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High Gasoline Prices and Mortality From Motor Vehicle Crashes and Air Pollution

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Learning Objectives

- Outline the assumptions made when using a simulation-based partial equilibrium model to estimate the public health effects of a hypothetical 20% increase in the cost of gasoline, sustained over a 12-month period.
- Summarize what the model predicted would be the effects of increased gasoline cost on fatal motor vehicle crashes and deaths related to particulate matter in air pollution.
- Recall what the findings suggest about whether and to what extent increasing taxes on gasoline would alter mortality rates.

Abstract

Objective: To estimate the effects of increasing gas prices on mortality. **Method:** We developed a simulation-based partial equilibrium model that estimated the public health effects of a 20% rise in gas prices. Estimates on price elasticity for gasoline, price elasticity of motor vehicle crashes, relations among gasoline use, air pollution, and mortality were drawn from literature in economics, epidemiology, and medicine. **Results:** For sustained 20% increases in gasoline prices over 1 year, and assuming other prices and factors were constant, we estimated: 1994 (range, 997 to 4984) fewer deaths from vehicle crashes and 600 (range, 300 to 1500) fewer deaths from air pollution. Combining both, we estimated 2594 fewer deaths. A Monte Carlo simulation involving varying assumptions on elasticities and relations indicated that 95% of the combined reduction in deaths was between 1747 and 3714. **Conclusion:** Results suggest that high gas prices have public health implications. (J Occup Environ Med. 2008;50: 249–254)

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The price-per-barrel of crude oil rose from \$40.18 in January, 2005 to \$64.32 in May, 2006—a 60% increase.¹ A gallon of unleaded regular gasoline increased from \$1.82 in January, 2005 to \$3.00 in July, 2006—a 64.8% increase.¹ Similar increases were experienced overseas, but because of high taxes, prices in other countries were much higher than in the United States. For example, prices in some countries (and US price-per-gallon) in July, 2006 were as follows: \$6.27 in France; \$6.50 in Germany; \$6.53 in Italy; \$5.27 in Spain; \$6.72 in UK; \$4.91 in Japan; and \$3.47 in Canada.² Economics suggests, other things equal, that increases in gas prices should reduce gas use. It is likely that reduced gas use has public health implications. In this article, we address two implications of increasing gas prices for mortality: fewer vehicle crashes and less air pollution. Because “other things” are not equal in the real world and because current data on all the necessary information were not available, we constructed a simulation, partial equilibrium, model. The model estimated changes in mortality resulting from a 20% increase in real (inflation-adjusted) gasoline prices sustained over 1 year. One-way and multiway sensitivity analyses allowed for alternate 10% and 50% increases in price, as well as alternate assumptions involving the links from gas prices to mortality.

Materials and Methods

We developed a simulation model that assumed 1) an increase in price reduced the quantity of gasoline de-

manded; 2) there were only two links between high gas prices and mortality; and 3) other things such as level of national income, employment, coal production, electricity use, and, importantly, all other prices did not change. That is, the increase in price was “real” in the language of economics—it was over and above any inflation of all other prices in the economy. These three assumptions imply, in the language of economics, that we took a “partial” rather than a “general equilibrium” approach. We discuss each of these assumptions below.

An enduring insight from economics is that for most products, a significant price increase will result in a decrease in the quantity demanded, other things being equal. The other things include, for example, prices of related goods, such as new trucks. The numerical estimate that describes this relation for product X is called the “price elasticity of demand” for X. An elasticity of 0.2 suggests that for a 10% increase in the price of X, the quantity demanded of X will drop by 2%. Economic theory holds and empirical evidence suggests that short-run elasticities are smaller than long-run elasticities, meaning that a recent price increase elicits a smaller change in quantity demanded than a more remote, sustained price increase. For gasoline, there are no clear guidelines for this timing differential, but “short-run” is frequently described as less than 1 or 2 years and “long-run” as more than 1 or 2 years. One reason for larger long-run elasticities is that consumers have more opportunity to adapt. For example, consumers have more time to buy small cars.

Two reviews of the price elasticity of demand for gasoline suggest 0.25 as a mean estimate for the short-run.^{3,4} Using this estimate, a 20% increase in gas price, other things being equal, would result in a 5% reduction in gas use over 1 year.

The first link between gasoline price and mortality in the model involved motor vehicle crash deaths,

including deaths among pedestrians and bicyclists. Economic theory and evidence suggest that after a gas price increase, people drive less, accounting for much of the reduced gasoline consumption, especially in the short-run.^{5–10} Theoretically, fewer miles driven ought to be associated with fewer vehicle deaths, other things being equal. In fact there is evidence for a price association with vehicle deaths.^{6,7,9,10} One of the most recent of these studies estimates an elasticity for price and fatalities of 0.23 applying over 2 years.⁶ Interpretation of this elasticity is as follows: a 10% increase in price is associated with a 2.3% reduction in fatalities; and a 20% increase would be associated with a 4.6% reduction.

For the model, we chose 2003 as a base-year because it was the last of several recent years (2000 to 2003) that did not see dramatic changes in gas prices. The average price-per-gallon including taxes for all grades of gasoline in 2003 was \$1.638. The Centers for Disease Control and Prevention (CDC) collects national vital statistics information. For the base-year, 2003, CDC report 43,340 motor vehicle crash deaths.¹¹

We constructed alternative estimates and scenarios around the base-case using: 10% and 50% as increases in gas prices; 40,965 and 44,065 as numbers of deaths in the year before the price increase (minimum and maximum figures reported by the CDC¹¹ between 1999 and 2003 for motor vehicle crash deaths); and 0.16 and 0.29 as price elasticities for vehicle deaths.⁶

The second link between price and mortality involved air pollution.¹² Among the dozens of toxic agents in air pollution, particulate matter (both PM_{2.5} and PM₁₀) has received the most research confirmation as a cause of mortality.^{13,14} Mokdad et al.¹⁵ estimated that particulate matter in air pollution caused 24,000 deaths in 2000 (range, 22,000 to 52,000). We assumed the same numbers in our base-case.

The contribution of motor vehicle traffic to pollution is considerable. A recent study estimated the contribution to ambient particulate matter pollution ranged from 20% to 76% for PM_{2.5} and from 35% to 92% for PM₁₀.¹⁶ In consideration of this wide range, we used the “about half” estimate by Kunzli et al.¹⁷ for our base-case. We also assumed that a given percentage decrease in gallons of gasoline consumed resulted in the same percentage decrease in deaths. The base-case was then 24,000 (deaths from all air pollution) × 50% (pollution attributable to motor vehicles) × 0.25 (demand-price elasticity) × 20% increase in price.

Again, alternative estimates and scenarios were built around the base-case such that 22,000 and 52,000 were examined as upper and lower estimates of the number of deaths attributed to air pollution,¹⁵ and 30% and 70% as percentages of air pollution due to motor vehicles.

The multiway sensitivity analysis combined all the alternative estimates for each link. We assumed that the base-case and each of the scenarios were equally likely. The Monte Carlo simulations randomly drew 10,000 values from Tables 1 and 2 and summed them. One simulation allowed for only a 20% increase in price. Another simulation allowed for 10%, 20%, and 50% increases.

Results

Results for the decreased numbers of deaths due to fewer highway crashes are presented in Table 1 (1994 fewer deaths; possible range, 997 to 4984). Plausible changes in increased gas prices from 10% to 50% had the greatest effect on the estimate of decreased numbers of deaths. Changing the plausible level of all vehicle deaths in the base-year (40,965 vs 44,065) had the least effect on changing estimates of numbers of deaths avoided.

Table 2 presents results for the decreased numbers of deaths due to particulate matter in air pollution (600 fewer deaths; possible range,

TABLE 1
Motor Vehicle Deaths

Example	Assumption	Fewer Deaths
Base-case	+20% price	1,994
	43,340 deaths*	
Lower-bound scenarios	0.23 price-vehicle deaths elasticity†	997
	+10% price	1,884
	40,965 deaths‡	1,387
Upper-bound scenarios	0.16 price-vehicle deaths elasticity†	4,984
	+50% price	2,027
	44,065 deaths§	2,514
	0.29 price-vehicle deaths elasticity†	

*Centers for Disease Control and Prevention, National Center for Health Statistics (NCHS) Data on Injuries (webappa.cdc.gov/cgi-bin/broker.exe, accessed August 29, 2007). This number, 43,340, was for year 2003.

†From Grabowski and Morrissey.⁶

‡The lowest figure from 1999 through 2003 was 40,965 in 1999. Same CDC source as in first footnote.

§The highest figure from 1999 through 2003 was 44,065 in 2002. Same CDC source as in first footnote.

TABLE 2
Air Pollution Deaths

Example	Assumption	Fewer Deaths
Base-case	+20% price	600
	24,000 pollution deaths*	
	50% pollution due to vehicles†	
	0.25 demand-price elasticity‡	
Lower-bound scenarios	Price-mortality relation linear-in-logs	
	+10% price	300
	22,000 pollution deaths*	550
	30% pollution due to vehicles	360
Upper-bound scenarios	0.15 demand-price elasticity‡	360
	+50% price	1,500
	52,000 pollution deaths*	1,300
	70% pollution due to vehicles	840
	0.50 demand-price elasticity‡	1,200

*Mokdad et al.¹⁵

†Kunzli et al.¹⁷

‡Graham and Glaister³ and Goodwin et al.⁴

300 to 1500). Assumptions regarding the increase in gas prices and amount of air pollution generated by motor vehicles were responsible for the greatest variation in estimates of deaths.

The Monte Carlo simulations, which summed one base-case or scenario from Table 1 with one base-case or scenario from Table 2, also generated results. In the first simulation, which assumed only a 20% increase in price together with alternative assumptions on elasticity, pollution, and deaths, 95% of the reduction in combined deaths was between 1747 and 3714. In the second simulation, which

allowed 10%, 20%, and 50% increases in price together with alternative assumptions, 95% of the reduction in combined deaths was between 1547 and 5824.

Discussion

Our results suggested that increases in real gas prices, sustained over 1 year, would result in 2594 (95% simulation interval, 1747 to 3714) fewer deaths due to fewer vehicle crashes and reduced air pollution combined.

This study has strengths. First, it seems to be the only study to date to address two mortality implications of

high gas prices. Second, it is timely. Not only did gas prices rise dramatically in 2004 to 2006 but the need for “carbon taxes” are also frequently discussed in the debates on global warming, reduced dependence on foreign oil, and reduced terrorism.¹⁸ In addition, researchers have suggested that higher gas prices and taxes would lead to less smog, greater visibility, and less congestion.^{8,19} Third, our base-case numbers corresponded to actual values on prices and deaths for the United States in 2003, before the substantial increase in prices. In fact, recent years have shown that our simulated 10%, 20%, and 50% increases in gas prices are plausible. Fourth, the figures on price elasticity for gas, price elasticity for vehicle crash deaths, and relations between air pollution and mortality were drawn from leading economic and epidemiologic studies.

Given the increase in gasoline prices from 2002 to 2007, we might expect corresponding reductions in motor vehicle deaths. Unfortunately, data on motor vehicle deaths are not available beyond 2005.²⁰ Moreover, there are many aggregate influences on vehicle deaths apart from gasoline prices.^{6,10} Nevertheless, recent and prior history provides some tentative support for our hypothesis. From 2000 to 2002, nominal and real gasoline prices decreased 10.5% and 13.6%, respectively.²¹ Number of deaths and deaths per 100,000 in the population increased 4.7% and 1.9%, respectively.²⁰ From 2002 to 2004, nominal and real prices increased 37.7% and 31.0%, respectively. Deaths and death rates decreased 3.1% and 4.5%, respectively.²⁰ Finally, a leading newspaper recently reported sharp declines in miles driven from November 2005 to May 2007.²² “The average American motorist is driving substantially fewer miles for the first time in 26 years because of high gas prices and demographic shifts . . .”²²

The “oil shocks” of the 1970s and early 1980s also provide evidence. From 1972 to 1975, the nominal and

real price of gasoline increased 58.7% and 23.4%, respectively.^{23–25} Motor vehicle fatalities and fatalities per 1000 in the population decreased 18.5% and 20.4%, respectively. From 1979 to 1982 the nominal and real gas prices increased 46.6% and 10.2%, respectively.²³ Motor vehicle fatalities decreased 14.4% and fatalities per 1000 in the population decreased 15.4%.²³

This study has limitations. We first consider limitations for the two links themselves and second, the “other things equal” assumption. Despite the logic of linking gas prices to gas use to vehicle miles and ultimately to crash deaths, only a handful of studies have provided evidence for this link.^{6,7,9,10} Another limitation for the vehicle crash deaths link involves the long-run. If prices are sustained into a third year and beyond, long-run effects manifest themselves. In the long-run, people will buy smaller cars and trucks. Although this has unambiguous beneficial effects on air pollution, the effect on vehicle crashes is unclear. Small cars, as a matter of physics, are more dangerous for occupants, especially if the other vehicle involved in the collision is a sports utility vehicle or large truck.²⁶ But, over time, with sustained high gas prices, the entire fleet of cars and trucks across the country may change. In the long-run, the frequency of large-on-small collisions may decrease when compared with small-on-small collisions.²⁶

Estimates of the air pollution link also have limitations. Air pollution may cause considerably more deaths than suggested in the base-case. The base-case considered only particulate matter pollution. But many pollutants (carbon monoxide, nitrogen dioxide, and ozone) emanate from vehicle exhaust and together they are likely to add considerably to the death toll of air pollution.²⁷ Second, we only considered 1 year. Evidence suggests that exposure to pollution in 1 year may result in health problems in future years.²⁸ Third, we did not account for the morbidity toll. Gas-

exhaust-related air pollution has been linked to many respiratory illnesses including bronchitis and asthma, cardiovascular hospital admissions, and absent days from work and school.^{27,29}

There are limitations outside of the two links—other things do not remain “equal.” Ours is a partial, not a general equilibrium model. Rapid and significant increases in gasoline prices may have macroeconomic effects on national income, unemployment, inflation, foreign deficits, and the international value of the dollar, as well as numerous microeconomic effects.

We first consider the macroeconomic effects on income. Other things being equal, increasing the price of gasoline leads to less after-gas income per gasoline consumer. Reduced income may lead to increased mortality in large populations for a number of reasons. Individuals may no longer be able to afford medical insurance, physician visits, or medicines; and lack of insurance, visits, and medicines are associated with mortality.^{30,31} Increased financial stress may translate into physiological stress for many individuals.³² Their reduced income may cause them to work longer hours which, in turn, worsens health.³³ This link between reduced income and increased mortality may be profound for poor people.³⁴ Evidence supports the idea of an inverse relationship between income and mortality so that as income decreases mortality rises.^{32,35–37}

Increased national unemployment has been alternatively alleged to increased and decreased mortality rates. On the one hand, increased national unemployment as experienced by the unemployed may result in stress and worry that can trigger myocardial infarction.³⁸ On the other hand, increased national unemployment likely coincides with decreased production of goods and services so that for those who remain employed (the majority of the labor force), there is less work to do on-the-job;

they can enjoy more leisure-time while at work.³⁹

An economics literature entitled “risk–risk analysis” has addressed the dollar amount associated with one extra death. A literature review suggested a population income reduction of \$2 million to \$33 million (1992 dollars) would result in one additional death.^{40,41}

But an increase in gasoline prices does not mean income will disappear from all consumers. Americans employed in, or who received dividends from, the oil industry likely experienced an increase in income. Perhaps a better income measure would be the dollar amount of imports for oil and gasoline, because imports represent a loss of national income. (Estimates of price–income–mortality effects are available from the authors.)

There are limitations for the income–mortality link. Some researchers question whether changes in population income (holding other things constant like education and access to medical care) result in changes in population health.⁴² But in defense of the link, it could argue that education and access to health care should not be held constant. Education is strongly influenced by parental income and medical insurance coverage is influenced by current income.^{30,43}

A different defense of the income link involves regressivity. Increasing gas prices are equivalent to increasing gas taxes from the consumers’ point-of-view. Increasing gas taxes are regressive because the poor spend a higher proportion of their income on gasoline than do the rich and increasing gas taxes, like increasing cigarette taxes, have implications for regressivity.⁴⁴ An increase in the price of gas will fall heavily on the poor.¹² And even critics acknowledge that some poverty can lead to mortality.⁴²

The income link is also limited because we do not consider reductions in all income, just income after spending on gas. We assumed in-

creased expenditures on gas were tantamount to income losses. Most of consumer income is spent on goods and services that provide to consumers what economists call “utility.” It may be the fall in utility, brought about by the reduction in after-gas income, which increases mortality. To the extent that consumers view driving as a chore, the argument that increased gas spending is an income loss may be reasonable. To the extent that driving provides joy, this argument may not be reasonable.

We turn now to microeconomic effects. Domestic automakers and their unions are likely to experience significant economic declines, and the decline of unions has been linked to rising income inequality which, in turn, has been linked to increased mortality.^{45,46} Production and consumption of coal (23% of all energy), natural gas (23% of all energy), nuclear power (8%), and renewable energy (6%) would likely increase due to increased gas prices as consumers and businesses switch from gas to other sources of energy.⁴⁷ Each of these may have mortality implications. An increase in coal mining might result in an increase in more accidents and deaths. An increase in nuclear power production might increase the risk of nuclear accidents. High prices of heating oil and natural gas may result in more people freezing to death in their homes. Whereas more than 55% of petroleum is used in the production of gasoline, petroleum is also used for other products including plastics, aviation fuel, and kerosene.⁴⁷ Changes in production and consumption of these products may also have public health implications.

There are disparate, unrelated public health implications due to high gasoline prices which we ignored. Increasing gas prices will increase demand for real estate close to jobs, which will result in increasing rents (gentrification) in the inner city. This increase in price of real estate in inner cities will have two effects on the health of those in low-income

housing: 1) some rents will increase, forcing some residents to become homeless and thus compromise their health; 2) some landlords may not raise rents, but instead respond by not spending to improve housing conditions, thus harming the health of residents.⁴⁸ Less driving might result in more walking and bicycling that might improve health and reduce obesity. (Our vehicle crash link already accounted for changes in pedestrian and bicycling deaths).⁶ Had we used years of potential life lost rather than mortality, the public health implications would be larger because vehicle crashes kill a disproportionate share of young people.⁴⁹ Greater use of mass transit and carpooling might lead to increases in infectious diseases as greater numbers of people are in close proximity. Greater use of mass public transit may result in an increase in violent crime. Increased gas prices lead to increased costs of transportation that might result in fewer visits to physicians offices for routine preventive care such as mammography.⁵⁰

Finally, this study has implications for the debate surrounding gasoline taxes. Because taxes raise prices, our study suggests increased taxes will reduce mortality. But there are many other effects of gasoline taxes. These effects are addressed by Parry et al,⁵¹ and by Porter⁸ in an especially thoughtful discussion in chapter 17. On the positive side, advocates point to reduced dependency on foreign oil, “less air pollution both locally and globally . . . fewer accidents, less congestion, fewer parking problems . . . less road maintenance . . . less water pollution.”⁸ On the negative side, critics point to the American distaste for any tax, macroeconomic inflation and unemployment, the appearance of being “discriminatory” (why tax good X but not Y?), and regressivity. In response, advocates suggest combining an increase in the gasoline tax with a reduction in some other regressive tax such as the payroll tax, and point out that a gradual increase in the gasoline

tax would not result in macroeconomic disruptions.

In conclusion, recent and future gas price increases were and will be significant and will likely have mortality implications. Moreover, in the years ahead, there may be political pressure to raise gas taxes especially given that US taxes are low compared with other countries. It is likely that vehicle crashes and air pollution will figure prominently in future analyses of the effects of gas prices on population health.

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