Working Papers in
Trade and Development

Gasoline Prices and Road Fatalities: International Evidence

Paul J. Burke

and

Shuhei Nishitateno

August 2014

Working Paper No. 2014/18

Arndt-Corden Department of Economics
Crawford School of Public Policy
ANU College of Asia and the Pacific

This Working Paper series provides a vehicle for preliminary circulation of research results in the fields of economic development and international trade. The series is intended to stimulate discussion and critical comment. Staff and visitors in any part of the Australian National University are encouraged to contribute. To facilitate prompt distribution, papers are screened, but not formally refereed.

Copies may be obtained at WWW Site
http://www.crawford.anu.edu.au/acde/publications/

Gasoline Prices and Road Fatalities: International Evidence

Paul J. Burke and Shuhei Nishitateno

August 2014

This study utilizes data for 144 countries from 1991–2010 to present the first international estimates of the gasoline price elasticity of road fatalities. We instrument each country's gasoline price with that country's oil reserves and the yearly international crude oil price to address potential endogeneity concerns. Our findings suggest that the average reduction in road fatalities resulting from a 10% increase in the gasoline pump price is in the order of 3–6%. Around 35,000 road deaths per year could be avoided by the removal of global fuel subsidies.

Key words: road deaths, road safety, gasoline price, subsidy, taxation
JEL Codes: R41, H23, O18, Q43

Burke (corresponding author): Arndt–Corden Department of Economics, Australian National University, Canberra, ACT 0200, Australia. Phone +61 2 6125 6566, E-mail paul.j.burke@anu.edu.au

Nishitateno: School of Policy Studies, Kwansei Gakuin University, Hyogo 669–1337, Japan. Phone +81 79 565 7957, E-mail shuhei0828@kwansei.ac.jp

Gasoline Prices and Road Fatalities: International Evidence*

I. INTRODUCTION

While a negative impact of gasoline prices on road fatalities has been documented for the United States (US), there is limited international evidence on whether road death rates are higher in countries with lower gasoline prices. In this study we employ data for a panel of 144 countries during 1991–2010 to present international estimates of the gasoline price elasticity of road fatalities. To address the potential endogeneity of gasoline prices we use each country's underground oil reserves and the international crude oil price as instruments for that country's gasoline price. We find that the mean long-run gasoline price elasticity of road deaths is in the order of -0.3 to -0.6, and that around 35,000 lives could be saved on roads each year by phasing out global fuel subsidies. We also use our results to estimate the number of deaths that could be avoided on US roads by an increase in fuel taxes.

Road safety is a leading public health issue. Road crashes are the cause of 1.3 million deaths every year; the ninth-leading cause of death globally and the number-one cause of death for people between 15 and 29 years of age (data for 2011; World Health Organization [WHO] 2013a). Road death rates are particularly high in middle- and low-income countries, which each year see an average of 20 and 18 deaths per 100,000 population, respectively. There are around 9 road deaths per 100,000 population each year in high-income countries. Up to 50 million people worldwide also suffer non-fatal injuries each year, bringing large human and financial costs. The global road death toll is expected to increase to around 2.4 million per year by 2030 in a business-as-usual scenario, making road crashes the fifth-leading cause of death (WHO 2013b). Finding ways to reduce global road deaths is an increasingly important policy imperative.

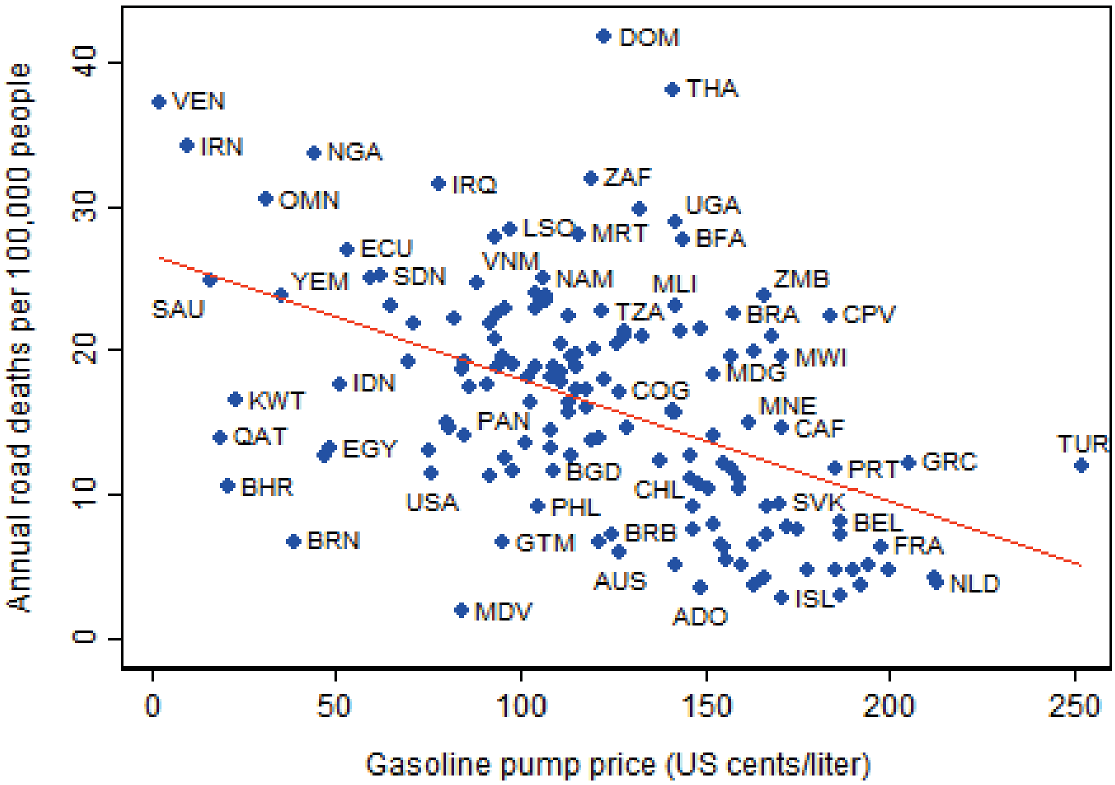
A negative relationship between the gasoline pump price (in US cents) and annual road deaths per 100,000 population for a large cross-section of countries in 2010 is presented in Figure 1. Countries with low gasoline prices, such as Venezuela and Iran, have among the highest road death rates, whereas road fatalities tend to be less frequent in high-price countries. Figure 1 also demonstrates substantial variation in road fatality rates among

* We are grateful for comments from Joseph Doyle, Ryan Edwards, Yusaku Horiuchi, Brantley Liddle, Anthony Ockwell, two referees, and participants at seminars at the Australian National University, Beijing Institute of Technology, Kwansei Gakuin University, Monash University, and the University of Tasmania.

countries with similar gasoline prices. A number of additional variables, including per capita incomes, road-use laws, and road infrastructure, will be considered in explaining this variation.

FIGURE 1

Road Deaths and Gasoline Pump Prices, 2010



Notes: Includes 153 countries. Road death data are estimates from the WHO (2013b). These cover more countries in 2010 than the International Road Federation (2012) data that we use in our empirical estimations, and provide a similar estimate of the gasoline price elasticity of road deaths (-0.4). Gasoline price data are from GIZ (2012), as recorded in a November survey.

The large cross-country variation in retail prices for gasoline — a tradable commodity — exists primarily because of differences in tax and subsidy policies. Venezuela had the lowest average price of gasoline in 2010: just 2 US cents per liter. Venezuela's gasoline price is substantially below the international price for crude oil (51 cents per liter in 2010; GIZ 2012), and so involves a large subsidy for consumers. In contrast, some governments impose high taxes on gasoline that result in high retail pump prices. In Turkey, for instance, the average gasoline pump price was 252 US cents per liter in 2010, including 139 cents of taxes (International Energy Agency [IEA] 2013a).

There are several ways in which higher gasoline prices may reduce road deaths. It is likely that the principal channel is a reduction in the distance travelled in motor vehicles as people respond to the incentive to substitute away from using a more expensive commodity. Reduced driving decreases the exposure of both vehicle occupants and others to road crashes. Reductions in distance travelled may be a result of people transitioning to less transport-intensive activities, alternative transport options, and closer workplaces. Some of these responses take time, so the long-run gasoline price elasticity of road deaths is likely to exceed the short-run elasticity.

In addition to reducing distance travelled, higher gasoline prices might also lead to a reduction in road deaths per kilometer driven. One reason is that, to conserve fuel, drivers might reduce high-speed driving and also their rates of acceleration and braking.[1] Another is that high-risk drivers, including the young, the old, and those taking leisure-related trips, are particularly sensitive to gasoline prices (Grabowski and Morrisey 2004; Cullotta 2008; Morrisey and Grabowski 2011). Higher gasoline prices also result in substitution from heavier to lighter, more fuel-efficient, private vehicles (e.g. light trucks to automobiles), and lighter vehicles are associated with a lower overall number of road deaths per kilometer travelled (Gayer 2004; White 2004). Substitution to bus travel may also reduce overall road safety risks.

There are ways in which higher gasoline prices might actually lead to more rather than fewer road deaths. One is: by reducing congestion, higher gasoline prices can allow remaining drivers to travel at faster speeds (Burger and Kaffine 2009), which increases the risk of fatal crashes. Substitution to particularly risky types of fuel-efficient vehicles, such as motorcycles, may also cause additional road deaths when gasoline prices rise (Hyatt et al. 2009; Wilson et al. 2009).[2]

Existing evidence for the US indicates that higher gasoline prices reduce road fatalities and/or crashes (Leigh and Wilkinson 1991; Haughton and Sarkar 1996; Grabowski and Morrisey 2004, 2006; Sivak 2009; Chi et al. 2010, 2011, 2012, 2013a, 2013b; Montour 2011). As for gasoline demand itself, the response of road deaths to gasoline prices in the US is inelastic.

---

[1] Speeds over 80 kilometers per hour are generally associated with lower fuel efficiency (U.S. Department of Energy 2013). The Congressional Budget Office (2008) reports that higher gasoline prices indeed cause drivers on uncongested Californian roads to slightly reduce their speeds.

[2] Recent evidence on the safety risks associated with motorcycle travel is provided by Nishitateno and Burke (2014).

Grabowski and Morrisey (2004), for instance, use data for 48 US states for the period 1983–2000 and find a gasoline price elasticity of road fatalities of -0.3 when responses over a two-year period are considered.

Most international studies on the determinants of road fatalities (e.g. Page 2001; Noland 2005; Anwaar et al. 2012) concentrate on other issues, although Litman (2012) presents a scatterplot for 16 Organization for Economic Co-operation and Development (OECD) countries that shows a negative association between average gasoline prices and traffic fatality rates. As far as we are aware, there has been no prior international estimate of the gasoline price elasticity of road deaths.

II. APPROACH

We estimate the following specification:

(1) $$\ln D_{c,t} = \alpha + \beta_1 \ln G_{c,t} + \beta_2 \ln Y_{c,t} + \beta_3 \ln P_{c,t} + \gamma X_{c,t} + \delta_c + \omega_t + \varepsilon_{c,t}$$

where D is road deaths in country c in year t, G is the gasoline price in year-2010 US cents, Y is gross domestic product (GDP) in real purchasing power parity-adjusted US dollars, P is population, and X is a vector of additional controls included in later estimations. δ_c and ω_t are country and year fixed effects, and ε is an error term. We also present specifications that control for country-specific time trends.

Our primary interest is in identifying the long-run gasoline price elasticity of road deaths.[3] To this end we initially estimate Equation (1) for a cross-section of countries in the year 2010, as so-called "between variation" has a natural long-run interpretation. We then proceed to panel estimates using the pooled ordinary least squares (OLS), between, and fixed-effects estimators. The between estimator uses average data for each country and provides estimates of long-run effects (Baltagi and Griffin 1983, 1984; Pesaran and Smith 1995; Pirotte 1999, 2003; Baltagi 2008; Stern 2010). Fixed-effects estimations control for time-invariant factors such as the extent of mountainous terrain, but when a static fixed-effects equation is estimated the coefficients represent shorter-run effects. To explore the dynamics of the response to higher gasoline prices and for a further estimate of the long-run gasoline price elasticity of road deaths, we then table results for distributed lag specifications (with country fixed effects). For checks on the importance of functional form, we also estimate negative

[3] The long-run response is more important from a policy viewpoint than the short-run response.

binomial models (with and without country fixed effects) and models using per capita measures of road deaths and GDP.[4]

An issue of concern is that the gasoline price term in Equation (1) may be correlated with the error term. The level of demand for road transport might have a material effect on a country's average gasoline pump price, for instance, while also affecting road deaths (Grabowski and Morrisey 2004, 2006; Morrisey and Grabowski 2011). Alternatively, governments may impose higher gasoline taxes in countries with low demand for road use, as argued by Hammar et al. (2004). It is also possible that the set of factors affecting gasoline tax/subsidy policies might include road safety concerns. Perhaps even more importantly, there might be omitted policy variables that are associated with gasoline prices: interventionist governments might tax gasoline and have strict road rules, for example. These concerns mean that we cannot be sure that single-equation estimation of Equation (1) will produce unbiased and consistent estimates of the effect of gasoline prices on road deaths.

To address the potential endogeneity of gasoline prices we present estimates using the two supply-side instruments for the gasoline price employed by Burke and Nishitateno (2013) in their recent study of the gasoline price elasticity of demand. The first is a country's per capita underground oil reserves, as oil-rich countries such as Venezuela are more likely to subsidize gasoline and oil-poor countries such as the Republic of Korea are more likely to tax it. The second is a measure of the annual average international crude oil price, as higher crude oil prices flow through to higher gasoline pump prices in most countries. It is likely that our instruments affect road deaths via gasoline prices rather than other channels.

The advantage of using two instruments is that doing so allows verification of the effect of gasoline prices on road deaths using independent sources of variation in gasoline prices. The exclusion restrictions are that oil reserves and the global oil price are not correlated with unobserved determinants of road deaths (across countries and over time, respectively). In addition to using the instruments separately we also present estimates using both instruments

[4] Negative binomial models are often used in studies of road deaths (see, for instance, the papers of Chi et al.). As will be documented, negative binomial models provide long-run gasoline price elasticities of road deaths that fall within our reported range. Our focus is primarily on linear models (in log-log form) because these are better suited to an instrumental variable context.

together. Existing studies on the effect of gasoline prices on road deaths in the US do not use instrumental variable (IV) approaches.[5]

Our estimates are for a panel of 144 countries for 1991, 1993, 1995, 1998, 2000, 2002, 2004, 2006, 2008, and 2010: ten years for which average gasoline price data are available from the November surveys of GIZ (2012). Our data on road fatalities are primarily from the International Road Federation [IRF] (2012) and include all reported deaths that occur within 30 days of a road crash. Alternative estimates of road deaths in 2010 from the WHO (2013b), as used in Figure 1, provide similar results. We focus on fatalities because international data on non-fatal road crashes are less reliable (Luoma and Sivak 2007; Sauerzapf et al. 2010; WHO 2013b). Nevertheless, the accuracy of the data on road deaths is likely to vary. If the reporting of road deaths improves in a way that is correlated with economic development, our GDP variable will control for some data quality differences. Because of missing data, on average each country is included in our sample for 5.8 of the ten years. The countries in our sample represented 94% of the world's population in 2010. A full list of data sources is in the Appendix.

III. RESULTS

A. Main Specifications

Results for single-equation specifications, controlling for GDP and population, are in Table 1. Column 1 is for a year-2010 cross-section of countries, and indicates that a 1% higher gasoline price on average reduces road fatalities by 0.4%. Cross-sectional estimates utilize only between variation, and so this is a first estimate of the long-run effect of gasoline prices on road deaths. Columns 2 and 3 present results using the pooled OLS (with year dummies) and between estimators. The point estimates of the gasoline price elasticity of road deaths are slightly smaller (-0.3), but remain distinguishable from zero at the 1% significance level.

Column 4 of Table 1 controls for both year and country fixed effects, which removes most of the variation in gasoline prices in our sample.[6] This makes it difficult for within-country gasoline price movements to affect road deaths. Static models relying on only within variation are also likely to provide short-run effects because of the under-specification of dynamics (Baltagi 2008). Likely as a result of these factors, the fixed-effects estimate in

[5] In their study of Los Angeles freeway speeds, Burger and Kaffine (2009) also use the world oil price to instrument the local gasoline price. Grabowski and Morrisey (2006) do not use an IV approach in their study of road deaths but hope that state gasoline taxes provide an exogenous source of variation in gasoline prices.
[6] A regression of log gasoline price on country and year dummies has an R^2 of 0.90.

column 4 is insignificant. We obtain a significant coefficient in the fixed-effects specification in column 5 which includes a linear time trend for each country in the sample.

TABLE 1
Results for Single-Equation Specifications

Dependent variable: Ln Road deaths

Specification	2010	Pooled	Between	Fixed effects	
	(1)	(2)	(3)	(4)	(5)
Ln Gasoline price	-0.40***	-0.30***	-0.35***	0.01	-0.10*
	(0.11)	(0.07)	(0.08)	(0.10)	(0.06)
Ln GDP	0.00	0.17***	0.23***	0.34**	0.34***
	(0.07)	(0.04)	(0.04)	(0.15)	(0.10)
Ln Population	0.98***	0.79***	0.72***	1.09**	0.12
	(0.08)	(0.05)	(0.05)	(0.46)	(0.37)
Year fixed effects	No	Yes	No	Yes	No
Country-specific time trends	No	No	No	No	Yes
R^2	0.87	0.86	0.88	0.16	0.61
Observations	101	837	837	837	837
Countries	101	144	144	144	144

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Standard errors are robust and clustered at the country level (except for the between estimate). The R^2s reflect the power of the explanatory variables and year dummies (but not the country fixed effects). Coefficients on constants not reported.

Table 2 shows our IV results. Our cross-sectional and panel estimates instrumenting with per capita oil reserves (columns 1-2) indicate that higher gasoline prices significantly reduce road deaths, with the cross-sectional estimate providing an elasticity of -0.3. We are prevented from controlling for country fixed effects when instrumenting with oil reserves per capita as there is almost no useful time-series variation in per capita oil reserves. Columns 3 and 4 instrument with the log real international crude oil price. Country-specific linear time trends are included instead of year dummies, as year dummies would be perfectly collinear with our instrument.[7] The gasoline price elasticities in these estimates are -0.5 and -0.4. It is reassuring that we obtain similar results using different instruments. Column 5 uses both instruments and obtains a gasoline price elasticity of road deaths of -0.5.

Column 6 of Table 2 uses both instruments and controls for the full set of controls that will be used in Table 4. The results suggest a stronger negative effect of gasoline prices on road

[7] Results are similar without these country-specific time trends.

deaths, with an elasticity of -0.9. Given the smaller sample size, weaker first-stage identification, and the possibility that some of the controls could themselves be endogenous, we do not include the column 6 estimate in our "headline" results. The robustness of our IV estimates to the addition of controls such as road infrastructure variables does, however, reduce the concern that the result is driven by a violation of the IV exclusion restriction.

TABLE 2
Instrumental Variable Results

Dependent variable: Ln Road deaths

Instrument/s	Oil reserves per capita ('000 tonnes)		Ln Real world oil price		Both	Both
Specification	2010	Pooled	Pooled	Fixed effects	Pooled	Pooled, with full set of controls from Table 4
	(1)	(2)	(3)	(4)	(5)	(6)
Ln Gasoline price	-0.31***	-0.24***	-0.51***	-0.39**	-0.46***	-0.91***
	(0.07)	(0.06)	(0.12)	(0.16)	(0.08)	(0.20)
Ln GDP	0.00	0.16***	0.14**	0.46***	0.14**	0.00
	(0.07)	(0.04)	(0.06)	(0.12)	(0.06)	(0.09)
Ln Population	0.98***	0.79***	0.92***	0.02	0.92***	1.00***
	(0.07)	(0.04)	(0.08)	(0.39)	(0.08)	(0.10)
Year fixed effects	No	Yes	No	No	No	No
Country-specific time trends	No	No	Yes	Yes	Yes	Yes
R^2	0.87	0.86	0.95	0.58	0.95	0.99
First stage						
Coefficient on Oil reserves per capita	-0.49***	-0.33***	-	-	-0.69***	-0.79***
Coefficient on Ln Real world oil price	-	-	0.29***	0.24***	0.28***	0.13***
Partial R^2 on instrument/s	0.23	0.13	0.15	0.13	0.26	0.19
F statistic on instrument/s	12.31	12.71	108.75	59.05	59.79	14.41
Robust endogeneity test *p*-value	0.45	0.50	0.04	0.06	0.00	0.00
Sargan over-identification test *p*-value	-	-	-	-	0.35	0.36
Observations	101	837	837	830	837	408
Countries	101	144	144	137	144	91

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Standard errors are robust and clustered at the country level. The R^2s reflect the power of the explanatory variables (except country fixed effects). Coefficients on constants and the additional controls in column 6 are not reported. The instrumented variable is the log gasoline price. The null of weak instruments is rejected if the *F* statistic on the instrument/s exceeds the Stock-Yogo critical value. The Stock-Yogo 5% critical value for 10% (15%) maximal IV size is 16.38 (8.96) with one instrument and 19.93 (11.59) with two instruments. The overidentification test is for specifications with robust but unclustered standard errors. Column 4 drops seven singletons.

Stock and Yogo (2005) tests indicate that our instruments provide adequate identification strength. Specifically, the null hypothesis of 15% maximal IV size is rejected in each of the IV specifications. The first-stage coefficients, as expected, indicate that oil reserves and the oil price are negatively and positively correlated with the gasoline price, respectively.[8] Overidentification tests in columns 5–6 do not reject the null hypothesis that the instruments are valid. The IV results instrumenting with oil reserves per capita (columns 1–2) are similar to the single-equation estimates, meaning that endogeneity tests fail to reject the null that the log gasoline price is exogenous.[9] In contrast, endogeneity tests in columns 3–6 suggest that there is due cause to treat gasoline prices as endogenous.

The estimated coefficients for the control variables in Tables 1 and 2 are of interest. As expected, countries with larger populations typically have more road deaths, which is merely a scale effect. The panel results indicate that countries with larger economies also on average have more road fatalities, presumably because more people can afford private road vehicle travel. The income elasticities are smaller than the income elasticities of gasoline consumption of around +1.0 obtained by Burke and Nishitateno (2013), likely because richer countries dedicate more resources to improving road safety. A non-linear relationship between GDP per capita and road deaths will be considered in coming specifications.

Table 3 shows distributed-lag estimates with country and year fixed effects. Because these rely solely on within variation, we commence the gasoline price terms from year *t*-1 to allow time for responses to November prices. As a result, our estimation sample here extends to 2009 rather than 2010. Lags are included for every second year given the biennial nature of GIZ's gasoline price data, and the sample reduces with each additional lag. The long-run gasoline price elasticity is the sum of the coefficients for each gasoline price term.

The results in Table 3 provide an estimate of the long-run gasoline price elasticity of -0.6 when lags to year *t*-9 are considered (significant at the 10% level). Similar, and statistically stronger, long-run multipliers are obtained in pooled OLS and between estimates of distributed lag models. We also find generally similar estimates in specifications with country-specific time trends (see base of Table 3). We cannot rule out that even larger elasticities may be obtained from distributed lag models once longer time-series are available.

[8] The first stage in column 5 of Table 2 indicates that the partial effect of a 1% increase in the real world oil price is on average a 0.3% increase in the domestic gasoline price, holding other factors constant. Having an additional tonne of in-ground oil reserves per capita on average reduces the local gasoline price by 0.07%.

[9] Burger and Kaffine's (2009) results on the effects of gasoline prices on rush-hour vehicle speed and Burke and Nishitateno's (2013) estimates of the gasoline price elasticity of demand are also similar across their OLS and IV specifications.

TABLE 3

Distributed Lag Results

Dependent variable: Ln Road deaths

	(1)	(2)	(3)	(4)	(5)
Ln Gasoline price$_{t-1}$	-0.04	0.02	0.13	0.05	-0.06
	(0.08)	(0.07)	(0.08)	(0.09)	(0.17)
Ln Gasoline price$_{t-3}$		-0.12	-0.23*	-0.04	0.17
		(0.12)	(0.13)	(0.12)	(0.19)
Ln Gasoline price$_{t-5}$			-0.19***	-0.17	-0.34*
			(0.07)	(0.11)	(0.19)
Ln Gasoline price$_{t-7}$				-0.20**	-0.34**
				(0.09)	(0.17)
Ln Gasoline price$_{t-9}$					-0.06
					(0.14)
Ln GDP$_t$	0.28*	0.31*	0.37***	0.53**	0.71*
	(0.16)	(0.17)	(0.11)	(0.26)	(0.40)
Ln Population$_t$	1.19**	1.11*	0.42	0.19	0.26
	(0.48)	(0.61)	(0.64)	(0.85)	(0.94)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Long-run gasoline price elasticity	-0.04	-0.10	-0.29**	-0.36*	-0.63*
Same elasticity: Pooled OLS estimate	-0.31***	-0.35***	-0.39***	-0.47***	-0.57***
Same elasticity: Between estimate	-0.27***	-0.29***	-0.40***	-0.37***	-0.59***
Same elasticity: Estimate with country-specific time trends (as well as country fixed effects)	-0.06	-0.12	-0.35**	-0.58**	-0.96**
R^2	0.15	0.14	0.14	0.12	0.16
Observations	762	569	442	336	237
Years	1992-2009	1994-2009	1996-2009	2005-2009	2007-2009
Countries	149	145	140	133	129

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Standard errors are robust and clustered at the country level. The R^2s reflect the power of the explanatory variables and year dummies (but not the country fixed effects). Coefficients on constants not reported.

Based on our single-equation and IV estimates using between variation in Tables 1–2 and our estimates using distributed lags in Table 3, we conclude that the average long-run gasoline price elasticity of road deaths is likely in the order of -0.3 to -0.6. This is an inelastic response, meaning that higher gasoline prices do reduce road deaths, but in a less-than-proportionate manner. Burke and Nishitateno (2013) obtained similar estimates of the long-run gasoline price elasticity of demand, suggesting that our result is primarily related to the relationship between gasoline prices and the propensity for road travel. We do not have sufficient data for our international sample to decompose the effects of gasoline prices on road deaths into specific channels such as distance travelled or travel speeds, although such research would be of interest when data permit.[10]

B. Robustness

In some countries a large share of the vehicle fleet runs on diesel rather than gasoline. Table 4 presents estimates using the average of the gasoline and diesel prices and controlling for additional variables: land area, the length of each country's road network, the share of roads that is paved, the vehicle and motorcycle stocks, measures of the importance of rail and air transport, the share of the population aged 15–24 (who are typically overrepresented in road crashes), the urban population share, alcohol consumption, blood alcohol limits for drivers, the maximum speed in urban areas, measures of the rule of law and control of corruption, economic growth, and infant mortality. Controlling for road infrastructure variables helps to address the concern that our main result operates via the additional road funding that is possible when gasoline taxes are high. The log infant mortality rate is included as a proxy of overall health conditions in each country (noting that few infant deaths are caused by road crashes). We show between estimates for static models given our desires to estimate long-run effects and maximize sample size.

The results in Table 4 provide fuel price elasticities of road deaths of -0.3 to -0.45 (significant at the 1% level) and suggest that fuel prices are one of the most statistically robust cross-country determinants of road death rates. Countries with better control of corruption, higher dependence on air travel, lower alcohol consumption and stricter speed laws have fewer road deaths. Interestingly, countries with better "rule of law" ratings have more road deaths (holding all other variables, including corruption, constant), perhaps because reporting of road deaths is more complete. Once the full set of other variables has been controlled for, we find no evidence that the number of motor vehicles in each country is a strong predictor of road deaths.[11]

---

[10] The International Road Federation (2012) and OECD (2013a) provide some international data on vehicle or passenger kilometers travelled, but these are unavailable for the majority of our sample and are of questionable quality. The OECD (2013b) notes that there is no common international method for calculating passenger distance travelled in road vehicles. Studies of the US provide somewhat conflicting results on how gasoline prices affect road deaths: Grabowski and Morrisey (2004) find that the effect of higher gasoline prices on road deaths operates via a reduction in vehicle distance travelled, whereas Haughton and Sarkar (1996), Grabowski and Morrisey (2006), Chi et al. (2010, 2013b), and Montour (2011) report that there is also a reduction in road deaths per vehicle-kilometer travelled.

[11] In regressions with a smaller set of controls, a positive and significant effect of motor vehicle numbers on road deaths is obtained. Estimates of β_1 remain similar.

TABLE 4
Results with Additional Controls

Dependent variable: Ln Road deaths. Estimator: Between

	(1)	(2)	(3)
Ln Average gasoline and diesel price	-0.31***	-0.41***	
	(0.08)	(0.13)	
Ln Gasoline price			-0.45***
			(0.13)
Ln GDP	0.23***	0.23	0.21
	(0.04)	(0.15)	(0.15)
Ln Population	0.72***	0.67***	0.71***
	(0.05)	(0.13)	(0.13)
Ln Land area		0.05	0.05
		(0.05)	(0.05)
Ln Road distance		0.04	0.04
		(0.10)	(0.10)
Paved road share (%)		0.00	0.00
		(0.00)	(0.00)
Ln Motor vehicle stock (4+ wheels)		0.11	0.09
		(0.12)	(0.12)
Ln Motorcycle stock		-0.02	-0.02
		(0.04)	(0.04)
Rail share of energy used in transport (%)		0.01	0.01
		(0.01)	(0.01)
Ln Air passengers		-0.11*	-0.11*
		(0.07)	(0.06)
Population aged 15-24 (%)		0.03	0.04
		(0.03)	(0.03)
Urban population (%)		-0.00	-0.00
		(0.00)	(0.00)
Ln Alcohol consumption per adult		0.11**	0.11**
		(0.05)	(0.05)
Blood alcohol limit for drivers in 2011		1.11	1.22
		(2.25)	(2.24)
Maximum speed in urban areas in 2011		0.01***	0.01**
		(0.00)	(0.00)
Rule of law score		0.40**	0.40**
		(0.20)	(0.20)
Control of corruption score		-0.36**	-0.37**
		(0.17)	(0.17)
Economic growth rate (%)		-0.02**	-0.02**
		(0.01)	(0.01)
Ln Infant mortality rate		0.02	-0.02
		(0.14)	(0.14)
R^2	0.88	0.95	0.95
Observations	832	408	408
Countries	144	91	91

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Coefficients on constants not reported. Log Alcohol consumption per adult is lagged one year to increase sample size.

The effect of gasoline prices on road deaths may operate via some of the control variables in Table 4, including GDP. We obtain similar estimates for the gasoline price term if the controls are lagged, however. Pooled OLS estimates also provide similar results (although with slightly smaller point estimates of the gasoline price elasticity of road deaths). Because we control for log real GDP, our coefficient estimates for β_1 are identical if our gasoline price measure is scaled by real GDP. While our list of controls in Table 4 is long, there are many other factors that influence road safety. Current data constraints for our large international sample mean that we leave the task of including additional control variables to future research, perhaps for a smaller set of countries.[12]

Table 5 presents results using per capita measures of road deaths and GDP, and controlling for population density instead of population. The Table also shows estimates for sub-samples of OECD and non-OECD countries and an estimate controlling for regional dummies. The results are similar to those in Table 1, confirming that it makes little difference if variables are in total or per capita terms.[13] Column 2 controls for the square of log GDP per capita to account for the road deaths Kuznets curve (see, for instance, Law et al. 2011). The results suggest that the road death rate typically increases until a mid-range GDP per capita, and subsequently falls (holding other factors constant). We continue to observe a negative and statistically significant gasoline price elasticity of road deaths.

Column 3 of Table 5 includes the squared log gasoline price to test whether the gasoline price elasticity of road deaths varies at different gasoline price levels. Road deaths appear to be more responsive to changes in the gasoline price when the price is already high. The estimated gasoline price elasticity of road deaths at the 25^{th}-percentile gasoline price is -0.5, increasing to -0.8 at the 75^{th} percentile.[14] Column 4 includes an interaction between the log gasoline price and log GDP per capita. The estimate provides no evidence that the gasoline price elasticity of road deaths varies by development level. We also obtain statistically significant estimates of the effect of gasoline prices on road deaths for sub-sets of OECD and non-OECD countries (columns 5 and 6). Data on road fatalities are likely to be more reliable

[12] We obtain similar gasoline price elasticities of road deaths in specifications that also control for seatbelt usage rates, rural road speed limits, or expert assessments of the effectiveness of helmet law enforcement (all measured in 2011; WHO 2013b, 2013d). Because data limitations further reduce our sample, we omit these controls from Table 4.

[13] Because the dependent variable is just a rescaling by population, the effect of including our additional control variables in this regression is the same as in Table 4.

[14] In unreported specifications we find that the gasoline price elasticity of road deaths is similar when *changes* in gasoline prices are either small or large.

for OECD countries, and so the gasoline price elasticity of road deaths of -0.5 for the OECD sub-sample increases our confidence in the main results. Column 7 controls for regional dummy variables, which allows some time-invariant regional-specific characteristics such as driving culture to be considered. The results are similar.

TABLE 5

Estimates for Road Deaths per 100,000 Population

Dependent variable: Ln Road deaths per 100,000 population. Estimator: Between

Sample	Full	Full	Full	Full	OECD	Non-OECD	Full, with regional dummies
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Gasoline price	-0.30*** (0.08)	-0.24*** (0.08)	1.26*** (0.45)	-0.80 (0.69)	-0.47* (0.24)	-0.17* (0.10)	-0.28*** (0.09)
Ln GDP per capita	0.26*** (0.04)	2.88*** (0.49)	0.29*** (0.04)	0.02 (0.34)	-0.09 (0.15)	0.39*** (0.06)	0.20*** (0.06)
Ln Population density	-0.09*** (0.03)	-0.07** (0.03)	-0.09*** (0.03)	-0.09*** (0.03)	0.06 (0.05)	-0.15*** (0.04)	-0.09** (0.04)
(Ln GDP per capita)^2		-0.15*** (0.03)					
(Ln Gasoline price)^2			-0.22*** (0.06)				
Ln Gasoline price* Ln GDP per capita				0.05 (0.08)			
GDP per capita at turning point ($)	-	12,828	-	-	-	-	-
Estimated gasoline price elasticity for x^{th}-percentile gasoline price							
25th	-	-	-0.52***	-	-	-	-
50th	-	-	-0.70***	-	-	-	-
75th	-	-	-0.83***	-	-	-	-
R^2	0.29	0.41	0.35	0.30	0.16	0.39	0.33
Observations	837	837	837	837	270	567	837
Countries	144	144	144	144	34	110	144

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Coefficients on constants not reported. The OECD sub-sample includes all 34 current member countries. The regional dummies are based on the seven World Bank (2013a) regions. Year dummies are not included because the between estimator is being employed.

Table 6 presents cross-section, pooled and fixed-effect negative binomial estimates. Negative binomial models are suited to a count dependent variable and are preferred over Poisson models because our road death data exhibit over-dispersion (variance exceeds the mean). As in Table 5, we use road deaths weighted by population (now in unlogged form). The coefficients for the gasoline price, which can again be interpreted as elasticities, are significantly different from zero, and range from -0.4 (using between variation in the cross-sectional estimate) to -0.2 (using static within variation, and so likely representing a shorter-run effect). An unreported fixed-effect negative binomial model with additional lags provides a long-run gasoline price elasticity of road deaths of -0.6 (significant at the 5% level). In an additional check — available on request — we also estimated an IV negative binomial model, obtaining similar results to our linear IV estimates (but for which weak instrument test and other information is not available). In short, results using negative binominal models fall within our reported range.

TABLE 6

Negative Binomial Models

Dependent variable: Road deaths per 100,000 population

Sample	2010	Pooled	Pooled, with full set of controls from Table 4	Pooled, with country fixed effects
	(1)	(2)	(3)	(4)
Ln Gasoline price	-0.42***	-0.25***	-0.29***	-0.17***
	(0.09)	(0.07)	(0.11)	(0.06)
Ln GDP per capita	2.79***	2.43***	3.21***	2.55**
	(0.67)	(0.45)	(0.61)	(0.99)
Ln Population density	-0.08**	-0.08***	-0.03	0.19
	(0.04)	(0.03)	(0.09)	(0.21)
(Ln GDP per capita)^2	-0.16***	-0.13***	-0.18***	-0.12**
	(0.04)	(0.03)	(0.04)	(0.05)
Year fixed effects	No	Yes	Yes	Yes
GDP per capita at turning point ($)	7,206	11,289	9,537	30,371
Observations	101	837	408	830
Countries	101	144	91	137

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Standard errors are robust and clustered at the country level. Column 4 results obtained by including country dummies in a negative binomial estimation. Coefficients on constants not reported.

A lingering concern may be that there are additional time-varying policies affecting road deaths that are not possible to control for, and may be correlated with gasoline prices. While our specifications generally have relatively high R^2 values, there are clearly other variables (such as road safety advertising campaigns) that are likely to affect road deaths. It is important to note, however, that omitted variables could only be causing a serious identification problem across our full suite of estimates if they are correlated with gasoline prices (in our single-equation estimates) and *each* of our instruments (in our various IV estimates). This is unlikely. The world oil price is unlikely to be affected by or have any short-term influence on road safety policies, for instance. Our IV strategy, together with our use of numerous controls (alcohol consumption; country fixed effects; country-by-country time trends, regional dummies; etc), make us confident that our results represent consistent estimates of the causal effect of gasoline prices on road deaths.

It is important to explicitly note that many other factors, including those that we have not been able to represent in our estimations, also have important influences on road death rates. There are many, sad, stories behind individual road crashes. There is also substantial evidence that specific interventions such as helmet laws can reduce road death rates (e.g. Passmore et al. 2010). The results in this paper do not challenge this evidence. Instead, the results provide macro-level guidance on one economic variable — the price of gasoline — that has a macro-level effect on road deaths. This variable is amenable to policy.

IV. ESTIMATING THE NUMBER OF AVOIDED DEATHS FROM FUEL PRICE REFORM

Some countries, particularly the oil-rich, provide large price subsidies to consumers of gasoline. Table 7 presents estimates of the number of road deaths that could be avoided if countries with gasoline prices lower than those in the US (76 cents per liter in 2010) increased their average gasoline price to the US level. The estimates are based on a conservative long-run gasoline price elasticity of road deaths of -0.4 (e.g. column 1 of Table 1). Like GIZ (2012), we consider the gasoline price in the US — the lowest of all OECD countries — as the divider between countries that subsidize gasoline consumption and the rest. While the US does apply state and federal taxes on gasoline, these could be considered to be the minimum required to adequately cover road infrastructure and externality costs (GIZ 2012). There are alternative approaches that could be used to measure the size of fuel subsidies (e.g. Davis 2014).

The results in Table 7 suggest that around 35,000 lives per annum could be saved in 23 countries by removing the subsidies that were in place in 2010.[15] 35,000 lives is 3% of the global annual road death toll. The countries in which fuel subsidy reform offers the largest

[15] These are *ceteris paribus* estimates for the year 2010. Population and GDP growth will concurrently place upward pressure on road deaths in most of these countries. There is also the chance that subsidy removal could lower the global oil price and therefore increase road deaths in *other* countries, but the magnitudes involved in such a process are difficult to model.

potential reductions in road deaths are Iran (10,600 avoided deaths per year) and Venezuela (>5,000 avoided deaths per year). The removal of fuel subsidies would also result in large reductions in road deaths in Indonesia (4,500), Nigeria (4,200), Saudi Arabia (2,700), Egypt (1,800), and Algeria (1,700).[16]

How many road deaths could be avoided if the US itself had higher taxes on gasoline? A simulation using our results implies that around 8,500 lives per year could be saved if US gasoline taxes were increased to bring the US gasoline price to the United Kingdom (UK) level (192 cents per liter in 2010). This would reduce US road fatalities by around a quarter. A reduction of this magnitude is not historically infeasible: the number of annual road deaths in the US fell by 9,600 (17%) as gasoline prices spiked during the years 1973–1975, for instance (Leigh and Geraghty 2008). Annual road deaths in the US also reduced by 9,800 between 2006 and 2010 as gasoline prices increased and the economy entered recession (and due to other factors; Sivak and Schoettle 2010).

How many more road deaths would occur if countries that currently have high gasoline taxes move down to US-level gasoline prices? The case of the UK is illustrative. Our estimates indicate that the UK would have around 1,800 additional road deaths per year if it had US-level gasoline prices, a 95% increase over current levels. The UK's road death toll has been falling over recent years; our estimates indicate that moving to US-level prices would return the country to a circa-1995 road death toll.

We ask one final question: How large a role has increases in real gasoline prices played in the reductions in road deaths that have been achieved in most developed countries? The answer is that higher gasoline prices have had a material effect in reducing road deaths, but are typically not the majority of the story. This results from the relative inelasticity of road deaths to gasoline prices. An example will help. During 2002–2010, France's annual road death toll fell from around 7,700 to around 4,000. During this period, real gasoline pump prices in France increased by 57%. Our estimates suggest that the contribution of this price increase to the reduction in France's road death toll is about 800 annual road deaths, or around 20%. Other factors explain the majority of the reduction in road deaths in France in recent years. Similar is true of most other developed countries.[17]

[16] Several of the countries listed in Table 7 (e.g. Indonesia, Iran, Nigeria) have reduced gasoline subsidies since 2010. Future researchers might explore the effects of these recent subsidy reductions on road safety.
[17] Our estimates indicate that only 13% of the previously-mentioned reduction in US road deaths over the period 2006-2010 was due to rising gasoline prices.

TABLE 7
Gasoline-Subsidizing Countries: Estimated Road Deaths Avoided
if Gasoline Price Were Equal to the Level in the United States
(76 cents per liter, 2010)

(1)	(2)	(3)	(4)	(5)
Country	Gasoline pump price (US cents)	Road deaths per 100,000 population (WHO, 2013b)	Road deaths (WHO, 2013b)	Estimate: avoided road deaths if gasoline price were 76 US cents
Venezuela	2	37	10,791	>5,000
Iran	10	34	25,224	10,600
Saudi Arabia	16	25	6,800	2,700
Libya	17	n.a.	n.a.	584
Qatar	19	14	247	158
Bahrain	21	11	132	103
Turkmenistan	22	n.a.	n.a.	382
Kuwait	23	17	452	202
Oman	31	30	845	144
Algeria	32	n.a.	n.a.	1,700
Yemen	35	24	5,698	1,000
Brunei Darussalam	39	7	27	15
Nigeria	44	34	53,339	4,200
United Arab Emirates	47	13	956	210
Egypt	48	13	10,729	1,800
Indonesia	51	18	42,434	4,500
Ecuador	53	27	3,911	259
Malaysia	59	25	7,085	345
Sudan	62	25	10,935	331
Angola	65	23	4,407	141
Bolivia	70	19	1,910	38
Kazakhstan	71	22	3,514	51
Azerbaijan	75	13	1,202	6
Sum for 23 countries				*~35,000*

Notes: Countries are ordered by column 2 value. Column 5 estimates use a gasoline price elasticity of road deaths of -0.4 and are rounded to the nearest hundred if >1,000. Estimates are capped at ">5,000" for Venezuela given the imprecision associated with estimates using such large price changes. Regression estimates use IRF reported road death data rather than the WHO death estimates. The WHO data are their estimates and are shown because they provide superior country coverage in 2010 (only).

V. CONCLUSION

This study has utilized the substantial variation in international gasoline pump prices to examine the effect of gasoline prices on the number of people dying in road crashes. Our results indicate that higher gasoline prices significantly reduce road deaths, with our point estimates of the mean long-run gasoline price elasticity of road deaths lying between -0.3 and -0.6. The effect is an inelastic one, as also obtained in studies of the US (e.g. Grabowski and Morrisey 2004).

The international community is mobilizing a number of strategies to improve road safety during the United Nations' Decade of Action for Road Safety 2011–2020. The Plan for the Decade of Action (WHO 2010) is silent on the potential role of fuel pricing. Reductions in fuel subsidies and increases in fuel taxes could, however, make a large contribution to the Plan's objectives. Countries providing the largest fuel subsidies are particularly compelling candidates for reform. Globally, around 35,000 road deaths could be avoided each year by the removal of the fuel subsidies that were in place in 2010.

Finally, there are likely to be large changes in road transport over coming decades. Moving toward non-oil powered vehicles may involve a reduction in the marginal cost of driving. If so, our results suggest that this could feed into higher road death rates. At the same time, however, vehicle safety will continue improving. The economic and other factors affecting road death rates will remain a stimulating field of research.

REFERENCES

Anwaar, A., P. Anastasopoulos, G. P. Ong, S. Labi, and M. B. Islam. 'Factors Affecting Highway Safety, Health Care Services, and Motorization — An Exploratory Empirical Analysis using Aggregate Data.' *Journal of Transportation Safety & Security*, 4(2), 2012, 94–115.

Baltagi, B. H. *Econometric Analysis of Panel Data*. 4th ed. West Sussex: John Wiley & Sons, 2008.

Baltagi, B. H., and J. M. Griffin. 'Gasoline Demand in the OECD: An Application of Pooling and Testing Procedures.' *European Economic Review*, 22(2), 1983, 117–137.

Baltagi, B. H., and J. M. Griffin. 'Short and Long Run Effects in Pooled Models.' *International Economic Review*, 25(3), 1984, 631–45.

Burger, N. E., and D. T. Kaffine. 'Gas Prices, Traffic, and Freeway Speeds in Los Angeles.' *Review of Economics and Statistics*, 91(3), 2009, 652–657.

Burke, P.J., and S. Nishitateno. 'Gasoline Prices, Gasoline Consumption, and New-Vehicle Fuel Economy: Evidence for a Large Sample of Countries.' *Energy Economics*, 36, 2013, 363–70.

Chi, G., A. G. Cosby, M. A. Quddus, P. A. Gilbert, and D. Levinson. 'Gasoline Prices and Traffic Safety in Mississippi.' *Journal of Safety Research*, 41(6), 2010, 493–500.

Chi, G., T. E. McClure, and D. B. Brown. 'Gasoline Prices and Traffic Crashes in Alabama, 1999-2009.' *Traffic Injury Prevention*, 13(5), 2012, 476–84.

Chi, G., J. R. Porter, A. G. Cosby, and D. Levinson. 'The Impact of Gasoline Price Changes on Traffic Safety: A Time Geography Explanation.' *Journal of Transport Geography*, 28, 2013a, 1–11.

Chi, G., M. A. Quddus, A. Huang, and D. Levinson. 'Gasoline Price Effects on Traffic Safety in Urban and Rural Areas: Evidence from Minnesota, 1998–2007.' *Safety Science*, 59(1), 2013b, 154–62.

Chi, G., X. Zhou, T. E. McClure, P. A. Gilbert, A. G. Cosby, L. Zhang, A. A. Robertson, and D. Levinson. 'Gasoline Prices and their Relationship to Drunk-Driving Crashes.' *Accident Analysis and Prevention*, 43(1), 2011, 194–203.

Congressional Budget Office. *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*. Washington DC: Congressional Budget Office, 2008.

Cullotta, K. A. 'As Gas Prices Rise, Teenagers' Cruising Declines.' *New York Times*. 29 June 2008.

Davis, L. W. 'The Economic Cost of Global Fuel Subsidies.' *American Economics Review: Papers & Proceedings*, 104(5), 2014, 581–585.

Feenstra, R. C., R. Inklaar, and M. P. Timmer. *The Next Generation of the Penn World Table*. www.ggdc.net/pwt, Version 8.0, 2013.

Gayer, T. 'The Fatality Risks of Sport-Utility Vehicles, Vans, and Pickups Relative to Cars.' *Journal of Risk and Uncertainty*, 28(2), 2004, 103–133.

GIZ. *International Fuel Prices 2010/2011*. 7th edn, Bonn and Eschborn: GIZ, 2012.

Grabowski, D. C., and M. A. Morrisey. 'Gasoline Prices and Motor Vehicle Fatalities.' *Journal of Policy Analysis and Management*, 23(3), 2004, 575–593.

Grabowski, D. C., and M. A. Morrisey. 'Do Higher Gasoline Taxes Save Lives?' *Economics Letters*, 90(1), 2006, 51–55.

Hammar, H., A. Löfgren, and T. Sterner. 'Political Economy Obstacles to Fuel Taxation.' *Energy Journal*, 25(3), 2004, 1–17.

Haughton, J., and S. Sarkar. 'Gasoline Tax as a Corrective Tax: Estimates for the United States, 1970-1991.' *Energy Journal*, 17(2), 1996, 103–126.

Hyatt, E., R. Griffin, L.W. Rue III, and G. McGwin Jr. 'The Association Between Price of Regular-Grade Gasoline and Injury and Mortality Rates Among Occupants Involved in Motorcycle- and Automobile-Related Motor Vehicle Collisions.' *Accident Analysis and Prevention*, 41(5), 2009, 1075–9.

International Energy Agency. *Energy Prices and Taxes*. Paris: International Energy Agency, 2013a.

International Energy Agency. *World Energy Statistics and Balances*. Paris: International Energy Agency, 2013b.

International Road Federation. *World Road Statistics 2012*. Geneva: International Road Federation, 2012. Data also obtained from back issues.

Law, T. H., R. B. Noland, and A. W. Evans. 'The Sources of the Kuznets Relationship Between Road Fatalities and Economic Growth.' *Journal of Transport Geography*, 19(2), 2011, 355–65.

Leigh, J. P., and E. M. Geraghty. 'High Gasoline Prices and Mortality from Motor Vehicle Crashes and Air Pollution.' *Journal of Occupational & Environmental Medicine*, 50(3), 2008, 249–54.

Leigh, J. P., and J. T. Wilkinson. 'The Effect of Gasoline Taxes on Highway Fatalities.' *Journal of Policy Analysis and Management*, 10(3), 1991, 474–81.

Litman, T. 'Pricing for Traffic Safety: How Efficient Transport Pricing can Reduce Roadway Crash Risks.' *Transportation Research Record*, 2318, 2012, 16–22.

Luoma, J., and M. Sivak. 'Characteristics and Availability of Fatal Road-Crash Databases in 20 Countries Worldwide.' *Journal of Safety Research*, 38(3), 2007, 323–7.

Montour, C. P. 'Death and Taxes: The Effect of Gasoline Prices on Traffic Fatalities.' *St. Olaf College Economics Department's Omicron Delta Epsilon Journal of Economic Research*, 1(3), 2011, 37–62.

Morrisey, M. A., and D. C. Grabowski. 'Gas Prices, Beer Taxes and GDL Programmes: Effects on Auto Fatalities Among Young Adults in the US.' *Applied Economics*, 43(25), 2011, 3645–54.

Nishitateno, S., and P. J. Burke. 'The Motorcycle Kuznets Curve.' *Journal of Transport Geography* 36, 2014, 116–123.

Noland, R. B. 'Fuel Economy and Traffic Fatalities: Multivariate Analysis of International Data.' *Energy Policy*, 33(17), 2005, 2183–90.

Organisation for Economic Co-operation and Development. *OECD.Stat Extracts*. http://stats.oecd.org/, 2013a.

Organisation for Economic Co-operation and Development. *OECD Factbook 2013: Economic, Environmental and Social Statistics*. Paris: Organisation for Economic Co-operation and Development, 2013b.

Page, Y. 'A Statistical Model to Compare Road Mortality in OECD Countries.' *Accident Analysis and Prevention*, 33(3), 2001, 371–85.

Passmore, J., Tu, N.T.H., Luong, M.A., Chinh, N.D., and Nam, N.P. 'Impact of Mandatory Motorcycle Helmet Wearing Legislation on Head Injuries in Viet Nam: Results of a Preliminary Analysis.' *Traffic Injury Prevention*, 11(2), 2010, 202–206.

Pesaran, M. H., and R. Smith. 'Estimating Long-Run Relationships from Dynamic Heterogeneous Panels.' *Journal of Econometrics*, 68(1), 1995, 79–113.

Pirotte, A. 'Convergence of the Static Estimation Toward the Long Run Effects of Dynamic Panel Data Models.' *Economics Letters*, 63(2), 1999, 151–8.

Pirotte, A. 'Convergence of the Static Estimation Toward the Long Run Effects of Dynamic Panel Data Models: A Labour Demand Illustration.' *Applied Economics Letters*, 10(13), 2003, 843–7.

Sauerzapf, V., A. P. Jones, and R. Haynes. 'The Problems in Determining International Road Mortality.' *Accident Analysis and Prevention*, 42(2), 2010, 492–9.

Sivak, M. 'Mechanisms Involved in the Recent Large Reductions in US Road Fatalities.' *Injury Prevention*, 15(3), 2009, 205–206.

Sivak, M., and B. Schoettle. 'Toward Understanding the Recent Large Reductions in U.S. Road Fatalities.' *Traffic Injury Prevention*, 11(6), 2010, 561–6.

Stern, D. I. 'Between Estimates of the Emissions-Income Elasticity.' *Ecological Economics*, 69(11), 2010, 2173–82.

Stock, J. H., and M. Yogo. 'Testing for Weak Instruments in Linear IV Regression,' in *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, edited by D. W. K. Andrews and J. H. Stock. Cambridge, UK: Cambridge University Press, 2005, 80–108.

United Nations. *World Population Prospects: The 2010 Revision*. http://esa.un.org/wpp/, 2010.

United Nations Economic Commission for Europe. *Statistical Database*. http://w3.unece.org/pxweb/, 2013.

U.S. Department of Energy. *Driving More Efficiently*. www.fueleconomy.gov, 2013.

U.S. Energy Information Administration. *International Energy Statistics*. http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm, 2011.

White, M. J. 'The 'Arms Race' on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety.' *Journal of Law and Economics*, 47(2), 2004, 333–55.

Wilson, F.A., J. P. Stimpson, and P. E. Hilsenrath. 'Gasoline Prices and their Relationship to Rising Motorcycle Fatalities, 1990-2007.' *American Journal of Public Health*, 99(10), 2009, 1753–8.

World Bank. *World Development Indicators*. http://data.worldbank.org/, 2013a.

World Bank. *Worldwide Governance Indicators*. http://www.govindicators.org, 2013b.

World Health Organization. *Global Plan for the Decade of Action for Road Safety 2011-2020*. Geneva: World Health Organization, 2010.

World Health Organization. *Top 10 Causes of Death*. http://www.who.int/mediacentre/factsheets/fs310/en/index.html, 2013a.

World Health Organization. *Global Status Report on Road Safety 2013: Supporting a Decade of Action*. Geneva: World Health Organization, 2013b.

World Health Organization. *Global Information System on Alcohol and Health*. http://apps.who.int/gho/data/view.main?showonly=GISAH, 2013c.

World Health Organization. *Global Health Observatory Data Repository*. http://apps.who.int/gho/data, 2013d.

APPENDIX: VARIABLE DESCRIPTIONS

Road deaths: Number of reported deaths that occur within 30 days of a road crash. Includes all deaths (e.g. of vehicle occupants, motorcyclists, cyclists, and pedestrians). International Road Federation (2012). Data for nine countries were supplemented with figures from the Organisation for Economic Co-operation and Development (2013a) and the United Nations Economic Commission for Europe (2013).

Gasoline price: Average retail gasoline pump price in year-2010 US cents per liter. Prices were collected by GIZ (2012) in mid-November surveys. Data are for unleaded Octane 95 gasoline. Indonesia's price is for subsidized gasoline. The US GDP deflator from the World Bank (2013a) was used to deflate prices.

GDP: Expenditure-side real GDP at chained purchasing power parities, in 2005 $US. Feenstra et al. (2013).

Population: Total population, in people. Feenstra et al. (2013).

Oil reserves per capita: Proved underground reserves of crude oil, thousand tonnes per capita. U.S. Energy Information Administration (2011). One year's lag or lead used for a small number of missing observations.

Real world oil price: Average cost of total crude imports of the members of the IEA in year-2010 US dollars per barrel. IEA (2013a). The US GDP deflator from the World Bank (2013a) was used to deflate prices.

Average gasoline and diesel price: Simple average of the gasoline and diesel retail pump prices in year-2010 US cents per liter. Prices were collected by GIZ (2012) in mid-November surveys. Gasoline prices are for unleaded Octane 95 gasoline. Indonesia's gasoline price is for subsidized gasoline. The US GDP deflator from the World Bank (2013a) was used to deflate prices.

Land area: A country's total land area, excluding inland water bodies, national claims to continental shelf, and exclusive economic zones, in square kilometers. World Bank (2013a).

Road distance: Length of the total road network, in kilometers. International Road Federation (2012). Data linearly interpolated.

Paved road share (%): % of road length that is surfaced with crushed stone, hydrocarbon binder, bituminized agents, concrete, or cobblestones. International Road Federation (2012). Data linearly interpolated.

Motor vehicle stock (4+ wheels): Number of motor vehicles with 4 or more wheels. Includes cars, buses, lorries, and vans. International Road Federation (2012). Several apparent errors were removed. Data linearly interpolated.

Motorcycle stock: Two- or three-wheeled road motor vehicles. International Road Federation (2012). Several apparent errors were removed. Data linearly interpolated.

Rail share of energy used in transport (%): % share of rail sector's energy use in total energy used in the road, rail, and domestic aviation sectors. IEA (2013b).

Air passengers: Domestic and international passengers of air carriers registered in the country. World Bank (2013a).

Population aged 15-24 (%): % of population aged 15-24. Five-yearly United Nations (2010) data on the 15-24 year old population were linearly interpolated. Data on total population from Feenstra et al. (2013).

Urban population (%): People living in urban areas as defined by national statistical offices as a share of the total population. World Bank (2013a).

Alcohol consumption per adult: Annual alcohol consumption (in liters of pure alcohol) per adult (age 15+). WHO (2013c).

Blood alcohol limit for drivers in 2011: Legal blood alcohol concentration (BAC) for general drivers in 2011 (or nearby year), expressed as a %. This variable is missing for countries with no limit (which only slightly reduces the sample). This variable is not time varying. WHO (2013d).

Maximum speed in urban areas in 2011: Maximum speed limit for cars on residential roads in 2011, in kilometers per hour. This variable is not time varying. WHO (2013d).

Rule of law score: A measure of perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Approximate possible range is -2.5 (worst) to 2.5 (best). World Bank (2013b).

Control of corruption score: A measure of perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as capture of the state by elites and private interests. Approximate possible range is -2.5 (worst control of corruption) to 2.5 (best). World Bank (2013b).

Economic growth rate (%): Annual percentage change in expenditure-side real GDP at chained purchasing power parities, in 2005 $US. Feenstra et al. (2013).

Infant mortality rate: Number of infants dying before reaching one year of age, per 1,000 live births. World Bank (2013a).

Population density: Population per squared kilometer of land area. World Bank (2013a).

Working Papers in Trade and Development
List of Papers (as at 2014)

11/01 BUDY P RESOSUDARMO and SATOSHI YAMAZAKI, 'Training and Visit (T&V) Extension vs. Farmer Field School: The Indonesian'

11/02 BUDY P RESOSUDARMO and DANIEL SURYADARMA, 'The Effect of Childhood Migration on Human Capital Accumulation: Evidence from Rural-Urban Migrants in Indonesia'

11/03 PREMA-CHANDRA ATHUKORALA and EVELYN S DEVADASON, 'The Impact of Foreign Labour on Host Country Wages: The Experience of a Southern Host, Malaysia'

11/04 PETER WARR, 'Food Security vs. Food Self-Sufficiency: The Indonesian Case'

11/05 PREMA-CHANDRA ATHUKORALA, 'Asian Trade Flows: Trends, Patterns and Projections'

11/06 PAUL J BURKE, 'Economic Growth and Political Survival'

11/07 HAL HILL and JUTHATHIP JONGWANICH, 'Asia Rising: Emerging East Asian Economies as Foreign Investors'

11/08 HAL HILL and JAYANT MENON, 'Reducing Vulnerability in Transition Economies: Crises and Adjustment in Cambodia'

11/09 PREMA-CHANDRA ATHUKORALA, 'South-South Trade: An Asian Perspective'

11/10 ARMAND A SIM, DANIEL SURYADARMA and ASEP SURYAHADI, 'The Consequences of Child Market Work on the Growth of Human Capital'

11/11 HARYO ASWICAHYONO and CHRIS MANNING, 'Exports and Job Creation in Indonesia Before and After the Asian Financial Crisis'

11/12 PREMA-CHANDRA ATHUKORALA and ARCHANUN KOHPAIBOON, 'Australia-Thailand Trade: Has the FTA Made a Difference?

11/13 PREMA-CHANDRA ATHUKORALA, 'Growing with Global Production Sharing: The Tale of Penang Export Hub'

11/14 W. MAX CORDEN, 'The Dutch Disease in Australia: Policy Options for a Three-Speed Economy'

11/15 PAUL J BURKE and SHUHEI NISHITATENO, 'Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries'

12/01 BUDY P RESOSUDARMO, ANI A NAWIR, IDA AJU P RESOSUDARMO and NINA L SUBIMAN, 'Forest Land use Dynamics in Indonesia'

12/02 SHUHEI NISHITATENO, 'Global Production Sharing in the Japanese Automobile Industry: A Comparative Analysis'

12/03 HAL HILL, 'The Best of Times and the Worst of Times: Indonesia and Economic Crises'

12/04 PREMA-CHANDRA ATHUKORALA, 'Disaster, Generosity and Recovery: Indian Ocean Tsunami'

12/05 KYM ANDERSON, 'Agricultural Trade Distortions During the Global Financial Crisis'

12/06 KYM ANDERSON and MARKUS BRUCKNER, 'Distortions to Agriculture and Economic Growth in Sub-Saharan Africa'

12/07 ROBERT SPARROW, ELLEN VAN DE POEL, GRACIA HANDIWIDJAJA, ATHIA YUMNA, NILA WARDA and ASEP SURYAHADI, 'Financial Consequences of Ill Health and Informal Coping Mechanisms in Indonesia'

12/08 KYM ANDERSON, 'Costing Global Trade Barriers, 1900 to 2050'

12/09 KYM ANDERSON, WILL MARTIN and DOMINIQUE VAN DER MENSBRUGGHE, 'Estimating Effects of Price-distorting Policies Using Alternative Distortions Databases'

12/10 W. MAX CORDEN, 'The Dutch Disease in Australia: Policy Options for a Three-Speed Economy' (revised version of Trade & Development Working Paper 2011/14)

12/11 KYM ANDERSON, 'Policy Responses to Changing Perceptions of the Role of Agriculture in Development'

12/12 PREMA-CHANDRA ATHUKORALA and SHAHBAZ NASIR, 'Global Production Sharing and South-South Trade'

12/13 SHUHEI NISHITATENO, 'Global Production Sharing and the FDI–Trade Nexus: New Evidence from the Japanese Automobile Industry'

12/14 PREMA-CHANDRA ATHUKORALA, 'Sri Lanka's Trade Policy: Reverting to Dirigisme?'

12/15 PREMA-CHANDRA ATHUKORALA and SISIRA JAYASURIYA, 'Economic Policy Shifts in Sri Lanka: The Post-conflict Development Challenge'

12/16 PREMA-CHANDRA ATHUKORALA and JUTHATHIP JONGWANICH, 'How Effective are Capital Controls? Evidence from Malaysia'

12/17 HAL HILL and JAYANT MENON, 'Financial Safety Nets in Asia: Genesis, Evolution, Adequacy, and Way Forward'

12/18 KYM ANDERSON, GORDON RAUSSER and JOHAN SWINNEN, 'Political Economy of Public Policies: Insights from Distortions to Agricultural and Food Markets'

13/01 KYM ANDERSON, 'Agricultural Price Distortions: Trends and Volatility, Past and Prospective'

13/02 PREMA-CHANDRA ATHUKORALA and SWARNIM WAGLÉ, 'Export Performance in Transition: The Case of Georgia'

13/03 JAYANT MENON and THIAM HEE NG, 'Are Government-Linked Corporations Crowding out Private Investment in Malaysia?'

13/04 RAGHBENDRA JHA, HARI K. NAGARAJAN & KOLUMUM R. NAGARAJAN, 'Fiscal Federalism and Competitive Bidding for Foreign Investment as a Multistage Game'

13/05 PREMA-CHANDRA ATHUKORALA, 'Intra-Regional FDI and Economic Integration in South Asia: Trends, Patterns and Prospects'.

13/06 JAYANT MENON, 'Can FTAs Support the Growth or Spread of International Production Networks in Asia?'

13/07 PETER WARR and ARIEF ANSHORY YUSUF, 'World Food Prices and Poverty in Indonesia'.

13/08 PETER WARR & ARIEF ANSHORY YUSUF, 'Fertilizer Subsidies and Food Self-Sufficiency in Indonesia'.

13/09 MIA AMALIA, BUDY P. RESOSUDARMO, & JEFF BENNETT, 'The Consequences of Urban Air Pollution for Child Health: What does self reporting data in the Jakarta metropolitan area reveal?'

13/10 PREMA-CHANDRA ATHUKORALA, ‘Global Production Sharing and Trade Patterns in East Asia’.

13/11 KYM ANDERSON, MAROS IVANIC & WILL MARTIN, ‘Food Price Spikes, Price Insulation, and Poverty’.

13/12 MARCEL SCHRÖDER, ‘Should Developing Countries Undervalue Their Currencies?’.

13/13 PREMA-CHANDRA ATHUKORALA, ‘How India Fits into Global Production Sharing: Experience, Prospects and Policy Options’.

13/14 PETER WARR, JAYANT MENON and SITTHIROTH RASPHONE, ‘Public Services and the poor in Laos’.

13/15 SAMBIT BHATTACHARYYA and BUDY R. RESOSUDARMO, ‘Growth, Growth Accelerations and the Poor: Lessons from Indonesia’

13/16 PREMA-CHANDRA ATHUKORALA and ARCHANUN KOPHAIBOON, ‘Trade and Investment Patterns in Asia: Implications for Multilateralizing Regionalism’

13/17 KYM ANDERSON and ANNA STRUTT, ‘Emerging Economies, Productivity Growth, and Trade with Resource-Rich Economies by 2030’

13/18 PREMA-CHANDRA ATHUKORALA and ARCHANUN KOHPAIBOON, ‘Global Production Sharing, Trade Patterns and Industrialization in Southeast Asia’

13/19 HAL HILL, ‘Is There a Southeast Asian Development Model?’

14/01 RAMESH CHANDRA PAUDEL, ‘Economic Growth in Developing Countries: Is Landlockedness Destiny?

14/02 ROSS McLEOD, ‘The ill-fated currency board proposal for Indonesia’

14/03 ALIN HALIMATUSSADIAH, BUDY P. RESOSUDARMO AND DIAH WIDYAWATI, ‘Social Capital to Induce a Contribution to Environmental Collective Action in Indonesia: An Experimental Method’

14/04 SHUHEI NISHITATENO and PAUL J. BURKE, ‘The motorcycle Kuznets curve’

14/05 PREMA-CHANDRA ATHUKORALA, ‘Sri Lanka’s Post-conflict Development Challenge: Learning from the Past’

14/06 PREMA-CHANDRA ATHUKORALA, ‘Industrialisation through State-MNC Partnership: Lessons from the Malaysia’s National Car Project’

14/07 DELWAR HOSSAIN, ‘Differential Impacts of Foreign Capital and Remittance Inflows on Domestic Savings in the Developing Countries: A Dynamic Heterogeneous Panel Analysis’

14/08 NOBUAKI YAMASHITA, TOSHIYUKI MATSUURA *and* KENTARO NAKAJIMA, ‘Agglomeration effects of inter-firm backward and forward linkages: evidence from Japanese manufacturing investment in China’

14/09 SHUHEI NISHITATENO, ‘Network Effects on Trade in Intermediate Goods: Evidence from the Automobile Industry’

14/10 KYM ANDERSON and ANNA STRUTT, ‘Implications for Indonesia of Asia’s Rise in the Global Economy’

14/11 KYM ANDERSON and ANNA STRUTT, ‘Food security policy options for China: Lessons from other countries’

14/12 HAL HILL and JAYANT MENON, ‘Cambodia: Rapid Growth in an Open, Post-Conflict Economy’

14/13 ALOYSIUS G. BRATA, PIET RIETVELD, HENRI L.F. DE GROOT, BUDY P. RESOSUDARMO and WOUTER ZANT, ‘Living with the Merapi volcano: risks and disaster microinsurance’

14/14 HANS G. JENSEN and KYM ANDERSON, ‘Grain price spikes and beggar-thy-neighbor policy responses: A global economywide analysis’

14/15 KYM ANDERSON, ‘Contributions of the GATT/WTO to global economic welfare: Empirical evidence’.

14/16 PREMA-CHANDRA ATHUKORALA, ‘Global Production Sharing and Asian Trade Patterns: Implications for the Regional Comprehensive Economic Partnership (RCEP)’.

14/17 PREMA-CHANDRA ATHUKORALA and RAVEEN EKANAYAKE, ‘Repositioning in the Global Apparel Value Chain in the Post-MFA Era: Strategic Issues and Evidence from Sri Lanka’.

14/18 PAUL J.BURKE and SHUHEI NISHITATENO, ‘Gasoline Prices and Road Fatalities: International Evidence’