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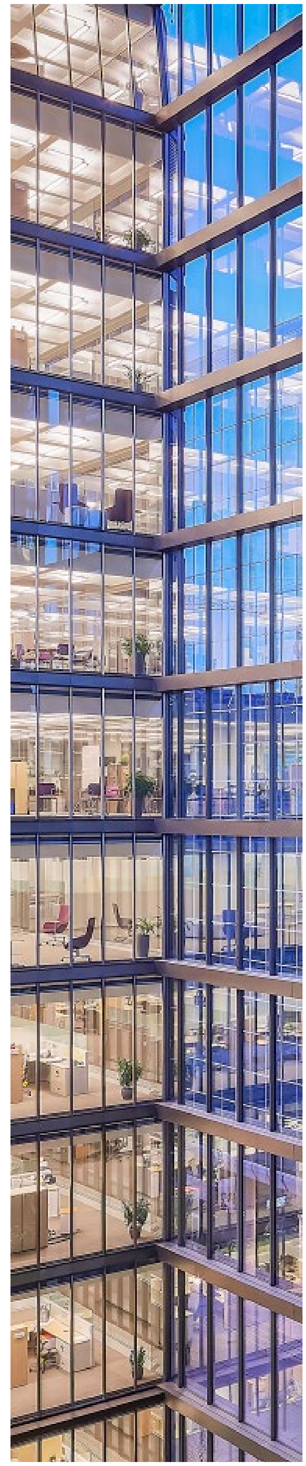

We Didn't Start the Fire: Effects of a Natural Disaster on Consumers' Financial Distress

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Abstract

Global climate change is increasing the frequency and severity of natural disasters. We use detailed consumer credit data to investigate the impact of the 2016 Fort McMurray wildfire, the costliest wildfire disaster in Canadian history, on consumers' financial stress. We focus on the arrears of insured mortgages because of their important implications for financial institutions and insurers' business risk and relevant management practices. Our findings suggest that wildfires have caused more mortgage arrears in severely damaged areas, with both economic and statistical significance. For other areas with relatively minor damage, the increase in arrears is small and statistically insignificant.

Topics: Climate change; Econometric and statistical methods; Financial stability; Credit and credit aggregates

JEL codes: C21, D12, G21, Q54

Résumé

Les changements climatiques qui s'opèrent à l'échelle mondiale font que les catastrophes naturelles sont de plus en plus fréquentes et graves. Nous utilisons des données détaillées sur le crédit à la consommation afin de connaître les effets des feux de forêt qui ont ravagé Fort McMurray en 2016 – les plus coûteux de l'histoire du Canada – sur les tensions financières subies par les consommateurs. Nous nous concentrons sur les arriérés de paiement de prêts hypothécaires assurés, en raison des leurs grandes répercussions sur les institutions financières ainsi que sur le risque d'activité et les pratiques de gestion afférentes des assureurs. Nos résultats semblent indiquer que les feux de forêt ont entraîné une hausse significative – tant sur le plan économique que sur le plan statistique – des arriérés de paiement sur les prêts hypothécaires dans les régions sévèrement touchées, et seulement une hausse faible et statistiquement non significative dans les régions où les dommages étaient relativement mineurs.

Sujets : Changements climatiques; Méthodes économétriques et statistiques; Stabilité financière; Crédit et agrégats du crédit

Codes JEL : C21, D12, G21, Q54

1 Introduction

Global climate change is increasing the frequency and severity of natural disasters. OECD (2003) highlighted this as an emerging risk in the 21st century. These disasters destroy physical assets, such as homes, which have detrimental financial implications for the affected individuals. A recent report by The Insurance Institute of Canada (2020) highlights that extreme weather will impact every area of insurance with the following risks: more people and assets are in the path of weather-related losses, which results in *physical risks*; climate change accountability leads to *liability risks*; and changes needed in response to climate change create *transitional risks*.

The aforementioned climate-related risks also affect the stability of the financial system. The Network for Greening the Financial System, an international network of 87 central banks, recommends that central banks and supervisors integrate climate-related risks into financial stability monitoring and microsupervision (NGFS, 2019).[1] Uncertainty related to the climate also increases the difficulty of assessing its potential economic impacts (Burke et al., 2015). Understanding the potential effects of natural disasters, which have become more frequent and severe due to climate change, on household finance is particularly important in Canada because elevated household indebtedness has already been identified as a vulnerability in the financial system (Cateau et al., 2015).

We conducted an empirical case study of the impact of the 2016 Fort McMurray Wildfire, the costliest wildfire disaster in Canadian history. According to Statistics Canada (2017), 5,890 km^2 of land and approximately 8% of all private dwellings were destroyed by the fire, making this the largest insured loss for insurance providers. This disaster also created substantial indirect costs as the evacuation temporarily halted oil sand production near Fort McMurray. The estimated output loss was 0.4% of real GDP in the second quarter of 2016. The wildfire's total cost is estimated at $9.9 billion Canadian dollars, with about $3.7 billion in insured losses.[2]

Wildfires offer a unique opportunity for an in-depth analysis of the economic consequences of natural disasters. This incident resulted in uneven destruction within Fort McMurray. The wildfires severely burned some areas, while evacuated residents residing in less damaged areas were able to return home the following month. This differential impact allows us to identify the severity of the direct impact on individuals with property losses versus those with relatively indirect effects.

[1] In Canada, the Bank of Canada and the Office of the Superintendent of Financial Institutions launched a pilot project on climate risk scenarios in 2020.

[2] All dollar figures are quoted in Canadian dollars – 1 Canadian dollar was about 0.75 US dollar in 2016, refer to https://www.bankofcanada.ca/rates/exchange/.

Using detailed monthly consumer credit data from 2014 to 2018, we categorized individuals into two groups based on whether they lived in (1) severely damaged areas or (2) less damaged areas and analyzed the economic effects of wildfires on these groups separately. We focus on financial distress in insured mortgages measured by loan delinquency for the following reasons. First, residential properties are immobile and vulnerable to damage from natural disasters. Second, mortgages are the single largest loan item for most individuals. Third, the effect of natural disasters on mortgage delinquency has strong implications for mortgage insurers, financial institutions, and policymakers providing explicit guarantees via mortgage insurance.[3]

The wildfire's treatment effect is estimated using a synthetic control method (SCM). This method is often used for policy evaluations in finance, economics, and political science. It aims to create a hypothetical control unit that resembles Fort McMurray's characteristics, yet never experiences wildfires. The treatment effect is measured as the difference in mortgage arrears between the actual and hypothetical control outcomes. We find that wildfires have a substantial impact on mortgage delinquencies. After controlling for confounding effects, such as oil price changes, we attribute the doubling of delinquencies in severely damaged areas almost entirely to the wildfire effect. However, this increase was temporary and quickly dissipated between 12 and 18 months after the event. In contrast, we find minor and statistically insignificant effects in areas with less damage, with these impacts dissipating after only three months.

Our findings highlight the need to account for climate risk in consumers' lending decisions, as there may be spillovers to other finance and insurance industry stakeholders. Spillovers can appear in terms of an increase in the financial burden due to the loss of use, delay in insurance settlements, or disruption in income streams. It is incumbent on the finance and insurance to understand and manage their exposure to these risks. A potential reason for credit performance worsening is limited risk sharing (Favilukis et al., 2017), as households fail to insure against catastrophic risks due to prohibitively high insurance prices (Kousky and Cooke, 2012) or whole market failure in equilibrium (Raykov, 2014). Our findings support recent research that suggests the need to account for climate risk in the pricing of assets and bonds (refer to Gollier, 2014; Pedersen et al., 2020; Bolton and Kacperczyk, 2020; Flammer, 2021).

Potential changes in pricing may have long-lasting effects on the Canadian housing finance system because the public securitization of insured mortgages provides a cost-effective supply of funding to lenders, supporting competition in the mortgage market (Mordel and Stephens, 2015). This study also highlights the need for preparedness for natural disasters, which may

[3] Refer to Appendix A for details on Canadian mortgage insurance.

be in the form of debt forbearance or debt-relief programs from the finance industry, or disaster relief from the public sector.

This study is closely related to the growing literature on the effects of natural disasters. Gallagher and Hartley (2017) find a temporary and modest increase in mortgage delinquency after Hurricane Katrina in 2005. This outcome can be explained by a small and transitory effect on income (Deryugina et al., 2018), which can be attributed to wage gains from a weaker labor supply as residents migrate out of the affected areas (Groen et al., 2020). Regarding the distribution of federal flood assistance for Hurricane Harvey, Billings et al. (2019) argue that fewer assistance loans are allocated to financially constrained homeowners, resulting in more insolvency. In the long run, (Ratcliffe et al., 2020) suggests that natural disasters lead to declines in credit scores and loan performance. Overall, the impacts of natural disasters vary significantly owing to differences in severity, disaster aid levels, media coverage, and political interest (Edmiston, 2017; Issler et al., 2019). Individuals can obtain sufficient liquidity from other channels (Morse, 2011). Recently, Paudel (2021b) suggests that the coronavirus disease 2019 (COVID-19) reduced the number of human-induced forest fires and Bilyk et al. (2020) examines how the COVID 19 shock affects Canadian households by comparing the pandemic and natural disasters. In addition to household finance, catastrophic disasters may also affect bank funding and reduce the supply of loans (Hosono et al., 2016) as well as firm survival (Basker and Miranda, 2017). From a macroeconomic perspective, Cavallo et al. (2013) utilized SCM to study the impact of catastrophic natural disasters on economic growth. The author did not find any significant effects.

Our work differs from the existing literature in several ways. Unlike floods and hurricanes, wildfires are arguably unpredictable in terms of geographical location. Households may be less prepared than those living i n floodplains or coastal areas. Unlike Hurricane Katrina's extensive damage to New Orleans' oil-producing facilities, oil-sand production surrounding Fort McMurray was only temporarily halted, which prevented the effect from propagating through supply chains (Barrot and Sauvagnat, 2016; Hsu et al., 2018) and limited the loss of jobs to a transitory income shock. The distinct pattern of wildfire damage also enables us to better quantify the losses from the physical risks of a natural disaster. Namely, the heterogeneous impacts across different neighborhoods in Fort McMurray allow us to study the treatment effect based on the intensity level of the damage. This approach provides the advantage of using synthetic control over a difference-in-differences setup, which requires splitting the control and treatment groups at the boundary of the event. Finally, our focus on insured mortgages at a monthly frequency also offers new insights for risk management on the evolution of mortgage arrears compared to previous studies using quarterly or annual data.

The rest of the paper is organized as follows: Section 2 provides background information on the 2016 Fort McMurray Wildfire, Section 3 describes our data set and reports relevant stylized facts, Section 4 specifies the empirical methodology, Section 5 presents the results on loan defaults, and Section 6 concludes the study description.

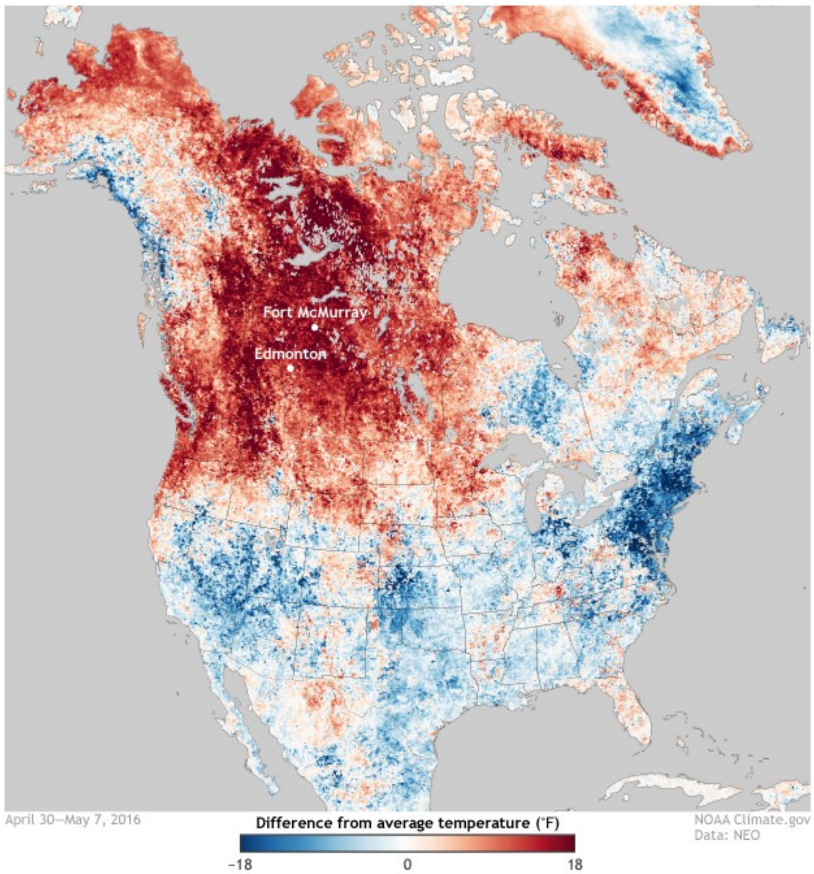
2 2016 Fort McMurray Wildfire

Fort McMurray is a remote city in northeast Alberta, Canada. It is nestled in the boreal forest and is located near Athabasca oil sands, the world's third-largest proven oil reserve. Owing to its proximity to oil sands, the local economy depends heavily on petroleum production and the energy sector.

Anthropogenic activities have contributed to climate change (Bush and Lemmen, 2019). In 2011, Alberta experienced two large fires, namely the 2011 Slave Lake Wildfire, which displaced the residents of Slave Lake, and the Richardson Fire, which burned nearly 1.7 million acres of the boreal forest. These events prompted the Alberta government to set up funding for mitigation and disaster response purposes. While this approach represents a pretreatment response that could bias our results, these actions were largely reversed with large budget cuts in 2015 (Alberta Government, 2016). In fact, 45% of the budget for the FireSmart preventative program, which aimed to prevent wildfires through tree thinning in vulnerable communities, was cut. Additionally, almost 17% of the funding set aside as part of the 2011 Slave Lake Wildfire recommendations was cut (Williams, 2016). Hence, Fort McMurray and Alberta were largely unprepared to deal with the devastating impacts of the 2016 wildfire.

Anthropogenetic climate change has also led to rising temperatures in northern Canada (Amano et al., 2021) and has increased the likelihood of wildfires (Flannigan et al., 2015; Gillett et al., 2004; Hanes et al., 2019). In particular, anthropogenic forcing has caused extreme fire risk events in the Fort McMurray region to become 1.5 to 6 times more likely (Kirchmeier-Young et al., 2017) and has also increased the area burned (Kirchmeier-Young et al., 2019). Figure 1 illustrates the unseasonably hot weather in the spring of 2016 that provided the perfect conditions for the rapid spread of a fire that started in a remote area approximately 15 kilometers outside of Fort McMurray. Igniting on May 1, several months before the typical start of the season, the rapid spread allowed little warning time for residents. By May 3, an emergency evacuation order was imposed, displacing all 88,000 residents. As the wildfire moved away from Fort McMurray, residents were allowed to re-enter Fort McMurray on a voluntary, phased basis between June 1 and June 15, subject to local safety conditions .

Figure 1: Deviation from the average temperature between April 30 and May 7, 2016

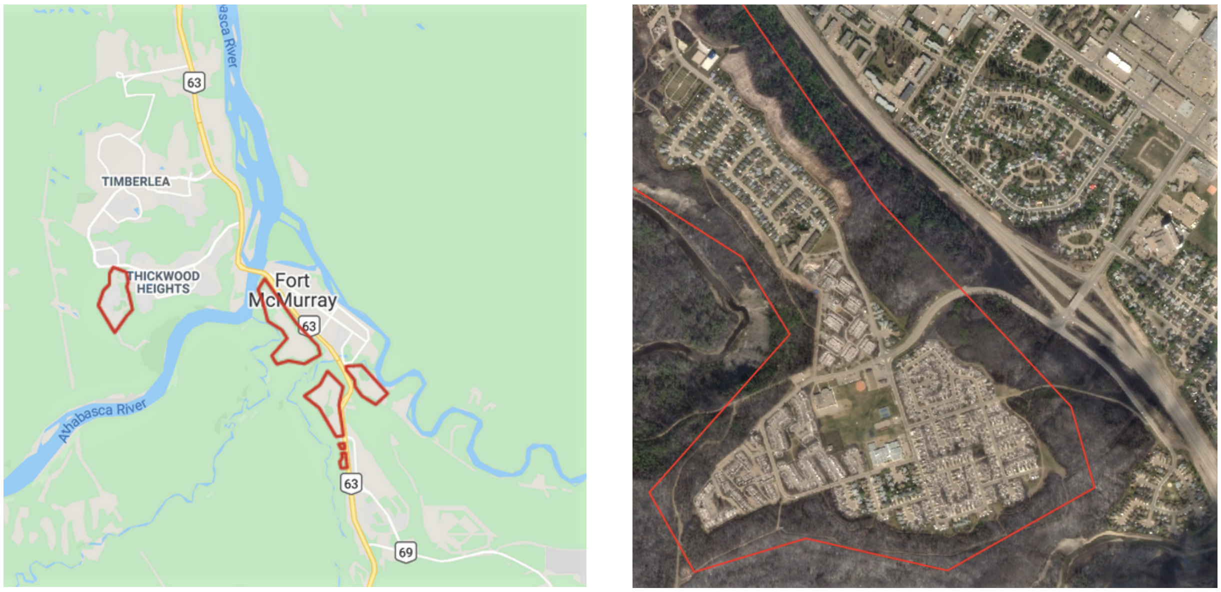


The wildfire damage in Fort McMurray was uneven. The neighborhoods of Abasand Heights, Beacon Hill, and Waterways were severely burned and declared unsafe for reoccupation. Significant damage was also reported in the neighborhood of Wood Buffalo Estate and Saprae Creek, according to the satellite imaging provided by Google Crisis Map (2016). The locations of severely damaged neighborhoods in Figure 2a. To illustrate the dramatic difference in the extent of wildfire damage, Figure 2b signifies the Abasand Heights area that was completely burned down (gray area in the lower half of the red-line bounded region) contrasted against the adjacent Lower Townsite neighborhood (top right corner), which remained intact.

The magnitude of wildfires and evacuations led to a slowdown in oil production in the third quarter of 2016, causing significant losses in oil extraction operations. However, given the minimal amount of damage sustained by oil sand facilities, the impact on production in the region was short-lived, with a rapid rebound in the number of barrels produced beginning in August (CER, 2017). Hence, for most people living in Fort McMurray, the disruption in employment income from oil extraction was only temporary.

Figure 2: 2016 Fort McMurray Wildfires

(a) Map of areas with severe damage (b) Satellite image of Abasand Heights



Note: Severely damaged neighborhoods are marked by red boundaries in Panel 2a, which include Abasand Heights, Beacon Hill, Waterways, and Wood Buffalo Estate (Saprae Creek is excluded for scaling purpose). Panel 2b contains the extent of damages in Abasand Heights in the lower part of the red-line bounded area. Source: Google Crisis Map (2016).

The government of Alberta provided direct financial help to affected residents, with $1,250 per adult and $500 per child in the household. Similarly, the Canadian Red Cross provided affected individuals with $600 per adult and $300 per child financial support. Some energy companies extended lump-sum payments or interest-free loans to their employees, while banks offered payment deferrals on loans for up to four months, relief on fees, and flexible credit arrangements.[4]

3 Data and Stylized Facts

We use consumer credit data spanning January 2014 to December 2017 provided by TransUnion®, a major consumer credit reporting agency in Canada.[5] The dataset contains anonymized account-level information on a monthly frequency for various loan types, including outstanding balances, loan performance history, consumers' credit scores, their ages,

[4]Refer to Government of Canada Fort McMurray disaster relief website and Government of Alberta's Fort McMurray and the Wood Buffalo Region wildfire recovery website.

[5]TransUnion® and Equifax® are the two major credit bureaus in Canada. We acquired access to TransUnion®data through the Bank of Canada. Refer to Appendix A in Ho et al. (2022) for TransUnion's data coverage.

and the encrypted postal code of their primary residence.[6] It covers major loan types, including mortgages, home equity lines of credit (helocs), credit cards, auto loans, as well as other lines of credit and installment loans.

While constructing our sample, we drop accounts that have not been updated for 90 days (one quarter) or have missing information on the outstanding balance. The outcome variable of interest is the loan amount in arrears, defined as a loan that is 90 or more days past the payment due day. This definition is commonly employed in the finance industry to measure delinquency severity. Insured mortgages are covered under mortgage insurance.[7] We use credit card utilization, defined as the outstanding balance as a percentage of the total credit limit, as a proxy measure for an individual's liquidity.

Outstanding loan balances are aggregated by geographic area. Fort McMurray is divided into two separate treated regions, *severely damaged areas* and *other areas*, based on the extent of wildfire damage observed in Figure 2.[8][9] Potential control regions are divided by Forward Sortation Area (FSA), that is, the first three digits of the postal code.[10] Our potential control units include all FSAs in the provinces of Alberta and Saskatchewan, which are located at least 100 km away from Fort McMurray to avoid any potential spillover effects to the surrounding areas. We also exclude FSAs in rural areas and FSAs with fewer than 5,000 credit-active residents from our sample.

The descriptive statistics for the dataset are presented in Table 1. On average, there were 60,082 credit- active individuals living in Fort McMurray, with 6,559 residing in areas with severe damage. The potential control set contained 126 FSAs with an average credit-active population of 21,949 individuals. Insured mortgages in Fort McMurray have, on average, \$450,000 in outstanding balance, which is higher than that of other control areas. The

[6]For privacy protection, postal codes are encrypted in a way that we only observe the first three digits, known as the Forward Sortation Area (FSA). The last three digits, known as the local delivery units , are encrypted and replaced by a unique identifier.

[7]The data set does not contain information on whether mortgage insurance is obtained through transactional insurance or portfolio insurance. Refer to Appendix A for more details on mortgage insurance in Canada.

[8]Neighborhoods severely damaged include Abasand Heights, Beacon Hill, Waterways, Wood Buffalo Estate, and Saprae Creek. We use *postal codes* to identify these neighborhoods as severely damaged areas. This granular geographical categorization alleviates the issue of the impacts' scale within the treated areas because an urban postal code in Canada is a very small area (usually a block on a street) that contains about 20 adult individuals on average.

[9]Alternatively, the intensity of damage caused by wildfires can be proxied by fire radiative power (Bowman et al., 2017; Tedim et al., 2018; Paudel, 2021a) because it is strongly correlated with fireline intensity (Johnston et al., 2017), biomass burned (Kumar et al., 2011), and the behavior of spreading flame (Kremens et al., 2012).

[10]Notably, there are only three FSAs in Fort McMurray (T9H, T9J, T9K). As the damage caused by the wildfire, as shown in Figure 2, is not limited to, or evenly distributed across, specific FSAs, using them as geographic units for the treated regions cannot provide precise categorization for the severely damaged areas.

Table 1: Descriptive Statistics from January 2014 to December 2017

	Fort McMurray		Other control FSAs	
	Severely damaged	Other areas	Mean	SD
N_{ind}	6,559	53,523	21,949	11,051
Mortgage	$ 448,559	$ 457,434	$ 251,391	$ 43,923
% mortgage insured	73.7%	77.8%	65.2%	8.0%
Credit Card Utilization	34.8%	33.8%	29.5%	4.2%
% of near-prime	20.8%	20.5%	16.9%	3.7%
% of suprime	6.1%	6.0%	5.8%	1.9%

Note: The severely damaged areas in Fort McMurray are categorized by observed damages in Figure 2. Other areas in Fort McMurray contain the remaining areas within the city limit. For control units, there are 126 other FSAs in Alberta and Saskatchewan included in the sample.

fraction of mortgages insured in Fort McMurray is also higher than that of other FSAs. However, the ratio of insured mortgages in Fort McMurray is generally consistent with a CMHC (2019) report, which showed that 57% of outstanding mortgages were insured in the first quarter of 2015.[11] Moreover, our stylized facts also show that residents of Fort McMurray have higher credit card utilization, and a larger fraction of them have below-prime credit scores.

The arrears rate of mortgages in Fort McMurray is illustrated in Figure 3. Arrears in neighborhoods with severe damage stood at 0.59% in the month before the wildfire and increased to over 0.90% by October 2016, as shown in Panel 3a. The arrears peaked at 1.16% and began to fall in May 2017, reaching approximately 0.8%. This observation is in stark contrast to areas with limited damage (Panel 3b), where a spike in arrears was not observed. Here, the arrears rate was at a similar level to heavily damaged areas prior to the wildfires (0.67%) and remained roughly constant until the end of 2017.[12] Additionally, Figure 3 shows that the arrears of insured mortgages are only slightly above those of all mortgages, suggesting that the loan portfolios of insured and non-insured mortgages may not be very different.

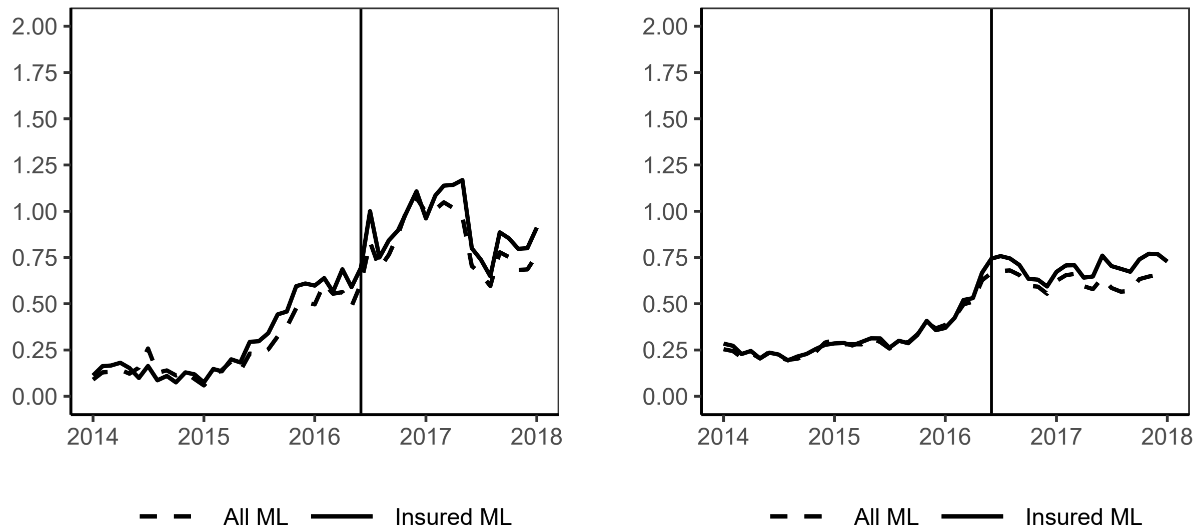
Our empirical findings suggest that wildfires may have induced financial distress in individuals who suffered property damages, which can have important implications for the

[11] Refer to Appendix A for details about the Canadian mortgage insurance market.

[12] While new mortgage loans in Fort McMurray may have been delayed due to the wildfire, we do not have a separate treatment for new mortgage loans because mortgage origination is an infrequent event (see Appendix A). New mortgage loans originate when there is a property transaction or when mortgage holders refinance their loans. In either case, the mortgage inflow and outflow will offset each other; hence, the remaining net flow of loans will be small relative to the outstanding balances. Indeed, the total outstanding loan balances in Fort McMurray continued to shrink after the wildfires.

Figure 3: Mortgage loan arrears in Fort McMurray

(a) Severely damaged areas (b) Other areas



Note: The solid line refers to the arrears rate of insured mortgages (insured ML) while the dashed line represents the arrears rate of all mortgages (all ML). Arrears rates are reported in percentage points, and the vertical black line indicates the first period affected by the wildfire, i.e., May 2016.

management practices of insurance companies and mortgage insurers. However, it is also crucial to note that the arrears rates illustrate significant upward pre-treatment trends due to 2014–15 oil price shock. The price of Western Canada Select (WCS) sharply plummeted from US$ 86.56 per barrel in June 2014 to US$ 17.88 in January 2016, before slowly recovering to US$ 44.02/barrel in December 2017. For Fort McMurray, whose economy is dependent on oil sands, the price of oil can be an important confounding factor, modeled below through the introduction of a common factor model.[13] In Section 4, we outline how the SCM is utilized to construct a data-driven control unit that accounts for confounding factors.

4 Empirical Method

We estimated the treatment effect of wildfires using the SCM developed by Abadie et al. (2010). SCM provides a transparent and data-driven method for selecting control units for comparison, which is particularly useful for our analysis given the uniqueness of Fort McMurray's geographical location and its dependence on the natural resource industry. Generally,

[13] The negative impact of oil price decline is discussed in TransUnion (2015).

SCM uses pretreatment observations to construct a hypothetical (synthetic) unit that jointly matches the treatment unit's characteristics and the outcome of interest. The synthetic unit is then used as a control and compared with the actual outcome to estimate the treatment effect. For brevity, we only outline the general estimation model and our econometric application in this section; interested readers are referred to Abadie et al. (2010) for details.

Suppose we observe $j = 1, \ldots, J+1$ regions for $t = 1, \ldots, T$ time periods. We denote T_0 as the number of pretreatment periods, with $1 < T_0 \leq T$ and i as the region being treated. Let Y_{it} be the treatment outcome in region i at an observable time t, and let Y_{it}^N be the outcome in the absence of the treatment, which we can never observe. We define the treatment effect as $\alpha_{it} = Y_{it} - Y_{it}^N$ in the post-treatment period $t = T_0 + 1, \ldots, T$. We estimate Y_{it}^N by assuming it is given by a factor model:

$$Y_{it}^N = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \epsilon_{it}, \tag{1}$$

where δ_t is an unknown common factor, Z_i is a vector of observed exogenous covariates with parameter θ_t, λ_t is a vector of unobserved factors with unknown factor loading μ_i, and ϵ_{it} are unobserved shocks with zero mean.

We define a vector of weights $W = (w_1, \ldots, w_{j\neq i}, \ldots, w_J)'$ for the set of control units, such that $w_j \geq 0$ for all $j \neq i$ and $\sum_{j\neq i}^{J+1} w_j = 1$. This vector is utilized to compute the weighted average of the control units, which serves as a synthetic control for the treated region i. Hence, the outcome variable for synthetic control is

$$\sum_{i\neq j}^{J+1} w_j Y_{jt} = \delta_t + \theta_t \sum_{i\neq j}^{J+1} w_j Z_j + \lambda_t \sum_{i\neq j}^{J+1} w_j \mu_j + \sum_{i\neq j}^{J+1} w_j \epsilon_{jt}. \tag{2}$$

The optimal weights $W^* = (w_1^*, \ldots, w_{j\neq i}^*, \ldots, w_J^*)'$ are chosen such that:

$$\sum_{j\neq i}^{J+1} w_j^* Y_{jt} = Y_{it}, \;\; \sum_{j\neq i}^{J+1} w_j^* Z_j = Z_i, \;\; \text{and} \;\; \sum_{j\neq i}^{J+1} w_j^* \mu_j = \mu_i \text{ for all } t = 1, \ldots, T. \tag{3}$$

We show that a synthetic control that can fit the observed covariates (Z_i) and a long series of pretreatment outcomes (Y_{it}) is a sufficient condition for fitting the unobserved confounders (μ_i), providing an unbiased estimate of Y_{it}^N. The difference between the observed outcome and the synthetic control is specified as an estimator of the treatment effect α_{it}. We denote the estimator by $\widehat{\alpha}_{it}$,

$$\widehat{\alpha}_{it} = Y_{it} - \sum_{j\neq i}^{J+1} w_j^* Y_{jt} \tag{4}$$

for treatment period $t = T_0 + 1, \dots, T$.

To account for the time-varying effect of unobserved factors, linear combinations of pre-treatment outcomes, such as annual average values, can also be included in a region's characteristics. There can be at most $M \leq T_0$ linearly independent combinations of pretreatment outcomes, denoted by $\bar{Y}_i^1, \dots, \bar{Y}_i^M$. Let $X_i = (Z_i', \bar{Y}_i^{K_1}, \dots, \bar{Y}_i^{K_M})'$ be a vector of pretreatment characteristics of the treated region i, and X_0 be a matrix of the same characteristics in the control region with the jth row representing region j. The SCM estimator is implemented by choosing W^* that minimizes the distance between the observed and synthetic units, measured by

$$||X_i - X_0W||_V = \sqrt{(X_i - X_0W)'V(X_i - X_0W)} \tag{5}$$

where V is a diagonal matrix of the parameters for the distance measure. The optimal V^* is chosen to minimize the mean squared prediction error (MSPE) of the outcome variable between the treated and synthetic controls over the pre-treatment periods. Put differently, we find V^* that solves

$$\min_V (Y_i - Y_0W^*(V))'(Y_i - Y_0W^*(V)), \tag{6}$$

where $W^*(V)$ is the optimal weight given V.

In our empirical application, the outcome of interest is the arrears rate of insured mortgages in Fort McMurray and the rest of Alberta and Saskatchewan. Our predictors (Z_i) of loan arrears include the quarterly averaged fraction of insured mortgage holders who have (1) credit card utilization between 60 and 80%, (2) credit card utilization at least 80%, (3) near-prime credit scores, and (4) subprime credit scores. We also included the average log values of the outstanding mortgage balance from January 2014 to April 2016. The predictor variables are augmented by the quarterly averaged mortgage arrears rate to formulate our set of regional characteristics (X_i).

5 Results

The results of our synthetic analysis of the Fort McMurray wildfire are reported in Table 2. It shows a comparison between the observed characteristics (X_i) and synthetic characteristics (X_0W^*) in the first quarter of 2016. In general, our synthetic units matched well with the observed units. footnoteThe quarterly characteristics also match up in other quarters. Additional results are available upon request. This provides empirical support that the selected set of potential control regions is sufficient to imitate the Fort McMurray regional

Table 2: Characteristics of Fort McMurray: observed vs. synthetic

	FM – severely damaged		FM – other areas		
Variables	Observed	Synthetic	Observed	Synthetic	Controls
log of insured ML	13.00	12.28	13.03	12.45	12.41
Utilization 60% – 80%	9.11	8.89	8.38	8.54	7.21
Utilization $\geq$ 80%	21.69	21.01	19.51	19.67	15.04
% near prime holders	22.27	21.31	20.53	20.76	17.10
% subprime holders	6.59	7.54	6.56	6.69	5.88
Arrears rate	0.63	0.61	0.49	0.48	0.32

Note: Log of insured ML refers to the averaged log values of the outstanding balances in insured mortgages from January 2014 and April 2016. All other values are the average in the first quarter of 2016, expressed in percentage points.

economy.[14] The average of all the potential control FSAs is reported in the last column of the table. Our results show that we can use the set of controls to construct a synthetic unit that reflects the higher liquidity risk in Fort McMurray before the disaster: higher credit card utilization, a larger fraction of below-prime borrowers, and higher arrear rates in insured mortgages.

The synthetic controls' composition is displayed in Table 3. The top five heaviest weighted control FSAs accounted for 100% and 79.6% of the total weights for the synthetic severely damaged and other areas, respectively. The synthetic unit for the severely damaged areas in Fort McMurray is similar to North Battleford, an energy sector-dependent city with a comparable population size in a neighboring province. Homeownership rates are similar in both cities, with approximately 63% to 67% of the residents owning their homes. The synthetic units for the severely damaged areas and the other areas also share several common donors such as Whitecourt, Cold Lake, and Grande Prairie East. However, the synthetic unit for other areas in Fort McMurray has more diverse weights and is more similar to other places with more diversified local economies. This difference is reflected in the steeper increase in mortgage arrears in severely damaged areas between 2015 and 2016 in Figure 3. The estimated weights also show that the synthetic units are comprised of FSAs far away from Fort McMurray, suggesting that the local spillover effect from wildfires is likely to be minimal.

The time series of arrears for the actual and synthetic units are shown in Figure 4. As expected, the arrear rates of the synthetic units closely resemble the observed paths

[14] Technically, it means the treated unit is a convex combination of the control units, given the restriction of non-negative weights in the vector W.

Table 3: Top five FSA weights in the synthetic Fort McMurray

Severely damaged			Other areas		
Weight	FSA	Name	Weight	FSA	Name
0.269	S9A	North Battleford	0.172	T9M	Cold Lake
0.259	T4H	Olds	0.167	T8X	Grande Prairie East
0.232	T7S	Whitecourt	0.164	T7S	Whitecourt
0.146	T8X	Grande Prairie East	0.162	S4A	Estevan
0.095	T9M	Cold Lake	0.131	T3M	Calgary-Auburn Bay-Mahogany

Note: FSAs starting with letter "T" refer to areas in Alberta, and FSAs starting with letter "S" refer to areas in Saskatchewan.

of arrears in Fort McMurray before the wildfire. We focus on a post-treatment period of only one year to avoid picking up any confounding effect that could bias the results. For instance, any natural disaster event following the 2016 Fort McMurray Wildfire affecting any of our positively weighted FSAs in Table 3 could lead to a downward bias in our estimates. However, we note that no substantial events occurred in these areas in 2017.[15]

For severely damaged areas (Panel 4a), arrears in the synthetic unit slightly decreased from May 2016 to June 2017 before increasing again in the second half of 2017.[16] This pattern roughly mirrors the overall mortgage arrears in Alberta and Saskatchewan, wherein mortgage arrears stabilized after the WCS oil price recovery and was maintained at about US$40 per barrel. Arrears in the synthetic control for other areas of Fort McMurray show a similar pattern, as illustrated in Panel 4b. Although the synthetic units have different compositions, they present similar levels of arrears, approximately 0.6% in April 2016, before the wildfires.

The wildfire's effect, measured by the differences between the actual and synthetic arrears, is shown in Figure 5. The 90% confidence set is also included in the figure, which is calculated following Firpo and Possebom (2018) and Ferman et al. (2020).[17] For severely damaged areas (Panel 5a), wildfires increased mortgage arrears gradually by 0.5% before the end of 2016.[18]

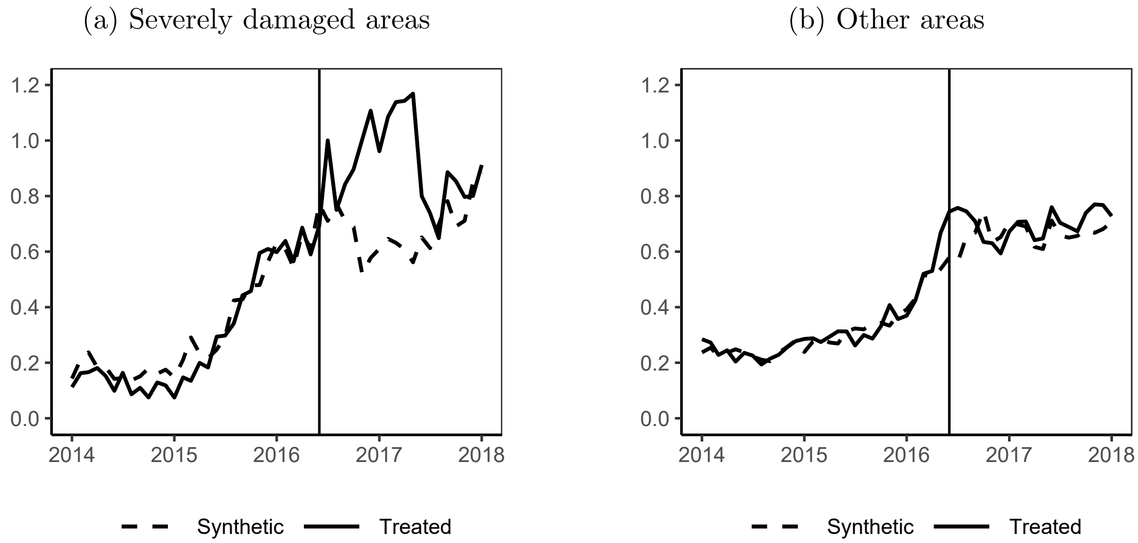
[15] We cross-reference the Canadian Disaster Database, which compiles all of the natural disasters that have occurred in Canada since 1900, and do not find any significant event affecting our positively-weighted control FSAs.

[16] In our robustness check, this pattern is robust to our model specifications.

[17] These methods assume random sampling, so they are conservative. Clustered-robust counterpart formulae are not available at this time.

[18] Arrears increased sooner than 90 days after payment deferrals expired, i.e. 7 months after the wildfire, because the length of delinquency depends on whether borrowers resumed their agreed repayments *after* their payment deferrals. Specifically, if borrowers failed to make their agreed repayments after their deferrals expired, the whole period of deferral would be counted as missed payments.

Figure 4: Paths of actual and synthetic mortgage arrears



Note: The solid line is the observed arrears rate in the treated area. The dashed line is the arrears rate in the synthetic unit. The arrears rate is reported in percentage points, and the vertical black line indicates the first period affected by the wildfire, that is, May 2016.

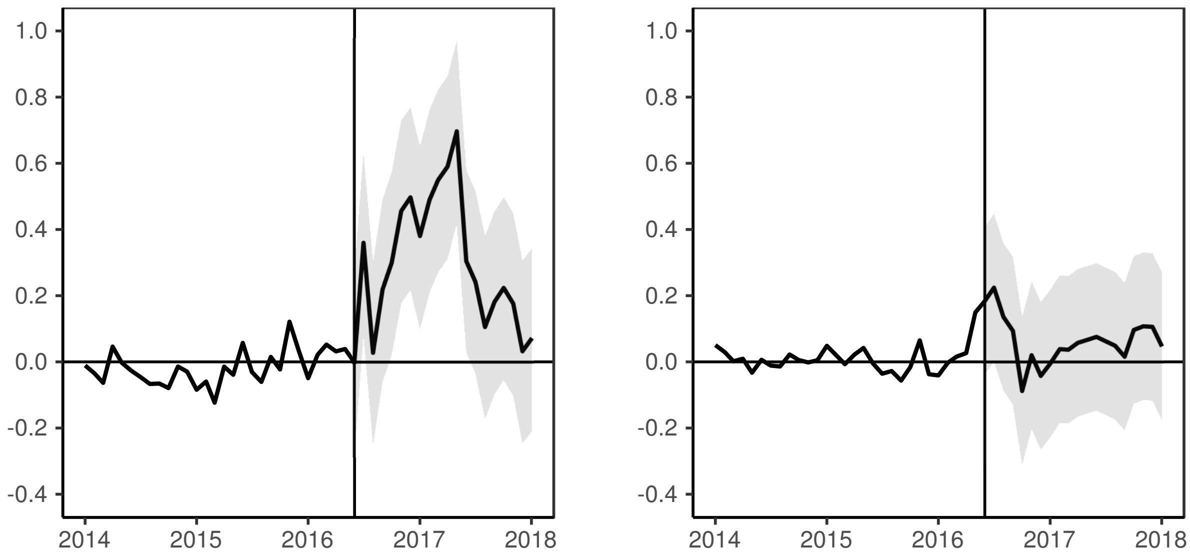
The effect peaked in May 2017 with the level of the arrears increasing by 0.7%. Putting this number into context, mortgage arrears in Alberta during the 2008-2010 Great Recession rose by 0.67%, from 0.17% in January 2007 to 0.84% in January 2011. In terms of severity, our estimates show that the financial distress of affected individuals devastated by wildfires is comparable to that of the Great Recession, although the events are of different scales. This wildfire effect subsided substantially and became statistically insignificant starting in June 2017, 12 months after the disaster. The entire wildfire effect had almost dissipated by the end of 2017.

To shed further light on the movements of the arrears rate, changes in the aggregate stock of outstanding mortgages and their arrears are reported in Figure 6a. Values are normalized to one in May 2016 for illustrative purposes. In the first six months after the wildfires, that is, in the second half of 2016, the rising stock of arrears is the main driver of the arrears rate. The sustained stock of arrears and decreasing stock of outstanding mortgages, as residents left Fort McMurray due to adverse economic situations, contributes to the continued increase in the arrears' rate in 2017. The subsequent decrease in the arrears rate is not attributed to delinquent loans exiting the stock through a higher number of foreclosures and write-offs, nor is it attributed to a pent-up demand for new mortgages when the economy recovers from wildfires.[19] Instead, our results suggest that the paying off of delinquent mortgages is the

[19] Our data shows that mortgage write-offs remained stable at very low levels throughout the sample

Figure 5: Gap between actual and synthetic mortgage arrears

(a) Severely damaged areas (b) Other areas



Note: The solid line refers to the point estimate of the treatment effect. The shaded area represents the 90% confidence set. The arrears rate (gap) is reported in percentage points, and the vertical black line indicates the first period affected by the wildfires, that is, May 2016. The 90% confidence set is calculated via the method proposed by Firpo and Possebom (2018) and Ferman et al. (2020)

reason why the arrears rate drops.

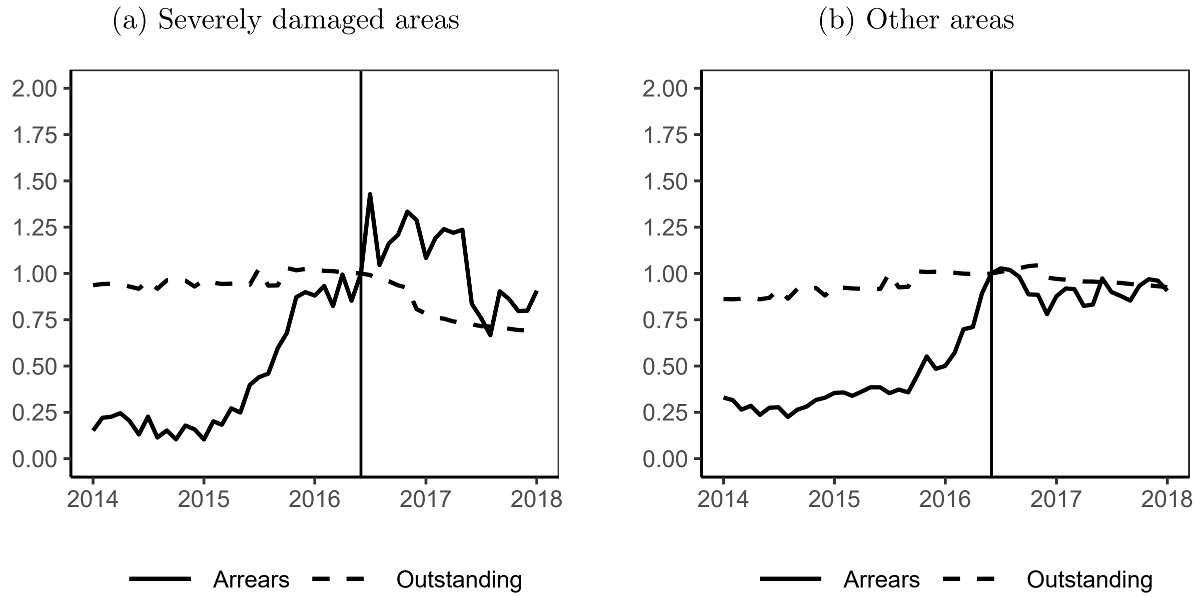
For other areas in Fort McMurray that are less impacted by fires, we only find minor and statistically insignificant effects on mortgage arrears (Figure 5b). The point estimate of the wildfire effect suggests a 0.2% increase in arrears immediately after wildfires, which disappears only three months after the incident. Our results suggest that the wildfire effect, if any, on individuals who do not experience severe property losses is short-lived. This lack of effect is because wildfire-induced income loss is temporary, given the rapid rebound in oil production in August 2016.[20] Changes in the aggregate stock of mortgages (Figure 6b) further suggest that both the outstanding balances and the total amount of arrears have remained stable after the wildfires, thereby limiting the secondary effects of wildfires.

Several factors can explain the pattern of treatment effects in severely damaged areas. While most damaged residential properties are covered by fire insurance, insurance policies in most cases do not cover mortgage payments on damaged properties. The required mortgage payments and additional living expenses for dislocated individuals can be a potential source

periods.

[20]Considering that Fort McMurray is a remote mono-product local economy heavily relying on oil extraction, which was disrupted but resumed soon after the wildfire, the local spillover effect from the severely damaged area to other areas is limited.

Figure 6: Total outstanding balances and arrears (May 2016 = 1.0)



Note: The solid line refers to the total amount of arrears in insured mortgages whereas the dashed line point represents the total outstanding balances. The vertical black line indicates the first period affected by the wildfires, that is, May 2016. Dollar values are normalized to 1.0 in May 2016.

of financial stress. Such a financial burden may be further aggravated by the prolonged period of time required for insurance settlements due to the sheer number of claims.[21] This situation is illustrated by the timing of the impacts: the treatment effect becomes significant in the fourth quarter of 2016, which coincides with the ending of (up to four -month) loan payment deferrals offered by financial institutions.[22] So far, our analysis on the 2016 Fort McMurray Wildfire show that the increase in mortgage arrears are temporal and transitional. To further shed light on consumers' financial distress, we also estimated the treatment effect on credit card outstanding balances and credit scores of insured mortgage holders. Our results also suggest that the negative treatment effect on credit card balances and credit scores are temporal. Detailed results are reported in Appendix C.

Our findings offer an insightful comparison with Gallagher and Hartley's (2017) study on the impacts of Hurricane Katrina by providing further evidence that the timing of delin-

[21] According to the Insurance Bureau of Canada and the provincial government, there were over 60,000 insurance claims resulting from the wildfires, of which 25,498 were residential claims.

[22] Arrears increased sooner than 90 days after the expiry of the deferrals, or seven months after the wildfires because the length of delinquency depends on whether borrowers resumed their agreed repayments *after* their payment deferrals. Specifically, if borrowers fail to make their agreed repayments after their deferrals expire, the whole period of deferral will be counted as missed payments.

quency changes is closely linked to the length of loan deferral or forbearance.[23] The wildfire effect in Fort McMurray is also more persistent, suggesting there may exist an interaction between the length of deferral or forbearance and the duration of financial stress. Furthermore, the distinct pattern of damage in Fort McMurray also provides evidence that financial distress is mostly due to direct physical damage to properties.[24] This notion implies that disaster relief provided by various entities, such as direct financial subsidies and loan deferrals, may be sufficient for those who suffer from temporary loss of income, but may not be enough for the most severely affected individuals.

In terms of financial systemic risk, our findings shed light on the importance of incorporating climate-change liability risk and its uncertainty into financial stability analyses. The financial impact of natural disasters, which are more frequent and severe due to climate change, may propagate through financial linkages between stakeholders. For instance, the risk management and practices of property and casualty insurers can affect insurance settlements, which, in turn, may induce financial stress that impairs consumers' ability to repay their loans extended by other financial institutions. In the case of mortgage lending, an increase in delinquency and defaults due to climate-related events can potentially increase the risk of mortgage insurers and investors of mortgage-backed securities if the risk of these events is not fully accounted for. Notably, policymakers can reduce the impact of natural disasters on the financial system through disaster prevention and relief programs.[25]

This study highlights the importance of the physical risk associated with climate change. Wildfire is the second-largest natural disaster risk in Canada (Ibrahim, 2016), which has become increasingly common (Mamuji and Rozdilsky, 2018), and our estimates are informative for other areas damaged by or under the threat of wildfire.[26] Due to severe damage and extensive media attention, affected individuals in the 2016 Fort McMurray Wildfire may have received more assistance, potentially lessening the disaster's impact on financial distress compared to individuals suffering from other small-scale disasters (Edmiston, 2017; Issler et al., 2019). Our findings are also valid for the ongoing concerns of climate risk because insurance coverage improves recovery outcomes but only has a modest impact on risk reduction (Kousky, 2019). Income and level of economic development in Canada also have a role

[23] Gallagher and Hartley (2017) observe a similar delayed effect in delinquency due to 12-month loan forbearance provided by financial institutions in the U.S.

[24] Gallagher and Hartley (2017) find a significant effect on mortgage delinquency in both the most and the least flooded quartiles.

[25] The optimal design of policy and risk management tools is a complex issue beyond the scope of this study. Interested readers are referred to Lewis and Nickerson (1989) and Husted and Nickerson (2019), among others, for discussions on public policy design.

[26] According to the Government of Canada, about 8,000 wildfires occur each year in Canada, among which 55% are human-caused.

in mitigating disaster risk (Kellenberg and Mobarak, 2008). Natural disasters in developing countries are generally characterized by more fatalities and uninsured losses (Linnerooth-Bayer et al., 2011), suggesting that financial distress induced by natural disasters is likely to be higher in lower-income countries.

6 Conclusion

Using anonymized consumer credit data, we quantify the 2016 Fort McMurray Wildfire's financial stress on the affected mortgage holders. This distinct pattern of damage sheds light on the potential outcome of exposure to physical risks. We find that areas severely damaged by wildfire had significantly more mortgage arrears. The transitional pattern of arrears suggests that insurance settlements, debt forbearance measures, and government assistance programs may have played important roles in reducing and postponing financial stress. For other areas with limited damage, the increase in arrears is small and statistically insignificant.

Our results suggest that climate risk may have important spillover effects between insurers, financial institutions, and policymakers. While home insurers' exposure to physical risks is apparent, their practices, interacting with those of mortgage lenders, may reduce or aggravate affected individuals' financial stress. In turn, financial stress may translate into inferior loan performance and increase mortgage insurers' business risk. The extent of government assistance also has a role in consumers' financial stress levels. This issue is complex and can be loosely viewed as a risk of liability for stakeholders. It is not surprising that Central banks and policy institutions have started and continue to measure the many physical risks in order to understand the interplay with financial risks, see Duprey et al. (2021).

Natural disasters also raise awareness about the transitional risks of climate change. In Fort McMurray's case, the Regional Municipality of Wood Buffalo (RMWB) secured $14 million in FireSmart for fire mitigation. They also launched a "Build Back Better" campaign to promote the use of fire-resilient materials. However, KPMG's (2017) independent review, commissioned by the Alberta Emergency Management Agency, suggests that this intervention is unlikely to happen because insurance payments were only available to rebuild properties to *pre-fire* conditions. In this regard, recent work by Ouazad and Kahn (2019) finds that financial institutes in the U.S. adjust their decisions on mortgage securitization in response to climate risks. It is also important to investigate whether mortgages and home insurance pricing adjust following a natural disaster and whether such adjustments affect consumers' decisions. We leave the examination of this notion to future research.

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Online Appendices

A Primer on the Canadian mortgage insurance market

This section explores the impact of a large wildfire on mortgages that are portfolio or transactionally insured. We focus on insured mortgages because insurance has a key role in Canada as it allows lenders to access cost-effective funding, which, in turn, enables borrowers to access homeownership through reliable funding sources that are not subject to economic cycles (Mordel and Stephens, 2015). There are two types of mortgage insurance: (1) transactional insurance and (2) portfolio insurance. While the credit bureau data used in our study allows us to determine whether a loan is insured, it does not enable us to distinguish the type of insurance on the loan. Despite this limitation, we provide a brief description of mortgage insurance in this appendix.

In Canada, federally regulated lenders and many provincially regulated financial institutions are required to insure mortgages with a down payment of less than 20% of the purchase price through transactional insurance (Crawford et al., 2013). Such loans are commonly referred to as high-ratio mortgages. This insurance type, purchased by the borrower, protects the lender if the borrower defaults on the mortgage loan.

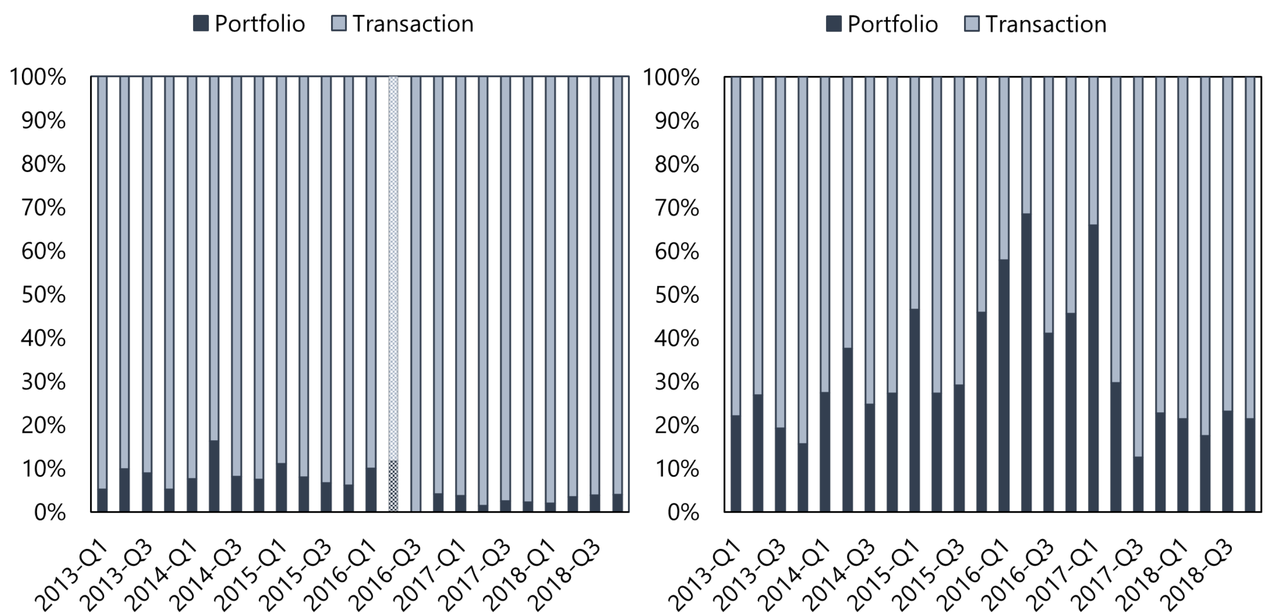
However, mortgages with down payments of greater than 20% can also be insured. These low-ratio loans are commonly insured through portfolio insurance but can also be insured on a transactional basis. Insuring low-ratio mortgages allows lenders to reduce the repayment risk on mortgages, as well as securitize loans through the National Housing Act Mortgage-Backed Securities (NHA MBS) (Crawford et al., 2013). Along with the Canadian Mortgage Bond (CMB), the NHA MBS supports the public policy objectives of providing efficient functioning, competitiveness, and stability of housing finance in Canada (Mordel and Stephens, 2015).

Overall, three federally approved mortgage insurers exist in Canada: two private-label insurers, Sagen (formerly Genworth Canada) and Canada Guarantee, and the public insurer, Canada Mortgage and Housing Corporation (CMHC). Each receives an explicit government guarantee, which is activated if the insurer fails to honor its commitment to the mortgage lender. Being a crown corporation, CMHC mortgage insurance receives a 100% public guarantee, while the guarantee to private insurers is 90% (Mordel and Stephens, 2015). Both public and private insurers are subject to limits on the total value of the new guarantees. For CMHC, this limit is $600 billion, while for the private insurer, it is capped at $300 billion.

Historically, the share of newly originated mortgages that are portfolio-insured in Fort McMurray has been low (Figure A.1a). Between 2013 and the first quarter of 2016, portfolio-

Figure A.1: Share of newly originated mortgages that are portfolio and transaction insured

(a) Fort McMurray (b) All of Canada



Note: The chart shows the share of mortgages that are transaction or portfolio insured in the flow of newly originated mortgages. The shaded bar in chart (a) indicates the quarter wherein the wildfire started in Fort McMurray.

insured mortgages in Fort McMurray accounted for an average of 9% of new origination (Table A.1, column 1). This observation is in stark contrast to the 38% national average for newly originated mortgages (Figure A.1b).

However, in 2016, the Department of Finance, Office of the Superintended of Financial Institutions (OSFI), and CMHC implemented a series of policy changes aimed at managing housing market risk (CMHC, 2019). Among these were policies aimed at tightening mortgage qualification criteria to address what OSFI deemed "relaxed mortgage underwriting practices by lenders." The most notable of these is the "stress-test" introduced in October 2016, which required high-ratio borrowers to qualify at the higher of the mortgage contract rate or the Bank of Canada conventional five-year fixed posted rate (Bilyk and teNyenhuis, 2018).[27] Moreover, CMHC increases securitization guarantee fees for NHA MBS and CMB to promote the development of private market funding alternatives for low-ratio portfolio insurance (CMHC, 2019). These policies effectively contributed to a reduction in the number of mortgages originating, which coincided with the same period as the Fort McMurray wildfire (Table A.1, column 3). This aspect, combined with the fact that mortgage origina-

[27]OSFI expanded the stress-test to include low-ratio mortgages in January, 2018.

Table A.1: Mortgage origination by insurance type (average quarterly)

	2013 Q1 – 2016 Q1	2016 Q3 – 2018 Q4	Change
Fort McMurray	340	205	-39.7%
Portfolio	28	5	-82.1%
Transactional	312	200	-35.9%
Canada	102,890	74,420	-27.7%
Portfolio	39,498	24,908	-36.9%
Transactional	63,393	49,512	-21.9%

Source: Quarterly data on mortgage origination from CMHC and OSFI.

tions are relatively infrequent events, limits our ability to assess the impact of wildfires on originations.

B Sensitivity Test

In this appendix, we conduct two robustness tests outlined in Abadie (2021). In Appendix B.1, we conducted a backdating exercise to check the sensitivity of our results to different model specifications. In Appendix B.2, we conducted a leave-one-out analysis to examine if the treatment effect estimates are driven by certain donors in the synthetic units. Overall, the results from our robustness checks supports our original findings.

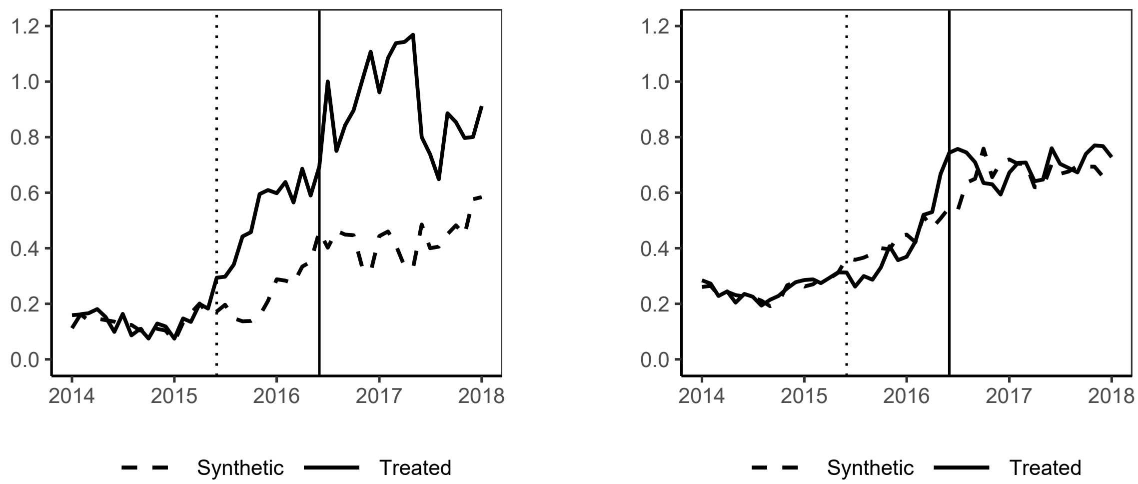
B.1 Backdating the Intervention

As a placebo study, we hypothetically backdated the wildfire to May 2015, which is 12 months before the actual occurrence of the event. This exercise evaluates the credibility of our results by examining whether a shorter pre-treatment period would produce a similar synthetic control estimator that captures the surge in mortgage arrears since 2015 because of the oil price crash, as observed in Figure 3. It also addresses the potential existence of anticipation effects in 2016 owing to a longer fire season and changes in the fire prevention budget.

Specifically, we excluded the pretreatment period from May 2015 to April 2016 in estimating the synthetic weights (W^*) in equation (5) and the relative importance of the predictors (V) in equation (6). As the benchmark estimation included quarterly averaged data as predictors, for consistency, we excluded the quarterly average for 2015 Q2–Q4 and 2016 Q1 from the model. We also exclude the period from May 2015 to April 2016 when calculating the average log values of the outstanding mortgage balance. The results are presented in Figure B.1.

Figure B.1: Paths of actual and synthetic mortgage arrears (Backdated)

(a) Severely damaged areas (b) Other areas



Note: The solid line is the observed arrears rate in the treated area. The dashed line is the arrears rate in the synthetic unit. The arrears rate is reported in percentage points. The vertical dotted line indicates the first period of the *backdated* intervention, that is, May 2015. The vertical solid line indicates the first period affected by the wildfire, that is, May 2016.

For severely damaged areas, we found that synthetic controls with backdated intervention produce *lower* levels of arrears, which implies larger treatment effects of wildfires. Although the backdated synthetic control estimator qualitatively shows a similar trend in mortgage arrears due to the oil price crash, this increase appeared only after 2016 and failed to reproduce the level of mortgage arrears between May 2015 and May 2016. These results suggest that including the pretreatment period from May 2015 to May 2016 (with a substantial increase in mortgage arrears) is essential for capturing the oil price effect on severely damaged areas.

In contrast, for the other areas in Fort McMurray, the backdated synthetic control estimator produced results very similar to the benchmark ones in Figure 4b. The different effects of backdating on severely damaged areas and other areas are attributed to the data-driven weights assigned by SCMs. In the benchmark estimation, the synthetic weights for the severely damaged areas are concentrated in five FSAs that heavily rely on the oil industry, while the synthetic weights for the other areas are spread across 13 FSAs with more diversified local economies.

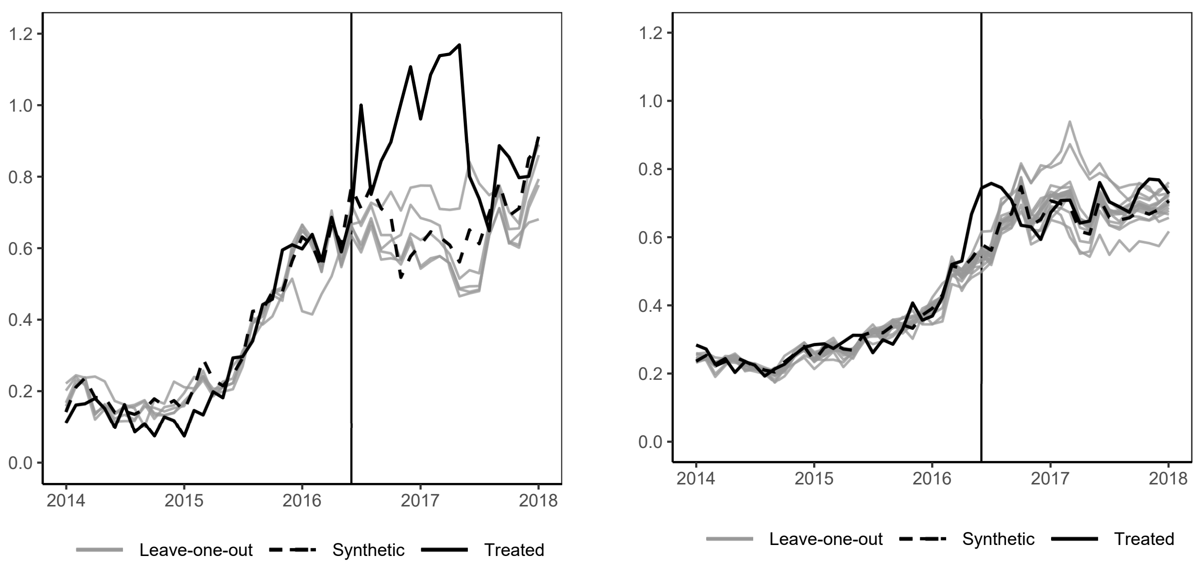
B.2 Leave-One-Out Analysis

We conduct a leave-one-out exercise as suggested by Abadie (2021). Specifically, we exclude from the sample each of the FSAs that contribute to the synthetic control in Table 5 one-at-a-time and then re-estimate the synthetic control estimator using the subsample. In all, we conduct five leave-one-out exercises for severely damaged areas and sixteen such exercises for other areas, each of which was estimated using a (different) subsample of the 125 FSAs. This leave-one-out exercise is similar to Abadie et al. (2015) in that we compare the leave-one-out estimates with the synthetic units for the severely damaged areas and the other areas. The results are presented in Figure B.2. Overall, these leave-one-out estimates track the original synthetic units and supports our original findings.

Figure B.2: Paths of actual and synthetic mortgage arrears (leave-one-out)

(a) Severely damaged areas

(b) Other areas



Note: The solid line is the observed arrears rate in the treated area. The dashed line is the arrears rate in the synthetic unit. The arrears rate is reported in percentage points, and the grey solid lines are the estimates from the leave-one-out synthetic units. The vertical solid black line indicates the first period affected by the wildfire, that is, May 2016.

C Analysis on Credit Scores and Credit Card Balances

In this appendix, we provide detailed treatment effect estimates for credit scores and credit card balances. Overall, our results indicate that the wildfire effects are temporal and transitional, as discussed in Section 5.

For credit card outstanding balances, we modified our model specification accordingly to include quarterly averaged fraction of insured mortgage holders who have (1) credit card utilization between 60 and 80%, (2) credit card utilization at least 80%, (3) near-prime credit scores, and (4) subprime credit scores. We also included the average log values of the outstanding credit card balance from January 2014 to April 2016. The predictor variables are augmented by the quarterly averaged credit card balances to formulate our set of regional characteristics (X_i) as predictors (Z_i).

Results for the synthetic units are reported in Figure C.1 and the treatment effect estimates are reported in C.2. In both the severely damaged and other areas, the credit card balances decreased temporarily after the wildfire. Compared to the other areas, the severely damaged areas show a larger and and more persistent decrease. The reduction in credit card balances was peaked at about $500 in the first quarter of 2017, which coincides with the rising mortgage arrears rate. These results are consistent with reduced consumption due to the income and the wealth effects in response to a negative shock.[28] However, the negative effects of the wildfire in both areas are not statistically significant at 15% level.

For consumer credit scores, we modified our model specification accordingly to include quarterly averaged fraction of insured mortgage holders who have (1) credit card utilization between 60 and 80%, (2) credit card utilization at least 80%, (3) near-prime credit scores, and (4) subprime credit scores. We also included the average log values of the outstanding insured mortgage balance from January 2014 to April 2016. The predictor variables are augmented by the quarterly averaged credit scores to formulate our set of regional characteristics (X_i) as predictors (Z_i).

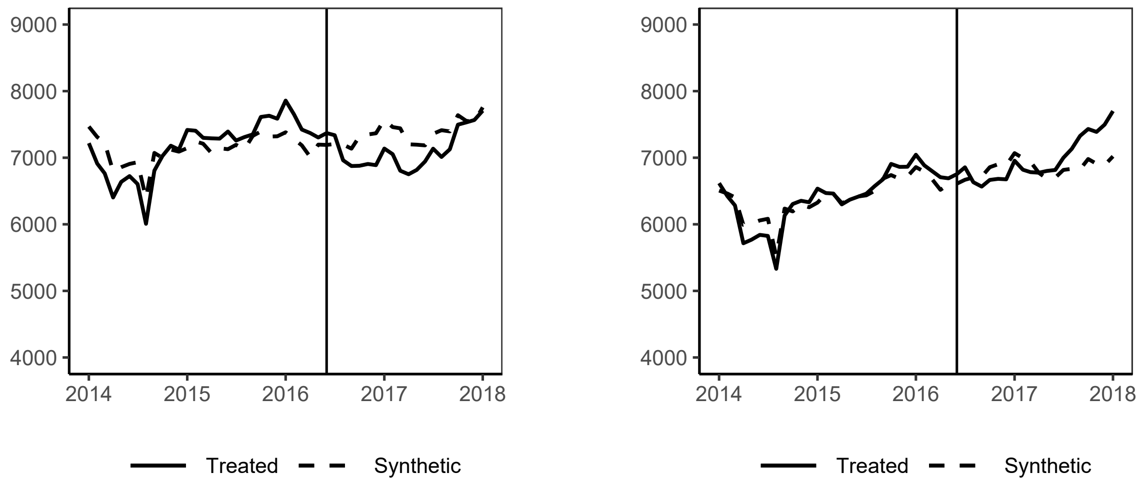
Results for the synthetic units are reported in Figure C.3 and the treatment effect estimates are reported in C.4. Both severely damaged and other areas both exhibit a statistically significant drop in credit scores immediately after the wildfire. However, the decrease was short-lived and economically insignificant (5 points decrease out of an average of about 765).[29] The average credit score for insured mortgage holders in the severely damaged areas statistically significant improved since 2017 as insurance claims being settled and homeowners emigrated from that area, while the average credit score in the other areas recovered around the same time and remained stable afterwards.

[28] Note that the outstanding balances also include both revolving balances and the interest charges.

[29] According to TransUnion®, a good credit score is within the range of 721–780.

Figure C.1: Paths of actual and synthetic credit card balances

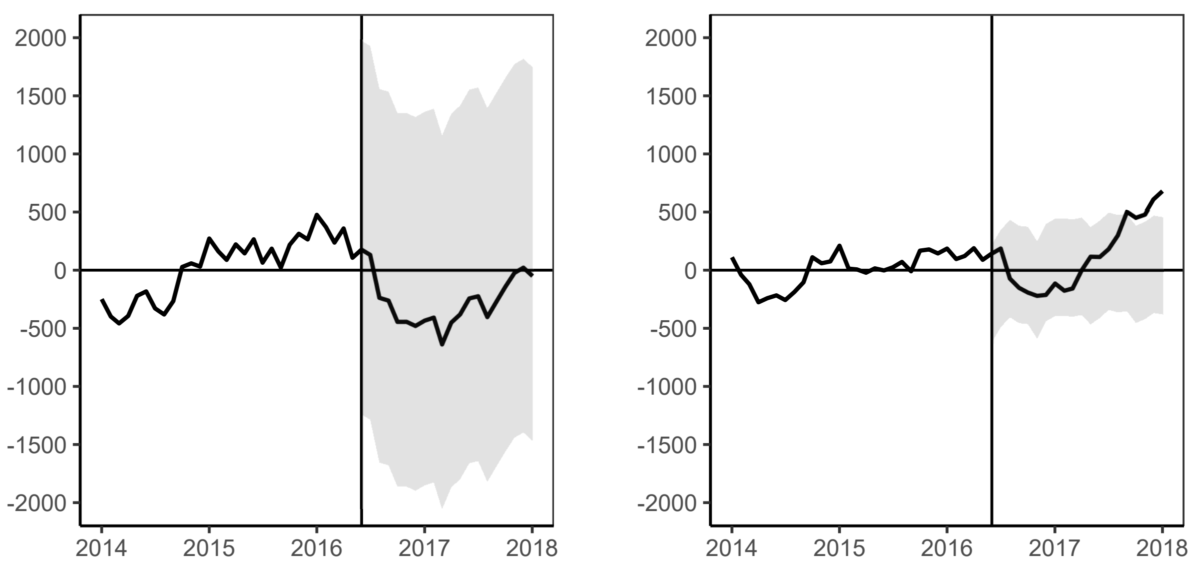
(a) Severely damaged areas (b) Other areas



Note: The solid line is the observed arrears rate in the treated area. The dashed line is the arrears rate in the synthetic unit. The arrears rate is reported in percentage points, and the vertical black line indicates the first period affected by the wildfire, that is, May 2016.

Figure C.2: Gap between actual and synthetic credit card balances

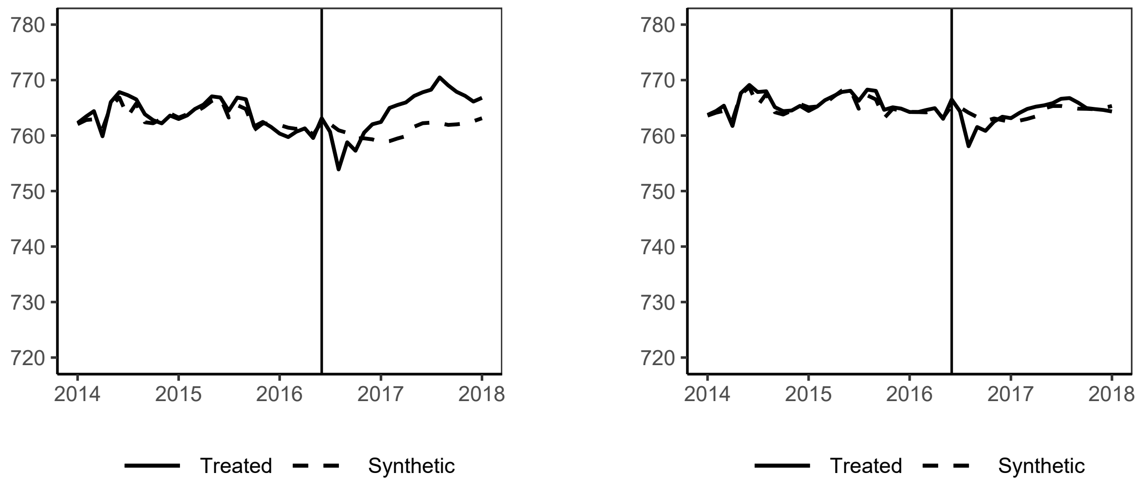
(a) Severely damaged areas (b) Other areas



Note: The solid line refers to the point estimate of the treatment effect. The shaded area represents the 90% confidence set. The arrears rate (gap) is reported in percentage points, and the vertical black line indicates the first period affected by the wildfires, that is, May 2016. The 90% confidence set is calculated via the method proposed by Firpo and Possebom (2018) and Ferman et al. (2020)

Figure C.3: Paths of actual and synthetic credit scores

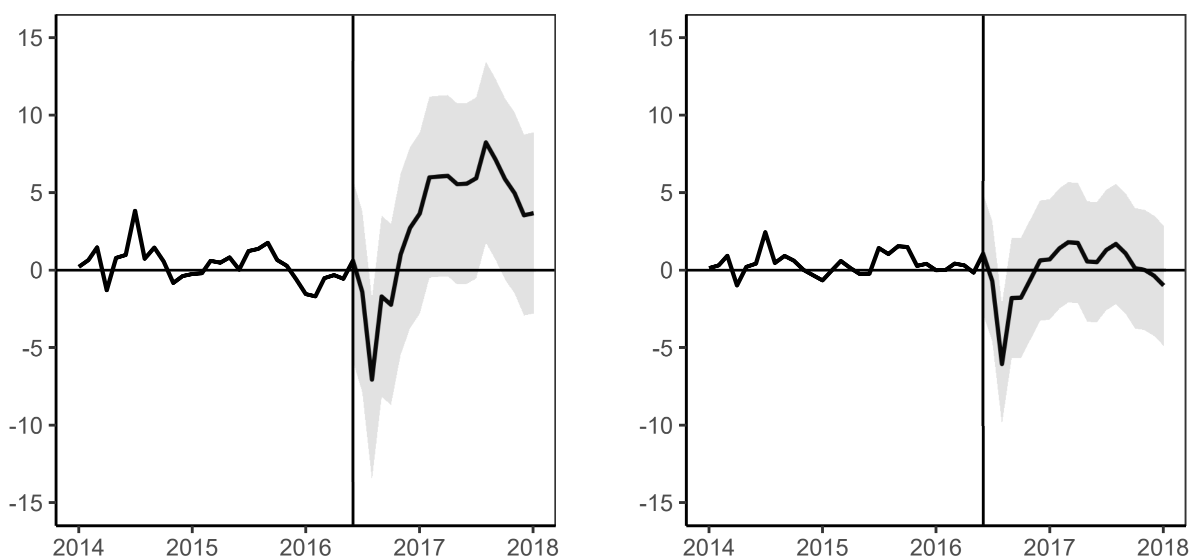
(a) Severely damaged areas (b) Other areas



Note: The solid line is the observed arrears rate in the treated area. The dashed line is the arrears rate in the synthetic unit. The arrears rate is reported in percentage points, and the vertical black line indicates the first period affected by the wildfire, that is, May 2016. According to TransUnion® scoring model, a good credit score is within the range of 721–780.

Figure C.4: Gap between actual and synthetic credit scores

(a) Severely damaged areas (b) Other areas



Note: The solid line refers to the point estimate of the treatment effect. The shaded area represents the 90% confidence set. The arrears rate (gap) is reported in percentage points, and the vertical black line indicates the first period affected by the wildfires, that is, May 2016. The 90% confidence set is calculated via the method proposed by Firpo and Possebom (2018) and Ferman et al. (2020)