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Contents

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Andreas Psarras[1], Theodore Panagiotidis*[2], and Andreas Andronikidis[1]

[1]Department of Business Administration, University of Macedonia, Greece

[2]Department of Economics, University of Macedonia, Greece

*Corresponding author: tpanag@uom.edu.gr

Abstract

This study examines the relationship between petrol prices and vehicle collisions using Greek data from 2012 to 2021. Generalized autoregressive conditional heteroscedasticity models are employed for daily motor vehicle collisions. Our analysis reveals that petrol prices have a significant impact on vehicle collisions. Fatal vehicle collisions decrease during relatively high petrol prices, whereas light-injury vehicle collisions increase. No significant relationship was found between severe-injury vehicle collisions and fuel prices. We also analyze daily data on motorcycle vehicle collisions and find a positive relationship between these accidents and fuel prices. When considering models with lagged fuel prices, our results indicate that in all cases, vehicle collisions decrease during periods of increasing fuel prices. These findings suggest that policies targeting motorcycling safety are particularly necessary during times of rising fuel prices.

Keywords: Petrol prices; Traffic safety; Road accidents; Motorcycle accidents.

JEL classification: R41; I19.

Abbreviations: AIC-Akaike information criterion; ARCH-autoregressive conditional heteroskedasticity; ARCH LM-Lagrange multiplier test for autoregressive conditional heteroskedasticity; AR-autoregressive term of mean equation; ARIMA-autoregressive integrated moving average; BIC-Bayesian information criterion; CI-confidence interval; fp-ln 95 unleaded petrol price (euro cents per liter); GARCH-generalized autoregressive conditional heteroscedasticity model; MA-moving average term of mean equation; MVC-daily number of motor vehicle collisions (or casualties) in Greece

1. Introduction

Motor vehicle collisions have decreased during the last decade in developed countries (Naqvi et al., 2020). This trend has been attributed to various factors, including economic ones, that significantly impact travel behavior and traffic safety (Zhu et al., 2015). Fuel prices are affected by two main factors: (a) the price of crude oil and (b) fuel-related taxes, which are set by the government (Naqvi et al., 2023; Özmen and Akçelik, 2017). From this perspective, fuel prices can be regarded as an important economic factor (Malkidis and Fountas, 2020) that can impact vehicle collisions.

Fuel prices can influence traffic safety through different aspects, including travel frequency and distance, commute modes, and driving behaviors (Chi et al., 2010; Rodrıguez-López et al., 2016). An increase in fuel prices could affect how people use their vehicles (will they use it only when it is necessary, frequency of trips for pleasure, etc). The relative cost would also affect the use of the same vehicle by more than one person when they are co-workers or want to reach the same place (carpooling). Public means of transportation, walking or biking, can be preferred to reduce travel costs. Increased fuel prices can also change how people drive their cars, driving slowly without harsh braking and sudden speeding in a more fuel-efficient manner (Singh and Kathuria, 2021). In the long term, sustained high fuel prices can lead people to change their workplace, residential location, or vehicle to one with lower energy consumption and better safety technologies. These adjustments generally result in less car usage, reduced traffic congestion, lower exposure to accidents, and safer driving behaviors. All of these can contribute to a decrease in the risk of accidents.

The literature examining the effects of fuel prices on vehicle collisions is limited, but generally establishes a negative relationship between them (Grabowski and Morrisey, 2006; Zhang and Burke, 2021). Nehiba (2020) claims that diesel fuel taxes reduce the total quantity involved in truck collisions through reduced truck miles, while substantially increasing the number of fatal collisions through the increase in cargo weight. On the other hand, Chang et al. (2022) reveal that gasoline price and alcohol consumption per capita are positively associated with road fatality risks. Chi et al. (2012) suggest that when gas prices are higher, there are fewer drunk-driving crashes, particularly among property-damage-only crashes. Other studies report a positive relationship between fuel price and patterns of motorcycle collision casualties (Best and Burke, 2019; Hyatt et al., 2009; Safaei et al., 2021; Wilson et al., 2009; Zhang and Burke, 2021; Zhu et al., 2015). Previous research uses econometric approaches (for instance ARIMA; GARCH; Poisson; negative binomial regression), employing data from a state or country[1] (Naqvi et al., 2020) (some studies employ data from more than one state[2]).

Figure 1 shows monthly vehicle collisions and the mean price of 95 unleaded petrol in Greece from 2012 to 2021. It is not straightforward to graphically identify an apparent effect of fuel prices on vehicle collisions (the correlation coefficient between the monthly values of the two variables is 0.405). Thus, an econometric analysis would be employed.

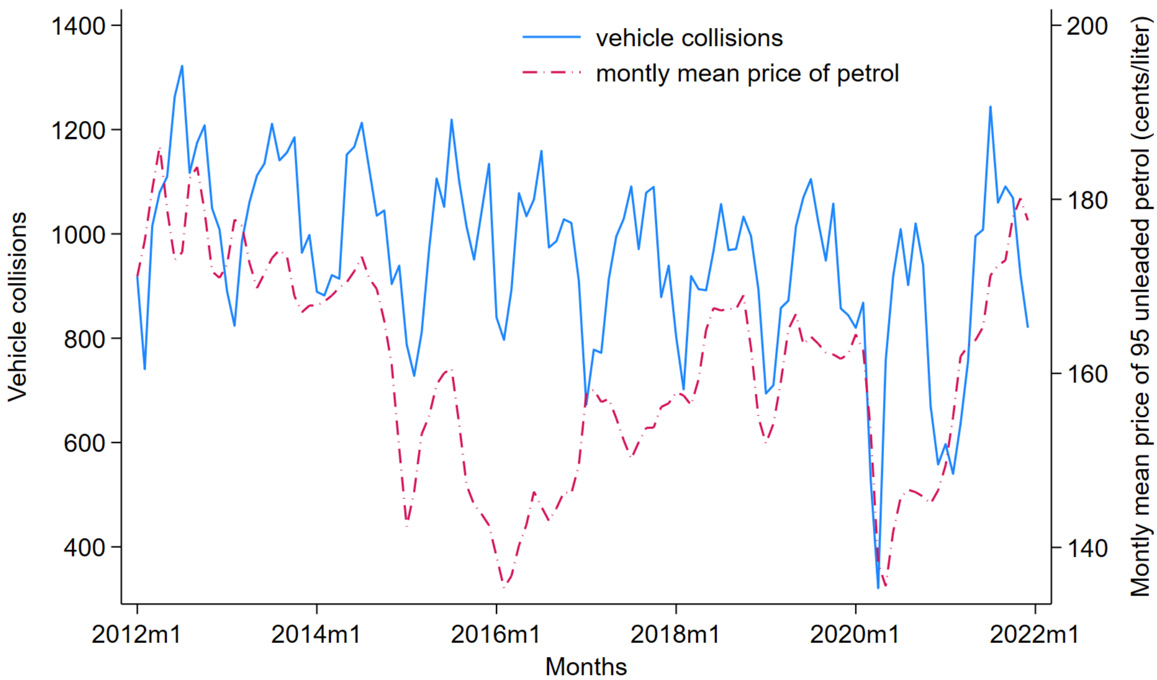

Figure 1: Monthly vehicle collisions and mean fuel prices in Greece, 2012-2021.

The existing literature predominantly focuses on the United States, with only a few exceptions. No analysis has been undertaken in Greece, where fuel prices are higher due to increased taxes. The contribution of this study lies in the evaluation of the effect of fuel prices on vehicle collisions in Greece. By examining this relationship, we aim to provide

[1]Florida (Chang et al., 2022); Mississippi (Chi et al., 2010); Minnesota (Chi et al., 2013); Alabama (Chi et al., 2012); Australia (Burke and Teame, 2018); New Zealand (Best and Burke, 2019)

[2]European Union member states (Naqvi et al., 2023); United States (Grabowski and Morrisey, 2006; Hyatt et al., 2009; Nehiba, 2020; Safaei et al., 2021)

valuable insights into how fluctuations in fuel costs influence road safety and road traffic accidents. We aim to fill the gap in the existing literature and inform policymakers on how fuel prices and traffic safety are related. The article proceeds as follows: the second section presents the data and the methodology; the third section discusses the results; the fourth the robustness tests; and the last section concludes.

2. Materials and Methods

2.1 Data

We employ the daily number of motor vehicle collisions and casualties in Greece[3] over the 2012-2021 period. These are obtained from the Hellenic Statistical Authority (anonymized microdata of statistical surveys[4]). The data exclude damage-only collisions, and the method of recording vehicle collisions follows the Vienna Convention's international criterion (fatalities include only those cases in which death occurred in less than 30 days due to vehicle collisions). The two most popular fuel products in Greece are petrol and diesel (Laliotis et al., 2023). We collected 95 unleaded petrol daily prices from the observatory[5] of fuel prices in Greece (Ministry of Development and Investments) over the 2012-2021 period. We use petrol prices for the estimations due to the large share of petrol-powered vehicles in Greece (91.1%). In comparison, diesel and electric-powered vehicles share are 8.1% and 0.5%, respectively (Spyropoulos et al., 2022). Table 1 presents the summary statistics of the collected data.

[3]It is worth mentioning that the weekly number of motor vehicle collisions and casualties were initially employed; however, the analysis results reveal that weekly fuel prices (95 unleaded petrol, 100 unleaded petrol, diesel, and liquefied petroleum gas) were not related to vehicle collisions. To ensure that the latter is accurate, we employ the daily number of motor vehicle collisions and casualties in Greece.

[4]https://www.statistics.gr/en/public-use-files.(Accessed on 23 June 2023). During the analysis, there were available daily data for the vehicle collisions until 2021.

[5]http://www.fuelprices.gr/. (Accessed on 23 June 2023) the online daily data start from 2017. George Koras, the web administrator of fuelprices.gr, was kind enough to provide us with older fuel prices via e-mail. The available data for fuel prices start from 2012.

[6]www.statistics.gr/en/statistics/-/publication/SDT04/-. Accessed on 23 June 2023.

[7]OECD, Eurostat and UNECE, 2010.

Table 1: Summary statistics of data.

Variable	Mean	Std. Dev.	Min	Max
Fatalities	2.082	1.661	0	14
Light injuries	34.815	10.322	2	79
Severe injuries	2.387	1.943	0	14
Vehicle collisions that a motorcycle participates	18.192	6.533	0	41
Fatal vehicle collisions	1.941	1.471	0	10
Severe injury vehicle collisions	2.2	1.715	0	11
Light injury vehicle collisions	27.332	7.673	2	55
95 unleaded petrol price (euro cents per liter)	160.477	12.131	133.434	187.332

There are 3653 total observations for each variable included in the above. All the variables are daily. Explanatory notes[6], [7]: '1. Vehicle collisions: Any accident involving at least one road motor vehicle in motion on a public road or square to which the public has access (excluding yards, industrial sites, or vehicle depots of public transport enterprises), resulting in at least one injured or killed person. Accidents involving only material damage were excluded. 2. Vehicle: Includes motor vehicles, trolleybuses, motorcycles, bicycles, motorbikes, agricultural and road-making machines, and animal and hand-drawn vehicles. Railway vehicles are excluded unless the road accident involves at least one of the above types of vehicles; therefore, railway vehicles are considered vehicles, 3. A person injured: Any person who sustained an injury due to an injury accident and who normally needs medical treatment; 4. Fatality: any person killed immediately or died within 30 days as a result of an accident; 5. Severe injury: Any person who sustained an injury as a result of an injury, such as brain damage, mutilation, or multiple injuries, which may result in a lack of awareness or life-threatening conditions (hospitalized for more than 24 hours); 5. Light injury: Any person who sustained minor and not life-threatening injuries.'

2.2 Data analysis

Poisson and negative binomial distributions can be employed to analyze count data (Wooldridge, 1999). The Poisson process has limitations in dealing with over-dispersion commonly found in vehicle collision data (Quddus, 2008). While Poisson and negative binomial regression models and their extensions help analyze cross-sectional data with the assumption that observations are independent of each other and have been used in previous studies to control autocorrelation by introducing a time trend variable (Noland and Karlaftis, 2005). However, these models are not suitable for time series data and can lead to incorrect estimation of parameters (Naqvi et al., 2020). Unit root tests have been employed. The Augmented Dickey-Fuller test indicates stationarity for all the variables, except 95 unleaded petrol price. Using the first log differences of the latter leads to stationarity. Autocorrelation was confirmed by the Durbin-Watson test (the null hypothesis that errors are serially uncorrelated was rejected; Durbin-Watson d-statistic=1.018 for daily light injury vehicle collisions-test results were similar for the rest of the Table 1 variables). Autoregressive integrated models (ARIMA) can effectively analyze over-dispersed count data with autocorrelation problems. However, an ARCH-LM test indicates the presence of autoregressive conditional heteroscedasticity (ARCH) effects[8] (small p-values

[8]An initial ordinary least squares regression indicated that ARCH effects are present in the residuals.

lead to rejection of the null hypothesis of no ARCH effects for all the Table 1 variables). As a result generalized autoregressive conditional heteroscedasticity (GARCH) models have been utilised to address autocorrelation and ARCH effects.

We used the natural logarithm of collisions and fuel price variables. We used the Schwarz's Bayesian information criterion (BIC) to determine the optimal level of lags (Becketti, 2013). Applying ARCH LM tests on the residuals, to check for remaining ARCH effects, shows that autocorrelation and ARCH effects problems have been addressed and that the GARCH model is acceptable (null hypothesis, that no ARCH effects are present, is not rejected due to high *p*-values).

The GARCH(1,1) specification that we follow can be written as follows (Equation 1):

$$lnMVC_t = \beta_0 + \sum_{j=1}^{p} \beta_j lnMVC_{t-j} + \sum_{i=1}^{q} \alpha_j \epsilon_{t-i} + \beta_1 \Delta lnpetrol_t + \epsilon_t \tag{1}$$

The variance equation is presented in Equation 2:

$$\sigma_t^2 = \gamma + \alpha \epsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \tag{2}$$

The dependent variable $lnMVC$ is the natural logarithm of the daily number of motor vehicle collisions (or casualties) in Greece. The independent variable, $lnpetrol$, is the natural logarithm of the daily 95 unleaded petrol price in euro cents per liter in Greece. Subscript t denotes time (day in this case). Equation 2 shows the conditional variance σ_t^2 as a function of a constant term γ, information on the previous period's volatility, captured by the lag of the square of the error term of Equation 1 (ϵ_{t-1}^2); and the previous period's conditional variance (σ_{t-1}^2). After applying the log-operator on zero and one, missing or zero values are replaced with a small (0.0001) non-zero value (see for instance, Sucarrat and Escribano (2018)).

3. Results and Discussion

The following Tables (2 and 3) present the results of the GARCH(1,1) models for motor vehicle collision casualties and collisions, respectively [9]. The magnitude of the coefficients displayed in the two tables are qualitatively similar (light injuries variable with light injury vehicle collisions, severe injuries with severe injury vehicle collisions, and fatalities with fatal vehicle collisions), ensuring the robustness of the results. In all cases, a lag on the mean equation was used, except for the model in which the collisions of light vehicles injured are the dependent variable (two lags of the MA were selected; the choice was driven using BIC). The coefficient on fuel prices is positive only in light injuries and light injury vehicle collisions. In the latter cases, the coefficient is statistically significant, indicating that an increase in fuel price will increase light injury vehicle collisions and casualties (a 1% increase in petrol fuel price is associated with a 12% increase in light injuries and an 8.5% increase in light injury vehicle collisions). This is not in line with the literature that suggests that increasing fuel prices will decrease vehicle collisions (Chi et al., 2012, 2010). In the case of severe injuries, the coefficients of fuel prices are negative but not statistically significant. Finally, the fuel price coefficient is negative and significant at the 5% level, in the case of fatal vehicle collisions. This indicates that an increase in 95 unleaded petrol prices will decrease fatal motor vehicle collisions (estimates indicate that an increase of 95 unleaded petrol price by 1% leads to a decrease in the number of fatal vehicle collisions by 15%). Similar conclusions were reached by Naqvi et al. (2020) and Grabowski and Morrisey (2006). In general, an increase in 95 unleaded petrol prices is associated with an increase in light injuries and a decrease in fatal vehicle collisions. To explain this conflict, we collect data for motorcycles participating in vehicle collisions. We followed the same diagnostic tools (see the data analysis section). Table 4 shows the regression results of the GARCH(1,1) model, having the number of vehicle collisions in which at least one motorcycle participates and the number of vehicle collisions without a motorcycle, as a dependent variable respectively.

[9] We also check for asymmetries in volatility by applying the Engle and Ng (1993) test, known as the sign and size bias test, to determine whether an asymmetric model is required for a given series, or whether the symmetric GARCH model can be deemed adequate (Brooks, 2019). The tests reveal asymmetry in volatility in half of the models. Applying exponential GARCH, for the models with asymmetries, did not change the significance of the coefficients compared to symmetric GARCH results.

Table 2: Regression results, GARCH(1,1) model: motor vehicle collisions casualties.

	Dependent variables		
	ln light injuries Coef. [95% CI]	ln severe injuries Coef. [95% CI]	ln fatalities Coef. [95% CI]
ln95 petrol	12.176** [2.18-22.171]	-6.966 [-24.693-10.76]	-8.59 [-25.672-8.48]
Constant	3.531*** [3.47-3.592]	0.657*** [0.477-0.837]	0.604*** [0.515-0.693]
1 lag AR	0.976*** [0.968-0.985]	-0.995*** [0.99-0.999]	0.991*** [0.984-0.998]
1 lag MA	-0.837*** [-0.86 to -0.813]	-0.948*** [-0.96 to -0.935]	-0.96*** [-0.975 to-0.945]
ARCH	0.058*** [0.041-0.074]	0.019*** [-0.004-0.034]	0.016 *[-0.015-0.033]
GARCH	0.848*** [0.791-0.906]	0.973*** [0.95-0.996]	0.974*** [0.94-1.00]
Constant	0.007*** [0.004-0.01]	0.002 [-0.001-0.006]	0.003 [-0.003-0.01]
Chi-square	56963.772	29136.182	2748.573
obs		3652	
Akaike crit.	735.675	5590.467	5360.469

*** p-value<0.01, ** p-value<0.05, * p-value<0.1. In95 petrol: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: AutoRegressive term of the mean equation.

Table 3: Regression results, GARCH(1,1) model: motor vehicle collisions.

	Dependent variables		
	ln light injury vehicle collisions Coef. [95% CI]	ln severe injury vehicle collisions Coef. [95% CI]	ln fatal vehicle collisions Coef. [95% CI]
ln95 petrol	8.561* [-0.683-17.805]	-5.498 [-22.24-11.242]	-15.24** [-29.472 to -1.009]
Constant	3.303*** [3.288-3.318]	0.604*** [0.443-0.775]	0.564*** [0.544-0.584]
1 lag AR	0.3*** [0.265-0.335]	0.994*** [0.99-0.998]	
1 lag MA		-0.947*** [-0.96 to -0.934]	
2 lags MA	0.108*** [0.072-0.144]		
ARCH	0.048*** [0.038-0.059]	0.019** [-0.004-0.034]	0.015* [-0.029-0.034]
GARCH	0.915*** [0.895-0.936]	0.973*** [0.95-0.996]	0.975*** [0.941-1.009]
Constant	0.003*** [0.002-0.004]	0.002 [-0.001-0.005]	0.002 [-0.037-0.009]
Chi-square	153.688	24989.696	2991.257
obs		3652	
Akaike crit.	5441.909	5250.507	5026.443

*** p-value<0.01, ** p-value<0.05, * p-value<0.1. In95 petrol: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: AutoRegressive term of the mean equation.

Table 4 shows that the coefficient of 95 unleaded petrol price is positive and statistically significant, indicating that an increase in fuel prices will lead to an increase in vehicle collisions in which at least one motorcycle participates (a 1% increase in the 95

Table 4: Regression results, GARCH(1,1) model: number of vehicle collisions that motorcycles participate/do not participate.

	Dependent variable	Dependent variable
	ln vehicle collisions that a motorcycle participates Coef. [95% CI]	ln vehicle collisions that no motorcycle participates Coef. [95% CI]
ln95 petrol	17.529*** [4.258-30.799]	6.391 [-3.295-16.078]
Constant	2.869*** [2.846-2.893]	3.489*** [3.4 73-3.505]
2 lag AR	0.268*** [0.231-0.304]	0.217*** [0.181-0.253]
1 lag MA	0.334*** [0.3-0.369]	0.24*** [0.205-0.274]
ARCH	0.062*** [0.047-0.078]	0.037*** [0.308-0.043]
GARCH	0.875*** [0.842-0.909]	0.936*** [0.923-0.948]
Constant	0.009*** [0.006-0.012]	0.002*** [0.001-0.003]
Chi-square	439.192	283.938
obs	3652	3652
Akaike crit.	3084.226	1376.523

*** p-value<0.01. In95 petrol: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: Autoregressive term of the mean equation.

unleaded petrol price is associated with 17.5% increase in vehicle collisions that at least one motorcycle participates). The coefficient of 95 petrol price in the case of vehicle collisions with no motorcycles participating is not statistically significant. The last results are in line with the conclusion Best and Burke (2019) that the number of serious injuries to cyclists tends to increase when fuel prices are high and the findings Zhang and Burke (2021) that gasoline prices positively affect motorcyclist deaths. The literature suggests that increasing fuel prices can increase motorcycle usage (Hyatt et al., 2009; Wilson et al., 2009) due to low fuel consumption - especially in urban areas where travel distances are shorter and can be a convenient alternative to cars (relatively congestion-free mode and easily parked in any spot). Brown et al. (2021) argue that the use of motorcycles has continued to increase over the years, attracting road users for a variety of reasons such as their lower running costs and the ability to navigate easily through congested traffic. This growing popularity can be attributed to motorcycles that offer an economical alternative to cars, particularly in urban areas where traffic congestion is a significant problem. Lower fuel consumption and maintenance costs make motorcycles a cost-effective mode of transportation, while their agility allows for more efficient movement in dense traffic, reducing travel time for commuters. Research has also shown that motorcycle users are particularly vulnerable on city roads because more people tend to use such modes in cities (Papadakaki et al., 2018). Increasing fuel prices leads to more motorcycle riders on the road and, consequently, more injuries (Hyatt et al., 2009; Safaei et al., 2021; Zhu et al., 2015). The fatal vehicle collision density is higher in rural than in urban areas (Zwerling et al., 2005) due to high speeds, road conditions, and late medical attention of the crash victims. In other words, increasing the number of motorcycles used in urban areas can increase no-fatal vehicle collisions. A further justification for the latter is Figures 2 and 3, which present the number of motorcycles participating in vehicle collisions with fatal and light-injury vehicle collisions, respectively. In Figure 3, the two plotted lines follow the same trend, in contrast to Figure 2, where the trend is not always the same (there are months when the two lines have the opposite trend).

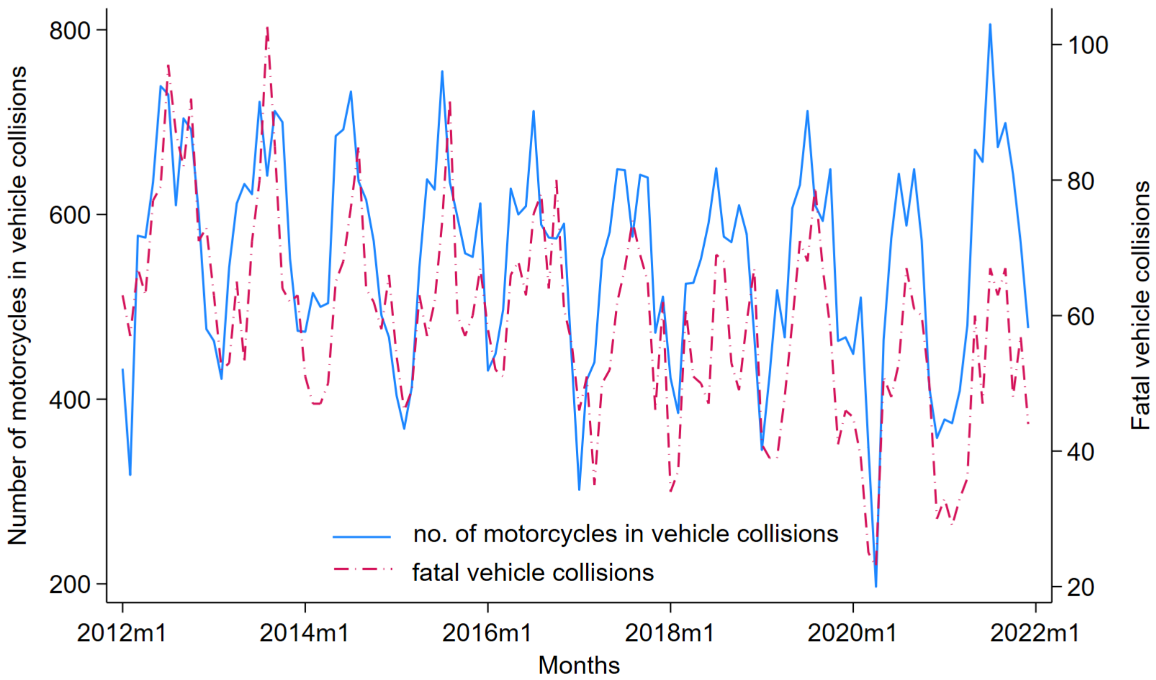

Figure 2: Monthly number of motorcycles in vehicle collisions and fatal vehicle collisions in Greece, 2012-2021.

We collect the monthly number of new registrations of motorcycles with an engine displacement of more than 50cc in Greece for the period 2012-2021 (data were obtained from the Hellenic Statistical Authority[10]) and plot them in the same figure with the mean monthly price of 95 unleaded petrol (Figure 4) to see if the increase of fuel price is associ-

[10]https://www.statistics.gr/en/statistics/-/publication/SME24/-. Accessed on 14 November 2023.

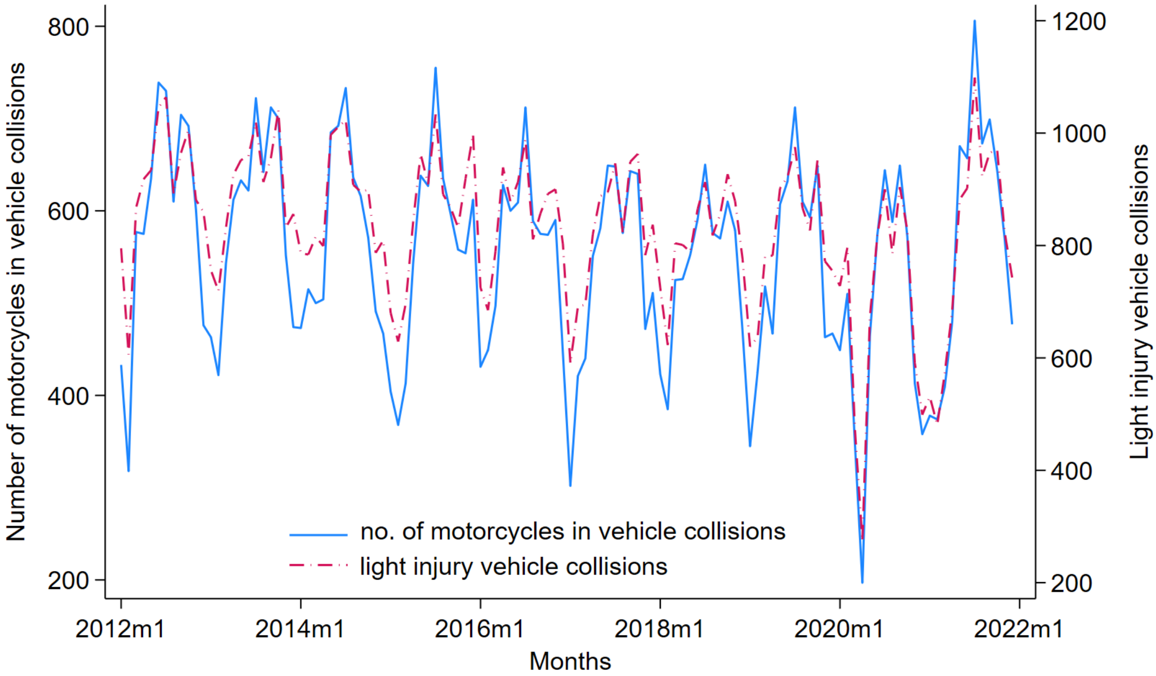

Figure 3: Monthly number of motorcycles in vehicle collisions and light-injury vehicle collisions in Greece, 2012-2021.

ated with more new motorcycle registrations, following Zhang and Burke (2021) findings that there is a positive relationship between gasoline prices and motorcycle registrations. The two lines show similarities in trends; however, seasonality is believed to influence the registration of motorcycles in Greece (most of the motorcycles are registered for the first time in April-November every year). Table 1 reveals that, in general, more than half of the daily vehicle collisions are accidents in which at least a motorcycle participates, which is impressive considering that motorcycles account for 19.4% of the vehicle fleet in Greece in 2022. Möller et al. (2020) argue that motorcycle riders have the highest injury and fatality rates among all road users. An increase in motorcycle vehicle collisions with increased petrol prices seems to be a factor in the number of motorcycles on the road (Hyatt et al., 2009).

We explored the potential lagged effect of petrol prices on vehicle collisions by re-estimating the model and using each time lagged value of the petrol price by one to ten days, as an independent variable. It is not only the news of an increase in fuel prices that might affect driving patterns but also the days following the increase, such as the day when the vehicle owner pays to fill the fuel tank. This immediate financial impact can lead to changes in driving behavior, as vehicle owners may become more conscious of their

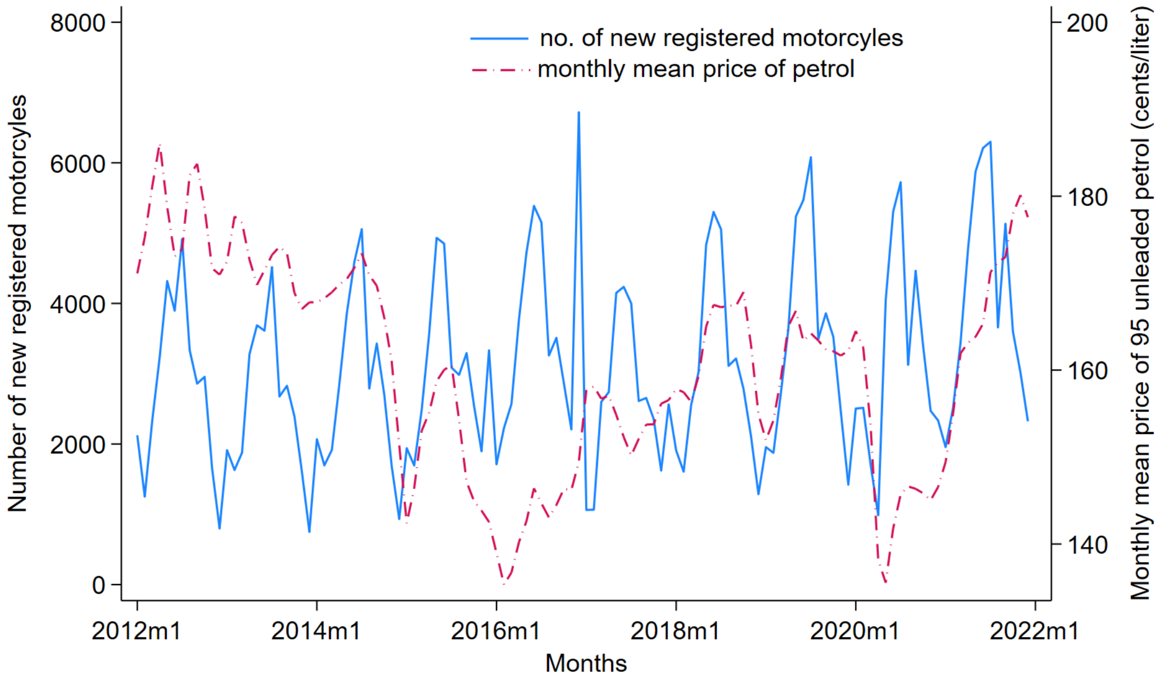

Figure 4: Monthly number of newly registered motorcycles and monthly mean price of 95 unleaded petrol in Greece, 2012-2021.

fuel consumption and seek to minimize costs. These behavioral adjustments are reflected in the study's findings, which are reported in the accompanying Tables 5 to 7. In all cases, there is a statistically significant coefficient with a negative value for the lagged variables, indicating that the relationship between petrol prices and vehicle collisions, eventually, gets negative after some days. Severe vehicle collisions (see Table 6) and vehicle collision accidents with motorcycles are not exceptions (see Table 7).

Table 5: Regression results, GARCH(1,1) model: light-injury vehicle collisions and lagged fuel prices.

	Dependent variable ln light injury vehicle collisions Coef. [95% CI]			
2-day lagged fp	-17.963*** [-26.957 to -8.969]			
4-day lagged fp		-10.555*** [-18.431 to -2.678]		
5-day lagged fp			-26.614*** [-35.598 to-17.631]	
6-day lagged fp				-12.781*** [-21.572 to -3.99]
Constant	3.304*** [3.289-3.318]	3.304*** [3.289-3.318]	3.304*** [3.29-3.319]	3.304*** [3.289-3.318]
1 lag AR	0.294*** [0.259-0.329]	0.294*** [0.259-0.329]	0.29*** [0.255-0.326]	0.294*** [0.259-0.329]
2 lag MA	0.107*** [0.071-0.143]	0.103*** [0.067-0.139]	0.109*** [0.073-0.146]	0.104*** [0.068-0.141]
ARCH	0.051*** [0.04-0.062]	0.05*** [0.039-0.061]	0.053*** [0.041-0.064]	0.05*** [0.039-0.062]
GARCH	0.909*** [0.888-0.931]	0.912*** [0.891-0.932]	0.906*** [0.884-0.928]	0.91*** [0.888-0.932]
Constant	0.003*** [0.002-0.004]	0.003*** [0.002-0.004]	0.003***[0.002-0.004]	0.003***[0.002-0.004]
Chi-square	371.626	363.269	379.307	372.12
obs	3650	3648	3647	3646
Akaike crit.	921.805	929.714	904.628	928.157

*** p-value$<$0.01. fp: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: Autoregressive term of the mean equation.

Table 6: Regression results, GARCH(1,1) model: severe-injury and fatal vehicle collisions and lagged fuel prices.

	Dependent variable	Dependent variable
	ln severe injury vehicle collisions Coef. [95% CI]	ln fatal vehicle collisions Coef. [95% CI]
4-day lagged fuel price		-14.299** [-28.125 to -.0473]
9-day lagged fuel price	-15.583* [-32.392-1.226]	
Constant	0.634*** [0.47-0.797]	0.564*** [0.544-0.584]
1 lag AR	0.995*** [0.99-0.999]	
1 lag MA	-0.947*** [-0.96 to -0.934]	
ARCH	0.019** [0.004-0.034]	0.016* [-0.003-0.034]
GARCH	0.973*** [0.95-0.996]	0.975*** [0.942-1.009]
Constant	0.002*** [0.95-0.996]	0.003 [-0.004-0.009]
Chi-square	210393.382	4109
obs	3643	3648
Akaike crit.	6026.074	6185.522

*** p-value<0.01, ** p-value<0.05, * p-value<0.1. CI: Confidence Interval. MA: Moving average term of the mean equation. AR: AutoRegressive term of the mean equation. Fuel price: ln 95 unleaded petrol price (euro cents per liter).

Table 7: Regression results, GARCH(1,1) model: vehicle collisions with/without motorcycles and lagged fuel prices.

	Dependent variable ln vehicle collisions with motorcycles Coef. [95% CI]	Dependent variable ln vehicle collisions with motorcycles Coef. [95% CI]	Dependent variable ln vehicle collisions without motorcycles Coef. [95% CI]	Dependent variable ln vehicle collisions without motorcycles Coef. [95% CI]
2-day lagged fp	-13.04** [-24.942 to -1.139]		-19.68*** [-29.115 to -10.245]	
4-day lagged fp		–15.388*** [-26.363 to -4.414]		-10.621** [-19.2 to -2.042]
Constant	2.87*** [2.846-2.893]	2.87*** [2.846-2.893]	3.49*** [3.475-3.506]	3.49*** [3.475-3.505]
2 lag AR	0.261*** [0.225-0.297]	0.259*** [0.222-0.295]	0.211*** [0.175-0.247]	0.209*** [0.173-0.245]
1 lag MA	0.331*** [0.297-0.366]	0.33*** [0.295-0.365]	0.238*** [0.203-0.272]	0.236*** [0.201-0.271]
ARCH	0.064*** [0.048-0.079]	0.067*** [0.05-0.083]	0.039*** [0.032-0.045]	0.038*** [0.032-0.044]
GARCH	0.873*** [0.839-0.907]	0.866*** [0.83-0.902]	0.932*** [0.919-0.945]	0.934*** [0.922-0.946]
Constant	0.009*** [0.006-0.012]	0.01*** [0.006-0.013]	0.003*** [0.002-0.003]	0.002*** [0.002-0.003]
Chi-square	431.346	409.576	277.408	266.685
obs	3649	3647	3650	3648
Akaike crit.	3085.211	3084.163	1362.674	1373.353

*** p-value<0.01, ** p-value<0.05. fp: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: AutoRegressive term of the mean equation.

Figure 5 summarizes all statistically significant values of the coefficients of the petrol price (lagged and contemporaneous) for different types of vehicle collisions (Tables 3 to 7). Different types of vehicle collisions are represented with different symbols (for instance, light injury vehicle collisions with a circle, vehicle collisions without motorcycles with an X, etc.). Only in the case of light injury vehicle collisions and vehicle collisions with motorcycles when the same-day petrol prices are included, there is a positive relationship (a 1% increase in petrol fuel price is associated with an 8.5% increase in light injury vehicle collisions and a 17.53% increase in vehicle collisions with motorcycles, respectively). In all the other cases, a 1% increase in petrol prices is associated with a decrease in vehicle collisions.

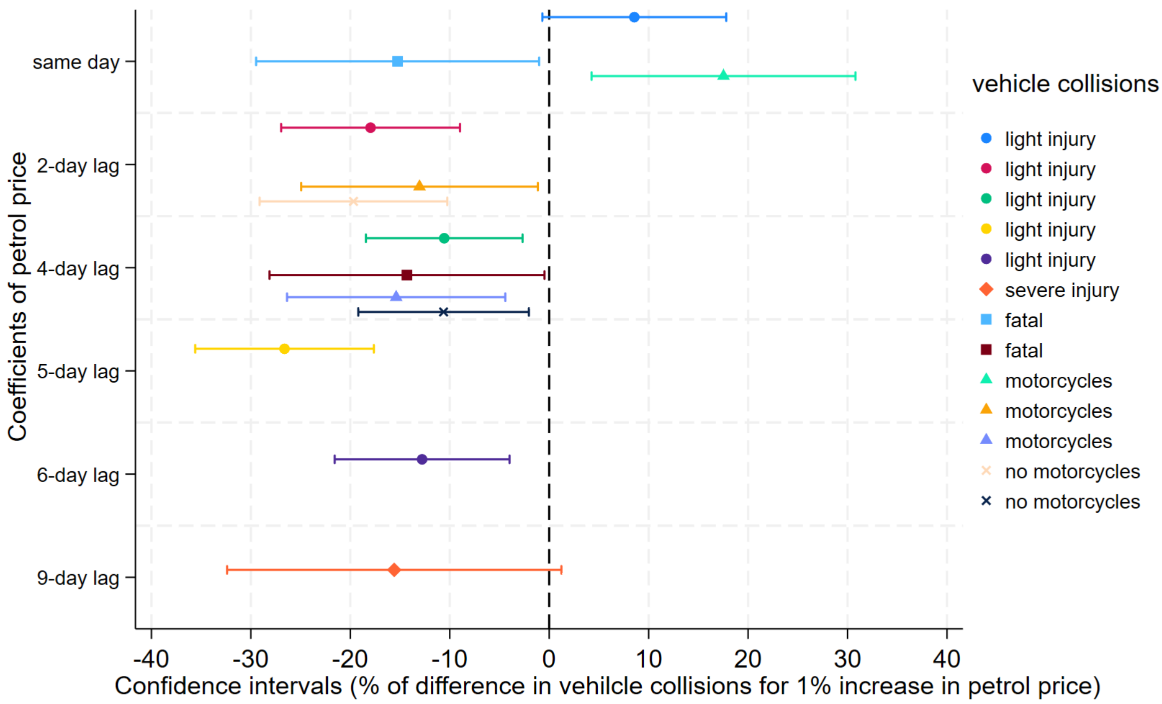

Figure 5: Effect of petrol price increase on vehicle collisions.

4. Robustness tests

The data employed in the research includes the COVID-19 pandemic period. During this period, the Greek government implemented interventions to control the spread of the disease. The suspension of educational institutions, the closure of the borders, the curfews and the closure of restaurants, cafes, retail stores and other establishments were some of the interventions that may have affected the number of vehicle collisions during the COVID-19 pandemic. To provide evidence that the pandemic restrictions did not affect the study results, we add a dummy variable named *lockdowns*, in the model (see Equation 3), which takes the value of one (1) for the period March 23, 2020, to May 31, 2020, and the value of zero (0) for all other dates of the sample (note that the Greek government implemented interventions on March 23, 2020, and lifted most of them by June 1, 2020). Equations 3 and 4 that are used follow:

$$lnMVC_t = \beta_0 + \sum_{j=1}^{p} \beta_j lnMVC_{t-j} + \sum_{i=1}^{q} \alpha_j \epsilon_{t-i} + \beta_1 \Delta lnpetrol_t + \beta_2 lockdowns + \epsilon_t \quad (3)$$

$$\sigma_t^2 = \gamma + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \quad (4)$$

The only difference between Equations 1 and 3 is the inclusion of the *lockdowns* dummy variable. Equations 2 and 4 are identical. Tables 8 and 9 present the results. In the cases where the coefficient of the fuel price is statistically significant the coefficient of the dummy variable is also statistically significant, however, the coefficients of the variables in Tables 8 and 9 are almost the same as those in Tables 2 and 3, respectively. In the cases where the coefficient of the fuel price is not statistically significant, the coefficient of the dummy variable is not statistically significant either (except for the last column in Table 8, where the coefficient of *lockdowns* is statistically significant, however, the coefficient of $ln95petrol$ variable obtains a value similar to Table 2 and once again not statistically significant). Tables 8 and 9 are similar to Tables 2 and 3, respectively, which provides evidence that the data during the COVID-19 pandemic did not affect the study results.

Table 8: Regression results, GARCH(1,1) model: motor vehicle collisions casualties(including COVID-19 dummy variable).

	Dependent variables		
	ln light injuries Coef. [95% CI]	ln severe injuries Coef. [95% CI]	ln fatalities Coef. [95% CI]
ln95 petrol	11.851** [1.813-21.889]	-8.573 [-26.367-9.22]	-12.127 [-29.276-5.021]
lockdowns	-0.232** [-0.411 to -0.052]	-0.14 [-0.375-0.093]	-0.272** [-0.5-0.045]
Constant	3.533*** [3.474-3.591]	0.663*** [0.488-0.838]	0.613*** [0.534-0.693]
1 lag AR	0.975*** [0.966-0.984]	-0.995*** [0.99-0.999]	0.991*** [0.982-0.998]
1 lag MA	-0.835*** [-0.86 to -0.811]	-0.949*** [-0.961 to -0.936]	-0.96*** [-0.975 to-0.946]
ARCH	0.058*** [0.041-0.075]	0.019*** [-0.004-0.034]	0.018* [0-0.037]
GARCH	0.845*** [0.785-0.904]	0.973*** [0.95-0.996]	0.971*** [0.936-1.005]
Constant	0.007*** [0.004-0.01]	0.002 [-0.001-0.006]	0.003 [-0.003-0.01]
Chi-square	51095.545	233582.308	76707.992
obs		3652	
Akaike crit.	731.664	6468.073	6433.69

*** *p*-value<0.01, ** *p*-value<0.05, * *p*-value<0.1. In95 petrol: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: Autoregressive term of the mean equation.

Table 9: Regression results, GARCH(1,1) model: motor vehicle collisions (including COVID-19 dummy variable).

	Dependent variables		
	ln light injury vehicle collisions Coef. [95% CI]	ln severe injury vehicle collisions Coef. [95% CI]	ln fatal vehicle collisions Coef. [95% CI]
ln95 petrol	8.41* [-1.023-17.805]	-6.895 [-23.706-9.914]	-16.08*** [-29.472 to -5.389]
lockdowns	-0.587*** [-0.696 to -0.479]	-0.121 [-0.342-0.1]	-0.387*** [-0.515 to -0.259]
Constant	3.306*** [3.291-3.321]	0.609*** [0.443-0.776]	0.572*** [0.552-0.592]
1 lag AR	0.297*** [0.262-0.331]	0.994*** [0.99-0.998]	
1 lag MA		-0.948*** [-0.96 to -0.935]	
2 lags MA	0.109*** [0.074-0.145]		
ARCH	0.034*** [0.025-0.043]	0.019** [0.004-0.034]	0.019* [0-0.039]
GARCH	0.94*** [0.926-0.959]	0.973*** [0.95-0.996]	0.97*** [0.937-1.002]
Constant	0.001*** [0.001-0.002]	0.002 [-0.001-0.005]	0.003 [-0.002-0.009]
Chi-square	515.146	215936.686	38.097
obs		3652	
Akaike crit.	894.014	6043.354	6150.17

*** *p*-value<0.01, ** *p*-value<0.05, * *p*-value<0.1. In95 petrol: ln 95 unleaded petrol price (euro cents per liter). CI: Confidence Interval. MA: Moving average term of the mean equation. AR: Autoregressive term of the mean equation.

5. Conclusion

This study examines the relationship between petrol prices and the number of vehicle collisions and casualties. To the best of our knowledge, there have not been any previously published papers that have studied this relationship using daily data from Greece. Our findings suggest that petrol prices significantly affect motor vehicle collisions.

An increase in fuel prices leads to a decrease in fatal vehicle collisions but an increase in light injury collisions and casualties. Fluctuating petrol prices may influence consumers' choice of travel mode. Specifically, the number of vehicle collisions involving at least one motorcycle increases with increasing petrol price. Higher fuel prices encourage more people to use motorcycles in urban areas, leading to more light injuries. These results underscore the need for improved motorcyclist safety measures during periods of high fuel prices, such as enforcing the use of helmets, motorcycle clothing, and other safety equipment, and increasing safety campaigns focused on motorcycle riders.

An increase in fuel prices may be the result of factors beyond government policy. Policymakers should anticipate fluctuations in fuel prices by promoting a safer transportation environment for road users. In Greece, enhancing the public transport system through subsidized buses, trains, and metros could decrease the prevalence of private vehicles and motorbikes in urban areas. It is imperative to expand existing routes and increase the frequency of transport modes to offer citizens high-quality, comfortable, and timely service. Furthermore, upgrading the road infrastructure by improving lighting, signage, and road surfaces, along with establishing separate lanes for motorcycles and bicycles, could mitigate accidents in motor vehicles during periods of elevated fuel prices. Strengthening the enforcement of traffic regulations, increasing random inspections for speeding, alcohol consumption, and license verification, and implementing a zero-tolerance policy for mobile phone use while driving can effectively support these policies.

Promoting the transition to hybrid and electric vehicles (EVs) can reduce reliance on gasoline, decrease accident risks, and modernize vehicle fleets, as many of these vehicles are equipped with advanced safety features. The government could facilitate this transition through financial incentives, such as encouraging the leasing of new safe vehicles, expanding electric vehicle /hybrid charging infrastructures, and installing faster, more affordable and more accessible public chargers. Additionally, offering reduced annual taxes, free registration for EVs and hybrids, and complimentary parking could further support this initiative.

We also included models using lagged values of petrol prices, revealing negative and statistically significant values for all kinds of vehicle collisions coefficients (light, severe, and fatal), with or without motorcycles. This indicates that an increase in petrol prices eventually leads to a short-term decrease in vehicle collisions. It appears that petrol prices have a short-term impact on vehicle collisions and casualties, as weekly data on fuel prices and vehicle collisions were not significantly associated.

A limitation of this study was the inability to provide additional characteristics (fatal, serious, or light injury) of motorcyclist collisions during periods of high fuel prices due to lack of data. It would be interesting to reexamine the effects of fuel prices on vehicle collisions as the share of electric vehicles increases in the near future. Notably, from 2035, all new cars and vans registered in the EU are set to be zero-emission, which could significantly alter the dynamics of how fuel prices impact vehicle collisions and casualties.

Declaration of interest

The authors report there are no competing interests to declare.

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