School of Public Policy | University of Calgary

MASTER OF PUBLIC POLICY

CAPSTONE PROJECT

Smoke Between Neighbours: Measuring the inter-provincial impacts of wildfires on PM 2.5 levels

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Submitted in fulfillment of the requirements of PPOL 623 and completion of the requirements for the Master of Public Policy degree

Capstone Approval Page

The undersigned, being the Capstone Project Supervisor, declares that

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2024-04-29

(Date)

Acknowledgements

I had the privilege of working with Dr. Benjamin Crost on this project, to whom I am endlessly grateful for his gift of knowledge and time. You have been so accommodating given the tight deadlines, and your support for this project has kept me going even when I felt unsure of my ability to finish on time. I have learned so much through you, and I am excited to continue expanding my knowledge in this area.

I also thank Dr. Lavinia Moldovan for sparking my interest in econometrics and providing her students, including myself, with endless opportunities and encouragement. You had an immense impact on me, and I hope you find evidence of your insight, generosity, and enthusiasm within this paper.

I am forever grateful for my mother and father for all the financial, emotional, and academic support they have given me throughout my Bachelor's and Master's degrees. Thank you for giving me the confidence I need to get this far in life; I am lucky to have such fantastic role models for parents.

I could not have done any of this without my wife, Tessa. You have been there at every major moment of my adult life—as a forever-student, a wildland firefighter, and as a husband. I am so happy I now get to share these next moments with you as we enter into the world of parenting. I would never have made it this far without your love and support.

It has been a difficult road to get to this point, but the wisdom and support of both the SPP staff and MPP cohorts have made it that much easier. So, I thank all of you and hope that our paths cross in the future.

Dedication

I dedicate this paper to my son, John Ryland.

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Abstract

This paper aims to understand the magnitude of cross-provincial spillovers from wildfire smoke, and the implications of these spillovers on how wildfire management is structured in Canada. Canada's wildfire management regime is decentralized—with provinces responsible for the majority of wildfire management duties. However, economic theories on decentralization show that, in the presence of inter-jurisdictional spillovers, such a system may not be optimal. If spillover effects are unilateral—one province affects another more than vice versa—then there is reason to have greater centralization. Although there are inefficiencies related to centralization, polycentric theories show that such inefficiencies may be necessary when it comes to emergency management due to the need for resource redundancy. My research uses Distributed Lag Models to determine the impact of wildfire burn area on smoke levels across 22 Canadian municipalities. The results show that, during the wildfire season, approximately 75% of PM 2.5 levels in Canadian municipalities is attributable to cross-border wildfires. Therefore, the impacts of cross-provincial spillovers are not only large, they are greater than intra-provincial wildfires on municipal smoke levels. These results show that wildfire smoke is a matter of national concern, which implicates greater federal responsibility in wildfire management.

Introduction

Wildfire smoke has transcended mere inconvenience for Canadians. In just one week in 2023, Ontario incurred an estimated $1.28 billion in total costs from wildfire smoke (Sawyer et al., 2023). Woodsmoke is known to create toxicological effects on the respiratory system, including permanent lesions of lung tissue (Naeher et. al, 2007). Canadian healthcare costs from wildfire smoke pollution amount to between $480 million to $1.8 billion per year with chronic impacts going into the tens of billions of dollars (Matz et al., 2020). The costs of wildfire smoke penetrate well beyond the confines of healthcare, placing unprecedented strain on labor markets (Borgschulte, Mark, et al., 2022), the environment (Sanderfoot, O. V., et al., 2022; Bernath, Peter, et al., 2022), and provincial wildfire programs (Hope et al. 2016). Air quality has improved since 1990 (Canada, 2023a), but the upward trajectory of wildfire exposure threatens this progress.

In Canada, natural disaster management is highly decentralized. Provinces bear primary responsibility for wildfire suppression within their borders while the federal government provides financial support to provinces through intergovernmental transfer payments and on-the-ground assistance via the Canadian Armed Forces (CAF) (*Emergency Management Act*, s.7; *National Defence Act*, s.273.6). Generally, this framework has worked well for Canada. Decentralization has allowed subnational governments to tailor their disaster management policies to the specific needs of their respective jurisdictions. For example, a province with lots of earthquakes, like British Columbia, will have more rigorous earthquake mitigation policies than a province which has few earthquakes, like Saskatchewan. Most natural disasters tend to be localized within the provinces, resulting in little need for cross-border collaboration. Wildfires are unique in this aspect: not only do fires often spread across borders, the smoke produced can have long-range effects that span the globe.

Wildfire smoke does not respect borders, so while it makes sense for provinces to design public programs to maximize benefits within their jurisdiction, they may not internalize benefits or costs accrued to other jurisdictions. This leads to what is often called an "interjurisdictional environmental spillover." In the absence of inter-provincial coordination or a centralized authority, and in the presence of significant spillovers, the existing wildfire management model could prove to be inefficient in maximizing national welfare. Empirical findings reinforce this perspective (Sigman 2002; Sigman 2005; Helland & Whitford 2002; Lipscomb & Mobarak 2017). However, the magnitude of environmental spillovers matters since decentralization can still confer benefits when spillovers are small, while larger spillovers indicate a need for more centralization or regional cooperation (Oates 2001). My paper aims to investigate the magnitude of spillover effects from wildfire smoke and how this may inform the structuring of wildfire management organizations by Federal-Provincial-Territorial (FPT) governments.

I use a distributed lag regression model (DLM) to answer the research question. This technique helps understand how wildfire smoke (Borgschulte et al. 2022; Jones & Berrens 2021), particulate matter (Spiteri & Brockdorff 2020; Lin et al. 2020), and decentralization (Hao et. al. 2022; Sigman 2005; Lago-Peñas et al. 2022) impact health, social, and economic outcomes. DLMs are ideal for estimating the effects of independent variables–like the area burned by wildfires–on dependent variables–levels of wildfire smoke–over several days. DLMs are especially adept at capturing unpredictable factors, like wind and atmospheric conditions, that vary the span of days it takes for smoke to travel across borders. Data on wildfire smoke has been collected through the National Air Pollution Surveillance (NAPS) program, while data on wildfire size has been collected through the Canadian National Fire Database (CNFDB).

The results find substantial cross-border spillovers of wildfire smoke, and therefore indicate that there are significant efficiency benefits associated from centralization or inter-provincial cooperation. The specifics of how the federal government amplifies its support is an important policy question. For example, these findings may lend support to the implementation of centralized policies like a Canadian Federal Emergency Management Agency or increased Capacity support for provinces and the CAF. Conversely, the decentralized framework model could be preserved should provinces undertake distinct tasks to support one another. In this scenario, the federal government increases its support to provinces rather than assuming their responsibilities. Either way, these results point towards a need to rethink how wildfires are managed in Canada.

This paper will begin with an overview of the current system of wildfire management in Canada, highlighting both its decentralized and centralized elements. I will then talk about economic and governance theories related to centralization, with an emphasis on its implications for addressing inter-jurisdictional environmental spillovers. Afterwards, the methodology section will be presented. This section will focus on the construction of the DLM model and provide an initial analysis of the data. These results will then be subject to a high-level analysis in the discussion section where governance and economic theories will be applied to interpret the results. Finally, the paper will conclude by consolidating and summarizing the key points presented throughout.

Wildfire Smoke in Canada

What makes wildfire smoke concerning is its size. Smoke particles are small enough to enter the bloodstream and lungs, causing cardiovascular and respiratory health complications (USA, n.d.). According to Health Canada, long-term exposure to wildfire smoke is linked to approximately 2,500 deaths annually, with the cost estimated to be about $410 million to $1.8 billion for acute health effects and $4.3 billion to $19 billion for chronic health impacts (Canada 2023b; Matz et al. 2020). These impacts have ripple effects in the labour market; for instance, one study estimates that wildfire smoke reduces annual labour earnings by 2% (Borgschulte et al. 2022, 19). These numbers are likely to increase since climate change is expected to increase the length and intensity of wildfire seasons (Sun et al. 2019).

Wildfire smoke can be transported significant distances through wind. As a consequence, there can be impacts on air quality far away from its origin. For example, wildfires from BC (Matz et. al 2020, 5), California (Global News 2020), and even Siberia (USA 2018) have led to increases in Canada’s air quality levels. Although wildfire smoke may only travel small distances when close to the ground, if wildfire smoke penetrates high enough, it can travel the globe (Western Fire Chiefs Association 2023). Prevailing winds exert a significant influence on the trajectory of wildfire smoke. In Canada, these winds generally drive smoke eastward, although the intricacies of wind dynamics introduce a level of unpredictability. Given the complexity of wind patterns and the potential for smoke particles to originate from vastly different wildfire locations, predicting the precise impact of a single wildfire on air quality levels across Canada can prove challenging.

Wildfire Management

Considering the significant potential damages caused by wildfire smoke, effective wildfire management is a critical policy priority. Wildfire policy is primarily the jurisdiction of provincial governments. No federal policy tool exists to dictate how provinces allocate budgets for wildland firefighting. As an example, British Columbia is the only province to have Rappel Crews that descend from helicopters into wildfires that cannot be easily accessed through conventional means. However, wildfires are not a predictable phenomenon, meaning when provinces that do not usually experience significant wildfires have an above-average season, they tend to be severely underfunded. For example, in 2018 Ontario had to rely heavily on imported wildland staff to deal with an unprecedented wildfire season (Canadian Broadcasting Corporation 2018). As the Ontario case shows, these deficiencies are generally mitigated through relations with out-of-province jurisdictions. These relationships are formalized through Compact Agreements and The Canadian Interagency Forest Fire Centre (CIFFC).[1]

The federal government is involved in direct wildfire suppression through their own national wildfire force and the CAF.[2] They maintain a small force of wildland firefighters to manage wildfires on national lands, numbering just 88 individuals tasked with safeguarding Canada's national parks (Canada 2023c). When disasters become too much for provinces to handle on

[1] CIFFC is a non-profit operated by high-ranking provincial wildfire-management public servants. There are two main resource sharing agreements created through CIFFC: the Mutual Aid Resource Sharing Agreement and the Canada/United States Reciprocal Forest Fire Fighting Agreement. CIFFC also requests assistance from international bodies on an as-need basis. Similarly, the Canadian Council of Forest Ministers (CCFM) collaborates on forest management more broadly, including wildfire management.

[2] The Federal Government has additional powers under the *Emergencies Act*. As it relates to wildfires, the government can declare a Public Welfare Emergency under this Act if they believe that there is a wildfire emergency that exceeds the capacity or authority of a province to deal with. If the emergency is confined to a single province, the governor in council must receive permission from the province to assist in the emergency (ss.14(2)). The use of the *Emergencies Act* is rare because it results in significant public, political, and legal scrutiny (see s.59-61 and s.63).

their own during the response phase, the federal government may take a more proactive approach by deploying the CAF (*National Defence Act* s.273.6). The CAF deployment for domestic disaster response falls under Operation LENTUS, and they cannot be deployed without a formal Request for Assistance (RFA) from the province that is affected (Canada 2023d).[3] However, CAF assistance during wildfires is often limited due to the lack of training for wildfire-specific disasters. In 2023, the CAF responded to eight RFAs, a trend that has stirred frustration within the CAF; the growing dependence on the CAF for disaster response diverts their attention from their core responsibilities (Brewster 2023). This is exacerbated by high turn-over and hiring difficulties in the CAF, reducing their personnel numbers (Burke 2024).

In the routine management of Canadian wildfires, the federal government involvement is more indirect. First and foremost, they provide information management services. The Federal government oversees aggregated databases of provincial wildfires, including the National Forestry Database, the Canadian National Fire Database (CNFDB), and the Canadian Disaster Database. Further, there are plans underway to launch the WildFireSat satellite, which will enable daily monitoring of wildfires and the dissemination of crucial information to the public (Canada 2023e). Their second indirect role is in the allocation of federal funds and resources to the provinces (as enabled through the *Emergency Management Act* s.7).[4] Through initiatives like the Fighting and Managing Wildfires in a Changing Climate (FMWCC) program, the federal government provides funding for training and equipment to provinces, territories, and Indigenous

[3] However, the CAF will often strategically pre-position themselves when they expect that a province will submit an RFA (Botha 2022).

[4] Section 7 of the EMA also allows the federal government to declare a provincial emergency as a national concern. However, as of the publishing of this paper, no such regulations have been made. The EMA also explicitly forbids any assistance to provincial emergencies without the express permission from the province (ss.6(3)).

groups.[5] Furthermore, in cases where response and recovery costs exceed manageable levels, the Public Safety Canada (PSC) steps in to offer financial assistance through the Disaster Financial Assistance Arrangements (Canada 2023f). The federal government also has a role in international relations. For example, Natural Resources Canada and PSC have provided funding to the International Association of Fire Fighters to "help build wildfire fighting capacity and enhance training best practices" outside of Canada (Canada 2023g).

Centralization versus Decentralization

It is clear that Canada has a highly decentralized wildfire management system where provinces are responsible for the direct wildfire management and the federal government's role is primarily through indirect support. However, if the costs of wildfire smoke are not borne by the province responsible for preventing that smoke, vis a vis wildfire suppression, then what does this say about the efficacy of Canada's decentralized wildfire management system? The pros and cons of decentralization and centralization need to be weighed if anything is to be said about Canadian wildfire management.

Economic Theories of Decentralization and Centralization

The obvious benefit of decentralization is that it allows jurisdictions to create bespoke wildfire programs. Different provinces have different needs, so standards, tactics, and budgets vary across the Canadian landscape. A central government, on the other hand, may end up applying a uniform standard and budget across the provinces, leading to inefficient allocations of provincial resources. For example, think of a central government that allocates provincial resources based on a national average of annual wildfire counts. Provinces with lower-than-average wildfire

[5] Academic institutions, for-profit organizations, and not-for-profit organizations can also receive funding from the training fund.

counts would have a resource glut, resulting in idle resources like air tankers, firefighters, and helicopters. On the other hand, provinces with higher-than-average wildfire counts would be ill-equipped.[6] It seems obvious that, in this case, decentralization provides the most efficient use of resources. This is exactly what the Decentralization Theorem states: "For a public good…it will always be more efficient…for local governments to provide the Pareto-efficient levels of output for their respective jurisdictions than for the central government to provide *any* specified and uniform level of output across all jurisdictions." (Oates 1972).[7]

There is, however, a case in which the Decentralization Theorem does not apply. Imagine a wildfire burning in some province. If the costs of suppressing that wildfire exceeds the benefit to the province, they may not put resources towards extinguishing that fire. But what if winds carry the wildfire smoke into a neighboring province, resulting in higher healthcare expenses for that region? In such a scenario, if the combined benefits for both provinces in extinguishing the wildfire outweigh the cost of suppression, what action should the initial province take? From an economic perspective, the answer is none, because there would still be no incentive for the initial province to act. The resulting cost to the neighbouring province is a local environmental spillover. Stated more generally, a local spillover occurs when the marginal abatement cost of pollution does not match the combined marginal abatement benefits gained by *all* residents

[6] This is under the assumption that provinces do not have uniform needs for wildfire management capacity. If they did, then decentralization and centralization would provide the same level of efficiency.

[7] Of course, it is possible that a centralized government could provide variable funding to provinces based on their needs. However, there are two issues with this approach. First, fairness considerations would likely create legal and political issues. For example, think about the antagonistic position Alberta and Saskatchewan take regarding Canada's Equalization program (Jacques et al. 2021). Second, provincial bureaucracies likely have the most comprehensive understanding of their respective political, ecological, and social landscape. This latter point is significant, considering that, in 2023, 68% of the federal public service was concentrated within Quebec and Ontario (Canada 2023h).

across *all* communities (Oates 2001).[8] To address this issue, two methods could be employed: centralization or regional cooperation.

A central government is more likely to take into consideration the costs and benefits of the whole nation. This may result in a more economically efficient outcome (Oates 1972, 8-10). The empirical literature does show some support for this view. Sigman (2005) found that decentralization under the Clean Water Act in the United States led to reduced water quality in transboundary waters. Another paper shows that countries with centralized political parties had a better response to the COVID pandemic than countries with decentralized parties (Lago-Peñas, Santiago, et al., 2022). Finally, Lipscomb & Mobarak (2017) find that pollution tends to increase at inter-jurisdictional borders. Despite the evidence, centralization still suffers from the same inefficiencies noted above. Therefore, it may be in the interest of governments to find a solution within the decentralized regime.

Regional Cooperation as an Alternative to Centralization

Regional Cooperation maintains the efficiency benefits of decentralization while also accounting for spillover effects. However, there are two issues with regional cooperation. First, regional cooperation requires there to be few to no negotiation costs. This harkens back to a theory posed by Ronald Coase (1960). The Coase Theorem states the criteria under which externalities can be resolved between two parties without the intervention of a third party–like a central government. One criterion is that there be few to no transaction costs. This means that any hindrance to negotiation will decrease the ability of the two parties to resolve the externality without a third

[8] This is only the case with pure public goods: a good that is both non-rivalrous and non-excludable in consumption. Air quality is considered a pure public good since, generally, my use of air does not reduce another person's use of air, and I cannot prevent someone from breathing air.

party. Applied to wildfire management: the more people involved in negotiations, and the more bureaucratic complexity, the greater the cost of negotiations, and thus, the greater the need for central intervention.

The second problem with regional cooperation regards what Oates (2001) calls the *form* that a local spillover takes. The *first form* is where both jurisdictions pollute into each other's territory. Here, the solution is simple: they both agree to reduce their respective pollution levels to the benefit of each other. The *second form* is when there is only one polluting jurisdiction. In this situation, one jurisdiction comes out on top of the other, since there is no incentive for the jurisdiction to reduce their level of pollution without some kind of compensation. I hypothesize that the case of wildfire smoke represents the second form. As mentioned earlier, prevailing winds tend to move East in Canada. This may provide western provinces more leverage to negotiate resource agreements, resulting in inefficient allocation of abatement benefits.

Polycentric Theories of Organization

The extent of decentralization can be thought of as a spectrum, where less spillover effects results in greater decentralization, and greater spillover effects result in greater centralization or regional cooperation. However, up to this point, the arguments have been economic in nature. Disasters are also political, social, and cultural events, and efficiency is not always the end-goal of wildfire management. To add another layer to this discussion, I want to briefly address the political science literature on polycentrism–an alternative way of governing that incorporates jurisdictions into a joint decision-making process by acknowledging strengths that each entity brings to the table.

At the beginning of this section, I talked about the potential for a uniform budgetary allocation from a central government leading to idle resources due to the over-provision of services. Although this may be inefficient, it may prove a necessity in the case of wildfire management. Take into consideration that (i) wildfire season intensity is generally difficult to predict, and (ii) provinces rely on each other to import resources during unexpectedly intense seasons. It would make sense, then, that some level of resource redundancy is actually a good thing, even if inefficient (Kelly et al. 2019, 11). This opens up the possibility for centralized action within wildfire management through, for example, centralized program funding. Polycentric theory recognizes the significant transactional costs associated with the negotiation of formal agreements due to bureaucratic complexity (6). However, it also acknowledges that in intricate systems such as wildfire management, complex bureaucratic structures may be essential. The complexity helps capture diverse attributes that negotiating jurisdictions assign to the socioeconomic and cultural value of their resources (Ostrom, 1998). Further, agreements can increase institutional stability and trust (Kelly et al. 2019, 12), and the transaction costs of agreements are likely to be lower if jurisdictions share similar politics, geography, and wildfire risk (Hamilton et al. 2023; Lipscomb & Mobarak 2017, 498).

Methodology

Data

The primary indicator for assessing wildfire smoke and its health effects in Canada is particulate matter less than 2.5 micrometers in diameter (PM 2.5) (Naeher et al., 2007; Borgschulte, Mark, et al., 2022, p.17; Canada, 2023i; Meng et al., 2019). Data on PM 2.5, measured in μg/m^3, is sourced from Environment and Climate Change Canada's (ECCC) National Air Pollution Surveillance (NAPS) Program (Canada, 2023j). NAPS monitors both PM 10 and PM 2.5

emissions. PM 10 is occasionally used as an indicator for wildfire smoke because it closely correlates with PM 2.5 and encompasses larger particulate matter sizes (Deloitte, 2014, p.31; Löfstedt, 2018). PM 1 has also been used to estimate wildfire smoke impacts, as its emissions are estimated to be three times higher than PM 2.5 emissions (Liu et al., 2017). However, the majority of particulate matter measurement tools do not account for PM 1 emissions, and, while PM 10 emissions may be standard in some regions, the literature increasingly favors PM 2.5 due to its more direct impact on human health (Löfstedt, 2018).

The NAPS Program has been gathering hourly PM 2.5 data from major metropolitan areas across Canada since the 1990s. However, since ECCC doesn't directly collect this data, its reliability can vary for PM 2.5 measurements, potentially leading to missing or inaccurate readings based on provincial collection processes. NAPS offers PM 2.5 measurements in both integrated and continuous formats. Integrated readings are sampled intermittently throughout the year and are generally deemed more accurate for lower concentrations of PM 2.5 (USA 1981). Nevertheless, this study uses Continuous measurements because they provide hourly estimates of PM 2.5 levels, enabling the creation of regression models across different time spans. To derive daily average PM 2.5 concentrations, I compute the mean of hourly PM 2.5 readings for each day.

Provincial authorities are responsible for collecting wildfire data, which is subsequently consolidated by the Government of Canada through the CNFDB. This study relies on the National Burn Area Composite (NBAC) data sourced from the CNFDB. The NBAC integrates data from Natural Resources Canada and provincial sources to construct a comprehensive national dataset spanning from 1986 to 2022, selecting the most reliable data for estimating burn areas (Canada n.d.). My analysis uses the date of initial reporting by an agency in the NBAC for wildfires. In cases where these dates were missing, they were substituted with the dates when hotspots were first detected. Days without reported fires are counted as having zero hectares burned.

Ideally, the data would reflect the daily increase in cumulative hectares burned per province rather than solely indicating the date of initial fire reporting. Condensing the total burned area into a single date per wildfire fails to capture the evolving impact of wildfires over extended periods. To address this, the data has been aggregated into a 25-day time-step and is lagged up to 7 times so that it spans the 6-month fire season—beginning of April through to the end of September—in which wildfire smoke may travel to, and increase the smoke levels of, a metropolitan area. Consequently, it is anticipated that this limitation remains insignificant for the overall analysis, as the lagged impact of a wildfire smoke will likely dwindle to zero over higher lags.

Reference Area

I conducted my model analysis on 17 municipalities, encompassing 11 provinces/territories. To decide which municipalities to include, I began by determining which Canadian Census Metropolitan Areas (CMA) had the greatest population as of the 2021 census. CMAs, as defined by Statistics Canada, delineate geographic regions with populations of 100,000 or more (Statistics Canada 2022a). Typically centered on major municipalities, CMAs also incorporate nearby populations from towns, reserves, and other communities. 42 CMAs are reported from the data, representing approximately 70% of the Canadian population. However, running a model on 42 CMAs would be computationally expensive. Therefore, I chose the top two most populous CMAs per province in the list of 42. If only one CMA was reported for a province, then I only included that single CMA. I also included Whitehorse and Yellowknife for the sake of territorial representation. As a result, the reference area accounts for approximately 60% of the total Canadian population in 2021 (Figure 1).

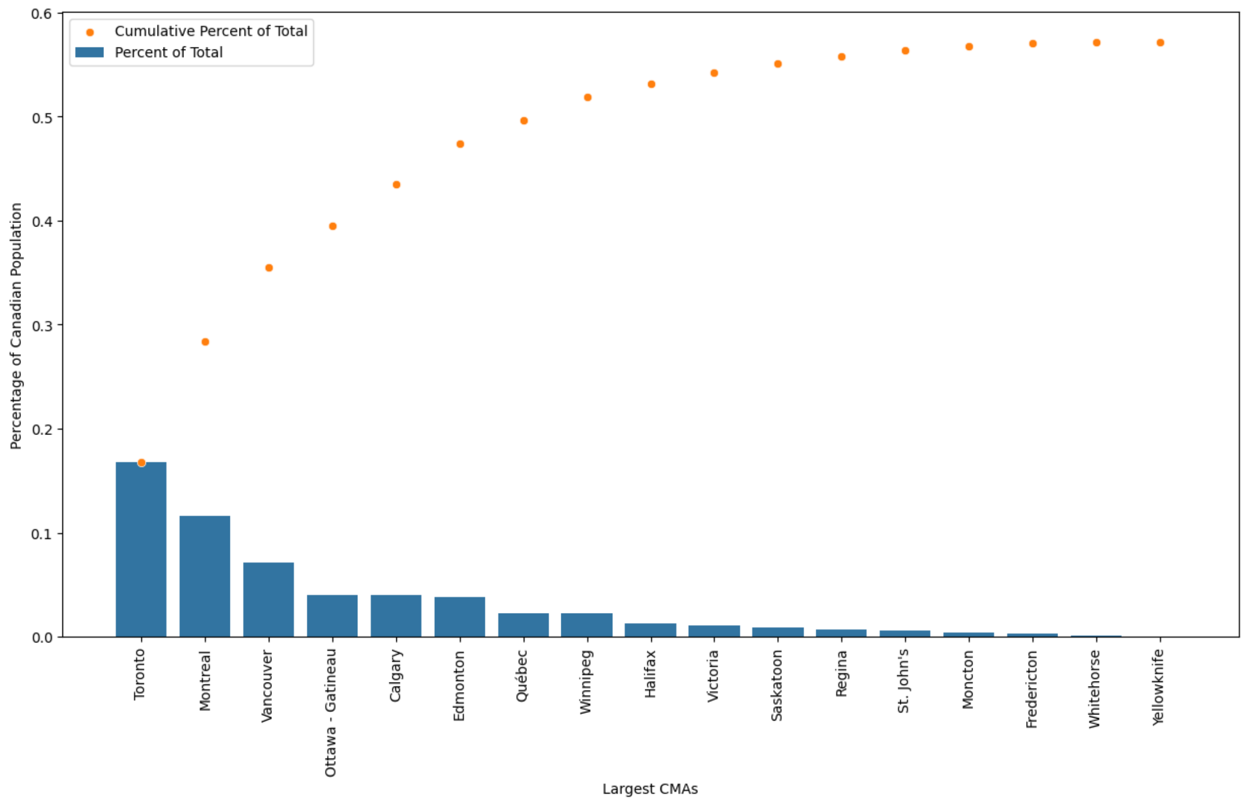


Figure 1: Reference Area CMAs expressed as a percentage of the total 2021 Canadian Population (Canada 2022b)

Model

Regression modeling serves as a common approach for assessing interjurisdictional environmental spillovers both within national borders (Sigman 2005; Lipscomb and Mobarak 2017; Yang and Chou 2018) and across nations (Sigman 2002; Spiteri and Brockdorff, 2020; Helland and Whitford 2003). Distributed Lag Model (DLM) techniques prove valuable in estimating the effects of one or more independent variables, such as wildfire burn area, on the dependent variable, namely PM 2.5 levels, over a variable number of days. Given the unpredictable nature of wildfire smoke dispersion, influenced by factors like wind conditions and atmospheric positioning, a DLM stands out as the optimal choice for this study. I use a maximum 6-month period—representing the fire season—to determine the lag length in each model, employing an Ordinary Least Squares (OLS) estimator with robust standard errors. The formula for each of the independent variables–the provincial wildfire burn areas–is given by the following equation.

$$X = \sum_{i=0}^{7} \beta_i Wildfire_{t-i}$$

X = sum of the lagged coefficients

β_i = coefficient at lag i

i =lag (where i = 0, 1…7)

$Wildfire_{t-i}$ = 100,000 hectares burned at time t and lag i

t = 25-day timestep (where t = 1998-04-01, 1998-04-26, 1998-04-51, etc.)

Here, the total lagged effect is given by the sum of the lag coefficients. When there is no lag (i=0), the coefficient represents the immediate effect of the sum of hectares burned in 25 days on the smoke level at a given metropolitan area during those same 25 days. Subsequent lags measure the non-immediate effects of wildfires on smoke levels over the wildfire season. These go up to 7 lags to encompass the whole wildfire season—represented as 175 days past April 25 (the immediate effect). OLS Regressions are calculated using the following equation for each metropolitan area:

$$PM2.5_t = \beta_0 + \sum_{p=0}^{10} X_p + \alpha_{step} + \varepsilon_t$$

$PM2.5_t$ = particulate matter less than 2.5 micrometers measured in µg/m3 at time *t*

X_p = sum of the lagged coefficients for wildfire burn area at each province *p*

p = Enumerated representation of each province/territory in the reference area (where *p* = Northwest Territories, British Columbia, Alberta, etc.)

α_{step} = seasonal fixed effects at *step* (where *step*=25 days)

ε = stochastic error term at time *t*

The explanatory variable in this study is the daily size of the wildfire area burned, measured in hectares. This variable is lagged over multiple days to accommodate the variability in smoke travel time from the province of origin to the city where PM 2.5 levels are measured. However, it is important to note that this method may not capture outlier cases where smoke travels for extended periods of time.

One of the issues that emerge with this model as it currently stands is the significant number of independent variables involved. This means that, without a regularization tool, overfitting the models is all but certain. To address this challenge, an L1 "lasso" regularization is used. L1 models are biased regression models that use the following equation:

$$L1(\beta) = \sum_{i=1}^{n}(y_i - f(x)_i)^2 + \lambda \sum_{j=1}^{m} |\beta_j|$$

y_i = observed value of the dependent variable

$f(x)_i$ = estimated value of the dependent variable

λ = shrinkage constant

L1 regularization is used for variable selection through the shrinkage constant. This constant inflicts a penalty on large coefficient values, thereby "shrinking" the sum of squared residuals in OLS equations by a factor of the absolute value of each coefficient. This reduces the coefficient of ineffective independent variables to zero. As mentioned, it is expected that the lags will reduce to zero over higher lags. As a result, L1 process will automatically eliminate these unnecessary lags for each model.

However, an optimal shrinkage parameter is needed; if the parameter is too large, then the model will remove effective variables, and if it is too small, it will include ineffective variables. Therefore, I employ a cross-validation method. Cross-validation is used to select hyperparameters–parameters that are not optimized within the model. Because this research uses time-series data, it is essential to conserve the order of observations. Therefore, a 5-fold cross-validation using the TimeSeriesSplit method from sklearn's model selection package is used. Rather than manually choosing hyperparameters for each model, I utilize a Grid Search. Grid searches automatically choose a hyperparameter based on which parameter maximizes a given target. In this research, the maximized target is chosen to be the negative mean squared error–a common choice for L1 regularization.

Non-zero independent variables from the L1 models are chosen as independent variables in the OLS regressions. OLS results are preferred over the L1 results since it mitigates bias and produces critical model statistics, such as P-values. To determine the optimal time-step, I run every model for all target cities over 30 time-step options, incrementing by a day for each option. The time-step yielding the highest average Adjusted R^2 values across all models is selected (see Figure 1). Since the 25-day time-step indicates the greatest average Adjusted R^2 score across models at 0.35, it is chosen as the optimal choice for my regressions.

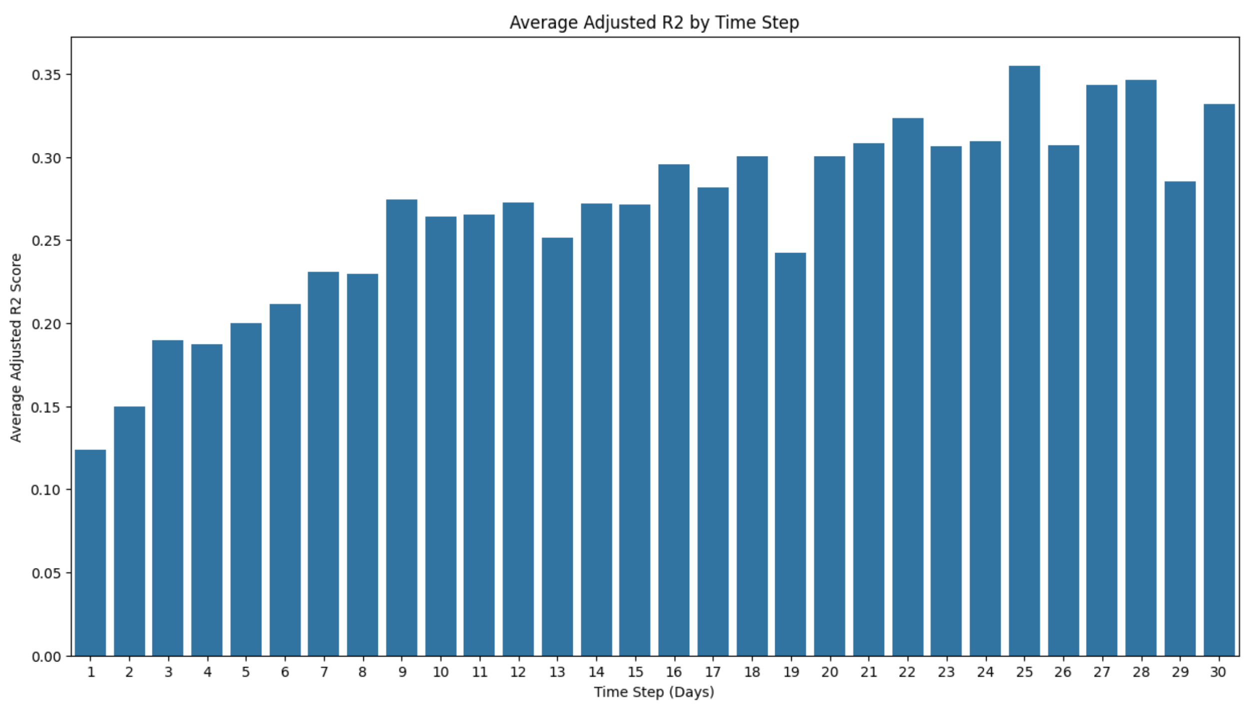


Figure 2: The mean Adjusted R^2 by time aggregation across all regression results within a 6-month period.

Results

Table 1 presents the model statistics for each regression analysis. Durbin-Watson scores hover between one to two; a Durbin-Watson Score of two means there is no serial correlation, while a score of one means there is some positive serial correlation. This suggests that most models have minimal occurrences of serial correlation among the residuals, but tend to skew right when serial correlation is present. To mitigate this, HC1 robust standard errors are used, which also address potential violations of homoscedasticity. This is particularly relevant given the right-tailed skewness of wildfires due to high-intensity seasons. All models exhibit high F-scores, and Adjusted R^2 scores typically exceed 20%, indicating that the selected independent variables explain a substantial portion of the variation in PM 2.5 levels.

City	R Squared	R Squared Adjusted	F Statistic	F Probability	Durbin-Watson	Skew	AIC	BIC
Calgary	0.53	0.48	7.64	0.00	1.61	0.71	964.85	1,018.56
Edmonton	0.40	0.36	3.81	0.00	1.63	1.86	959.23	997.21
Fredericton	0.39	0.35	15.43	0.00	1.33	0.68	600.10	633.29
Halifax	0.27	0.21	10.04	0.00	1.14	0.76	523.79	555.75
Moncton	0.31	0.25	12.80	0.00	1.02	1.06	627.65	667.04
Montreal	0.43	0.39	11.40	0.00	1.82	0.24	728.74	769.81
Ottawa-Gatineau	0.28	0.24	5.80	0.00	1.44	0.87	739.09	770.62
Quebec	0.34	0.27	17.49	0.00	1.56	0.94	701.19	750.89
Regina	0.49	0.38	9.53	0.00	1.71	2.25	770.67	843.85
Saskatoon	0.52	0.38	6.60	0.00	1.37	1.14	793.92	883.98
St. John's	0.26	0.20	12.28	0.00	1.00	0.38	573.38	610.72
Toronto	0.22	0.18	5.93	0.00	1.29	1.10	862.83	891.26
Vancouver	0.29	0.24	4.76	0.00	1.96	4.53	874.85	915.92
Victoria	0.40	0.32	4.27	0.00	1.53	2.17	780.04	845.52
Whitehorse	0.51	0.48	96.87	0.00	1.27	2.32	611.39	643.75
Yellowknife	0.93	0.91	181.74	0.00	1.56	-0.13	395.98	432.41

Table 1: Regression Model Statistics.

The R^2 values can be used to explore how well the model explains variations of PM 2.5 readings. Generally, the models perform well–scoring an average R^2 of 0.35. R^2 tend to be lower in southern major metropolitan areas, such as Vancouver, Ottawa-Gatineau, and Toronto. Previous research by Meng et al. (2019), suggests that factors such as agriculture, industry, and transportation also have a significant influence on PM 2.5 levels. Therefore, the lower R^2 values in these areas likely reflects these non-wildfire influence on PM 2.5 levels. Further, my model does not account for wildfires from the USA, which may contribute to lower scores–especially for cities close to the US border; this is likely why Winnipeg appears to have dropped out of the analysis. Yellowknife has the greatest Adjusted R^2 value at 0.93. Given the high concentration of wildfire smoke in the Northwest Territories (Figure 3), and the distance from the American border, it is reasonable to think that the data does indeed explain a significant portion of the PM 2.5 levels in Yellowknife. However, it is also possible the L1 regularization overfit the model, which would result in a higher Adjusted R^2 value.

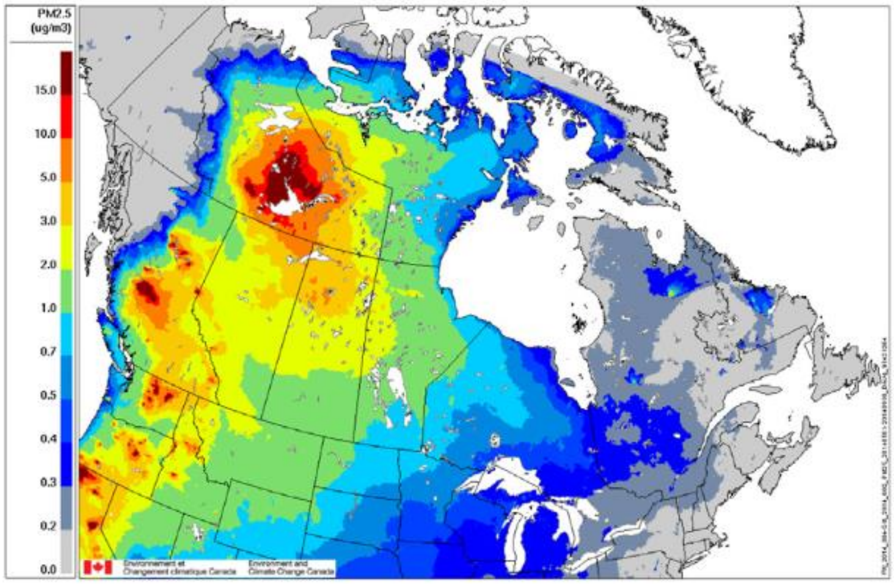


Figure 3: PM 2.5 concentrations (May to September) attributable to wildfires in 2014 (Matz et al. 2020).

Wildfire Origin	Calgary	Edmonton	Fredericton	Halifax	Moncton	Montreal	Ottawa-Gatineau	Quebec	Regina	Saskatoon	St. John's	Toronto	Vancouver	Victoria	Whitehorse	Yellowknife
AB																
Lag 0									2.2**	0.8						
Lag 1									0.43*	0.78*				-0.15		
Lag 2										0.73*				-0.26		
BC																
Lag 0	0.59**	1.39*	0.14						0.02	1.97**				0.38		-0.83**
Lag 1	2.37**	1.79**		0.14*					0.86**	0.99*			1.34**	1.37**		
Lag 2										0.25			0.21	-0.02		-1.24**
MB																
Lag 0										1.04*				-0.37		
Lag 1					0.43**			0.32	0.41							
Lag 2										-1.1						
NL																
Lag 1										4.15**						
NT																
Lag 0	-0.18					0.07		0.05	-0.03	0.13	0.09**		-0.12	-0.13		0.81**
Lag 1	0.47**	0.36		0.0		0.11*		0.02	0.08	0.34	0.14**		0.12	0.01		2.26**
Lag 2	0.02	0.28							0.15	0.18	0.07**		0.01	-0.23**		2.96**
ON																
Lag 0										-1.02						
Lag 1									0.68	1.48						
Lag 2	2.29**								0.67	0.65						
QC																
Lag 0			0.19**		0.03	0.38**	0.38**	0.22**	-0.16	-0.1	0.29**	0.33*				0.12*
Lag 1					-0.01			0.04	-0.16	-0.15						-0.49**
Lag 2							0.25*			0.33*						
SK																
Lag 0	0.32**					0.27**			0.96	0.29				-0.02		0.83**
Lag 1	0.25		-0.05	0.22**	0.08	0.22*		0.23	0.38	0.98*						
Lag 2	0.31								0.27					0.25*		
YT																
Lag 0									0.0	-0.13					1.19**	
Lag 1					0.09*			0.15**	-0.54*	-0.19				-0.14	0.7**	
Lag 2								0.22**		-0.27				0.26**	0.64**	

Table 2: Provincial Wildfire Determinants of PM 2.5 by CMA/City. One asterix (*) represents P-values less than 0.10. Two asterix' (**) represents P-values less than 0.05. Each lag is presented at 25-day intervals, with Lag 0 indicating the number of hectares burned during the same period as the reference area's average PM 2.5 levels.

Table 2 and Figure 4 illustrates the coefficients of the independent variables for each model. Coefficients have been weighted by percentage of the total Canadian population. This has been done for the results to adequately represent the impact of wildfire smoke on the Canadian *population*—as opposed to the Canadian *geography*. These coefficients quantify the extent to which PM 2.5 levels in the reference areas increase per 100,000 hectares burned in various provinces. Generally, statistically significant coefficients are positive, indicating a direct relationship between wildfires and increased PM 2.5 levels. However, statistically significant negative coefficients also appear, suggesting some degree of spurious correlation. False negatives are expected given the high number of independent variables. Because the magnitudes of these negative coefficients tend to be small, posing minimal concern for the overall integrity of the results, they have been removed from the analysis.

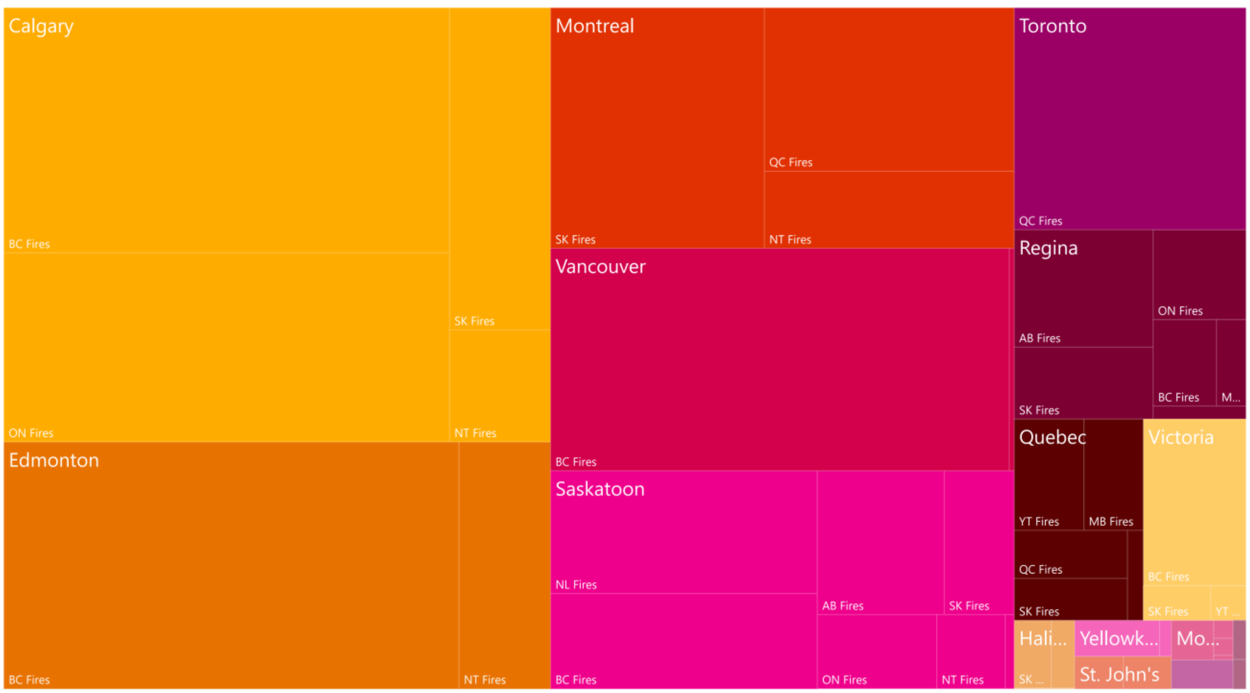


Figure 4: Population-Weighted Magnitude of Wildfire Smoke Origin on PM 2.5 levels for each CMA.

Wildfire Origin	In-Province Wildfires			Out-Of-Province Wildfires		
City	Sum of Coefficients	Weighted Sum of Coefficients	Percent	Sum of Coefficients	Weighted Sum of Coefficients	Percent
Calgary	0.000	0.0000	0.00%	6.621	0.2652	100.00%
Edmonton	0.000	0.0000	0.00%	3.821	0.1465	100.00%
Fredericton	0.000	0.0000	0.00%	0.328	0.0010	100.00%
Halifax	0.000	0.0000	0.00%	0.358	0.0045	100.00%
Moncton	0.000	0.0000	0.00%	0.632	0.0027	100.00%
Montreal	0.382	0.0443	36.60%	0.662	0.0768	63.40%
Ottawa-Gatineau	0.000	0.0000	0.00%	0.000	0.0000	0.00%
Quebec	0.000	0.0000	0.00%	0.000	0.0000	0.00%
Regina	1.611	0.0109	22.65%	5.503	0.0371	77.35%
Saskatoon	1.272	0.0109	8.43%	13.822	0.1186	91.57%
St. John's	0.000	0.0000	0.00%	0.592	0.0034	100.00%
Toronto	0.000	0.0000	0.00%	0.333	0.0559	100.00%
Vancouver	1.552	0.1109	92.06%	0.134	0.0096	7.94%
Victoria	1.750	0.0188	76.74%	0.530	0.0057	23.26%
Whitehorse	2.531	0.0019	100.00%	0.000	0.0000	0.00%
Winnipeg	0.000	0.0000	0.00%	0.000	0.0000	0.00%
Yellowknife	6.031	0.0033	86.29%	0.959	0.0005	13.71%
	0.890	**0.0118**	**32.65%**	**2.017**	**0.0428**	**78.35%**

Table 3: Coefficients by In-Province and Out-Of-Province Origin. Bolded numbers represent the average, while bolded Percent numbers represent the weighted average.

This study highlights the significance of extra-provincial wildfires on PM 2.5 levels, which are shown to be more impactful than intra-provincial wildfires on average. Across the reference area, inter-provincial wildfires contribute to approximately 78.35% of wildfire-caused PM 2.5 levels during the wildfire season. This number is calculated using the following formula:

$$\frac{\sum_{c=0}^{16} OOP_c}{\sum_{c=0}^{16}(OOP_c + IP_c)} * 100$$

OOP = Weighted Sum of Out-Of-Province Coefficients for each CMA *c*

IP = Weighted Sum of In-Province Coefficients for each CMA *c*

c = Enumerated representation of each CMA (were *c* = Calgary, Edmonton, Fredericton, etc.)

When considering only P-values significant at a 5% level, these proportions remain quite stable at 72.74%. To test the sensitivity of these results, I re-ran the regressions at a Daily, 5-Day, Weekly, 16-Day, 28-Day, and 30-Day time-step (Table 4). The results indicate that there is certainly some variance around this number—with inter-provincial spillover effects ranging from 57% to over 90% of all Canadian Wildfire-caused smoke. However, even at 57%, this indicates significant transboundary spillovers.

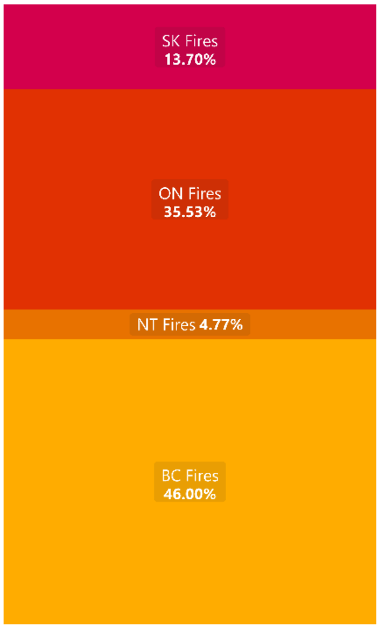
Time-Step (Days)	OOP	OOP (5%)	Average Adjusted R-Squared
5	91.06%	89.62%	0.12
7	89.23%	90.34%	0.23
16	70.53%	57.07%	0.28
25	78.35%	72.74%	0.35
28	69.17%	68.67%	0.35
30	72.81%	68.81%	0.33

Table 4: Results from other time-steps. OOP indicates the average population-weighted fraction of Out-Of-Province wildfire smoke origin across all reference-area CMAs. OOP (5%) represents this fraction when only coefficients at a 5% confidence level are included.

Discussion

These results show that the impacts of transboundary pollution across Canada account for approximately 75% of all wildfire smoke pollution during wildfires seasons—about three time as much as within-province wildfires! Even testing this number with different time steps, the results indicate significant wildfire smoke spillovers. At the beginning of this paper, a study was cited that estimated the annual cost of wildfire smoke pollution on Canada's healthcare system to be approximately between $480 million to $1.8 billion per year (Matz et al 2020). Taking into consideration my results, it is estimated that then healthcare cost of inter-provincial wildfire spillovers is $360 million to $1.35 billion.

Figure 5: Wildfire Smoke Origin for Calgary



These costs can be disaggregated even further. For example, the same study shows that the annual cost of acute premature mortalities attributable to wildfire smoke in Calgary is about $363 million (6). Given BC accounts for 46% of this total (Figure 5), it is estimated that $167 million dollars of that amount is due to BC wildfires.

Therefore, the impact of cross-provincial wildfire smoke spillovers is significant. These findings necessitate either strengthened regional cooperation or centralization. To a degree, such mechanisms are already in place. The federal government provides funding to the provinces through the Disaster Financial Assistance Arrangements and the Fighting and Managing Wildfires in a Changing Climate Program, and deploys the CAF when necessary. However, regional cooperation tends to be more significant than centralization in Canada. For example, provinces engage in resource sharing through the CIFFC Mutual Air Resource Sharing agreement. Additionally, Western provinces have a well-established compact agreement with their USA neighbours under the Northwest Wildland Fire Agreement.

The *form* that transboundary spillovers take matters as well. Earlier, it was hypothesized that transboundary spillovers will generally take the *second form*–where spillovers exhibit uneven distribution among provinces due to wind patterns. The results confirm this notion: Eastern provinces have a greater spillover effect on western provinces compared to vice versa (Figure 6). There are exceptions, such as the positive correlation between Ontario wildfires on Calgary's air quality, but the results show an inclination towards unilateral spillover effects. Moreover, these effects can travel significant distances, as shown by the positive correlation between Saskatchewan wildfires and Montreal's air quality.

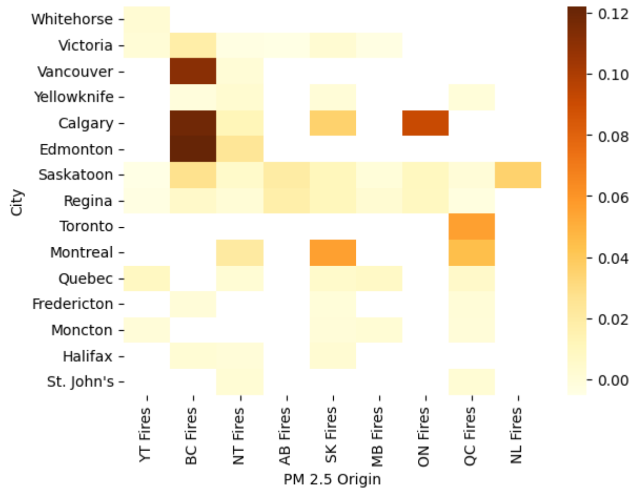


Figure 6: Heat map showing the impact of provincial wildfires on various CMA smoke levels.

There are two conclusions to draw here. Since these results suggest pervasive secondary-form spillovers, it is possible that Canada has a greater need for centralization over regional cooperation. However, the economics literature suggests that regional cooperation mechanisms can still exist through compensatory measures. Of course, it would be politically unpalatable to state that one province *pays* another province to maintain their wildfire force. However, these results indicates that there are benefits for provinces to providing increasing support to their neighbours *even if* they are experiencing significant wildfires themselves. This being said, wildfire resources are scarce, and therefore some level of greater federal involvement is necessary to even achieve these policy goals; a whole-of-society approach is needed.

Government documents recognize the need for a whole-of-society approach in combating wildland fires:

- The Emergency Management Strategy's places "Enhance whole-of-society collaboration and governance to strengthen resilience" as their first priority (Canada 2019).
- The National Risk Profile released by the PSC in 2023 states that "Whole-of-Society Governance and Collaboration of Emergency Management" is a significant shortfall in Canada (Canada 2023k, 128).
- The Council of Forest Minister's (CCFM) Wildland Fire Management Working Group 2021 action plan lists their first Action as "Enhance Whole-of-government Collaboration and Governance to Strengthen Resilience" (CCFM 2021).
- A Lessons Learned report from the Government of Alberta (GoA) following the Slave Lake wildfire in 2011 states that "Boundaries related to jurisdiction, mandate or geography must not prevent people from working together in an emergency" (GoA, 2013).

The primary problem with these documents is that their suggested solutions are often vague. This is likely because jurisdictional restrictions within Canadian wildfire governance hinder the ability of these documents to propose robust federal measures. For example, none of these documents appear to explore the possibility of a federal-level standalone emergency response team *despite* significant calls for such a policy (Asgary, 2023; Stackelberg, 2024; Karadeglija, 2024; Lindsay, 2024). If Canada remains path-dependent on traditional wildfire governance roles, whole-of-society pathways will remain closed.

There is a viable pathway for the federal government to expand their role in wildfire governance by recognizing wildfires as a matter of national concern. While section 92 of the *Constitution Act, 1867*, allocates matters of a local nature to the provinces, section 91 allocates the responsibility for "Peace, Order, and Good Government of Canada" (POGG) to the federal government. The POGG clause can be invoked if there are extra-jurisdictional impacts that cannot be resolved by any one province (*R. v. Crown Zellerbach Canada Ltd*, 1988, para 33). This study has demonstrated the significant and unilateral nature of extra-jurisdictional impacts from wildfire smoke, and shines a light on the viability of stronger federal measures.

Therefore, the federal government should increase their involvement in wildfire management. Centralized solutions should aim to replicate the optimal allocation of resources based on provincial needs, leaning towards over-provisioning when specific regional data or knowledge is lacking. While traditional economic perspectives may critique the inefficiencies associated with over-provision, polycentric theories argue that, in emergency management, over-provision creates necessary redundancies (Kelly et al. 2019). There are many approaches for the federal government to increase their involvement, so what follows are a few of the more salient policy options.

Policy Options

Federal Emergency Management Agency

There have been public discussions about the potential for the federal government to create an all-hazards centralized agency, similar to the Federal Emergency Management Agency (FEMA) in the US (Asgary, 2023; Stackelberg, 2024; Karadeglija, 2024; Lindsay, 2024). Federal Minister of Emergency Preparedness, Harkit Sajjan, has stated that this could mean more direct involvement of a federal response team to assist in disaster management across the nation (Rabson, 2023). The benefit of such an approach is that it would reduce the over-reliance on the CAF as the go-to federal tool when disasters become too large for the provinces given their limited resources.

A Canadian FEMA would deviate from the traditional conception of federal jurisdiction in emergency management. This being said, the federal government may take a more coordinated approach that focusses on utilizing local resources, rather than the USA's top-down approach (Rabson, 2023). Such an approach would follow the logic of polycentric governance—where governance of emergency management is allocated to not only governments, but also citizens. Examples of localized solutions can be found across Canada. For example, FireSmart Canada is a national program that endeavors to assist communities across Canada in protecting themselves from wildfires (FireSmart Canada 2024). The government is currently in discussions with the provinces regarding the implementation of a Canadian FEMA, and are even considering a pilot project in 2024 (Rabson, 2023).

Standardization

The creation of national standards is frequently shown to be lacking in emergency management, and are often recommended as a method to pursue whole-of-society approaches by making provincial wildfire policies compatible with one another. For example, there are no standards for data collection, yet information sharing remains one of the Federal government's core responsibilities in wildfire management. Further, Tymstra et al. (2020) states that there are no national standards for fire weather and behavior advisories, despite their importance in providing national situational awareness (7). As well, findings from the National Risk Profile (Canada 2023k) notes a lack of national standardization in wildfire risk assessments methodology (p.86). One can even imagine other kinds of standards that could be created, such as a standard for wildland firefighter respiratory protection.

However, it may not be politically nor legally feasible for the federal government to enforce standards without provincial buy-in. The federal government could incentivize provinces to adopt these standards through conditional funding. The federal government could also employ a bottom-up approach, whereby standards are negotiated at cross-jurisdictional tables, such as CIFFC or CCFM working groups. After an agreement is met, the standard would be enforced by the federal government. This is called Reverse Conjoint Federalism (Lin 2010).

Conjoint Federalism is when the federal government creates standards that must be met by subnational units. Reverse Conjoint Federalism is the opposite: when subnational units create their own standards and the federal government decides how each subnational unit meets those standards. According to Lin (2010), Conjoint Federalist structures of standard making are the most common, but may be the least efficient method. Interestingly, Lin finds that Reverse

Conjoint Federalism may provide significant efficiencies when it comes to standard creation in federal systems.

CAF Training and Capacity

Since the CAF is the primary federal tool used in wildfire management, there may be a place for them to expand upon this role. The primary issues with the over-reliance on CAF resources is that it (i) distracts from the core duties of the CAF, (ii) the CAF lacks the capacity to supply the necessary resources for domestic emergencies while still maintaining enough resources for their other responsibilities, and (iii) the CAF does not commit to regular wildfire suppression training (Brewster 2022; Brewster 2023; Botha 2022). Given the unique nature of wildfire response, which demands a specialized understanding of wildfire behavior and suppression tactics (Botha 2022, 142), the CAF finds itself entangled in a dilemma. They either reduce the time allocated to preparatory measures, like distributing comprehensive situation reports, or acknowledge wildfire training as a significant bottleneck in response efforts, owing to the extensive time investment required for soldier training.

In lieu of other federal resources that could assist with wildfires, it may make sense for soldiers to be trained in wildfire management and suppression semi-regularly. However, such a solution may not be feasible given a shortage of staff, time, and willingness to train soldiers on tasks that deviate from their core duties. Further, the CAF are only able act when they are given a formal request from a province, which would remain a barrier to federal action even if the CAF is provided more resources. This policy would align with Canada's NATO commitments; the parliamentary budget officer estimates that, in order to meet Canada's commitment to 2% of military spending on military, the federal government would need to spend an additional "$18.2

billion in 2022-23; $15.5 billion in 2023-24; $14.5 billion in 2024-25; $14.1 billion in 2025-26; and $13.0 billion in 2026-27" (Penney 2022).

The creation of a smaller subsection of the army that is specially trained in wildfire response could be considered as a policy solution. This could be done on a voluntary basis, or as a requirement for some positions, such as reservist personnel. Retired Lieutenant General Andrew Leslie notes that a dedicated climate disaster response force could be nested within the CAF (Ball 2023). As Leslie says, "we desperately need a focus on emergency and disaster preparedness."

Capacity Funding

Provinces frequently deal with funding issues in wildfire management. Tymstra et al (2020) states that "Projected increases in area burned suggest the current state of wildfire management in Canada will be unable to cope with a future landscapes [*sic*] with increasing wildfire activity" (7). The federal government has already acknowledged a need to improve extant financial assistance programs (Stackelberg, 2024). With greater fiscal capacity dedicated to wildfire management, the federal government could purchase a greater share of high-cost assets such as air tankers. Air tankers represent a significant cost to the provinces, and there are concerns that Canada's fleet is quickly reaching their end of life (Omstead 2023).

The federal government does cost-sharing with the provinces through the FMWCC: Equipment Fund (Canda 2023l). Part of the problem with the current layout of the FMWCC is that the fund has a lifespan of five years. This does not allow for costs to vary on a year-by-year basis. Therefore, one potential policy avenue would be for the federal government to turn this fund into an *annual* intergovernmental transfer. An annual transfer could be tied to certain conditions being met, yet should still be discretionary enough to allow provinces to continue tailoring their wildfire management programs to local needs and conditions. Further, it is possible for endowed provinces to crowd-out wildfire resources, such as helicopters and air tankers, during intense fire seasons. Giving a third-party discretion over how these resources are allocated would reduce the potential for such crowding-out effects.[9]

Conclusion

This paper set out to answer the question: what is the extent of inter-provincial spillovers from wildfire smoke, and what does this suggest for how Canadian governments manage wildfires? The nature of wildfire smoke is that it can have effects that span the globe, and therefore the burden of cost from this smoke cannot be said to be localized. In such a scenario, it would seem to be reasonable that wildfire management could constitute a matter of national, and even international, concern, yet wildfire management is largely decentralized in Canada, with the provincial governments taking on the burden of wildfire management responsibilities while the federal government plays an auxiliary role.

However, this is not necessarily a bad thing. Economic theories about decentralization tout the efficiencies of decentralized governance, yet, even this literature has to contend with the difficulties in governing public goods–such as wildfire smoke abatement–in the face of inter-jurisdictional spillovers. There are two solutions to these spillovers: increased centralization or regional co-operation. Economists tend to prefer a decentralized structure, since spill-over effects

[9] There is little to no evidence that provinces hoard resources.

do not resolve the efficiency issues related with centralization. However, regional co-operation may have high transaction costs, and if the spill-over effects are unilateral, then a decentralized solution may not be feasible. As this paper shows, in the case of wildfire smoke, it is likely that spill-over effects are unilateral.

Further, theories from the political sciences mention how inefficiencies related to redundancy of resource allocation may actually be preferable when it comes to emergency management. This is due to the high variability and cost of emergency situations; for example, a province may only have a 10% chance of a higher-than-average wildfire season, but the costs will be very high if they do not have the resources to mitigate the damages of such a season. Therefore, some of the economic arguments relating to inefficiencies of centralization may be moot as it regards wildfire management, especially if it is true that spill-overs are extensive and take on the second form of unilateral spillovers.

By employing a distributed lag model that looks at the lagged effects of provincial wildfires on smoke levels in various Canadian cities, my research showed both of these statements to be true; approximately 75% of wildfire-caused PM 2.5 can be accounted for by extra-provincial wildfires during the wildfire season, with Western provinces having the greatest impacts on Eastern provinces. These results generally align with previous research, but shed a new light on the state of emergency management in Canada. Further, these findings are relevant to discussions being held today as the federal government contemplates the creation of a Canadian FEMA.

Centralization must contend with traditional conceptions of federal constitutional responsibilities with respect to emergency management. The federal government does, however, also have a constitutional responsibility to the “Peace, Order, and Good Governance” of Canada, which involves dealing with matters of a national concern which cannot be addressed by any individual province in isolation. My research supports the notion that there are extra-provincial issues with respect to wildfire management that constitute a matter of national concern, while also respecting that there are efficiency gains to be realized through decentralized decision making. Something akin to Lin’s (2010) Reverse Conjoint Federalism is one governance structure that could be employed to ensure that the central government has a more direct role in wildfire management through enforcing how each province meets certain wildfire management goals and responsibilities, while still maintaining provincial autonomy over the creation of these goals and responsibilities.

Further, the federal government should try to increase the capacity of the CAF, and create opportunities for wildfire-specific training *prior* to a provincial Request for Assistance to ensure there are no bottlenecks in CAF response. However, it is also important to recognize that disaster management is not the primary mandate of the CAF, and therefore they should remain as a force of last-response. Instead, the federal government must continue to find ways to ensure sufficient capacity and efficient allocation of resources within the provinces. This can be achieved through annual transfer payments, as opposed to one-time payments, and control over coveted resources that may be subject to crowding-out effects from endowed provinces–for example, air tankers.

This project has shown that there is still room for both a centralized and decentralized response to emergency management in Canada, but that the current division of provincial-federal responsibilities may lean too heavily on the provinces. Future research should tie specific policies to transboundary smoke spillovers; for example, it would be interesting to determine if there are greater transboundary spillovers in provinces that implement monitored response policies when compared to those that commit to full-response policies. Currently, the federal government is taking steps by considering a Canadian FEMA and consulting provinces regarding the establishment of such an agency. It is paramount that the federal government carefully plans these next steps, since high-intensity wildfire seasons are likely to be the new reality for *all* Canadians.

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