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A comparison of recent crash fatality trends in Canada and the United States: Why do they differ?

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ABSTRACT

This study examined the divergence in traffic fatality trends between the United States and Canada from 2007 to 2021. While U.S. fatalities began increasing after 2011, Canada maintained a declining trend.

Using data on traffic fatalities and several variables related to travel exposure, demographics, and risk, we analyzed trends for both total and crash-type-specific fatalities. We sought to identify which crash types are primarily responsible for the trends and what risk factors may explain these trends. In both the U.S. and Canada, several common factors were identified, with the trends being in the opposite direction. These common factors included pedestrian and cyclist fatalities, and alcohol-involved, speeding-related, and truck-involved fatalities.

When accounting for exposure by looking at the rate of traffic fatalities per 100 million vehicle miles traveled (MVMT), it appeared that in the U.S., a significant amount of the differences in traffic fatalities over time was explained by variations in MVMT, indicating that the level of risk was relatively stable. Conversely, in Canada, the rate of traffic fatalities to MVMT consistently decreased, indicating that other risk factors had decreased. Statistical models confirmed that population and vehicle miles traveled have a positive association with the number of fatalities.

Depending on the crash type, gross domestic product per capita and the unemployment rate were additional significant exposure-related variables. The models also indicated that part of the difference in fatality trends may be due to Canada's more substantive and common laws related to driver distraction, seat belt use, and the use of speed safety cameras.

Keywords: traffic fatalities, fatality trends, risk factors, crash prediction, distraction, speed safety cameras, seat belts

1. INTRODUCTION

While road deaths in the United States increased 18% between 2010 and 2020 (from 32,999 to 39,007 deaths; National Highway Traffic Safety Administration [NHTSA], 2023), road deaths declined 22% in Canada (from 2,238 to 1,746 deaths; Transport Canada, 2024). To put this in perspective, approximately 118 per million Americans died in a crash in 2020, which is 2.5 times higher than in Canada where 46 per million Canadians were killed in the same year (Bell, 2022). This divergent pattern remains even after controlling for differences in exposure and acknowledging that Canadians drive fewer miles each year than the average American. In fact, one study revealed Canada had 43% fewer traffic fatalities per billion kilometers traveled (Schmitt, 2018) than the U.S.

Earlier research found several factors that impact nationwide crash and fatality trends, including specific aspects of traffic volume, economic conditions, demographics, laws, and trends in driver behaviors. A detailed investigation of the differential involvement of these variables in Canada and the U.S. could inform efforts to reduce crash deaths overall.

Factors related to the volume and type of travel have demonstrated the most direct relationship with traffic fatality risk. The number of vehicle miles traveled has been perhaps the most common measure used when studying traffic fatalities (e.g., Elvik, 2015; Lloyd et al., 2015; National Academies of Sciences, Engineering, and Medicine [NASEM], 2020), with increased travel logically associated with higher numbers of traffic fatalities.

Economic variables such as the poverty rate, unemployment, per capita tax revenues (Silver et. al., 2013), median household income (NASEM, 2020; Noland & Sun, 2014; Traynor, 2009;), inflation and unemployment rates (Kweon, 2015), and fuel prices (Grabowski & Morrisey, 2004; NASEM, 2020) also have an established relationship to traffic fatalities.

The distribution of vehicle model year has also impacted fatal crashes because newer vehicles typically have more safety features and better occupant protection. This has been demonstrated in several studies (Farmer & Lund, 2015; Kahane, 2015; NASEM, 2020). Vehicles older than 11 years were 1.3

times more likely to be crash-involved compared with vehicles less than 5 years old (Stamatiadis & Puccini, 1999). Increases in government spending on road infrastructure construction and maintenance has also been linked to reductions in traffic fatalities (Albalate et al, 2013; Calvo-Povo et al., 2020; NASEM, 2020).

Several demographic variables have been linked to road fatalities. Individual driver risk has been shown to be dependent on age, sex, and level of education. As such, the associated characteristics of the driving population play a role in traffic fatality rates (NASEM, 2020; Stamatiadis & Puccini 1999).

Although driver behavior has had a large impact on traffic fatalities, the standardized collection of relevant nationwide data has been challenging; this has likely played a role in behavior-related variables rarely being included when predictive models are developed for nationwide traffic fatalities. Some studies have looked at behavior measures to explain regional or temporal differences in injury and fatality rates. A 2017 Alabama-based study revealed that the odds of a distracted driver being at fault in a serious injury crash was 1.89 higher than a non-distracted driver, and a speeding driver increased the risk of a crash by 2.17 times. The same study demonstrated that the odds of an impaired driver being at fault were 1.14 times higher in a serious injury crash than an unimpaired driver (Adanu et al. 2017). In a similar vein, NASEM (2020) used beer and wine consumption per capita to predict alcohol-impaired driving rates and also used estimated rates of seat belt use to predict statewide fatal crash rates.

Research has also shown there are several relevant laws and enforcement strategies related to driving that can impact the number of traffic fatalities. State laws for alcohol-impaired driving, seat belt use, and driver licensing have revealed that harsher and more consistent laws and their enforcement led to lower rates of traffic fatalities (Silver et al., 2013). The effectiveness of harsher laws targeting alcohol-impaired driving (e.g., all-offender interlock laws, administrative sanction laws for drivers with a blood alcohol concentration (BAC) of 0.05% or higher, remedial programs) on reducing traffic fatalities has been proven in several other studies (Brubacher et al., 2014; Dang, 2008; McGinty et al., 2017; Teoh et al., 2021; Thomas et al., 2022; Vanlaar et al., 2017). Evaluations of the effects of diverse bans on cell phone use have shown reductions in traffic fatalities (Ferdinand et al., 2014; Lim & Chi, 2013; Zhu et al., 2021). NASEM (2020) utilized seat belt laws, motorcycle helmet laws, and DUI[1] laws to predict statewide fatal crash rates.

A recent systematic review of speed safety cameras by the Cochrane Collaboration concluded "…the consistency of reported reductions in speed and crash outcomes across all studies show that speed cameras are a worthwhile intervention for reducing the number of deaths," and found that serious injuries and fatalities were reduced by up to 44% near camera sites (Wilson, 2010). Thomas et al. (2008) concluded speed safety cameras were effective in reducing crashes and in particular for injuries, with crash reductions ranging from 20% to 25%. Studies of red-light cameras have found that angle crashes decrease while lower severity rear-end crashes may increase (Council et al., 2005; Vanlaar et al., 2014). Hu et al. (2011) compared citywide per capita rates of fatal red-light-running crashes and found fatal crashes decreased by 14% in cities with camera programs.

The present study investigated the divergent trends in traffic fatalities between the U.S. and Canada by collecting and analyzing roadway fatality data and data for potential explanatory variables related to driving exposure and risk factors. The study sought to identify which crash types are primarily responsible for the trends and what risk factors are contributing to these trends.

2. METHODS

2.1 Data collection

To explore factors that may explain the divergent trends in traffic fatalities in the U.S. and Canada, a diverse set of data were acquired. With respect to traffic fatalities, we considered not only total fatalities but also specific crash types characterized by various crash characteristics. We acquired detailed data on U.S. traffic fatalities from NHTSA's Fatality Analysis Reporting System from 2007 to 2021. For

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[1] The abbreviation DUI (driving under the influence) is used as a descriptive label and to create consistency, even though some states, provinces, and territories use other terms such as OWI (operating while impaired or intoxicated). Some states, provinces, and territories refer to different levels of severity of the offense.

Canada, we acquired these data from the National Fatality Database maintained by the Traffic Injury Research Foundation (TIRF) from 2007 to 2020 (2020 was the last year data were available at the time of this study).

Table 1 lists how we characterized traffic fatalities by crash type and if each crash type could be identified in the U.S. and Canadian data. Note that the defined crash types are not exclusive. For example, a traffic fatality could be both a pedestrian fatality and speeding-involved. Traffic fatalities in Canada could be classified in almost all the same categories as the U.S. fatalities, with some exceptions. While there was a variable to categorize traffic fatalities by the type of vehicle interaction, the information on whether a crash was a head-on, roadway departure, or rollover crash was unreliable due to the pattern of variation in the counts over time, and angle crashes were not a specified crash type in the Canadian data. These crash types were not included in the trend analyses.

Table 1

Data collected on traffic fatalities

Crash type	Crash type label	U.S.	Canada
Pedestrian fatalities	Pedestrian	Yes	Yes
Cyclist fatalities	Cyclist	Yes	Yes
Motorcyclist fatalities	Motorcyclist	Yes	Yes
Fatality with the highest driver BAC at 0.08% or higher	Alcohol-involved	Yes	Yes
Fatalities …			
with no restraint used	Seat belt-related	Yes	No
involving speeding	Speeding-involved	Yes	Yes
involving a large truck	Truck-involved	Yes	Yes
involving a senior driver (aged 65+)	Senior driver-involved	Yes	Yes
involving a young driver (age 15–20)	Young driver-involved	Yes	Yes
in head-on crashes	Head-on	Yes	Yes (but unreliable)
in angle crashes	Angle	Yes	No
involving a roadway departure	Roadway departure	Yes	Yes (but unreliable)
involving a rollover	Rollover	Yes	Yes (but unreliable)

Note. BAC = blood alcohol concentration.

We obtained data on factors related to exposure and risk that may influence rates of traffic fatalities from online searches and from various agencies, such as the U.S. Census Bureau, the Federal

Highway Administration (FHWA), the Insurance Institute for Highway Safety (IIHS), Transport Canada, and Statistics Canada. Information on road user behaviors and attitudes in the U.S. and Canada were obtained from TIRF and TIRF USA's annual Road Safety Monitor (RSM) surveys, which document self-reported survey responses from drivers. We investigated other sources of self-reported survey data but concluded that to ensure valid comparisons between the two countries, it was vital that both the questions posed to drivers and the sampling approaches for the surveys were consistent.

Table 2 lists the explanatory variable data that were available and collected in the U.S. and Canada and their source. These data included variables related to population, licensed drivers, educational attainment, economics, motor vehicle travel, driver behavior, and safety-related laws.

Most of the explanatory variables of interest that were available in the U.S. data were also available in the Canadian data. The exceptions were that data about licensed drivers by age and sex were not available in Canada, and data related to the unemployment rate and the percentage of workers using transit to commute included data for ages 15+ in Canada as opposed to ages 16+ in the U.S. Not all data on self-reported driver behaviors were available for all years for both countries. Data were available for the same years in Canada when those data were available in the U.S.

Creating variables reflecting traffic safety-related laws was challenging in that laws in both the U.S. and Canada can vary widely regarding to whom they apply and the specifics about the permitted or prohibited behaviors. For example, laws related to distracted driving varied in what behaviors are included (e.g., texting, emailing, grooming), which drivers are subject to the law (all, young drivers, commercial motor-vehicle drivers), and what penalties are imposed. Laws related to speed safety cameras vary by which locations they may be used at (all, school zones, work zones), speed thresholds for issuing citations, and citation amounts. To deal with this complexity, we created simplified variables for each year, for each state in the U.S., and for each province and territory in Canada and assigned a value of 1 or 0 to each, as follows:

Distraction: A value of 1 was assigned if laws banning at least one form of handheld cellphone use existed between January 1 and June 30 of that year. This includes laws that ban any kind of handheld phone use (texting only, calling and texting, age-specific restrictions), as variability in existing laws did not allow for more specificity*;* otherwise, 0 was assigned.

- *Recreational cannabis:* A value of 1 was assigned if recreational cannabis sales were legal between January 1 and June 30 of that year*;* otherwise, 0 was assigned.
- *Seat belt laws:* A value of 0 was assigned if no law existed between January 1 and June 30 of that year; otherwise, one of the following values was assigned depending on if the state, province, or territory's law allowed primary or secondary enforcement (primary enforcement laws allow police to stop and cite drivers solely for not wearing a seat belt. Under secondary enforcement laws, police can only ticket a driver for not wearing a seat belt if they stopped the driver for another violation.
    - 0.25 if secondary enforcement for only the front seats
    - 0.50 if secondary enforcement for all seats
    - 0.75 if primary enforcement for only the front seats (regardless of the laws covering rear-seat-belt use for adults)
    - 1.0 if primary enforcement for all seats
- *Speed safety camera laws:* A value of 0 was assigned if speed safety cameras were not permitted between January 1 and June 30 of that year; 1 was assigned if these cameras were permitted by law.

We then created national law-related variables by weighting the assigned value for each state, province, and territory by population.

Table 2

Data collected for explanatory variables

Variable group	Variable	U.S. source	Canadian source
Population	Total population	U.S. Census Bureau	Statistics Canada
	Population aged 15–19	U.S. Census Bureau	Statistics Canada
	Population aged 65+	U.S. Census Bureau	Statistics Canada
Licensed drivers	Licensed drivers	FHWA	Transport Canada
	Licensed drivers, aged 15–20	FHWA	n/a
	Licensed drivers, aged 65+	FHWA	n/a
	Male licensed drivers	FHWA	n/a
	Female licensed drivers	FHWA	n/a
Educational attainment	Percentage of the population that completed …		
	elementary school	U.S. Census Bureau	Statistics Canada
	high school	U.S. Census Bureau	Statistics Canada
	college	U.S. Census Bureau	Statistics Canada
Economic data	Unemployment rate	U.S. Department of Labor (ages 16+)	Statistics Canada (ages 15+)
	Median household income	U.S. Census Bureau	Statistics Canada
	GDP per capita (USD)	World Bank	World Bank
Travel-related data	Fuel consumed (millions of gallons)	FHWA	Statistics Canada
	Million vehicle miles traveled	FHWA	Statistics Canada
	Percentage of workers using transit to commute	U.S. Census Bureau (ages 16+)	Statistics Canada (ages 15+)
Self-reported behavioral data	Percentage of drivers who …		
	drove when likely over the legal BAC limit in the previous 30 days	TIRF USA RSM (some years)	TIRF RSM
	often text while driving	TIRF USA RSM (some years)	TIRF RSM (some years)
	often talk on their phone while driving	TIRF USA RSM (some years)	TIRF RSM (some years)
	often drive over the speed limit	TIRF USA RSM (some years)	TIRF RSM (some years)
Law presence and features data	Recreational cannabis	IIHS	Government websites
	Seat belt laws	IIHS	Government websites
	Speed safety camera laws	IIHS	Government websites, news articles
	Maximum posted speed limit	IIHS	Government websites, news articles
	Distraction-related laws	IIHS	Government websites, news articles

Note. FHWA = Federal Highway Administration; n/a = not applicable; GDP = gross domestic product; BAC = blood alcohol concentration; TIRF = Traffic Injury Research Foundation; RSM = Road Safety Monitor; IIHS = Insurance Institute for Highway Safety.

2.2 Analysis

Two types of analyses were undertaken. An initial descriptive analysis using tables and graphs investigated and compared trends in both countries for traffic fatalities by crash type, self-reported behaviors and attitudes, and the other factors that may influence traffic fatalities. Rates of change were calculated to obtain insight into the magnitude of the differences. This initial analysis guided our selection of crash types to further investigate and factors to include in the more detailed statistical analysis of these data. The more exhaustive statistical analysis sought to confirm the significance of, and quantify the observed relationships between, the explanatory variables and traffic fatalities.

3. RESULTS

3.1 Descriptive analysis

U.S. traffic fatalities declined from 41,259 in 2007 to a low of 32,479 in 2011 and then generally increased to a high of 43,230 in 2021. Table 3 contains the 2011 and 2021 fatality counts by crash type and provides several metrics that identify the crash types with the largest increases since 2011. These metrics include

- the difference between the 2021 and 2011 counts,
- percentage increase or decrease in the total fatality count from 2011 to 2021 by crash type,
- slope of a linear regression model of crash counts from 2011 to 2021, and
- slope of a linear regression model of each crash type divided by the slope for total fatalities from 2011 to 2021, expressed as a percentage

Based on these metrics, the crash types that were most associated with increases in U.S. traffic fatalities from 2011 to 2021 included:

- alcohol-involved
- pedestrian and cyclist
- senior-driver involved
- speed-involved
- truck-involved

Table 4 presents similar data for Canada from 2011 to 2020 taken from TIRF's National Fatality Database, which contains more information about crash types than is publicly available from other sources. These total fatality numbers differ slightly from Canadian government data (Transport Canada, 2024) due to TIRF's distinct quality control procedures that include updating data from the original sources. In contrast to the U.S. data, a general declining trend in traffic fatalities was maintained in Canada during 2007 to 2020. Canadian traffic fatalities declined from a high of 2,754 in 2007 to a low of 1,776 in 2020.

To compare with U.S. trends, changes in crash type were similarly examined in Canada from 2011 to 2020. The crash types that were most responsible for the decreases in Canadian traffic fatalities from 2011 to 2020 included:

- alcohol-involved
- young driver-involved
- speed-involved
- truck-involved
- seat belt-related

Table 3

U.S. traffic fatality counts in 2011 and 2021 by crash type

	All fatalities	Pedestrian and cyclist	Motor-cyclist	Truck-involved	Alcohol-involved	Seat belt-related	Speed-involved	Young driver-involved	Senior driver-involved
2011	32,479	5,139	4,630	3,781	9,865	10,215	10,001	4,782	5,636
2021	43,230	8,446	6,143	5,821	13,617	11,877	12,498	5,616	8,245
Difference between 2021 and 2011 counts	10,751	3,307	1,513	2,040	3,752	1,662	2,497	834	2,609
Percentage of change	100%	31%	14%	19%	35%	15%	23%	8%	24%
Slope of linear regression model	865.6	299.6	107.1	185.1	243.3	101.1	158.0	57.9	242.1
Slope/all fatalities slope	100%	35%	12%	21%	28%	12%	18%	7%	28%

Table 4

Canadian traffic fatality counts in 2011 and 2020 by crash type

	All fatalities	Pedestrian and cyclist	Motor-cyclist	Truck-involved	Alcohol-involved	Seat belt-related	Speed-involved	Young driver-involved	Senior driver-involved
2011	2,166	398	173	360	508	536	546	288	390
2020	1,776	331	250	273	356	450	449	138	341
Difference between 2020 and 2011 counts	−390	−67	77	−87	−152	−86	−97	−150	−49
Percentage of change	100%	17%	−20%	22%	39%	22%	25%	38%	13%
Slope of linear regression model	−34.4	−3.5	5.6	−6.7	−16.4	−14.2	−13.3	−14.3	2.7
Slope/all fatalities slope	100%	10%	−16%	19%	48%	41%	39%	42%	−8%

To further visualize the divergent trends, we compared the total U.S. traffic fatalities and the five crash types associated with the largest fatality increases in the U.S., and for which there was comparable Canadian data after normalizing the counts to 2007. This was achieved by dividing the count of fatalities for a given crash type in each country by the respective count in 2007. The results are shown in Figures 1–6. Trends for all traffic fatalities (Figure 1) and for pedestrian and cyclist (Figure 2), speed-involved (Figure 3), and alcohol-involved (Figure 4) fatalities began to diverge between 2011 and 2013 depending on the crash type. The largest increases in the U.S. for speed-involved and alcohol-involved fatalities occurred in 2020 and 2021, the years corresponding to the COVID-19 pandemic. Trends in truck-involved fatalities initially diverged in 2015 (Figure 6). The trends in senior driver-involved fatalities did not diverge until 2020 (Figure 5); a possible reason could be the greatly reduced driving exposure among Canadian seniors during the COVID-19 pandemic.

Figure 1

U.S. and Canadian traffic fatality counts, normalized to 2007

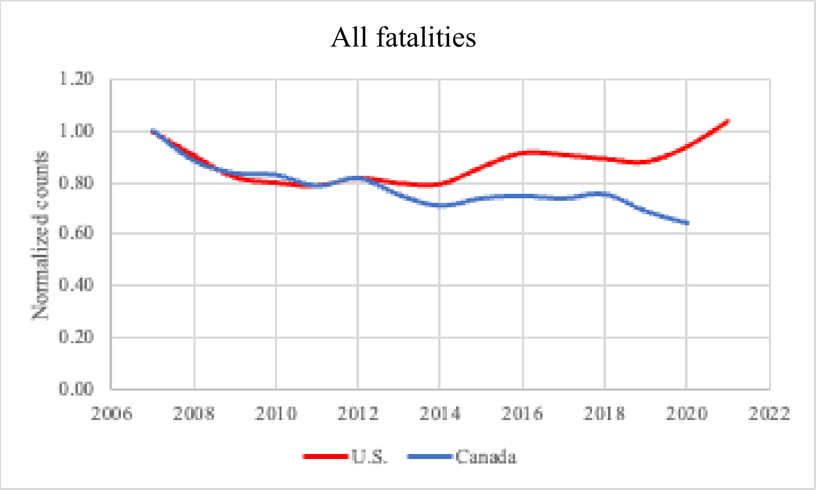


Figure 2

U.S. and Canadian pedestrian and cyclist fatality counts, normalized to 2007

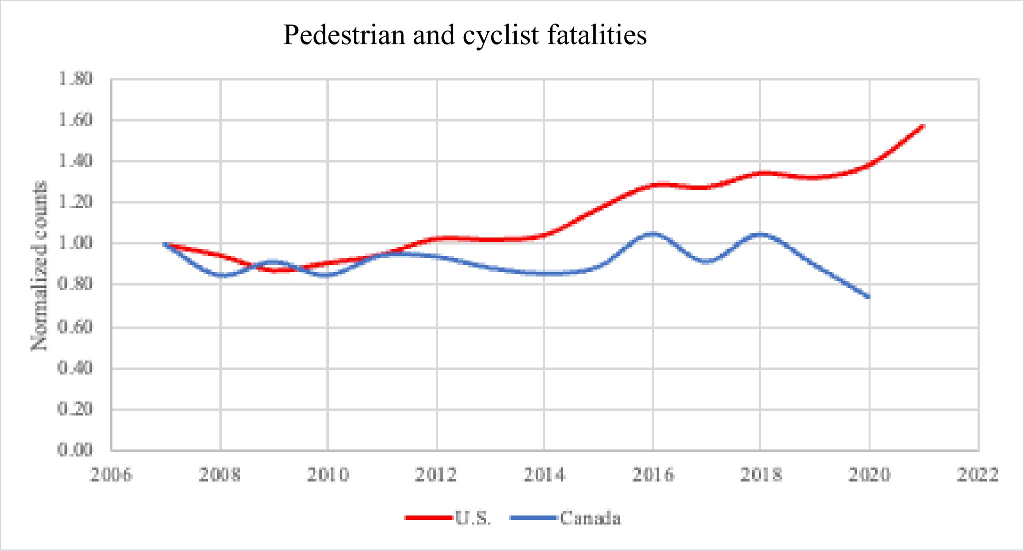


Figure 3

U.S. and Canadian speed-involved fatality counts, normalized to 2007

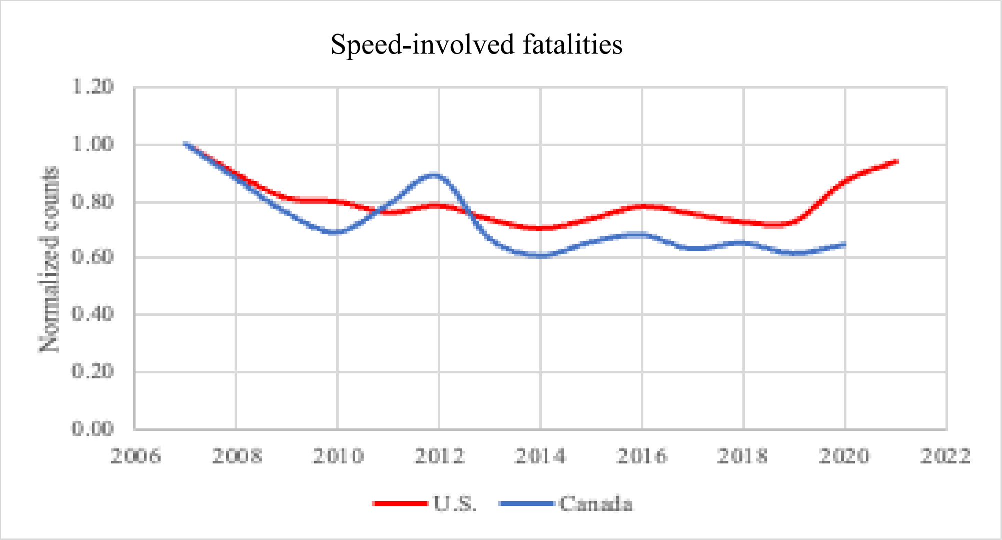


Figure 4

U.S. and Canadian alcohol-involved fatality counts, normalized to 2007

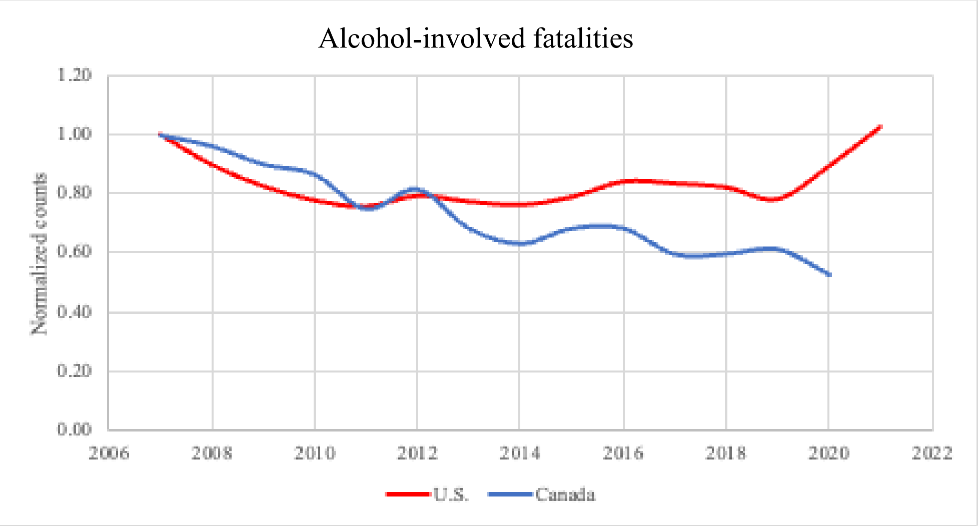


Figure 5

U.S. and Canadian senior driver-involved fatality counts, normalized to 2007

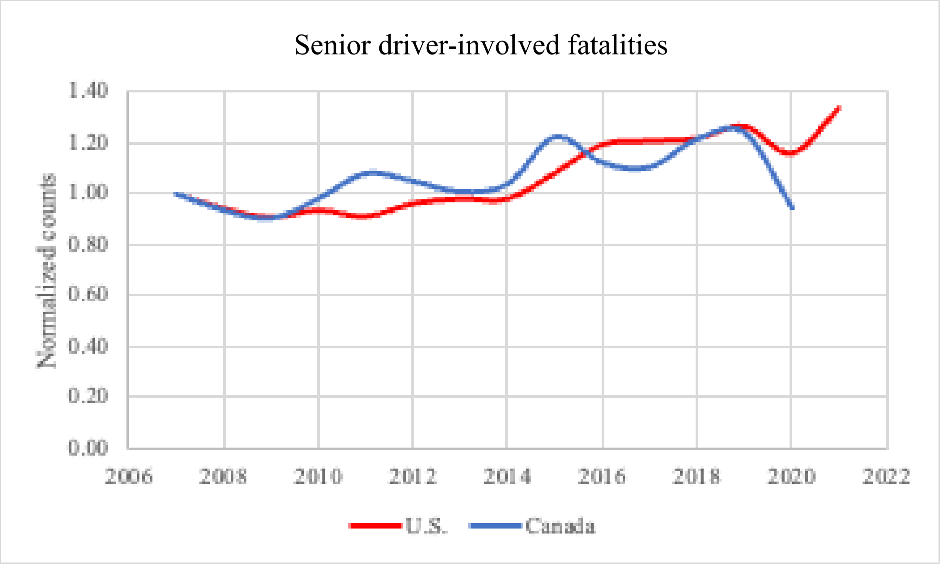
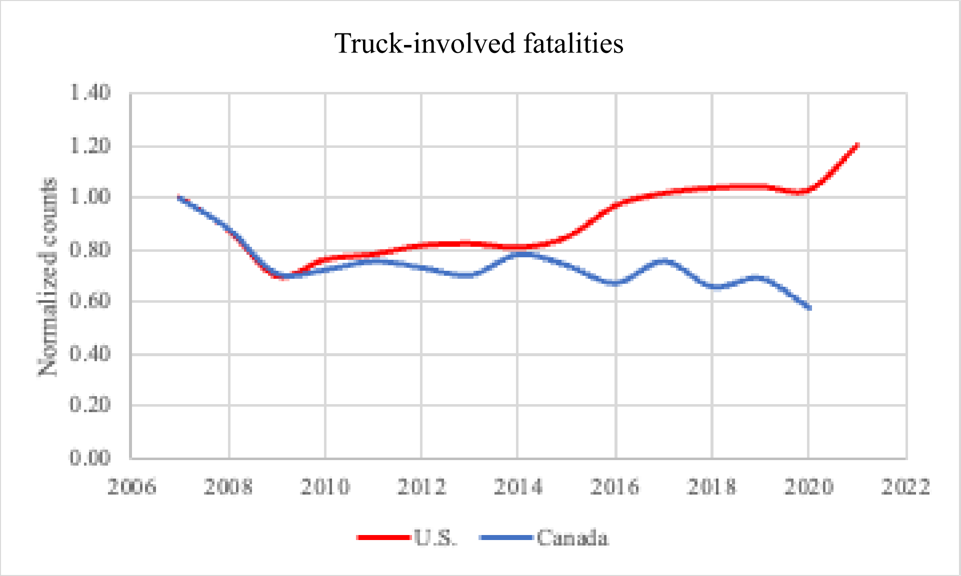


Figure 6

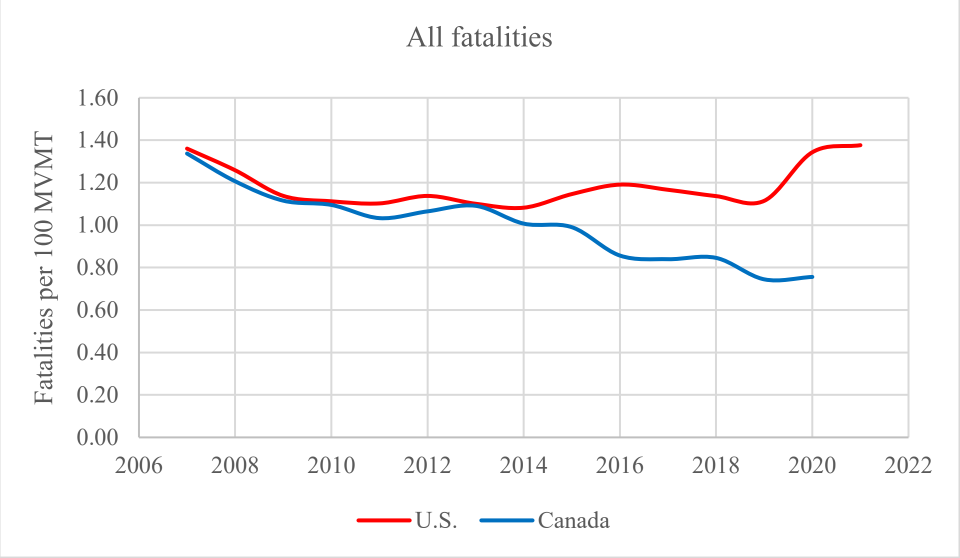
U.S. and Canadian truck-involved fatality counts, normalized to 2007



We also examined the trend in total traffic fatalities using the rate of traffic fatalities per 100 million vehicle miles traveled (MVMT). The reasoning was that exposure is usually the principal factor influencing the number of traffic fatalities. Figure 7 reveals that much of the difference in U.S. traffic fatalities over time. appeared to be explained by variations in MVMT. The fatality rate was relatively constant through much of the study period, although this ratio spiked in 2020 and 2021. This suggests the level of risk was relatively stable in the U.S. before 2020 despite measures being taken to improve road safety. In Canada, beginning in 2014, the ratio of traffic fatalities to MVMT had consistently decreased, indicating that the risk factors not related to MVMT were declining.

Figure 7

U.S. and Canadian traffic fatalities per 100 million vehicle miles traveled (MVMT)



Selected explanatory variables were also examined by normalizing their values to 2007, including total population, MVMT, and total licensed drivers. These variables were selected because they are basic exposure measures and are shown in Figures 8 to 10.

These figures reveal that during the study period, the total population growth when normalized to the 2007 counts was larger in Canada (Figure 8). Beginning in 2016, growth in MVMT had been greater in Canada, and the number of licensed drivers had grown to a larger extent in Canada. The MVMT data in Canada revealed a decline from 2013 to 2015 of an unknown cause (Figure 9). The unemployment rate was steady and comparable with related time periods, so economic activity was not a likely explanation. These data were modeled on survey data, so it is possible that differences in how the source data were collected or used influenced this trend. To the extent that these factors can account for the number of traffic fatalities, it suggests the divergent trends were not a result of these factors, and that the explanations are more likely due to other risk factors not related to exposure.

Figure 8

Total U.S. and Canadian population, normalized to 2007

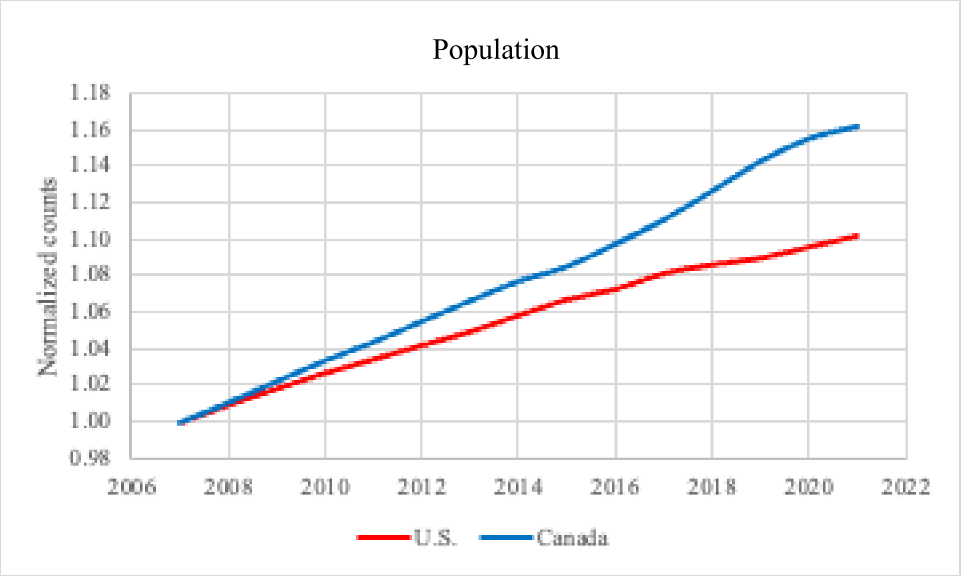


Figure 9

U.S. and Canadian MVMT, normalized to 2007

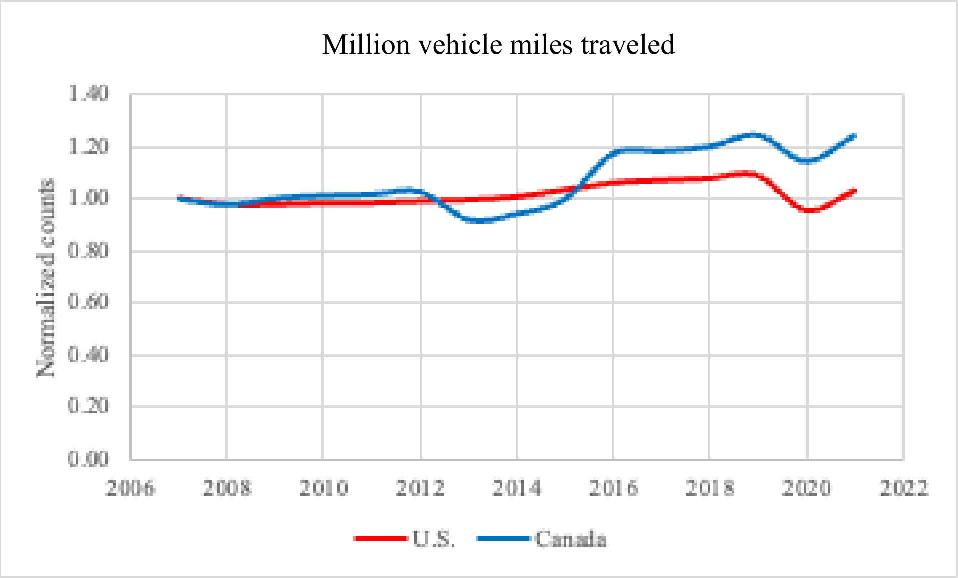
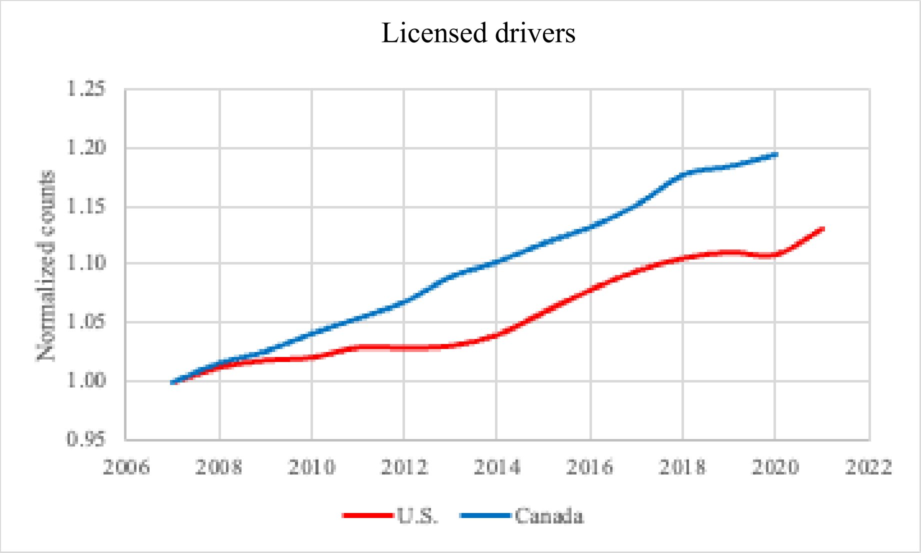


Figure 10

U.S. and Canadian licensed drivers, normalized to the 2007 counts



3.2 Statistical analysis

The statistical analysis involved developing crash prediction models to relate the observed number of traffic fatalities to the explanatory variables. We intended to identify factors that may explain the divergent trends in terms of risk while controlling for confounding factors such as the amount of travel. It is possible to control for known confounding factors, in principle, by estimating a multiple variable regression model. However, a difficulty with this type of cross-sectional design is that an unknown portion of the observed difference in crash experience can be due to factors that we cannot control for (e.g., data are not available or the factors are unknown). For this reason, exercize caution when making inferences on the basis of cross-sectional models.

The models were developed using generalized estimating equation techniques. These models are similar to generalized linear models but can account for a potential temporal correlation caused by using repeated measures, in the present case treating each country–year as a unique observation. Consistent with state-of-the-art crash frequency modeling, a negative binomial error distribution was adopted. The negative binomial model has been used extensively for crash data modeling because these data are frequently over-dispersed, meaning the variance of observed crash frequencies is greater than the mean.

When we assessed model fit, we included several goodness-of-fit statistics and considerations, including

- the logic of the direction of effect and the magnitude of estimated parameters,
- the *p* values of estimated parameters,
- the estimated value of the negative binomial overdispersion parameter, and
- Akaike's information criterion (AIC).

When comparing two or more potential models, the AIC penalizes for the addition of parameters, and thus selects a model that fits well but has a minimum number of parameters. AIC is not typically used as a goodness-of-fit measure in itself, but it can be used to compare the relative fit of alternate models. A lower AIC value indicates a better model fit.

Summary statistics for the explanatory variables we considered for each of the crash type models are provided in the Appendix. Most of the variable titles are self-explanatory, with the remaining summarized in Table 5.

Table 5
Explanatory variables with definitions

Variable name	Definition
PercElem	Percentage of the population aged 25+ with highest education attainment being elementary school
PercHS	Percentage of the population aged 25+ with highest education attainment being high school
PercColl	Percentage of the population aged 25+ with highest education attainment being college
PercTrans	Percentage of workers using transit to commute
PercDUI30	Percentage of drivers who reported driving when likely over the legal limit for alcohol in past 30 days
PercText	Percentage of drivers who reported texting while driving
PercCell	Percentage of drivers who reported talking on their phone while driving
PercSpeed	Percentage of drivers who reported often driving over the speed limit
CANNABIS	Variable related to recreational cannabis laws on a scale from 0 to 1

Variable name	Definition
DISTRACT	Variable related to mobile phone use laws on a scale from 0 to 1
SEATBELT	Variable related to seat belt laws on a scale from 0 to 1
SSC	Variable related to speed safety camera laws on a scale from 0 to 1
MAXSPEED	Variable related to maximum posted speed limit on any public roadway
PercElderly	Percentage of the population aged 65+
PercYoung	Percentage of the population aged 15–19
PercLicensed	Percentage of the population with a driver's license
N	Number of years of data available

Models were investigated for all traffic fatalities and the same five crash types in the descriptive analysis. These included pedestrian, alcohol-involved, speed-involved, truck-involved and senior driver-involved fatalities. Importantly, the crash type data were not exclusive and the categories overlapped.

There were some notable differences between the U.S. and Canada beyond the obvious ones related to population. Drivers in the U.S. traveled more on average than Canadians, with the average value of vehicle miles traveled per licensed driver equal to 14,049 in the U.S. and 8,901 in Canada. A larger percentage of Canadians also used transit, with an average of 11.8% of workers using transit to commute to work versus 4.8% of Americans. Regarding risky behaviors, drivers in the U.S. self-reported higher rates of risk-taking than Canadian drivers with respect to driving when likely over the legal limit for alcohol (7.5% vs. 5.6%), texting while driving (19.9% vs. 9%) and often driving over the speed limit (29.4% vs. 25.3%). Road safety-related laws and enforcement also tended to be stricter or more widespread or both in Canada as evidenced by higher average values across all years of Canadian data for each of the related variables for distraction-related laws (0.826 vs. 0.694), seat belt-related laws (1.000 vs. 0.738), and the permissibility of speed safety cameras (0.403 vs. 0.201). Finally, the variable created for the maximum posted speed limit is lower in Canada (65.0 mph) than in the U.S. (70.4 mph). Regarding the legalization of recreational cannabis sales, it was more widespread in Canada across the study period (0.200 vs. 0.079).

It is notable that Canada has "warn-range" programs for alcohol in all jurisdictions except in Quebec. These programs sanction drivers for a BAC between 0.05% and 0.079%, with a lower threshold of 0.04% in Saskatchewan. In these ranges, administrative penalties are applied but not criminal sanctions. These programs, which started in the 1980s for drinking and driving, have resulted in general and specific deterrent effects and enabled much more immediate penalties and certain penalties than relying on the justice system alone. Additionally, in Canada the refusal of the roadside breath test has been a criminal offense for decades and in 2018, changes to the Criminal Code of Canada removed the requirement for the officer to have suspicion of alcohol use as the basis for demanding the test.

Further differences not represented through the data in this study are related to weather conditions. Due to its colder weather and heavier snowfall, Canada has fewer year-round motorcycle riders, pedestrians, and cyclists, and the use of snow tires are more common in Canada.

Models were successfully estimated for all crash types despite the limited number of data points; 15 country–years for the U.S. and 14 for Canada. Alternate models were explored and the final models determined by considering the statistical significance of parameter estimation, logic and consistency of parameter estimates, and overall model fit. Table 6 lists the variables included in the models. Each of the models is described in detail in Table 7, showing the model form, estimated parameters, standard errors and *p* values. All parameters included in the final models were statistically significant at the 95% confidence level with three exceptions.

Table 6
Variables with definitions

Variable	Definition
POP	Total population
MVMT	Million vehicle miles traveled
PercElderly	Percentage of the population aged 65+
GDPCAP	Gross domestic product per capita in USD
UNEMP	Unemployment rate percentage
SSC	Variable representing speed safety camera laws on a scale of 0 to 1
SEATBELT	Variable representing seat belt laws on a scale of 0 to 1
DISTRACT	Variable representing distracted driving laws on a scale of 0 to 1
Constant, βs	The estimated model parameters
K	The estimated overdispersion parameter of the negative binomial distribution

The variables directly or indirectly related to exposure that were significant in one or more models included total population, MVMT, GDP per capita, percentage of the population aged 65+, and the unemployment rate. As expected, fatalities increased as these exposure variables increased, except for the unemployment rate which, as expected, a higher unemployment rate was associated with fewer fatalities. This is likely due to reduced travel among the unemployed. Variables related to risk that were significant in one or more models included the law-related variables for mobile phone use, automated speed enforcement, and seat belt use. The parameter estimates for these variables indicated that as these laws were more widely adopted, fewer fatalities occurred.

The estimates for SSC in the model for total fatalities and for DISTRACT for pedestrian fatalities were statistically significant at the 90% level, while the estimate for PercElderly in the senior driver-involved fatalities model had a larger *p* value of 0.230. The variable was included in the model due to the logic of its effect, being that as the percentage of the population aged 65+ increased, more senior driver-involved traffic fatalities were expected. A generalized linear model that did not account for temporal correlation also estimated a similar parameter estimate that was statistically significant.

Table 7

Prediction models for traffic fatalities

Crash type	Variable	Coefficient	Standard error	*p* value
$Fatalities/year = exp^{Constant}POP^{\beta 1}exp^{(SSC*\beta 2+GDPCAP*\beta 3+DISTRACT*\beta 4)}$				
	Constant	−13.13439	0.1364	<0.000
	POP	1.1738	0.0020	<0.000
	SSC	−0.3152	0.1701	0.064
	GDPCAP	0.0000169	0.0000018	<0.000
	DISTRACT	−0.3327	0.0585	<0.000
	K	0.0023	0.0007	
$Pedestrian\ fatalities/year = exp^{Constant}MVMT^{\beta 1}exp^{(GDPCAP*\beta 2+DISTRACT*\beta 3)}$				
	Constant	−7.1781	0.0828	<0.000
	MVMT	0.9702	0.0012	<0.000
	GDPCAP	0.000024	0.0000011	<0.000
	DISTRACT	−0.1104	0.0606	0.068
	K	0.0032	0.0012	
$Alcohol\text{-}involved\ fatalities/year = exp^{Constant}exp^{\left(\frac{POP}{1,000,000}*\beta 1+PercElderly*\beta 2\right)}$				
	Constant	7.3568	0.6306	<0.000
	POP	0.0108	0.0001	<0.000
	PercElderly	−0.0989	0.0404	0.014
	K	0.0104	0.0029	
$Speed\text{-}involved\ fatalities/year = exp^{Constant}POP^{\beta 1}exp^{(SSC*\beta 1+GDPCAP*\beta 2+SEATBELT*\beta 3)}$				
	Constant	−9.0875	0.7368	<0.000
	POP	0.9868	0.0287	<0.000
	SSC	−1.0437	0.3105	0.001
	GDPCAP	0.0000150	0.0000009	<0.000
	SEATBELT	−2.1588	0.3942	<0.000
	K	0.0082	0.0024	
$Truck\text{-}involved\ fatalities/year = exp^{Constant}POP^{\beta 1}exp^{(UNEMP*\beta 1+GDPCAP*\beta 2+SSC*\beta 3)}$				
	Constant	−11.7404	0.3355	<0.000
	POP	0.9992	0.0077	<0.000
	UNEMP	−0.0300	0.0080	<0.000
	GDPCAP	0.0000169	0.0000018	<0.000
	SSC	−0.9191	0.1723	<0.000
	K	0.0057	0.0017	
$Senior\ driver\text{-}involved\ fatalities/year = exp^{Constant}POP^{\beta 1}exp^{(PercElderly*\beta 1+UNEMP*\beta 2)}$				
	Constant	−16.6712	0.6012	<0.000
	POP	1.2940	0.0129	<0.000
	PercElderly	0.0228	0.0190	0.230
	UNEMP	−0.0322	0.0114	0.005
	K	0.0016	0.0006	

4. DISCUSSION

U.S. traffic fatalities declined from 2007 to 2011, then increased to a high in 2021. In Canada, a decreasing trend was observed from 2007 to 2020, the last year for which full data were available at the time of the study. The factors involved in fatal crashes were investigated to identify those non-exclusive crash types largely behind the observed trends. In both the U.S. and Canada, several common factors were identified, with the trends being in the opposite direction. These common factors included pedestrian and cyclist fatalities, and alcohol-involved, speed-involved, and truck-involved fatalities. The other identified notable factors behind the rise in traffic fatalities in Canada and the U.S. included younger driver and senior driver-involved crashes. When accounting for exposure by looking at the rate of traffic fatalities per 100 MVMT it appeared that in the U.S., a significant amount of the differences in traffic fatalities over time were explained by variations in MVMT, indicating that the level of risk was relatively stable in the U.S. Conversely, in Canada, the rate of traffic fatalities to MVMT had consistently decreased, indicating that other risk factors were decreasing. After normalizing traffic fatalities to the 2007 counts, the trends for all traffic fatalities and pedestrian and cyclist, speeding-involved, and alcohol-involved fatalities (as shown in Figures 1–4) started to diverge between 2011 and 2013 depending on the crash type.

The estimation of crash prediction models for traffic fatalities was challenging given the small number of observations, and few variables could be included in the models with statistically significant parameter estimates. Table 8 lists the explanatory variables included in one or more models, the hypothesized effect, and the implied effect from the estimated model parameters. In all cases, the model met the hypothesized effects. The most important explanatory variables were either population or MVMT as a measure of exposure. Depending on the crash type, GDP per capita and the unemployment rate were also significant exposure-related variables. Several variables related to road safety-related laws were significant variables in one or more models, including laws related to mobile phone use, speed safety cameras, and seat belt use. The percentage of the population aged 65 + was a significant variable for the model on alcohol-involved fatalities.

Table 8

Explanatory variables with the hypothesized and estimated effects

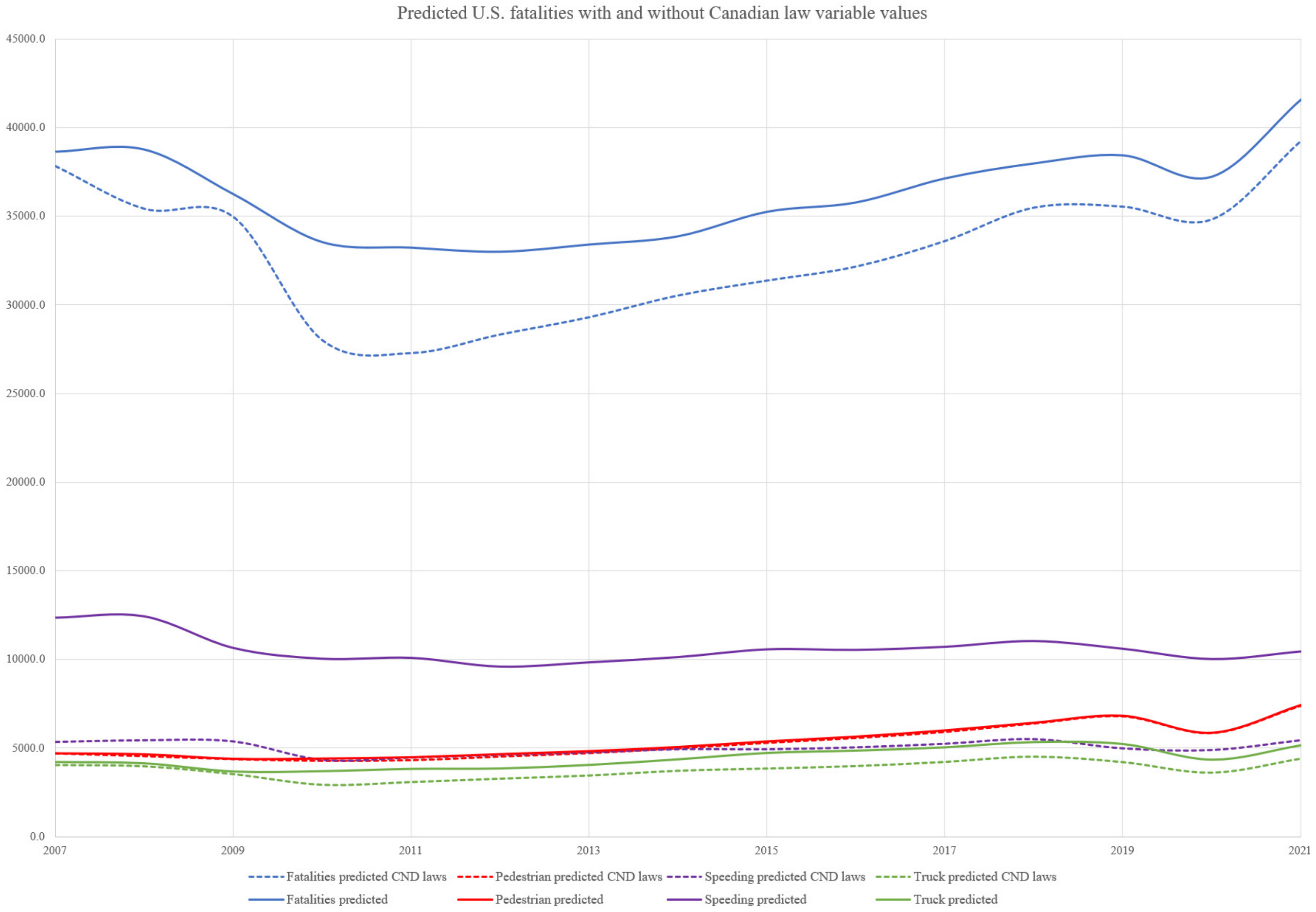
Variable	Hypothesized effect on fatalities	Model's estimated effect on fatalities
Population	Increases in population lead to more exposure to crash opportunities	Increased fatalities with a larger population [a]
Percentage of the population aged 65+	Senior drivers are less likely to drive while impaired from alcohol than other age groups	Fewer alcohol-involved fatalities as the percentage of drivers aged 65+ increases [a]
	A larger percentage of the population aged 65+ will lead to greater exposure for senior drivers	Increased fatalities involving senior drivers as the percentage of drivers aged 65+ increases [a]
MVMT	Increases in MVMT lead to more exposure to crash opportunities.	Increased fatalities with higher MVMT [a]
GDP per capita	GDP per capita reflects economic activity, and higher GDP is expected to lead to more travel and thus more exposure to crash opportunities.	Increased fatalities with higher GDP per capita [a]
Unemployment rate percentage	Higher unemployment reflects less economic activity, which w is likely to lead to less travel and thus less exposure to crash opportunities.	Fewer fatalities as the unemployment rate rises [a]
Distraction-related laws	As more of the population is subject to laws restricting mobile phone use while driving, distraction-related crashes are expected to decrease	Fewer fatalities as more of the population is subject to distraction-related laws [a]
Seat belt laws	Stricter seat belt laws are expected to lead to higher compliance and thus a lower probability of death in a crash, particularly for crashes involving drivers traveling at high speeds	Fewer speed-related fatalities as more of the population is subject to stricter seat belt laws [a]
Speed safety camera laws	As more of the population is subject to speed safety cameras, speeds are expected to decrease along with a decrease in crashes and a lower probability of death in a crash.	Fewer fatalities as more of the population is subject to speed safety cameras [a]

Other factors influencing the divergent fatality rates between Canada and the U.S. were proposed in a series of articles by reporter David Zipper (2022a, 2022b, 2023). One factor proposed is the movement of the U.S. auto market toward SUVs and pickup trucks and a trend towards larger vehicles within these classes while Canadian preferences have shifted more to subcompact and compact SUVs. Larger vehicles impact road safety by introducing larger kinetic forces that raise the risk of injury or death to occupants of lighter vehicles in a crash (Monfort & Nolan, 2019), and the shapes of the front ends of taller vehicles increase fatality risk to vulnerable road users (Hu et al., 2024). Zipper also cited the broader use of automated enforcement and the adoption of, and move toward, harsher administrative penalties for drivers with a BAC) of 0.05% or higher in Canada. The survey data used in this study indicated that the percentage of drivers who drive when likely over the legal limit was higher in the U.S. than in Canada, with respective averages of 7.5% and 5.6%.

The variables created in this study for laws related to cell phone use, seat belt use, and speed safety cameras all showed that these laws have covered more of the population in Canada than in the U.S. during the study period. Figure 11 plots the model predictions for those crash types that included at least one of the law-related variables. For each crash type, the prediction with the U.S. value and substituting the Canadian value for each year are shown. The plots show that with broader and stricter laws, fatalities would be expected to be lower but the underlying trend of rising or stable fatality counts remains, indicating that there are other underlying risk factors involved that need to be addressed.

Figure 11

U.S. model predictions with and without Canadian law variable values



Note. CND = Canadian.

In addition to these law-related variables, trends in impaired-driving enforcement may also partially explain the divergence in fatality rates between the two countries. Impaired-driving arrests have trended downward in the U.S., dropping from between 1 and 1.2 million annually prior to 2014 to just 600,000 in 2022. (Federal Bureau of Investigation, n.d.). Canada saw smaller declines, decreasing from 89,607 police-reported impaired driving incidents in 2011 to 70,400 incidents in 2018 before increasing to 85,673 in 2019, a 21.7% increase (Statistics Canada, 2021). Incidentally, this 2019 increase coincided with the implementation of new impaired driving legislation in December 2018, following the legalization of recreational cannabis in October 2018. It is also notable that while criminal impaired-driving arrests declined in Canada, most provinces moved to strengthen administrative impaired driving regimes at a BAC of 0.05%, which augmented criminal impaired-driving enforcement. Research has shown these programs are associated with both general and specific deterrent effects (Byrne et al., 2016).

There are several study limitations worth noting. For one, with respect to traffic fatality data, speeding involvement may not be reliably coded, which would impact the accuracy of the results for these crash types. Additionally, creating variables to represent laws impacting traffic safety was particularly challenging and it is possible that the limited number of laws represented in the models are reflecting other factors influencing the trends in fatalities. More generally, the risk factors for traffic fatalities are much broader than could be represented with the data available for and the models developed for this study. Relevant data would represent all pillars of the Safe System Approach (SSA), which recognizes that humans make mistakes and are vulnerable, responsibility is shared, safety is proactive, and redundancy is crucial. The pillars of the SSA include Safer People, Safer Vehicles, Safer Speeds, Safer Roads, and Post-Crash Care. Data representing all five pillars would be desirable. Finally, identifying steps that could reduce traffic fatalities in the U.S. would benefit from the collection of more extensive data at the state level, which would provide a larger dataset and presumably more informative models.

Finally, more recent data for the U.S. indicated that the upward trend may be starting to reverse. NHTSA (2024) estimated 2022 fatalities to be 42,514 and projects 2023 fatalities to be 40,990, which would be a 5.2% decrease compared with 2021. Whether this is the start of a long-term downward trend in traffic fatalities in the U.S. remains to be seen.

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6. APPENDIX

Table A1

Summary statistics for U.S. explanatory variables

Variable	*N*	Mean	*SD*	Minimum	Maximum
Population	15	318,000,000	9,865,357	301,200,000	331,900,000
Population aged 15–19	15	21,710,713	287,739	21,353,524	22,210,880
Population aged 65+	15	46,480,159	6,207,487	37,825,711	55,892,014
Licensed drivers	15	217,758,249	8,858,436	205,740,000	232,782,000
Unemployment rate	15	6.4	2.0	3.7	9.6
PercElem	15	4.6	0.7	3.5	5.8
PercHS	15	36.6	2.2	33.1	40.1
PercColl	15	58.8	2.9	54.1	63.3
Median income	15	69,199	5,054	63,350	78,250
GDP per capita	15	55,931	7,165	47,195	70,219
Gas sales (millions of gallons)	15	124,950	4,810	112,375	131,904
MVMT	15	3,060,496	117,385	2,903,622	3,261,772
PercTrans	11	4.8	0.8	2.5	5.2
PercDUI30	6	7.5	3.2	2.2	11.0
PercText	3	19.9	2.3	17.2	21.4
PercCell	3	28.1	2.0	25.9	29.7
PercSpeed	3	29.4	0.9	28.4	30.2
CANNABIS	15	0.079	0.116	0	0.325
DISTRACT	15	0.694	0.344	0	0.997
SEATBELT	15	0.738	0.045	0.634	0.782
SSC	15	0.201	0.083	0.103	0.368
MAXSPEED	15	70.4	1.0	69.0	71.5
PercElderly	15	14.6	1.5	12.6	16.8
PercYoung	15	6.8	0.3	6.5	7.3
PercLicensed	15	68.5	0.9	67.1	70.1

Table A2

Summary statistics for Canadian explanatory variables

	N	Mean	*SD*	Minimum	Maximum
Population	14	35,506,765	1,729,168	32,889,025	38,226,498
Population aged 15–19	14	2,156,103	72,402	2,057,182	2,255,781
Population aged 65+	14	56,067,767	862,222	4,421,379	7,082,151
Licensed drivers	14	24,785,429	1,458,977	22,606,000	26,971,000
Unemployment rate	14	7.2	1.1	5.7	9.7
PercElem	14	10.3	2.1	7	14
PercHS	14	35.6	2.4	31	38
PercColl	14	54.1	4.4	48	62
Median income	14	70,620	3,695	66,600	78,400
GDP per capita	14	47,198	4,047	40,876	52,669
Gas sales (millions of gallons)	14	15,518	677	14,165	16,440
MVMT	14	218,174	21,161	189,905	255,154
PercTrans	14	11.8	0.7	11.0	12.4
PercDUI30	14	5.6	1.7	2.6	8.6
PercText	6	9.0	3.0	4.8	13.1
PercCell	6	30.5	4.9	21.7	36.5
PercSpeed	3	25.3	0.8	24.5	26
CANNABIS	14	0.200	0.414	0	1
DISTRACT	14	0.826	0.338	0.015	1
SEATBELT	14	1.000	0.000	1	1
SSC	14	0.403	0.191	0.152	0.930
MAXSPEED	14	65.0	1.3	64.1	68.3
PercElderly	14	15.7	1.7	13.4	18.5
PercYoung	14	6.1	0.5	5.4	6.8
PercLicensed	14	70.2	1.0	68.7	70.7