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CAMA Working Paper 79/2021
September 2021

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Abstract

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JEL Classification

R41, H23, Q43

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ISSN 2206-0332

Fuel prices and road deaths: motorcyclists are different

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This study estimates the effect of gasoline prices on road deaths by vehicle mode using annual data for 62 countries for 2000–2018 and all states of the United States (US) for 1998–2018. Higher gasoline prices are associated with fewer overall road deaths. The proportional effect on motorcyclist deaths tends to be smaller or even have the opposite sign, especially in countries that are not highly dependent on motorcycles. For the US, a positive effect of gasoline prices on motorcyclist deaths is found, with an elasticity of about 0.3. There is also a positive relationship between gasoline prices and motorcycle registrations in the US. The results confirm that additional attention towards motorcyclist safety is warranted in times of high fuel prices.

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Acknowledgements: The authors are grateful for comments from anonymous reviewers, David I. Stern, Robert Breunig, and presentations at the Australian National University. The work was supported by the China Scholarship Council (CSC201706980025).

1. Introduction

Motorcycles are popular transport options given their relatively low ownership costs, compactness, and fuel economy (Nishitateno and Burke 2014). Yet motorcyclists are vulnerable road users, representing 28% of all global road deaths. Road accidents are the 8th-leading cause of deaths worldwide, in total resulting in about 1.35 million deaths annually as of 2016 (World Health Organization 2018).

It is known that there is a negative effect of fuel prices on overall road deaths (Grabowski and Morrisey 2004, 2006; Chi et al. 2010, 2012, 2013; Burke and Nishitateno 2015; Burke and Teame 2018; Best and Burke 2019; Naqvi et al. 2020). This emerges because higher fuel prices are likely to lead to people reducing their road trip frequency and distance while also substituting to carpooling, public transport, and more fuel-efficient vehicles. People may also drive in ways that conserve fuel such as by reducing rapid acceleration and braking. Yet the effect of fuel prices on motorcyclist deaths might differ. In particular, higher fuel prices may encourage substitution from automobiles to motorcycles due to their superior fuel economy, placing upward pressure on the number of motorcyclist deaths.

Only a limited number of studies have explored the effect of fuel prices on motorcycle safety. Wilson et al. (2009), Hyatt et al. (2009), Zhu et al. (2015a; 2015b), and Safaei et al. (2021) focused on the US, finding that there are more motorcyclist deaths when gasoline prices increase. Burke and Teame (2018) found no significant evidence that fuel prices affect the number of motorcyclist deaths in Australia, while Best and Burke (2019) found no significant effect of fuel prices on the number of serious motorcyclist injuries in New Zealand. There is yet to be an international study.

This study investigates if the effect of gasoline prices on motorcyclist deaths differs from effects on other types of road deaths. We present estimates for both an international sample and a panel of US states.

2. Methods

For the international estimates, a country fixed-effects estimator is initially employed, using annual data for 62 countries over 2000–2018. The static fixed-effects estimator is expected to produce short-run effects as it focuses on time-series variation within each country, with no dynamics (Baltagi and Griffin 1984).[1] Several other estimators are also used: a) a first-differenced estimator, which is expected to pick up short-run effects (Liker et al. 1985); b) a pooled ordinary least squares (OLS) estimator, which utilizes both the between and within variation for countries, likely producing medium-run effects (Burke and Yang 2016); c) a between estimator, which uses the average data for each country over time, likely producing long-run effects (Stern 2010); and d) a fixed-effects distributed-lag estimator, which incorporates effects that emerge in subsequent years due to delayed responses (Baltagi 2008). Examples of delayed responses to a high fuel price include that it can take time to switch to a motorcycle or to take a job closer to home. Delayed responses mean that long-run effects are expected to be larger than short-run effects.

We use data on road deaths by user group from the United Nations Economic Commission for Europe (UNECE), International Transport Forum (ITF), and national websites (see Table A1 in the Appendix). A broad definition of "motorcyclist" is applied that includes riders and passengers of motorcycles, motor scooters, and mopeds. Gasoline pump price data were obtained from the German Agency for International Cooperation (GIZ)'s November surveys and are deflated using the US gross domestic product (GDP) deflator from the World Bank World Development Indicators (WDI). We control for log real GDP per capita, log population, and a time trend.[2]

For the US analysis, static fixed-effect models are estimated for an annual dataset of all states plus the District of Columbia for 1998–2018. Road fatalities data are from the US National Highway Traffic Safety Administration (NHTSA). The Pesaran and Smith (1995) mean-group estimator, which averages separate estimates for each state, and a fixed-effect distributed-lag model are also used. We use the real gasoline price for each Petroleum Administration for Defence district or sub-district from the US Energy Information Administration. GDP and

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[1] Higher-frequency data (e.g. on a weekly, monthly, or quarterly basis) are likely to produce even shorter-run elasticities.

[2] Year fixed effects are not controlled for given that gasoline prices exhibit similar temporal variation in different countries.

population data are from the US Bureau of Economic Analysis. To explore a potential mechanism, we also use state-level data for the US for 1998–2018 to investigate the effect of gasoline prices on vehicle registration numbers. An annual first-differenced estimator is used to focus on factors affecting net changes.

Unit root issues are not a major concern given that both the international and US analyses have a smaller number of years than the number of countries/states (Entorf 1997). However, Pesaran (2004) tests suggest that the null of cross-sectional independence can be rejected for both the international and US estimations. Therefore, Driscoll and Kraay (1998) standard errors are used to determine significance levels for the fixed-effects, first-differenced, and pooled OLS estimates. These are robust to general forms of cross-sectional and temporal dependence (Hoechle 2007).

3. Results for the international sample

3.1 Static estimations

Results for the static estimations are shown in Table 1. The coefficients on the log real gasoline price using the fixed-effects estimator in Panel A are negative and statistically significant for both total road deaths and deaths of automobile occupants. The hypothesis that the effect of gasoline prices on motorcyclist deaths is zero cannot be rejected. Similar coefficients are obtained using the first-differenced estimator in Panel B.[3]

For total road deaths and automobile occupant deaths, the coefficients using pooled OLS in Panel C of Table 1 and the between estimator in Panel D are negative and statistically significant and also larger in absolute value than those in Panels A and B. For motorcyclist deaths, the estimates are negative but only statistically significant in Panel C. A test rejects the null of parameter equality for automobile occupants and motorcyclist deaths in panel A, although not in the other panels.

[3] The two-year difference is used as the international gasoline price data from the GIZ are available for every second year.

Table 1 Results for the international sample, static estimations

Dependent variable: Ln road fatalities$_t$			
	Total	Automobile	Motorcycle
	(1)	(2)	(3)
A. Fixed effects			
Ln real gasoline price$_t$	–0.141**	–0.189***	–0.003
			[0.069]
B. First-differenced			
Ln real gasoline price$_t$	–0.097**	–0.143***	–0.103
			[0.682]
C. Pooled OLS			
Ln real gasoline price$_t$	–0.529***	–0.524***	–0.245***
			[0.595]
D. Between			
Ln real gasoline price$_t$	–0.828***	–0.944***	–0.149
			[0.192]

Notes: Coefficients for constants, log real GDP per capita, and log population are not reported. *** p<0.01. ** p<0.05. * p<0.1. Driscoll and Kraay standard errors are used except in Panel D. Panel A controls for country fixed effects and a time trend. Panel C controls for a time trend. Panels B and D do not control for country fixed effects or a time trend. The numbers in square brackets are *p*-values for tests of parameter equality for automobile occupant and motorcyclist deaths, carried out without a cross-sectional dependence adjustment. An "other" sub-category of road fatalities exists, but results are not reported. R^2 values, standard errors, and information on stationarity of residuals available on request.

Table A2 presents a robustness check controlling for variables including log population density, the unemployment rate, urban population share, youth population share, and log alcohol consumption per capita (aged 15+). The coefficients on the log gasoline price for total and automobile occupant road deaths remain similar to those in Panel A of Table 1. The point estimate for motorcyclist deaths is positive, although not significantly different from zero.

Some third factors such as the demand for road transport could affect both gasoline prices and road deaths, meaning that omitted variable bias could continue to be an issue. To address this, in additional estimates we instrumented the log real gasoline price with the log global real crude oil price given that the cost of crude oil is a major contributor to the pump price of gasoline. We controlled for the world real GDP growth rate in this specification. The estimates remain similar to the OLS elasticities in Panel A of Table 1, with the effect of gasoline prices on motorcyclist fatalities again remaining statistically insignificant.[4]

[4] This and other additional estimates available on request.

To explore if the results vary by each country's level of motorcycle dependence, in additional estimates we also included an interaction term between the log gasoline price and the motorcycle share of all motor vehicles in use in 2016. Data from the World Road Statistics were used for this measure. Table A3 presents the results. For motorcyclist deaths, a statistically significant and negative coefficient is found for the interaction term. This implies that countries with high motorcycle dependencies tend to experience a decline in motorcyclist deaths when the gasoline price rises. In contrast, countries with low motorcycle dependencies tend to experience little change in motorcyclist death numbers when the gasoline price rises, and may even experience an increase. On average, the effect of gasoline prices on the number of motorcyclist deaths tends to be small (see Panel A of Table 1). The effect of gasoline prices on the numbers of total or automobile occupant deaths do not vary significantly by the level of motorcycle dependence.

3.2 Distributed lag model

A fixed-effects distributed lag model with lags back to t–7 was also estimated, with the long-run elasticity being the sum of coefficients for each gasoline price term. The results provide an estimate of the long-run gasoline price elasticity of total road deaths of –0.3 and of automobile occupant deaths of –0.5. Both are statistically different from zero. The elasticity for motorcyclist deaths is positive in point estimate terms and not statistically different from zero. This represents the average effect across all countries in the sample.

3.3 Summary of elasticities

Based on the above, the average gasoline price elasticity of total road deaths appears to be about –0.1 in the short run and –0.3 to –0.8 in the long run. The average gasoline price elasticity of automobile occupant fatalities is around –0.2 in the short run and –0.5 to –0.9 in the long run. For motorcyclist fatalities, negative effects are generally not found other than in countries with high levels of motorcycle dependence.

4. Results for the US

4.1 Fatalities

Table 2 presents estimates for state-level analysis for the US, a country with a relatively low motorcycle share of the motor vehicle stock (3% as of 2016). All coefficients on the log real gasoline price are negative except those for motorcyclist deaths. Interestingly, a 1% increase in gasoline prices is found to lead to an *increase* in motorcyclist deaths of about 0.3% on average, holding the other variables constant. The effect for motorcyclists is significantly different from that for other motor vehicle occupants. The estimates using a mean-group estimator and a fixed-effects distributed lag model also display a positive gasoline price elasticity of motorcyclist deaths of about 0.3.

Table 2 Results for US states

Dependent variable: Ln road fatalities$_t$						
	Total	Driver	Passenger	Motorcyclist	Pedestrian	Cyclist
	(1)	(2)	(3)	(4)	(5)	(6)
A. Static fixed effects						
Ln real gasoline price$_t$	–0.133**	–0.151**	–0.174**	0.327**	–0.364***	–0.182**
				[0.003]		
B. Mean-group						
Ln real gasoline price$_t$	–0.119***	–0.130***	–0.197***	0.341***	–0.300***	–0.182**
				[0.000]		
C. Distributed lag fixed effects						
Long-run elasticity	–0.390***	–0.473***	–0.412***	0.273**	–0.612***	–0.170
				[0.000]		

Notes: Coefficients for constants, log real GDP per capita, and log population are not reported. *** p<0.01. ** p<0.05. * p<0.1. Driscoll and Kraay standard errors are used except for Panel B. All regressions control for state fixed effects and a time trend. Panel C includes gasoline price lags back to *t*–4, with the long-run elasticity being the sum of the Ln real gasoline price coefficients. The "driver" and "passenger" sub-categories are for motor vehicles other than motorcycles (i.e. not only automobiles). The numbers in square brackets are *p*-values for tests of parameter equality for driver and motorcyclist deaths, carried out without a cross-sectional dependence adjustment. An "other" sub-category of road fatalities exists, but results are not reported.

The size of the positive gasoline price elasticity of motorcyclist deaths for the US in Table 2 is large relative to the implied effect for a country with a low motorcycle dependence as estimated in Table A3. The US thus seems to be a relative outlier. In the international static fixed-effects estimations we consequently also explored the use of an interaction term between the log gasoline price and a US dummy. The coefficient on the log gasoline price for the group of other countries is –0.01 (not statistically different from zero). For the US, the effect is positive and significant. The US thus does appear to differ from the average effect for the rest of the international sample.

4.2 Registrations

To explore one potential mechanism for a positive effect of gasoline prices on motorcyclist deaths in the US, Table 3 shows results for a first-differenced analysis of the effect of the log gasoline price on vehicle registrations. While no statistically significant effect is found for automobile registrations, for motorcycle registrations the coefficient on the log gasoline price is 0.086 (statistically different from zero). The combined evidence is thus in favor of a switching toward motorcycles when gasoline prices rise in the US. Zhu et al. (2015a) also found that motorcycle sales increase in the US when the gasoline price rises.

Table 3 Results for vehicle registrations, US states

Dependent variable: d.Ln vehicle registrations$_t$		
	Automobile	Motorcycle
	(1)	(2)
d.Ln real gasoline price$_t$	0.017	0.086** [0.098]

Notes: Coefficients for constants, log real GDP per capita, and log population are not reported. *** p<0.01. ** p<0.05. *p<0.1. Regressions use Driscoll-Kraay standard errors and control for state fixed effects and a time trend. The number in square brackets is the *p*-value for a test of parameter equality, carried out without a cross-sectional dependence adjustment.

In additional estimations we also explored the relationship between vehicle registrations and road fatalities in the US. A static fixed-effects estimator was used. The results suggest that a 1% increase in motorcycle registrations on average is associated with 0.14% additional motorcyclist deaths in the same year, holding the other variables constant. This implies that a potential mechanism via which higher gasoline prices lead to an increase in motorcyclist fatalities in the US is indeed likely to be additional motorcycle registrations.

5. Conclusion

This study has found that the effect of gasoline prices on motorcyclist fatalities exhibits differences from the effect on automobile occupant deaths. A higher gasoline price tends to reduce the number of both total road deaths and automobile occupant deaths. For the international sample, a higher gasoline price on average has a small and generally insignificant effect on the number of motorcyclist fatalities. However this elasticity tends to be negative in countries with high motorcycle dependencies and can even be positive in countries with low motorcycle dependencies such as the US. The gasoline price-motorcyclist fatalities elasticity is estimated to be 0.3 for the US.

The response of total road deaths to gasoline prices is similar to the road-sector gasoline price elasticity of demand for 118 countries obtained by Liddle and Huntington (2020). This suggests that the effect of gasoline prices on road deaths is closely linked to the relationship between gasoline prices and gasoline use. However this does not imply that it is only fuel prices that matter. Other variables such as the unemployment rate also have macro-level effects on road death tolls (see Table A2).

It is interesting to consider why a positive gasoline price elasticity of motorcyclist deaths tends to prevail in countries with low motorcycle dependencies such as the US but not countries with high motorcycle dependencies. The exact reasons are an interesting area for further research. One may be that the marginal motorcyclist is particularly risk-exposed in countries in which the overall majority of vehicles is an automobile or larger. In exploring one potential channel we found that higher gasoline prices encourage people to register motorcycles in the US.

The results for total road deaths support the case that removing gasoline subsidies or increasing fuel taxes is likely to help reduce overall road fatalities. Another implication of the results is that, given the low marginal cost of driving electric vehicles, one would expect upward pressure on road deaths unless there are commensurately rapid improvements in road safety. Other mechanisms such as road user charging may also help to overcome upward pressure on road deaths during this transition and beyond. A specific implication of the results on motorcyclist deaths is that road safety campaigns should ideally be increasingly focused on motorcyclists at times when fuel prices are high. This is particularly the case for the US and other countries that have historically had relatively low motorcycle dependence. Other approaches for boosting motorcyclist safety are also an important priority.

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Appendix

Table A1 Source of road fatalities data for each country

Country	Road fatalities source
Albania, Andorra, Austria, Azerbaijan, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom	UNECE
Argentina, Cambodia, Chile, Colombia, Jamaica, Japan, Korea (Rep), Malaysia, Mexico, Morocco, South Africa	ITF
Australia	Australian Department of Infrastructure and Regional Development
Brazil	Brazilian Mortality Information System
Botswana	Botswana Transport and Communications Statistics
China	China Statistical Yearbook
India	India Ministry of Road Transport and Highways
New Zealand	New Zealand Ministry of Transport
United States	US NHTSA

Notes: UNECE data are missing for 2018 for some countries. For these cases, data from ITF were used instead.

Table A2 Results with additional control variables, international sample

Dependent variable: Ln road fatalities$_t$. Estimator: Static fixed effects			
	Total	Automobile	Motorcycle
	(1)	(2)	(3)
Ln real gasoline price$_t$	–0.106**	–0.086**	0.081 [0.081]
Ln real GDP per capita$_t$	0.560***	0.569**	0.598**
Ln population density$_t$	2.063***	1.970***	2.007**
Unemployment rate (%)$_t$	–0.022**	–0.031***	–0.023***
Urban population share (%)$_t$	0.014***	0.023***	–0.030***
Youth population share (%, aged 15–24)$_t$	0.014***	–0.005	–0.007
Ln alcohol consumption per capita (aged 15+)$_t$	0.062	0.078	–0.435

Notes: Coefficients for constants are not reported. *** p<0.01. ** p<0.05. *p<0.1. All regressions use Driscoll-Kraay standard errors and control for state fixed effects and a time trend. The number in square brackets is a *p*-value for a test of parameter equality for automobile occupant and motorcyclist deaths, carried out without a cross-sectional dependence adjustment. Real GDP per capita, population density, the unemployment rate, urban population share, youth population share, and alcohol consumption are from the World Bank WDI. An "other" sub-category of road fatalities exists, but results are not reported.

Table A3 Heterogeneity analysis by motorcycle dependence, international sample

Dependent variable: Ln road fatalities$_t$. Estimator: Static fixed effects			
	Total	Automobile	Motorcycle
	(1)	(2)	(3)
Ln real gasoline price$_t$	–0.158**	–0.188**	0.148
Ln real gasoline price$_t$ × Motorcycle share$_{2016}$ (%)	–0.002	–0.004	–0.014***

Notes: Coefficients for constants, log real GDP per capita, and log population are not reported. *** p<0.01. ** p<0.05. * p<0.1. Driscoll and Kraay standard errors are used. All regressions control for state fixed effects and a time trend. The motorcycle share is as a percentage of all motor vehicles. This variable has a sample minimum of 0.24%, a maximum of 80%, and a median of 6.31%. An "other" sub-category of road fatalities exists, but results are not reported.