Impacts of Gas Price on Passenger Vehicle Use and Greenhouse Gas Emissions

Technical Background Document

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Study Selection

Many studies have investigated the impact of changes in gas price on gas demand and travel behavior. These studies have applied a variety of methodologies to data from the U.S., Canada, and other countries for time periods ranging from 1929 to today.

We focused on studies that are based on rigorous quantitative analysis and that allow estimations of price elasticities of gas demand and vehicle miles of travel (VMT). These studies are based on the estimation of either static econometric models using cross-sectional or time-series data, which do not allow for the analysis of the specific time scale of the response, or dynamic models using time-series data, which explicitly allow for a progressive build-up of the effects of gas price changes on travel behavior over a period of time.

The main focus of this literature review is on U.S. studies. However, several studies are available for Canada and Europe, and given the comparability of their economies to that of the U.S., we included these studies as well. These studies provide additional insights into travelers' response to changes in gas price in the context of more varied land development patterns and transportation systems than in the U.S., as well as a wider range of gas price values

Effect Size, Methodology, and Applicability Issues

A wide range of elasticity values is reported in the literature. Most economic studies that analyze the impact of changes in gas price focus on the estimation of the price elasticities of total gas consumption. Studies from the transportation sector provide more detailed evidence on specific aspects of travel behavior and, in particular, on the impact of the fluctuation of gas prices on VMT and other transportation-related variables (car ownership, use of public transportation, total CO_2 emissions). A useful resource that catalogues previous studies that estimated transportation elasticities worldwide is available from the BITRE Transport Elasticities Database.[1] In addition, extensive reviews of studies that investigate the price elasticity of gas demand and VMT have

[1] http://www.bitre.gov.au/tedb/, accessed on November 26, 2013.

been carried out by Goodwin et al. (2004), Glaister and Graham (2002), Espey (1998) and Dahl and Sterner (1991), among other authors.

Most studies use time-series data and are based on the estimation of robust econometric models. These models account for the possible problems associated with autocorrelation (i.e. when observed values of gas consumption at one point in time are correlated with past and future values of gas consumption) and heteroskedasticity (i.e. when errors in the model predictions of gas consumption vary by gas price). Researchers have used different functional forms for their models. The double-log functional form, which models the logarithmic transformation of gas demand as a function of the logarithmic transformation of gas price and other explanatory variables, is used in many studies. This functional form is popular because the model estimation is relatively simple and the resulting model coefficients can easily be interested in terms of gas demand elasticity. The ordinary least squares (OLS) method is commonly used for the estimation of the model coefficients. Studies usually include a time-lag variable to account for time-delayed effects, and focus on the estimation of either short-term elasticities, long-term elasticities, or both. Studies vary on what other factors (e.g. income) they control for by including additional explanatory variables in their models.

Different results are found in studies that analyze older data (from 1929 until the 1970s) from those of studies that use contemporary data (in particular, after year 2000). In their study from 2008, Hughes et al. provide a detailed analysis of the changes in the price elasticity of gas demand during the last four decades, providing evidence that gas demand has become more inelastic in recent years. The study analyzes data of total monthly gas consumption in the U.S. for the period from January 1974 to March 2006. In order to compare gas demand elasticities in different decades, the authors use a quasi-experimental design, selecting two different 5-year periods for analysis: November 1975 through November 1980 and March 2001 through March 2006. Both periods experienced a price peak with an increase of approximately $1.00 in gas price relative to the price at the beginning of the period. The short-run price elasticities differ considerably between the two periods: they range from -0.034 to -0.077 during 2001 to 2006, versus -0.21 to -0.34 for 1975 to 1980, while income elasticity remains relatively stable across the two periods. The authors conclude that the price elasticity of U.S. gas demand is significantly *more inelastic* in recent years than it was in previous decades, and attribute the observed changes in travelers' reaction to gas prices to "a structural change in the U.S. market for transportation fuel and shifts in land-use, social or vehicle characteristics during the past several decades."

Similar results are found by Small and Van Dender (2007), who demonstrate a decrease in the price sensitivity of gas demand using annual data for 48 American states over the period 1966-2004. The results of this analysis also show that the decrease in price sensitivity appears to be due in particular to the growth in the standard of living. Similar results were later confirmed by Hymel, Small and Van Dender (2010).

Boilard (2010) analyzes data for gas consumption by quarter between 1970 and 2009 in Canada in a similar study (not published on a peer-reviewed journal) in order to test the hypothesized reduction in price elasticity of gas consumption. This study estimates price and income elasticities for two periods of identical length, 1970-1989 and 1990-2009, using two different modeling methods. Table 1 reports the results from this study, which shows a reduction in long-term price elasticity of gas consumption in more recent years.

Table 1. Price Elasticities of Gas Demand in Canada (Boilard, 2010)

	1970-1989		*1990-2009*	
Approach	*Short Term*	*Long Term*	*Short Term*	*Long Term*
Model 1 (Dynamic Model)	-0.093	-0.762	-0.091	-0.256
Model 2 Error Correction Model)	-0.193	-0.450	-0.046	-0.085

Several studies have discussed the reasons behind the different ranges of elasticities observed in the various studies. Most studies agree that fuel price sensitivity has been decreasing (demand has become more inelastic) in recent years. This might be attributable to changes in society (e.g. increasing incomes), land development patterns, and/or in the vehicle fleet that reduce the impact of gas price on the total transportation costs of a household, and the quality, or lack thereof, of the available travel alternatives (in particular public transportation) that might impact travelers' automobile dependence.

However, several recent studies that use household-level gas consumption and VMT data report that gas consumption is more elastic (i.e. absolute elasticity values are higher) than earlier studies have shown (Wang and Chen, 2013; Levin *et al*., 2012; Spiller and Stephens, 2012). These findings might be attributable to either a different approach to studying gas price elasticities, in particular through the analysis of household-level data, or to actual changes in consumers' response to changes in gas prices associated with the peaks in gas price observed in recent years.

The literature also shows that gas demand and travel behavior tend to be more elastic when gas price is higher. Researchers report higher values of elasticities after the recent fuel price peak in 2008. In addition, the elasticity of gas demand appears to be affected by gas price volatility: when price volatility is high, the impact of gas price on gas consumption is lower, and demand is less elastic, all else equal. In other words, if the change in fuel price is perceived as temporary, the reaction of travelers is less extreme. In order to test this finding, Lin and Prince (2013) modeled gas demand elasticity with respect to instantaneous prices for years 1990 through March 2012 while controlling for the variance in prices over the previous 12 months. Results show that volatility in prices decreases consumer demand for gas in the intermediate run, but that demand appears to be less elastic in response to changes in gas price when gas price volatility is medium or high compared to when it is low. The authors suggest that studies that ignore the effects of volatility in fuel prices might lead to an overestimation of the long-run elasticity of gas demand with respect to fuel price, and to an underestimation of short-run elasticity. As suggested by the authors, this has important implications for the development of government policies, as price volatility may significantly affect the expected changes in VMT associated with changes in fuel prices. Another important question is whether elasticities vary by income. This question was recently addressed by Wang and Chen (2013). They analyzed cross-sectional data from the National Household Travel Survey (NHTS) for 2009 to investigate the VMT elasticity with respect to gas price among households in different income groups. Surprisingly, VMT for lower income households was less elastic than for higher income households, with values of price elasticity for VMT in the range from -0.24 for the lowest income class (below $25,000/year) to -0.40 for the highest income class (above $100,000/year). The authors attribute the findings to more significant constraints that lower income households might face when reducing VMT. Higher income households, might enjoy better travel alternatives, are less affected by disadvantageous locations and have more discretionary travel that they can forego. They are also more able to replace older vehicles with newer and more fuel efficient vehicles (and alternative fuel/hybrid vehicles). These results highlight the importance of considering equity impacts in analyzing the effects of changes in gas prices (and gas taxes).

Related Evidence

Nearly all the available studies assume that price elasticities (and traveler's reaction to modifications in gas price) are "symmetrical." That is, they assume that the effects of a reduction in gas price (or income) on gas demand and VMT are equal and opposite to the effects of an increase. Even if there are several situations in which this assumption might not hold, the problem is not easy to quantify. Different reactions to increases versus decreases in gas price are plausible. For example, an increase in gas price might induce changes in the car fleet through scrappage of inefficient vehicles in the intermediate or long-run, but increased scrappage might not be balanced by an equally sizable shift towards more inefficient vehicles when prices fall (Goodwin et al., 2004).

Also, not all components of travel behavior are equally affected by changes in gas price: using data from the Dutch household travel survey, Yang and Timmermans (2011) show that the number and length of commuting trips tend to be more stable with regard to gas price, while leisure/non-commuting trips and activity participation in non-work activities seem to be more highly affected by price changes.

Travelers' reaction to changes in gas prices might also produce additional effects on other components of the transportation system, contributing to increased patronage of public transportation and to reduced CO_2 emissions from transportation. This topic was explored by Maghelal (2011), who analyzed transit ridership data and data on carbon emissions obtained from the U.S. Environmental Protection Agency's National Emission Inventory (NEI) for major U.S. cities, in order to investigate the impact of ridership change and gas price change between January-June 2007 and January-June 2008. The study finds that the increase in gas price in 2008 was associated with an increase in transit ridership and with a reduction in estimated CO_2 emissions, even after controlling for the contemporaneous impact of other variables, such as the level of funding for public transportation. Similar findings were obtained by Maley and Weinberger (2009), who studied the relationship between gas price and transit ridership in Philadelphia, and by Lane (2010), who studied the effect of gas price on transit ridership using data from nine U.S. cities. Similarly, a statistically significant relationship between an increase in gas price and a reduction in CO_2 emissions was found by Yang and Timmermans (2012) using data from the Netherlands.

An important limitation in the estimation of the impact of gas price on travel behavior is associated with the different scopes of the studies, which assess the effects of gas price on gas demand, VMT, car ownership, or the use of cars, but not at the same time or using the same datasets. Because results cannot be summed across different studies, it is not easy to draw conclusions on the contemporaneous impact of gas price on more than one measure of travel demand. Moreover, in many studies that span several years, it is difficult to separate the effects of fuel price from the effects of other variables, for instance the effects of fuel economy standards for new vehicles (Clerides and Zachariadis, 2008) and their impact on the reduction of gas demand. This might lead to some biases that tend to over- or under-estimate the impact of changes in gas price, depending on the way each study is designed.

Overall, changes in gas price can lead to significant effects on travel behavior, with some (usually limited) effects visible in the short run and (most) others measurable only after several years (long-run effects). For example, using the average elasticities reported by Hymel, Small, and Van Dender (2010), a durable 10 percent inflation-adjusted gas price increase might cause (a) a decline in vehicle travel of approximately

0.26 percent in the short run and about 1.31 percent in the longer run, and (b) a reduction in total fuel consumption of 0.55 percent in the short run and 2.85 percent in the longer run. However, elasticities may vary by context, depending on the availability of alternatives to driving, the ease with which travelers can drive less, the specific characteristics of the geographic region, and the economic, cultural, and social background of travelers in that region.

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