce individuals to buy both insurance and mitigation by overcoming any financial incentives to treat them as substitutes. Wouter–Botzen, Kunreuther and Michel–Kerjan (2017) describe two such cases.

If government intervention in the private markets for property insurance and mitigation is meant to reduce or eliminate some identified source of inefficiency in those markets, a prerequisite that must be satisfied is that policymakers have the ability to ascertain whether the actual risk exposure of property owners and their communities is already economically efficient and, if not, by how much that actual exposure differs from its "efficient" level. Equivalently, justifying a role for government in enhancing market efficiency requires the policymaker to state a numerical estimate of efficiency in risk exposure and expenditures on insurance and mitigation. If, in addition, the policymaker argues that actual exposure is excessive and that expenditures on insurance and mitigation are deficient, he must be able to measure the degree by which exposure, insurance coverage and mitigation differ from their observable 'efficient' values.

Satisfying this minimal standard poses a significant dilemma for policymakers, since no such empirical benchmark currently exists in academic, industry or government research.[30] Its absence leaves those designing and implementing government policies intended to increase market efficiency without any means of knowing whether such policies are needed, or the direction or extent to which such policies should or could change the existing private exposure to risk. Without such knowledge, policymakers are reduced to the positions of making discretionary recommendations about what expenditures on insurance coverage and mitigation would improve both individual and collective economic welfare and being unable to measure whether policies already implemented increase or decrease efficiency.

## THE INTERACTION BETWEEN INSURANCE AND MORTGAGE MARKETS

An over–looked issue in regard to property risk and individual expenditures on insurance and mitigation is the effects of financial leverage on those variables. The presence of such leverage invariably has significant effects on the incentives of those holding equity in a property, but most analyses of property insurance and mitigation rely on the implicit assumption that properties are entirely financed with owner equity rather than a combination of mortgage debt and equity. In reality, the vast majority of both commercial and residential properties are leveraged and the owners of both vintage and new properties have a continuing need to service their outstanding mortgage balances. Omitting the effects of financial leverage could lead to erroneous conclusions about the behavior of property owners in regard to risk and compromise the intended effects of any specific government policy.

A basic proposition in financial economics is that, when two independent claims – equity and debt – exist on the value of a property, the two parties respectively owning these claims have opposing incentives with regard to risk. Since the legal liability of equity investors in a property (i.e., those repaying their mortgage debt) can be contingent on the value of the property, and such owners enjoying the benefits when property value is high but retaining the option to default if this value

[30] As an example, Kunreuther (1984), the most influential study of underinsurance against natural disaster risk, briefly discusses the empirical measurement of efficiency in the context of disasters other than fire but does not estimate a benchmark value for efficient insurance coverage in his research.

becomes less than their balance of outstanding debt, these investors prefer a larger degree of uncertainty regarding future values of the property. Mortgage lenders, on the other hand, who do not share the benefits of high property value but bear the loss through unpaid debt if that value is sufficiently small, have the opposite preference toward such future uncertainty.

The implication of these divergent preferences is that, under traditional economic assumptions, property owners will invest less in insurance coverage and mitigation than mortgage lenders desire. Lenders, in an effort to preserve or stabilize the value of the property collateralizing the mortgage loan, invariably insist on covenants in the mortgage contracts which are meant to accomplish this. A virtually universal covenant in Canadian residential and commercial mortgages is that the property owner must invest in some minimal amount of mitigation against fire risk and that he purchase insurance coverage for fire damage to the mortgaged property in at least the amount of the debt used to finance the purchase at the time of mortgage origination.

The presence of both financial leverage and such a mandatory minimum coverage level for mortgaged properties has two implications for the behavior of property owners. The first and most obvious implication is that compliance with the terms of their mortgage significantly constrains the extent to which they can freely choose their expenditures on insurance and/or mitigation. The second is that, to the extent that the property owner can choose, such loan covenants act as a serious disincentive to purchase insurance coverage above the minimum amount required by their lender.[31]

This disincentive is not a necessary result of financial leverage, but it is a direct result of the structure of the standard forms of commercial and residential mortgage contracts used by lenders in Canada and elsewhere. There are two primary reasons standard mortgage contracts inhibit the property owner's incentive to purchase more than the minimum amount of insurance required by his lender. First, the generic property insurance required by virtually all mortgage lenders in Canada is most often sold in increments of one–year contracts. Borrowers are consequently paying for an option given to the insurer to change price or refuse further coverage, while leaving the property owner constrained by his original mortgage covenant to buy coverage of the specified amount for his property.

The second reason arises from the fact that the property owner bears an attendant financial risk from the requirement for a minimum amount of property insurance as this requirement appears in standard mortgage contracts. Since changes in the value of the insured property do not induce a corresponding change in the amount of coverage originally required by the lender at origination, a decrease in property values leaves the property owner insuring a greater proportion of the market value of his property than he did originally. Similarly, conventional mortgage loan amortization means that, even at an invariant property price, the amount of coverage – which should equal the amount of the outstanding mortgage debt at each date of annual policy renewal – should be declining since the unpaid mortgage balance owed to the lender is declining. The absence of a

[31] The analogous disincentive to invest beyond the minimal extent of mitigation required by the lender is limited by the degree to which the lender or his agent can observe the physical means of mitigation.

provision, in the standard mortgage contract, for such contingent reductions in coverage over time is an obvious, but correctable, incentive for the property owner to assume a greater exposure to fire risk than he otherwise would.

## SUMMARY AND CONCLUDING REMARKS

The purpose of this appendix is to identify issues pertinent to providing an economic foundation for the role of private and public policies in influencing the level of expenditures by property owners on the means of managing fire risk and the means by which the insurance industry and government could promote that private choice of exposure to fire risk which would result in the maximum possible economic benefit to those property owners and to their communities as a whole. The appendix pursues this goal by rigorously examining the most important economic issues affecting a property owner's choice of insurance coverage, the extent of his investment in mitigation and his resulting exposure to risk from the occurrence of widespread fires.

The initial issue addressed in this appendix concerned the economic nature of the markets for fire insurance and mitigation. We first identified those inefficiencies and other features of these respective markets which could distort an individual's actual choice of exposure to fire risk relative to the efficient degree of exposure; why his corresponding expenditures on insurance and mitigation may be deficient relative to their efficient values; and what scope exists for both the insurance industry and the government to reduce the effects of these inefficiencies and induce the representative property owner to choose that degree of exposure which maximizes the economic welfare to the individual property owner, to the residents of his at-risk community and to society as a whole. We subsequently described a result of great significance to both the insurance industry and to government policymakers: while neither the industry nor the government could create the incentives required for efficient risk exposure by acting in isolation, the ***simultaneous*** provision by government of a subsidy compensating the property owner for the benefits his neighbors freely receive from his investment in mitigation and the incorporation by insurance companies of an appropriate rate of discount in premiums commensurate in magnitude with those mitigation expenditures could induce property owners to voluntarily purchase those amounts of mitigation and insurance that result in an exposure to fire risk that conveys the greatest possible economic benefit on both an individual and collective basis.

The economic aspects of industry and government provision to the public of education and information about fire risk was then addressed. While benefits to the public from additional knowledge about fire risk and the means of its reduction are inevitably positive, opportunities for moral hazard and the corresponding credibility of each party in regard to the accuracy of the information it provides were shown to be crucial factors determining the value of this benefit relative to the cost of providing it. The level of precision in this information that would maximize its credibility to the public was described and the superiority of coordination between industry and government in providing it, relative to either acting alone, was demonstrated.

The third contribution of this appendix is to identify and describe the three issues most important to providing an economic foundation for both public and private policies concerned with managing fire risk. The first issue is whether insurance firms have an economic incentive to reduce the risk of fire on those properties it is or may be providing coverage. We discussed the divergent incentives to increase the riskiness of coverage exhibited by the equity owners of the representative insurance firm, the management of that firm, and those investors supplying funds, through debt and similar fixed–income instruments, to the firm. While traditional assumptions about the respective economic environments of these three groups together imply that insurance companies would in general refrain from attempting to reduce the risk to which the properties they insure are exposed, plausible circumstances were identified and discussed in which insurers would in fact encourage property owners to reduce fire risk over some significant range of risk.

The second and closely related issue is whether insurance and mitigation are economic substitutes or complements. The reasoning underlying the common theoretical conclusion that they are substitutes – implying that increasing investment in mitigation would most likely lower the returns to supplying insurance – was explained, and the inconclusive results from empirical research on this question were discussed. Of great significance to both the insurance industry and government policymakers, an exception to the conclusion of substitutability was shown to occur in the exact circumstances when, as discussed above, insurers and government coordinate their simultaneous offers of premium discounting for coverage and subsidies to investment in mitigation. Insurance and mitigation would act as complements in this situation. A property owner receiving a full subsidy for investing in mitigation would respond by increasing his investment and, in response to a lower premium, his insurance coverage. Insurers would also benefit from offering a sufficiently large rate discount, commensurate with the observable extent of the property owner's mitigation, since such a response is a signal of that individual property owner's preference for lower risk and yields additional information to the insurer about each such property owner, thus allowing more accurate risk pricing on an individual basis.

The third issue, also of great significance to policymakers, is the absence of any empirical measure of efficiency in insurance coverage and mitigation. The absence of such a benchmark precludes the ability of policymakers to know whether actual coverage is or is not efficient and also eliminates any possibility of inferring whether policies promoting risk reduction are increasing or reducing economic welfare to the affected parties. Since the very basis of beneficial government intervention in these markets depends on the existence of such a numerical benchmark, establishing a means by which it can be measured from actual data is the most important priority for normative economic research on fire risk.

The final contribution of this appendix is to note that the use of both debt and equity to finance the purchase of a property has significant effects on the incentives of both property owners and mortgage lenders in reducing property risk and to offer the first demonstration that standard mortgage contracts contain direct disincentives to purchase fire insurance coverage above a lender–required minimum. The opposing incentives for efficient coverage exhibited by incentive–based insurance contracts and standard mortgage contracts create an additional need for coordination, this time between insurance companies and mortgage lenders.

Although the fundamental economic issues identified here are complex, three broad conclusions can be drawn from the descriptions and analyses in this appendix. First, the priorities for normative economic research guiding efficiency enhancing decisions by both government and the insurance industry include (a) the creation of methods to improve the measurement of exposure to fire risk posed by the individual property owner and by so doing establish an empirical measurement of the corresponding efficient exposure of risk which maximizes the economic welfare of the individual property owner and that of his community; (b) determining, on both a theoretical and empirical basis, precise circumstances in which insurers have an incentive to promote mitigation as well as insurance as a means of reducing the exposure of a given property to fire risk; (c) a detailed theoretical analysis of the efficacy of providing the public additional education and information regarding fire risk when two potential providers of such information are active and each has an incentive to bias such information for their respective benefit; and (d) substantial refinements in the empirical measurement of the monetary value of the 'spillover' externalities created by a given property owner's investment in mitigation.

Second, the possibility exists of achieving efficient levels of insurance, mitigation and risk exposure. This can be realized through the *simultaneous* provision of a public subsidy to compensate the individual property owner for the benefits he creates for other property owners through mitigation and a rate of discount in insurance premiums, based on the extent to which any individual property owner invests in mitigation, that is sufficient to induce that individual to purchase insurance coverage in the amount efficient for his situation. Implementing the correct values of the public subsidy and the premium discount, however, depend crucially on coordination between the insurance industry and government policymakers.

Finally, standard mortgage contracts and other debt market mechanisms currently exhibit significant disincentives for investment by property owners in reducing their exposure to fire risk through insurance and mitigation. The absence of contingencies in common mortgage contracts is the primary source of this adverse effect on exposure to fire risk. The design of contingent risk reducing covenants in mortgage contracts is a means of offsetting this incentive, but their successful implementation requires coordination between the insurance and mortgage lending industries

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