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The Impact of Fuel Price Fluctuations on Road Transportation Safety Across Europe

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Abstract: This study examines whether fluctuations in real fuel prices influence road-traffic accidents across 28 European countries from 2010 to 2023. Using a panel econometric framework combining two-way fixed effects and first-difference instrumental variable (FD-IV) estimation, Brent crude oil prices (in euros) serve as an exogenous instrument for domestic fuel prices. Results show no consistent causal link between fuel prices and accident totals. The baseline FD-IV model yields a short-term positive elasticity ($\beta \approx 0.21$, $p = 0.003$), implying that a 10% increase in diesel prices corresponds to a 2.1% rise in accidents; however, this effect disappears once pandemic years (2020-2021) are excluded. Robustness checks confirm the insignificance of the relationship across alternative specifications. The findings suggest that price-accident correlations are transient and crisis-driven rather than structural, underscoring that long-term road safety depends primarily on infrastructure quality, enforcement, and vehicle safety standards rather than energy price fluctuations.

Keywords: Fuel Prices, road accidents, instrumental variable (IV), brent crude oil, panel data analysis

1. Introduction

The stability of fuel prices plays a crucial role in shaping the dynamics of road transportation across Europe, influencing both economic activity and the safety of transport systems. Fluctuations in fuel prices can alter driving behaviors, vehicle usage patterns, and operational costs for both private and commercial users. Consequently, understanding how these price variations affect road safety is essential for designing policies that mitigate risks and enhance sustainable mobility outcomes [1]. Road-traffic accidents have declined across Europe in recent decades, largely due to advancements in vehicle safety, infrastructure, and enforcement. Yet, macroeconomic factors such as income shocks, recessions, and fuel price changes also affect driving exposure and accident rates, suggesting a broader economic dimension to road safety outcomes [2]. Studies from other transport sectors, such as maritime and rail, confirm that higher energy prices and speed regulations can reduce accident frequencies, linking fuel costs to safety-related behavior [3,4].

Fuel pricing reforms, including higher taxes and congestion-based pricing, are often implemented to reduce emissions, accidents, and congestion [5]. However, despite their environmental and fiscal benefits, the safety implications of these reforms remain less understood. In particular, Europe's fuel tax system, where petrol is relatively well-taxed but diesel remains under-taxed, may indirectly influence driving intensity and accident risk [6]. Similarly, evidence from freight transport shows that while diesel taxes can reduce vehicle miles traveled, they may simultaneously increase load weights and accident severity [7]. The COVID-19 pandemic further revealed how changes in fuel prices and mobility restrictions influence travel patterns and accident outcomes, with fuel price increases proving more effective in reducing traffic volume and offenses than lockdown measures [8]. Although technological innovations, such as driver-assistance systems and onboard diagnostics, have improved vehicle-level efficiency and safety, the broader macroeconomic interactions between fuel price volatility and accident trends remain empirically underexplored [9].

Building on this context, this study examines the causal relationship between fuel price fluctuations and road-traffic accident outcomes across 28 European countries from 2010 to 2023. By integrating economic, policy, and behavioral perspectives, the analysis contributes to understanding how energy market volatility translates into road safety dynamics. This will lead to the Research Questions:

RQ1: How do fluctuations in real fuel prices, driven by global oil market shocks, affect the total number of road-traffic accidents across European countries?

RQ2: Does this relationship persist after accounting for exogenous global oil shocks and excluding pandemic-induced mobility disruptions (2020-2021)?

2. Review of Literature

A growing body of research across Europe and beyond has examined how fuel prices, energy policies, and vehicle technologies shape road transport safety, mobility, and environmental outcomes. Evidence from EU panel analyses shows that higher fuel prices significantly reduce road fatalities, collisions, and casualties, with a 10% price increase lowering fatalities by 2.2–2.6% and injuries by 1.2–1.6% [10]. Similarly, travel-demand management simulations indicate that a 20% fuel-price increase can reduce vehicle-kilometres travelled (VKT) by 11.6% and injury crashes by 2.8% [11].

Yet behavioural responses vary: reduced-form models show that VKT decreases for gasoline but not diesel cars [12], and asymmetric nonlinear ARDL results reveal that Korean drivers reduce travel less when prices rise but increase travel sharply when prices fall [13,14].

Price responsiveness exhibits substantial heterogeneity. Household-level evidence from Germany shows strong variability in fuel-price elasticities across income and region groups [15], while Swedish county-level elasticities differ by a factor of four [16]. Broader European analyses find that both petrol and diesel demand are more price-elastic than previously assumed, especially when excise taxes are used as instruments [17], though long-run elasticities for U.S. trucking have declined from elastic in the 1970s to inelastic today [18]. In Japan, 16.57 million hourly observations show fuel-price increases can even raise expressway traffic through route-switching [19]. These mixed patterns highlight the importance of fuel-price uncertainty, which induces asymmetric travel responses [14] and the role of real-time behavioural adjustments, with fuel economy responding to price changes only contemporaneously [20].

At the policy level, studies show that fuel taxation remains a critical regulatory tool. Cross-country analyses reveal that petrol taxes in several EU states already approximate corrective levels, while diesel remains universally under-taxed [21]. Higher excise taxes modestly reduce passenger-car CO_2 emissions, with stronger effects in high-tax states [22]. Proposed reforms such as repealing diesel tax advantages or adopting carbon-content-based taxes could substantially cut emissions while raising revenue [17]. Meanwhile, decarbonization efforts, such as electrification and fuel-efficiency standards, shift long-term energy demand, with projections showing a significant move toward electricity by 2040 [23]. EU-wide decomposition studies attribute declining normalised energy consumption to efficiency and decarbonization policies despite rising motorisation [16].

Technological studies deepen this understanding. Large-scale vehicle-level data show a widening gap between official and on-road fuel efficiency, driven partly by fuel-efficient technologies like hybrids [24]. Chassis-dynamo experiments indicate that paraffinic diesel and higher-FAME blends can reduce NOx and TTW emissions without harming CO_2 efficiency, though low-density fuels may raise hydrocarbons, and Euro VI systems may increase N_2O [25]. Machine-learning models using high-frequency PEMS data demonstrate that ANN-based prediction significantly improves fuel-consumption estimation in heavy-duty trucks [26]. Floating-car-data approaches similarly show that VSP-bin distributions effectively estimate network-level fuel efficiency [27].

Fuel prices also shape broader transport dynamics. Higher fuel prices reduce purchases of conventional cars and accelerate the adoption of hybrids and EVs [28], while economic and trade variables exert contemporaneous but not causal effects on transport activity in Poland [29]. Freight-sector studies reveal that diesel excise differences influence cross-border refuelling and transport performance [30]. Finally, policy-simulation work shows mixed effects: while taxes, PAYD/PATP, and VMT charges generally reduce fatalities, CAFE standards can unintentionally increase them [31], and decarbonization reforms require compensatory tax adjustments to maintain fiscal sustainability [32].

3. Data and Methodology

The analysis uses a balanced annual panel for 28 European countries (EU-27 plus the UK) from 2010 to 2023. The dependent variable is the number of road-traffic victims (fatalities and injuries) from Eurostat. Real retail diesel and gasoline prices, sourced from the European Commission's Weekly Oil Bulletin, converted to annual euro-per-litre averages, and deflated using national HICP, serve as the main explanatory variables. Brent crude oil prices (EUR/barrel) from the Commission act as an instrumental variable capturing exogenous global supply shocks. The estimation proceeds in three sequential steps: at first, Two-Way Fixed-Effects OLS (Baseline): The baseline model regresses the logarithm of road-traffic accidents on the logarithm of real diesel prices, controlling for country and year fixed effects:

$$\log(Accidents_{it}) = \alpha_i + \gamma_t + \beta \log(P_{it}^{diesel}) + \varepsilon_{it} \tag{1}$$

where: α_i captures country-specific unobserved heterogeneity and γ_t captures time shocks common across countries. Secondly, First-Difference Instrumental-Variable Model (Main Specification): To address simultaneity bias (fuel prices reacting to national conditions such as GDP or mobility), the model employs a first-difference (FD) transformation to remove fixed effects and instruments price changes with Brent oil changes:

$$\Delta\log(Accidents_{it}) = \beta\,\Delta\log(P_{it}^{diesel}) + \varepsilon_{it} \tag{2}$$

with the first stage:

$$\Delta\log(P_{it}^{diesel}) = \pi\,\Delta\log(Brent_t) + u_{it} \tag{3}$$

The instrument $\boldsymbol{\Delta\log(Brent_t)}$ captures global oil shocks exogenous to domestic accident conditions. And last, for the Robustness and Sensitivity Tests: first, we calculate the exclusion of pandemic years 2020-2021 to test distortion effects. Secondly, by substituting gasoline for diesel prices. And finally, by applying winsorization (1-5%) and omitting small outlier economies (for example, Malta and Luxembourg). All regressions are estimated using clustered standard errors by country to account for serial correlation within panels. The primary parameter of interest, $\boldsymbol{\beta}$, measures the elasticity of accidents with respect to fuel prices, interpreted as the percentage change in accident totals associated with a 1% change in real fuel prices. Instrument strength is evaluated via the first-stage F-statistic and partial $\boldsymbol{R^2}$. An F-statistic exceeding 10 confirms strong instrument relevance; in this analysis, all F-statistics exceed 350 (diesel ≈ 618, gasoline ≈ 359). Identification relies on the exogeneity of Brent price shocks to domestic road-safety outcomes. While local retail prices may respond to national factors, Brent shocks originate from global supply conditions (OPEC output changes, geopolitical disruptiolns) unrelated to European accident determinants. Hence, the exclusion restriction is credible:

$$Cov(\Delta \log (Brent_t), \varepsilon_{it}) = 0 \quad (4)$$

The full empirical workflow was implemented in Python (pandas, statsmodels, linearmodels), with reproducible scripts for the Data merging and real-price deflation, Panel differencing and winsorization, IV estimation (2SLS using IV2SLS.from_formula), and the Cluster-robust inference and result visualization (matplotlib).

4. Results

4.1 Descriptive Statistics and Trends

Table 1 summarizes key variables across 28 European countries. Road-traffic victims average 901 annually, ranging from under 10 to over 4,000, reflecting population and infrastructure differences. Average diesel and gasoline prices are €2.48 and €2.64 per litre, with moderate variability (SD ≈ 0.35- 0.40). Brent crude averages €64.47 per barrel (SD = 17.6), ranging from €37 to €96. Overall, road accidents show a declining trend, and fuel prices closely track oil market fluctuations, supporting the instrumental variable analysis.

Table 1 Descriptive Statistics of Main Variables (2010-2023). Source: authors

Variable	Mean	Std. Dev.	Min	Max
Road-traffic victims	901.17	1,094.22	9.00	4,189.00
Real diesel price (€/litre)	2.48	0.35	1.71	3.60
Real gasoline price (€/litre)	2.64	0.40	1.69	3.53
Brent oil price (€/barrel)	64.47	17.59	36.77	95.81

Figure 1 shows a steady decline in road-traffic victims, from over 1,100 in 2010 to below 800 after 2020, reflecting safer roads and stronger regulations. A sharp dip appears in 2020-2021 due to reduced mobility during the pandemic. The red dashed line depicts volatile Brent crude oil prices, peaking in 2012 and 2022 and collapsing in 2015-2016 and 2020. The co-movement between Brent and fuel prices provides strong instrumental variation, supporting later causal analysis.

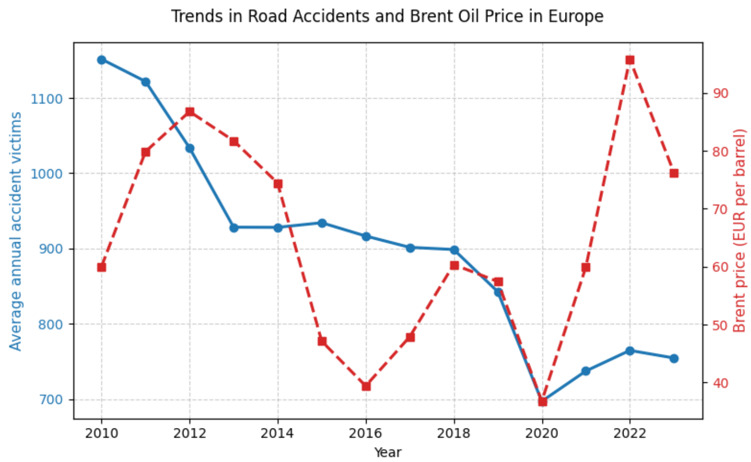

Fig. 1 Trends in Road Accidents and Brent Oil Price in Europe (2010-2023). Source: authors

4.2 Correlations and First-Stage Relationships

Table 2 shows a strong correlation between diesel and gasoline prices ($r = 0.87$), reflecting their shared dependence on global oil markets. Brent and diesel prices are moderately correlated ($r = 0.59$), confirming Brent's suitability as an instrumental variable. Accident rates show only weak links to fuel prices ($r \approx 0.13$-0.15) and none with Brent ($r = 0.02$), suggesting that oil shocks do not directly affect accidents, justifying the need for econometric controls to identify causal effects.

Table 2 Correlation Matrix of Main Variables (2010-2023). Source: authors

Variable	Road-traffic victims	Real diesel price	Real gasoline price	Brent oil price
Road-traffic victims	1.000	0.132	0.146	0.021
Real diesel price	0.132	1.000	0.866	0.586
Real gasoline price	0.146	0.866	1.000	0.385
Brent oil price	0.021	0.586	0.385	1.000

The first-stage diagnostics indicate very strong instruments across all specifications (Table 3): for diesel, $F = 618.10$ with partial $R^2 = 0.793$; for gasoline, $F = 359.20$ with partial $R^2 = 0.680$. Strength remains virtually unchanged when excluding 2020-2021 (diesel $F = 614.28$, partial $R^2 = 0.787$). These values far exceed conventional weak-instrument thresholds, confirming that Δlog(Brent) provides powerful and exogenous variation to identify the causal effect of Δlog(real fuel prices) on accident outcomes.

Table 3 First-Stage Regression Diagnostics (FD-IV), 2010-2023. Source: authors

Specification	Obs. (N)	Clusters	First-stage F	Partial R^2
FD-IV Diesel	356	28	618.10	0.793
FD-IV Diesel excl. 2020-21	302	28	614.28	0.787
FD-IV Gasoline	356	28	359.20	0.680

4.3 Baseline Fixed-Effects OLS (Levels)

The FE-OLS estimate for log(real diesel price) is 0.018 with p=0.941, indicating no statistically significant contemporaneous association between fuel prices and accident totals after controlling for country and year factors (Table 4). This aligns with the descriptive evidence that accident trends decline steadily while prices are volatile. Because retail prices also respond to macro shocks (mobility, GDP, pandemic) that may simultaneously influence accidents, the FE-OLS estimate can suffer from simultaneity bias. This justifies the FD-IV strategy in the next subsection, which uses Δlog(Brent EUR) as an external source of variation. Predicted vs. Actual Road Accidents under OLS Fixed Effects (2010-2023) is shown in Figure 2.

Table 4 Baseline Two-Way Fixed Effects OLS (Levels), 2010-2023. Source: authors

Variable	Coefficient	Std. Error	t-Statistic	p-Value
log(real diesel price)	0.018	0.244	0.074	0.941

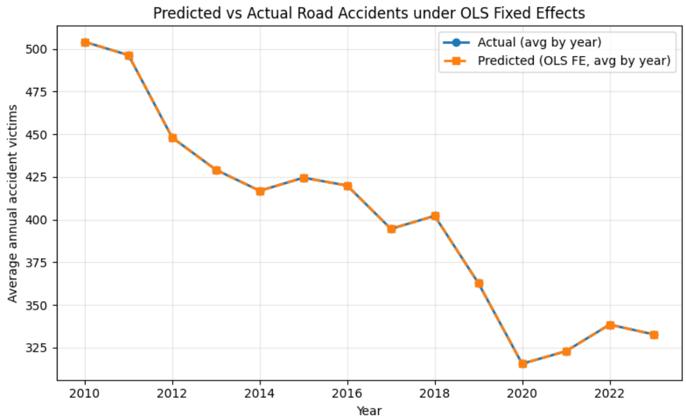

Fig. 2 Predicted vs. Actual Road Accidents under OLS Fixed Effects (2010-2023). Source: authors

4.4 First-Differences IV Estimation (Main Model)

Table 5 presents first-difference IV estimates using Brent (in EUR) as an instrument for diesel prices. A 10% rise in diesel prices corresponds to a 2.1% increase in road-traffic victims ($\beta = 0.211$, $p = 0.003$), supported by a strong first stage ($F \approx 618$). Excluding 2020-2021, the effect disappears ($\beta \approx -0.005$, $p = 0.958$), indicating the relationship is driven by crisis-period volatility. Similar results for gasoline confirm this pattern. Overall, the positive effect reflects short-term disruptions rather than a stable causal mechanism.

Table 5 FD-IV Estimation Results (2010-2023). Source: authors

Specification	β	SE	t	p	N	Clusters	First-stage F	Partial R^2
FD-IV Diesel (main)	0.211	0.071	2.96	0.003	356	28	618.10	0.793
FD-IV Diesel excl. 2020-21	-0.005	0.092	-0.05	0.958	302	28	614.28	0.787
FD-IV Gasoline (robustness)	0.305	0.104	2.93	0.003	356	28	359.20	0.680

Figure 3 shows a tight positive relationship between Δlog(Brent EUR) and Δlog(real diesel price) across country-years, with a clear upward fitted line. This visual corroborates instrument relevance (high partial R^2), consistent with the large first-stage F in Table 5. And the second plots Δlog(accidents) against the instrumented Δlog(diesel) (predicted from Brent). The fitted IV line has a small positive slope (≈ 0.211). The cloud is wide, indicating substantial residual variation, but the slope is statistically non-zero in the full sample. The modest magnitude and the loss of significance when excluding 2020-21 underscore that the measured elasticity is concentrated in high-volatility years and should not be over-generalized.

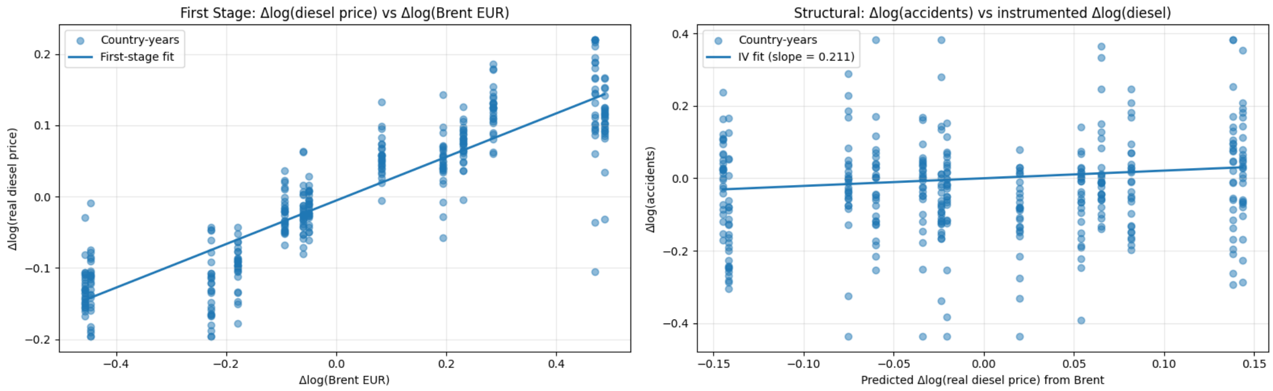

Fig. 3 Structural relation: Δlog(accidents) vs instrumented Δlog(diesel) and First stage: Δlog(diesel price) vs Δlog(Brent EUR). Source: authors

4.5 Robustness Checks

Table 6 confirms the robustness of the main FD-IV estimate ($\beta \approx 0.21$, $p = 0.003$). Excluding 2020-2021 reduces the effect to zero ($p \approx 0.998$), showing that the positive elasticity stems solely from crisis shocks. Using gasoline instead of diesel or trimming outliers yields consistent results, indicating that the relationship is episodic and not structurally driven by temporary oil price volatility rather than lasting behavioral effects.

Table 6 Robustness Summary (FD-IV). Source: authors

Specification	β	SE	t	p	N	Clusters	First-stage F	Partial R²
(a1) FD-IV Diesel (main, trim 1%)	0.211	0.071	2.96	0.003	356	28	618.10	0.793
(a2) FD-IV Diesel, excl. 2020-21 (trim 1%)	0.000	0.094	0.00	0.998	302	28	611.65	0.789
(b1) FD-IV Gasoline (trim 1%)	0.305	0.104	2.93	0.003	356	28	359.20	0.680
(b2) FD-IV Gasoline, excl. 2020-21 (trim 1%)	0.000	0.155	0.00	0.998	302	28	287.96	0.597
(c) Diesel , trim 0%	0.241	0.083	2.89	0.004	356	28	587.63	0.787
(c) Diesel , trim 1%	0.211	0.071	2.96	0.003	356	28	618.10	0.793
(c) Diesel , trim 2%	0.198	0.070	2.83	0.005	356	28	656.27	0.798
(c) Diesel , trim 5%	0.179	0.067	2.66	0.008	356	28	680.80	0.806
(c) Diesel , trim 1% & drop MT, LU	0.173	0.071	2.44	0.014	330	26	1571.26	0.825

The findings show that fuel prices do not serve as a consistent driver of road-accident outcomes in Europe. Although Brent oil prices strongly predict retail fuel prices ($F > 600$, $R^2 \approx 0.79$), the positive elasticity observed during 2020–2021 ($\beta \approx 0.21$–0.30) vanishes once pandemic years are excluded, indicating that the effect was driven by temporary mobility disruptions rather than structural behavior. Across 28 European countries (2010–2023), neither diesel nor gasoline prices exhibits a stable causal link with accident totals. This implies that fuel taxation or price fluctuations are ineffective as road-safety instruments, and that long-term progress depends instead on vehicle-safety standards, enforcement, and infrastructure improvements.

5. Discussion

For the first RQ, the results show no consistent causal link between real fuel price changes and road-traffic accidents in Europe from 2010–2023. Fixed-effects OLS yields an insignificant effect ($\beta \approx 0.02$), and while the FD-IV model shows a temporary positive elasticity during 2020–2021 ($\beta \approx 0.21$), this disappears once pandemic years are excluded. This confirms that the apparent relationship reflects short-term crisis disruptions rather than structural behavioral responses. Overall, fuel prices are not a persistent driver of accident totals, which depend more on infrastructure, enforcement, and vehicle technology. For RQ2, the findings show that the fuel price–accident relationship does not persist once global oil shocks and pandemic disruptions are removed. Although Brent oil prices strongly instrument fuel prices ($F > 600$, $R^2 \approx 0.79$), excluding 2020–2021 reduces the elasticity to zero ($\beta \approx 0.00$, $p \approx 0.96$). Robustness checks using gasoline prices, trimming extremes, and excluding small countries all produce the same null result. This confirms that the earlier positive effect was a temporary, crisis-driven anomaly, not a structural causal link. Overall, fuel price fluctuations do not explain accident trends once exogenous shocks are isolated.

6. Conclusion

This study examined whether fluctuations in real fuel prices, driven by global oil market shocks, affect road-traffic accident outcomes across 28 European countries from 2010 to 2023. Using a combination of two-way fixed effects and first-difference instrumental variable (FD-IV) models with Brent oil prices as an external instrument, the analysis finds no persistent causal relationship between real fuel prices and accident totals. While the full-sample FD-IV estimate suggests a temporary positive elasticity ($\beta \approx 0.21$), this effect disappears once pandemic years (2020-2021) are excluded, indicating that the observed correlation was event-driven rather than structural. Robustness tests using alternative fuels, trims, and outlier exclusions yield consistent null effects. These results imply that fuel prices are not an effective lever for road safety policy. Instead, accident trends are shaped primarily by long-term structural factors, such as vehicle safety standards, enforcement, infrastructure quality, and socio-economic conditions, rather than short-term energy price fluctuations. From a broader perspective, the findings reinforce the importance of distinguishing temporary macroeconomic shocks from sustained behavioral dynamics in policy analysis. Future research could extend this framework to micro-level mobility or driver-behavior data to capture more granular effects of fuel price volatility on transportation safety.

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