# TRAVELER RESPONSE TO THE 2005 GAS PRICE SPIKE

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## Abstract
Knowledge of how travelers respond to spikes in gas prices is key to planning for future instabilities in gas prices and offers insight into possible pricing strategies as mechanisms for reducing vehicle travel or improving efficiency of fuel use. A survey of over 500 residents in Austin, Texas capitalized on a severe spike in gas prices that transpired in September of 2005. This work examines how respondents' travel behavior changed during and following the spike. The paper describes the findings using basic descriptive statistics and uses ordered probit and binary logit models to determine which factors are responsible for behavioral changes in response to gas price spikes. Respondents indicated a strong tendency to reduce overall driving and/or chain together activities in more efficient tours as a way of coping with high prices, and nearly every gas-saving behavior questioned exhibited a significant percentage of persons reporting an increase. The results suggest that urban form, more than demographics, dictates the behavioral responses adopted by individual respondents. Finally, in the wake of the spike, respondents suggested many reasons for the price shifts and voiced support for policy measures that would encourage more efficient fuel use.

## Introduction
Gas prices are of undeniable importance to both consumers and economies at the local, state, and national levels in the US and abroad. Oil imports provide a significant percentage of North America and Europe's refined gasoline, however, the global oil market is notoriously unstable, and can produce sudden "price spikes" or "price shocks" (in which prices rise rapidly, in a manner that seems to belie previous, long-term tendencies). These spikes can generate

everything from consumer outrage to a damaging ripple throughout a nation's economy. Price spikes, especially for a commodity as economically fundamental as gasoline, present a unique problem. Due to their unforeseeable nature, they allow no leading adjustments on the part of consumers and businesses. An understanding of how consumers respond to spikes in gas prices is crucial to developing transportation policy that makes our economy less susceptible to the whims of global oil markets. Moreover, spikes in gas prices provide a brief but meaningful glimpse into how consumers might operate at prices higher than they are used to. Such observation can yield insight into how pricing strategies encourage both reductions in driving and more efficient use of fuel.

September of 2005 was such a period in the US. The confluence of a number of factors, including new, major oil-consuming nations, aging US refining infrastructure, and increased US demand, were pushed over the top by the Hurricane Katrina disaster. Between August and September prices rose from around $2.25/gallon to $3.00/gallon, a level comparable in real terms to the historical maximum reached during the early 1980s. In an effort to quantify and explore the behavioral responses of travelers to this spike, a survey of 563 residents was undertaken in Austin, Texas in February 2006. The survey asked respondents to rank the degree to which they changed a series of travel behaviors in response to heightened fuel prices during and following the spike, and it solicited opinions on issues of gas pricing and energy policies. This paper presents descriptive statistics of the (population-corrected) survey data, along with results of ordered probit model and binary logit model estimation.

## Literature Review

Economics suggests that a price change will affect consumption decisions, with each marginal change in price yielding a corresponding marginal change in demand. In the case of gasoline, travelers might react by decreasing overall travel either through eliminating trips, utilizing substitute modes, or by more efficiently using fuel. Elasticities of demand provide an easily understood metric of aggregate consumer price sensitivities.

Literature on gasoline demand elasticities generally separates these into short-run and long-run elasticities. In the 1970s and 1980s, numerous econometric studies were conducted, inspired by concerns over high fuel prices and energy conservation. In the 1990s, several researchers (e.g. Goodwin (1992), Dahl (1995), Espey (1998)) performed comprehensive studies of existing work on gasoline price elasticity and consistently determined it to be highly inelastic in the short term. More recently, Goodwin et al. (2004) updated work on gas price effects. Reviewing empirical studies since 1990 from around the world, they find that a 10% increase in the real price of fuel will produce a 1% reduction in vehicle miles traveled and a 2.5% reduction in fuel consumption, as well as a 1.5% increase in fuel efficiency of vehicles and a less than 1% decrease in net vehicle ownership. The authors speculate that fuel consumption falls more than volume of traffic because price increases trigger a more efficient use of fuel through technical improvements to vehicles and more fuel-conserving driving styles.

Two studies suggest that gasoline's short-run inelasticity may be over-estimated in the case of sudden spikes in price. Dargay and Gately (1997) question an assumption of most demand models of perfect price reversibility (price increases and decreases have equal and opposite effects), noting that in the 1980s as gas prices fell after rising from 1974-81, only a fraction of demand for gas was recovered. They hypothesized the existence of "hysteresis" or path dependency in gasoline demand, pointing out that consumers may respond more strongly to price spikes than reductions which generally result from inflation and that below a certain threshold the costs of adjustment to a price increase may outweigh benefits attained. They developed a model which allowed for imperfect price reversibility, and found that this model better explained changes in price which exceed some historical maximum. Perfectly reversible models, they argue, would overestimate the effects of price cuts and price recoveries which do not totally undo the demand reductions of the initial price rise, and would underestimate the effects of surpassing previous price levels. Thus, gasoline may be less inelastic in cases of sudden and large spikes, especially those which exceed historical maximums.

Dargay and Gately note that statistical evidence demonstrates that certain price rises provoke stronger consumer response, especially those of the 1970s which were sudden and large. These increases also occurred amid a climate of uncertainty about energy security (Espey, 1998). It is possible that uncertainty about future gas prices also caused people to "over-react" in an attempt to avoid the possibility of high future costs. Another factor is undoubtedly the presence of more fuel efficient vehicles in the market. In the 1980s the switch to a more fuel efficient vehicle was significantly easier than in the 1970s, which may be why the 1970 spikes seemed relatively dramatic.

Puller and Greening (1999) studied the short-term behavior of US households, and attempted to improve upon preceding gas demand models which account for price lags only on an annual basis. They imposed four different quarterly lag structures on gas prices, and selected as optimal a "snap back" lag structure in which demand has a large negative effect followed by a return to previous levels as consumers adjust to durable stock. In this way, they computed an impact elasticity of -.8 while still obtaining a short-run elasticity of -.35, which is consistent with previous literature. This model suggests that within the first quarter after a price change, consumers respond to a price rise with a much larger decrease in consumption than is indicated by total short run elasticity, but subsequently increase consumption as they develop more efficient ways of using existing vehicles.

A household's demand for gasoline has been decomposed in several ways. Eltony (1993) recognized three behavioral changes that households make in response to fuel price changes: driving fewer miles, purchasing fewer cars, and buying more fuel efficient vehicles. Running a model on data from Canadian households between 1969-1988, Eltony found these behaviors account for 75%, 15%, and 10% of a household's short term response to increased fuel prices. However his model neglects a household's ability to drive a more fuel efficient vehicle it already owns. Puller and Greening (1999) disaggregated gasoline demand to demand for vehicle miles traveled and demand for miles per gallon, and found an elasticity of -.69 for a household's vehicle miles traveled (VMT) and -.22 for fuel economy (miles per gallon [MPG]). They attributed these to households making large adjustments in the form of decreasing overall driving, but in the process reducing their demand for efficient driving by foregoing high efficiency miles such as vacations.

Another, potentially key aspect to consider in a household's demand for travel miles, and thus gasoline, relates to location. Numerous studies (e.g. Guiliano 1989 and Bina et al. 2005) have established a link between transportation and household location choice, finding that many households place a premium on access to certain types of amenities and activities. As Handy (2002) and others have noted, travel cost and time savings are expected to translate to higher land and property values. Moreover, households that locate in highly accessible neighborhoods may be more conscious of travel costs, and more likely to engage in gas-saving behaviors, following an increase in gas prices. The role of one's home neighborhood, for predicting such behavioral adjustments, is exhibited in the data sets studied here.

Choice of survey mode, formulation of questions, and instrument design all affect the quality of data collected (Zmud 2004). Mixing modes can lead to problems with measurement compatibility (for instance, Internet collection has been proven to yield higher trip counts than phone collection [Zmud 2004]), but such problems are minimized by offering consistent questionnaires, as done here. Respondent memory, understanding of question objectives, and motivation also affect response validity (Bradburn and Sudman 1982). Recall generally is enhanced by using closed response lists of reasonable length (as done here, while including a clear opportunity for "Other" responses) (Converse and Presser 1986), while motivation can be addressed by phrasing questions in a "non-threatening" manner (Bradburn and Sudman 1982). Event timeliness and salience affect response quality. More salient events are distinguished by their infrequency, economic cost, and/or continuing consequences, and are remembered well for longer periods of time (Bradburn and Sudman 1982). Cash and Moss (1972) note that highly salient events may be remembered for periods of a year or more. Thus, the three- to five-month period between the peak of prices and the survey's distribution seem appropriate here, given the unique nature and significant consequences of the 2005 gas price peak.

**Study Area and Period**

The present study was conducted in the Austin, Texas region. Respondents primarily lived within Austin city limits, and the vast majority lived within Travis County. When compared to the U.S. at large as well as similarly sized cities and regions (e.g., Las Vegas, San Antonio, Milwaukee and Nashville), Austin enjoys an extremely well educated and younger population, relatively high incomes, and a high proportion of current college students (10.1% of Travis County's population). This is due, in large part, to Austin's status as a state capital and home of one of the largest universities in the country, the University of Texas at Austin. In addition to their effects on Austin demographics, these two institutions serve as large trip attractors and foster a vibrant CBD, with many people commuting downtown. Indeed, Austin tends to be one of the most congested regions of its size (Lomax and Shrank 2005). While Austinites' behavior may not transfer everywhere, the region provides a good model for mid-sized, moderately urban cities with young, well-educated workforces.

Figure 1 shows a plot of the price of regular unleaded gasoline in Texas between December 2003 and April 2006. During the first part of the summer of 2005, prices rose in a manner relatively consistent with previous years; however, during August and September 2005, prices jumped abruptly, from $2.16/gal to $2.93/gal, an increase of 36% in slightly more than a month. Though this rise also coincided with the normal rise in gas prices that occurs during late summer months, as people drive more (Schoen 2006), the late summer's peak price far exceeded that of the most recent prior gas spike, during summer of 2004 (at $1.92/gal, in adjusted terms). It is worth noting that Austin's gas prices tend to be slightly higher than the rest of the state, while Texas' gas prices tend to lie below national average.

Two previous gas price spikes offer a historical precedent for the spike of 2005. Figure 2 shows a plot of the consumer price index of motor fuel in the US over time during the periods surrounding three major spikes. Prices rose from 38.5¢/gal in May 1973 to 55.1¢/gal in June 1974, a 43 percent increase. That spike was provoked by crude oil supply shortages in the US, due to an OPEC embargo, and led to significant governmental and automobile-industry response. In 1979, speculation following the Iranian revolution caused the price of oil to skyrocket. In the US, real prices rose from around $1.60/gal to $2.73/gal (in 2005 dollars) between March 1980 and March 1981, a 64 percent increase. This spike proved especially devastating to the US economy, ushering in a period of stagflation, but did not result in the same level of government response as the 1973 spike had.

Compared to historical spikes the spike of 2005 was much more abrupt. As Figure 2 demonstrates, the period of steep increase was shorter than those of the other spikes. In fact, the largest percentage monthly increase during the 1979-80 spike was just 7% (from January to February 1980), while the increase between average August and September prices in Texas in 2005 was 16%. The 2005 percentage increase was smaller than prior shocks over the period of increase than in prior shocks, but the rate of increase far exceeded those of previous spikes. Moreover, as Figure 2 indicates, the period surrounding (especially following) the 2005 spike was more volatile, with another significant rise in fuel prices occurring in 2006. Frequent oscillation could cause consumers to behave differently than in a situation where prices peak infrequently and then fall back, possibly motivating them to adjust to more fuel-efficient lifestyles and avoid future instabilities.

The uniquely abrupt and volatile nature of the 2005 spike makes it an interesting case study. Furthermore, expectations of future oil supply-demand imbalances persist, as global demand grows and many major oil producing nations remain "offline" (Iraq) or problematic for political reasons (e.g., Venezuela, Iran, and Russia) (Peterson 2006). High prices may well be here to stay, and it is important to understand how traffic will respond.

**Data Acquisition and Analysis**

The primary data source for this study was a survey of Austin residents. Two versions of the survey, a general version and student version, were used. A hard copy version of the survey (with postage-paid return envelopes) was distributed to approximately 400 households. The survey also was made available on the Internet and advertised to hundreds of Austinites via emails to their neighborhood associations. Hard-copy distribution was achieved by going door to door among 10 distinct neighborhoods, as recommended via an informal survey of several realtors[1]. The student version was only available electronically, and was distributed via various University of Texas colleges and academic departments, and primarily the College of Engineering. Data was collected between February and April 2006 and all collection methods

[1] The realtors were asked to compile a list of neighborhoods which they felt represented all neighborhood types in Austin with respect to demographics, density, and distance to the Central Business District (CBD). The most frequently recommended neighborhoods were visited, with Census Block Group data used to ensure that no neighborhood type was overlooked (however no formal analysis was done of realtor recommended neighborhoods).

were pursued simultaneously[2]. Different sampling schemes were used to achieve a greater penetration of the Austin population and generate a larger, more diverse sample.

After removing incomplete responses, the data set included 563 observations. 44% of these respondents were students, 38% were non-students responding electronically, and 18% were non-students responding via mail. Door-to-door distribution achieved a response rate of approximately 25%. (Response rates for internet distribution were impossible to ascertain due to the unknown size of email groups through which the survey was distributed.) As Table 1 indicates, the sample over-represents young males without college degrees and middle-age women with college degrees, while under-representing middle-aged males and females without college degrees. Accordingly, the sample was adjusted to represent Travis County 2000 demographics on the basis of age, educational attainment, and gender, jointly.[3] Students and non-students initially were combined into one sample. For "full-time student" respondents (i.e., those enrolled in 9 or more credit hours and working fewer than 35 hours/week), information about commutes to campus was substituted for work-commute information. Students residing on campus were considered to be working at home. All results reported here are on the basis of a population-weighted (bias-corrected) sample.

One irremovable bias in the sample may well be respondents' concern for the environment. Judging from the responses to the questions about energy policy in section 3 of the survey, the sample largely consisted of people with strong concerns about the environmental implications of energy consumption who may be more inclined to adopt conservation-oriented behaviors in the face of high prices. However, because the study examines responses to a spike in gas prices, this bias may be moderated: people concerned about the environment probably already travel in more fuel-efficient ways, and thus may not be able to easily exhibit as much of an increase in fuel-saving behaviors. In addition, the non-student survey was distributed only to single-household, detached homes, though these represent only 51.5% of housing units in Travis County according to the 2000 Census.

The survey covered respondent transportation needs, respondent vehicle ownership and usage, energy policy, and demographics. The surveys can be viewed online at http://www.ce.utexas.edu/prof/kockelman/public_html/GasPriceResponseSurvey.pdf. The core of the survey consisted of two multi-part questions in which participants were asked to consider a set of behaviors which reduce fuel consumption and rank the degree to which they exhibited a change in such behaviors in response to higher gas prices. This question was asked about behavior during the summer of 2005 (in the period surrounding Hurricane Katrina, when gas prices spiked) and after the summer of 2005 (but before prices rose again in 2006). Asymmetric scales for response were used, allowing for a higher degree of specificity in increasing such behaviors during the spike than post-spike. This choice of scales was based on a hypothesis that respondents may revert back to less efficient behavior (i.e., decreasing gas-saving behaviors) following the spike. Pilot versions of the survey seemed to confirm this response, though final

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[2] During the majority of the data collection period, gas prices hovered around $2.30/gal (regular, unleaded). Towards the end of April 2006, prices began to rise again, ultimately reaching about $2.95/gal again in May.

[3] Actual Travis County demographics were obtained from the 2000 Census Summary File Table PCT25 (Sex by Age by Educational Attainment for the population 18 years and over).

analyses suggested substantial increases in certain behaviors post-spike, indicative of a lagged response, as discussed below.

Data quality may be affected by the closed, self-reporting nature of many questions. In questions about changes in travel behavior, people were asked to report changes months after the fact, and many may have had problems remembering exactly how they responded to the spike, though literature on respondent memory suggests that people may remember their behavior during salient events up to a year after the fact. Individual interpretations of a "slight increase" or a "moderate increase" may represent different actual changes in behavior. Finally, opinions on gas pricing and energy policy could present an opportunity for respondents to advance personal beliefs via exaggerated response. This is a concern insofar as respondents were informed in the survey cover letter that study results may be used to inform future planning in the Austin area. For instance, in answering a question about a gas price threshold at which one would stop commuting solo to work, a respondent might claim to continue driving at any price level, without honestly assessing the truth of this claim, in order to promote auto-oriented transportation planning, at the expense of non-auto modes.

Additional data was obtained from other sources. The fuel economies of respondents' vehicles were obtained from a database maintained by the US Department of Energy and the US Environmental Protection Agency[4]. GIS software was used to geocode respondents' home locations and match these to neighborhood form and accessibility variables by Traffic Serial Zone (TSZ).[5] The neighborhood form variables include density of bus stops in the TSZ (stops/mi$^2$), Euclidean distance to the CBD, and total zonal density, defined as:

$$\rho_{Zonal} = \frac{Households + Jobs}{Area} \qquad (1)$$

where *Households* and *Jobs* are the total number of households and jobs in the TSZ in 1997 and *Area* is the area of the TSZ (in square miles). In addition, a series of regional Accessibility Indices (AIs) from Gupta et al's (2004) travel demand models of credit-based congestion pricing for the Austin region were added to the data set. Accessibility helped control for the role of home location in reactions to high gas prices. Table 2 summarizes all the explanatory variables used.

*Analysis of Behavioral Changes with Descriptive Statistics*

Summary statistics offer a general picture of the behavioral responses to high gas prices. Tables 3 and 4 summarize the (population-weighted) response during and after the spike. During the spike, behaviors seeing the most increase were "shopping around for gas" (67.4%), reducing

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[4] The database can be found at www.fueleconomy.gov. EPA fuel economies were used.

[5] Respondents' residences were located in TransCAD (Caliper, 2002), using the two nearest cross-streets respondents identified in the survey. Respondents often reported major streets that served as boundaries between TSZs and made fine-grained location of their residence difficult. In instances when a cross-street reported by a respondent formed the boundary between two or more TSZs (43.5% of cases), the location and accessibility variables for all TSZs touched by the street were averaged. Satellite imagery from Google Earth was used to identify instances in which it was highly unlikely that one of the TSZs included the participant's home (for instance, a cross-street demarcating a park and a residential neighborhood or a cemetery and a residential neighborhood).

overall driving (61.6%), and chaining activities (58.6%). Those experiencing the lowest increases were carpooling (21.5%), transit use (17.9%), and bicycle trips (15.6%). In general, behaviors exhibiting the greatest increase were easy adjustments to make, while those with lesser response may have been simply impossible or required comparatively significant lifestyle adjustments (for instance, carpooling).

After the spike, fewer people reported increases in gas-saving behaviors relative to their behavior during the spike, and some even reported decreases. More respondents (as weighted by population percentages, to correct for sample biases) reported no change in behavior, suggesting that spikes in gas prices did little to change these people's behavior and/or that more efficient behavior was retained even after the price spike. The ranking of behaviors eliciting the greatest behavioral shifts before and after the spike were similar, which may imply a hierarchy of gas-saving behaviors people are most likely to accept. The ranking of increased driving of a household's most fuel efficient vehicle increased *after* the spike, which may reflect new, more fuel-efficient household vehicle holdings (14.6% of households reported purchasing a new vehicle in the past year). Moreover, the after-spike averages were all close to 4 (the ranking for no change), as people who intensified their gas-saving behavior after the spike were "canceled out" by people whose behaviors reverted to pre-spike tendencies.

A not-insignificant percentage of respondents (about 6% [after correcting for population attributes]) reported that they had moved or changed jobs in response to high gas prices, and almost 3 times as many reported that they had *considered* doing this. Though these are corrected percentages, they may be heightened by the inclusion of many student respondents, who may possess higher than average residential mobility for their demographic class. In the longer term, far more may make such location adjustments, affecting urban form and moderating travel needs.

The average responses suggest some important behavioral reactions to moderate gas price spikes, however, many of these behaviors can occur simultaneously. To study this overlap, simple correlations of responses during the spike were computed. Responses were coded as a one if there was an increase in the behavior. Table 5 shows the results, with almost all pairs positively correlated. Only two pairs of behaviors were not correlated in a statistically significant way (driving the most efficient vehicle and carpooling, and driving the most efficient vehicle while increasing transit use). The strongest correlations were seen between driving slower and driving at steadier speeds ($p$ =.734) as well as reducing overall driving and chaining activities ($p$ = .555), likely because these behaviors can be easily accomplished simultaneously. The connection of behavior during and following the spike also was studied, with a post-spike increase and post-spike decrease (both relative to behavior during the spike) used as binary variables. There were strong correlations between non-response during and following the spike (i.e., no changes in gas-saving behaviors at either time) and, to a lesser extent, increasing a behavior during the spike and then further increasing following the spike - suggesting a lagged intensification of the behavior. This pattern was similar for all behaviors studied.

*Ordered Probit Models of Trip Chaining and Reductions in Overall Driving*

Ordered probit models were used to examine the likelihood of respondents increasing trip chaining or reducing their driving, in response to the gas price spike. (Shopping around for gas, though the most frequently reported behavior, lacked adequate variation across reported responses for analysis with an ordered probit model). The model was constructed as follows: Let $y$ signify a traveler's reported change in behavior and $y^*$ signify the latent level of continuous response underlying the reported change. Additionally, let $\mu_j$ ($j$=1, 2, 3) be the thresholds for behavioral change such that:

$y = 0$ (Decrease in behavior) if $y^* \leq 0$
$y = 1$ (No change in behavior) if $0 \leq y^* \leq \mu_1$
$y = 2$ (Slight increase in behavior) if $\mu_1 \leq y^* \leq \mu_2$
$y = 3$ (Moderate increase in behavior) if $\mu_2 \leq y^* \leq \mu_3$
$y = 4$ (Significant increase in behavior) if $y^* > \mu_3$

The latent response $y^*$ is specified as a linear function of explanatory variables ($x'$), unknown parameters ($\vec{\beta}$) and a standard normal random error term ($\varepsilon$):

$$y^* = x'\vec{\beta} + \varepsilon \qquad (2)$$

This specification was estimated using a set of explanatory variables that included each respondent's transportation needs, demographic attributes, and neighborhood/location characteristics. Table 2 provides summary statistics for all explanatory variables. Variables were eliminated in a stepwise manner on the basis of statistical insignificance (p-value > .01), and occasionally combined into more inclusive variables or redefined as binary (indicator) variables. The models were initially calibrated for the complete data set; however, these models had low goodness of fit (pseudo r-squared values), with full-time students highly unlikely to adopt either behavior. Accordingly, the models were re-calibrated excluding those respondents who answered the student version of the survey, which improved the parameter interpretability markedly. Table 6 thus displays summary statistics for explanatory variables after removing full-time students from the data set, and Table 7 offers the results of these sample-weighted ordered probit models.

The results suggest that, all else equal, individuals were most likely to increase trip chaining in response to the price spike if they lived in or near the CBD. The distance-to-CBD was the most practically significant explanatory variable, with a change of one standard deviation in this variable (3.72 mi) reducing $E(y^*)$ by 0.738. In general, the most practically significant explanatory variables were those describing the respondents' neighborhoods. Those residing further from the CBD and in areas with a higher fraction of residential land use were less likely to turn to trip chaining, while those enjoying higher levels of retail jobs near their home were more likely to chain trips[6]. These results suggest that individuals adopting trip chaining to cope with high gas prices may have done so largely because it was an easily available strategy (e.g., with many retail opportunities near their home). However, they may also reflect the fact that people living far from a central city, with fewer local amenities, already engage in high amounts of trip chaining because of the distances involved in traveling and there would not show much additional response to high gas prices. Interestingly, neither the respondent's amount of driving

[6] It should be noted that retail and service job levels had coefficient estimates of opposing signs in this model. These two variables are highly collinear ($p$ = +.917), which is the likely explanation for the odd sign on the service employment variable in this and other models.

(in miles per week) nor level of gas expenditures proved to be statistically significant predictors of trip chaining tendencies (in response to gas prices). Finally, both females and individuals not working for pay were more likely to increase their trip chaining than males and wage-earners, which may imply that stay-at-home mothers were responsible for a significant portion of the reported increases in trip chaining.

According to the models, reductions in overall driving occurred most among those living near high levels of retail jobs, a reduction that probably is explained in part by the trip chaining model, since these activities should be accomplished simultaneously. Surprisingly, both total driving and total number of home based non-work trips per week variables had negative effects on driving reductions, suggesting that such persons may already be "locked in" to less efficient and longer-distance travel situations. As expected, higher incomes also were associated with less inclination toward travel reduction, as these individuals are likely to be less price responsive. Few of the explanatory variables in the final model were practically significant[7]; however, a change in retail job intensities was associated with a .517 shift in $E(y^*)$, which is reasonably significant, and a change in service job intensities was associated with a -.885 shift in $E(y^*)$, though the negative sign is likely misleading (see footnote 6).

Both models had reasonable but somewhat low pseudo R-squared values (0.133 and 0.101), suggesting that these behavioral responses are more random than can be accounted for through regression models of standard demographic and urban form inputs.

*Binary Logit Models of Driving Slower and Driving at Steadier Speeds*

Binary logit models were used to analyze behaviors that a high percentage of respondents reported increasing, but which lacked adequate variation across levels of increase for ordered probit analysis. These include driving slower and driving at steadier speeds – both presumably to enhance fuel economy (and thus moderate increases in one's gasoline costs). Respondents chose to either increase (modify) or not increase (not modify) each behavior, in response to the price spike. Again, removing full-time students from the sample improved the models. Elasticities (for response probability) were computed with respect to all explanatory variables included in the final models. These set all variables to their mean values and relied on standard methods (see, e.g., Greene 2002). Table 8 summarizes the model results.

The model of driving slower predicts that individuals living in highly commercially developed neighborhoods were somehow most likely to reduce speeds during the spike. This was the most statistically and practically significant variable in the set. Perhaps those who live near large concentrations of commercial development also live near highways. (Large commercial developments, like power centers and shopping malls, are frequently sited near highways.) These respondents may find themselves driving on highways more frequently than others, with more opportunities to slow down and impact their vehicles' fuel economy. (Peak fuel economy is generally achieved at highway speed around 55 mph.) Such a hypothesis would also explain the inverse relationship between zoned density and reported speed reductions. Income and fuel economy were both inversely related to reduced speed. High income respondents are less sensitive to price and also may have higher values of travel time, which would decrease their incentive to slow down. Indeed, simple calculations involving a gas price of $3 per gallon reveal

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[7] "Practical significance" in this paper refers to an explanatory variables impact on the dependent variable.

that only if a vehicles occupants have a combined value of travel time (VOTT) less than $10 per hour and are driving a relatively fuel inefficient vehicle (20 mpg or less) will the savings on gas overcome the cost of time losses from traveling slower.[8]

Driving at steadier speeds is, according to elasticities in the final model, most strongly influenced by population density. Individuals living at low population densities were more likely to report driving at steadier speeds. To a lesser extent, respondents living near high levels of residential and commercial land use and high levels of basic jobs reported this behavior. These factors seem to suggest that respondents in suburban areas were most likely to drive at steadier speeds, possibly because suburban roads generally require less stop and go driving. In any case, it seems clear that urban form and land use patterns may be key drivers of human response to gas prices. To some extent, these proxy for other attributes (e.g., a respondent's frequency of highway driving frequencies and his/her automobile "captivity"). Nevertheless, it is interesting to witness how urban form may shape more than simply mode choice and VMT.

*Comparison of Models of Reported Behavior*

Table 9 compares the effects of the most statistically significant explanatory variables from the final models of reported behavior. There is clear consistency across models, since all regularly significant variables had similar effects across models. The most practically significant variables were those having to do with urban form; high levels of basic and retail jobs near respondents' homes were of high practical significance and directly related to reported increases in gas-saving behaviors in two models, while the presence of service industry jobs appeared to reduce gas-saving behaviors in all three. In general, variables related to transportation needs and demographics were statistically significant in models related to the amount of driving respondents did (trip chaining and overall reduction in driving), but not the style of driving (driving slower and driving at steadier speeds). Transportation needs and demographics, however, were not practically significant in any of the final models.

*Opinions on Energy Policy and Gas Pricing*

US energy policy may be critical to moderating future gas price spikes. Respondents were asked to consider scenarios of permanently higher gas prices and provide their opinions on policy and pricing. All responses were weighted to reflect actual Austin demographics. As a point of reference, the survey stated that gas prices in Europe range from $4/gallon to $8/gallon, and asked respondents to consider prices in this range. Given an adjustment period of two years, 16.2% of respondents stated that they felt that the US economy would adapt fine with prices in this range. 34.6% of respondents felt the economy would experience a slight downturn in economic growth, but no recession. 30.8% reported that they felt there would be a slight recession, and 18.4% thought there would be a severe recession. Clearly, there is a fair level of disagreement among Austinites.

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[8] Calculations were done using fuel economy loss estimates of 9.7% and 17.1% for 55 mph to 65 mph and 55 mph to 70 mph speed increases, respectively. These fuel economy reductions come from West et al.'s (1997) 9-vehicle averages. For a vehicle getting 35 mpg (e.g. the Honda Civic Hybrid using a conservative estimate), going 65 mph with a VOTT of $5/hr achieves the lowest total travel cost (gas cost plus time cost). At VOTTs of $10/hr or more, going 70 mph or more achieves the lowest travel cost. For a vehicle getting 20 mpg (e.g., an efficiently driven Ford Explorer), going 55 mph with a VOTT of $5/hr achieves the lowest travel cost, while 65 mph nets the lowest cost at a VOTT of $10/hr, and 70+ mph at VOTTs of $15/hr or more.

Of those who currently commute by driving alone 66.8% reported that they would continue to do so if prices were $4/gallon or less, while 27.8% reported that they would continue driving alone to work even if prices were to exceed $8/gallon. Using LimDep, a grouped data regression model was estimated in order to discern what factors influence a respondent's "break price" (i.e., the price at which he/she would stop driving alone to work). This model uses the survey-stated thresholds (of $4, $5, $6, $7, and $8 per gallon) to predict the unobserved, actual break price. It was found that the strongest factor inclining people to stop driving alone to work (or school) was full-time student status (which may act as a proxy for low income, though students have varying levels of financial independence). For each standard deviation increase in this indicator variable (0.49), the expected break price falls by $1.80. In addition, for each standard deviation increase in one's distance to the region's CBD (3.74 mi) and in population density (6368 people/mi$^2$), the expected break price is predicted to *rise* by $1.45 and $1.25 per gallon, respectively.

The survey also asked for opinions on Hybrid Electric Vehicles (HEVs), following a brief description of their typical fuel economy and cost. 36.7% of respondents feel that the long-term savings on gasoline justifies the initial investment in an HEV, while 31.4% feel that the initial investment is too high, and 10.4% simply feel that HEVs do not pay for themselves. 12.2% said they would consider owning (or do own) an HEV for reasons other than gas savings, with most of these mentioning environmental reasons or dependence on foreign oil as their justification. 9.2% of respondents selected "other," and common responses here included concerns about the long-term durability and maintenance costs of HEVs, support for alternative fuels instead of HEVs, problems finding desired types of vehicles in hybrid models, and concerns about the newness of the technology.

In response to a question about HEVs at European gas price levels, 41.1% of respondents reported that they would consider an HEV a worthwhile investment if prices reached $4/gallon or more, 61.3% of respondents reported this at $5/gallon or more, and 77.9% at $8/gallon or more. 9.5% of respondents felt that an HEV would not be a worthwhile investment at any price. At a gas price of $3/gallon, the annual gas-related savings per year to fuel a hybrid car (using a conservative estimate of 35 mpg for its fuel economy, but a somewhat liberal 15,000 miles/year driving assumption) instead of a typical compact car (26 mpg) would be $445/year. At $5 per gallon, the annual savings would be $742. To fuel a hybrid SUV (assuming a fuel economy of 30 mpg) instead of an average SUV (20 mpg), one could expect to save $750 annually at $3 per gallon, and $1250 at $5 per gallon. Over the course of 10 years, such vehicles' sticker-price differences (and battery replacement costs) may only make simple economic sense if gas prices reach $5/gallon. Of course, the global-warming, emissions/air quality and other (social and environmental) costs associated with less fuel efficient vehicles may be argued to tip the balance at lower gas prices.

In addition, several questions concerning energy policy were used to gauge how the severe price spike may have affected opinion. In response to a question in which respondents were asked to select three or more factors which were responsible for high gas prices during the summer of 2005, the most common factor selected was instability in the Middle East and other oil producing region (70.8% of respondents chose this). 54.3% of respondents indicated natural disasters, 53.1% selected OPEC's monopoly power, 46.5% selected the emergence of other major oil consuming nations (e.g., China and India), 38.8% selected the lack of recent oil reserve discoveries, 36.0% selected “other”, and 33.3% indicated oil company mergers. Common “other” (fill-in) responses included oil company greed, collusion, and price gouging, refining capacity shortages, and price speculation. The frequency of respondents blaming the oil and gas industry for high prices is somewhat unsurprising, since many major oil corporations have reported record-breaking profits during the past two years (Quinn, 2006). However, a congressionally mandated Federal Trade Commission (FTC) investigation of post-Katrina gas prices found no instances of illegal market manipulation (though it did find 15 instances of pricing that fit Congress’ definition of “price gouging”).

Respondents were asked which of a series of measures to address fuel supply shortages they would support. The most popular measure was incentives for fuel-efficient vehicles, supported by 71.0% of respondents. 68.2% supported incentives for alternative fuel use, 45.3% supported incentives for non-solo driving, 31.6% supported an increased gas tax 30.5% supported increased fuel efficiency standards, and 20.8% supported increased exploitation of domestic reserves (including, perhaps, the Artic National Wildlife Reserve [ANWR] area’s holdings). Mandatory limitations on driving were extremely unpopular, supported by only 5.9% of respondents. 13.2% of respondents selected “other”, and common suggestions included improved mass transit, subsidizing alternative fuel research, and better land-use planning. Several (10) respondents also reported that there were no fuel supply shortages and that high gas prices were a result of speculation and/or price gouging, giving answers such as “knee jerk reaction to world events which had no actual influence on oil prices.” Finally, respondents were also asked how much of a gas tax increase they would support if the revenues went to renewable energy research or mass transit. 34.3% indicated that they would support an increase of anywhere between $0.10 and $0.49, while 23.3% said they would not support any increase. Interestingly, 18.6% reported they would support an increase of $0.50-$0.99, and 10.8% said they would support an increase of more than $2.00.

**Conclusions**

The results suggest that travelers respond in a variety of ways to gas price spikes. Travelers seem most likely to respond by reducing their overall driving, a finding which seems consistent with Eltony’s (1993) study, which attributed 75% of short-term reductions in gasoline demand to a reduction in vehicle miles traveled. Studies of correlation suggest that much of this reduction may be achieved through increased use of other modes or trip chaining (as opposed to merely decreasing out of home activities). Adjustments in style of driving also appear to be a viable strategy of coping with high gas prices, as significant percentages reported increased attention to vehicle maintenance (presumably to ensure peak fuel efficiency), driving slower, and driving at steadier speeds.

The impact of land use patterns in one’s residential environment on response to high gas prices is striking; the observed response to gas prices transcends even factors like income, education, average gas expenditures, and average amount of driving. Instead, respondents appeared to adopt strategies for coping with high gas prices based on what was easily enabled by their neighborhood type. Behavioral changes based on reduced driving seem linked to respondents living in more central neighborhoods (closer to CBD) with more amenities. These respondents likely found it easier to use alternate modes like walking or biking, or trip chain because they lived in denser neighborhoods with less functionally segregated land use. Respondents reporting that they drove slower and at steadier speeds, meanwhile, lived near high levels of commercial area and low population densities, features which suggest more suburban neighborhoods. These respondents likely do more highway driving and were able to more easily drive in an efficient manner than those respondents who utilize urban streets. However, despite the apparent split between the types of responses of urban and suburban dwelling respondents, there is still a reasonable level of correlation between reduced overall driving and driving slower and at steadier speeds, suggesting that some respondents reacted to the 2005 spike by employing a series of strategies.

While the observed responses indicate that many respondents altered behavior following the September 2005 spike, the more interesting ramifications of this study concern how respondents would operate and think under scenarios where prices stayed at this level (or higher). Indeed, during the summer of 2006, gas prices again hit $3/gallon across the US, suggesting that high gas prices may be here to stay, or at least a regular summertime occurrence. The survey questions on energy policy seem to indicate that many respondents are ready to move away from transportation options and policies that depend on fossil fuels, or use them inefficiently. Majorities supported incentives for more fuel-efficient vehicle usage and alternative fuel use, and more than 30% of respondents supported non-SOV travel, an increased gas tax, and increased fuel economy standards. $4 per gallon appears to be a significant breakpoint for many respondents, both in terms of curbing SOV commuting and making HEV ownership a popular investment. In addition, the apparent link between reduced and more efficient trip planning and more residency in Austin's more urban neighborhoods (with better land use balance) suggests that higher gas prices may cause people to select better planned neighborhoods, with more mixed land uses and more transit- and pedestrian-friendly travel options. Permanently high gas prices may mean a painful period of adjustment for individual drivers as well as the US economy; however, they also could prove a priceless remedy to a variety of problems, including foreign oil dependence, deteriorating air quality, and auto-centric urban form.

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**Table 1: Sample Breakdown by Demographic Attributes**

| Demographic | Number of Respondents | Survey Percentage | Census Percentage |
|---|---|---|---|
| Young Male, No College Degree[9] | 169 | 30.02 | 16.29 |
| Young Male, College Graduate | 27 | 4.80 | 7.74 |
| Middle Age Male, No College Degree | 3 | 0.53 | 11.66 |
| Middle Age Male, College Graduate | 87 | 15.45 | 11.65 |
| Older Male, No College Degree | 2 | 0.36 | 2.08 |
| Older Male, College Graduate | 14 | 2.49 | 1.53 |
| Young Female, No College Degree | 77 | 13.68 | 13.58 |
| Young Female, College Graduate | 36 | 6.39 | 7.46 |
| Middle Age Female, No College Degree | 8 | 1.42 | 12.44 |
| Middle Age Female, College Graduate | 132 | 23.45 | 10.39 |
| Older Female | 8 | 1.42 | 5.18 |

[9] No College Degree includes currently enrolled college students. College Graduate includes those individuals with a two-year Associates Degree. The age breakdowns are: Young = 18-34 years of age, Middle Aged = 35-64 years, Older = 65 years and older.

## Table 2: Explanatory Variables Used

| Explanatory Variable | Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| SOV | Drive alone to work 2+ times/week | 0.552 | 0.498 | 0 | 1 |
| Bus | Take bus to work 2+ times/week | 0.206 | 0.405 | 0 | 1 |
| Walk | Walk to work 2+ times/week | 0.146 | 0.353 | 0 | 1 |
| Bicycle | Bike to work 2+ times/week | 0.073 | 0.260 | 0 | 1 |
| Bike/Ped | Walk or bike to work 2+ times/week | 0.202 | 0.407 | 0 | 1 |
| Carpool | Carpool to work 2+ times/week | 0.057 | 0.232 | 0 | 1 |
| Work at Home | Work at home 2+ times/week | 0.147 | 0.423 | 0 | 1 |
| Multiple Modes | Commute to work using different modes 2+ times/week each | 0.249 | 0.433 | 0 | 1 |
| Children | Take children to school or daycare | 0.121 | 0.326 | 0 | 1 |
| HBW Travel Time | Home-to-work travel time (minutes) | 13.86 | 13.00 | 0 | 90 |
| HBNW Trips/Week[10] | Number of non-work related driving trips/week | 6.04 | 4.17 | 2.5 | 20 |
| Gas Expenditures | Money ($) spent on gas/week | 78.11 | 53.58 | 25 | 250 |
| VMT/Week | Vehicle Miles Traveled/week | 81.97 | 66.24 | 25 | 250 |
| Fuel Economy | Average fuel economy of all households vehicles used 2+ times/week (mpg) | 23.55 | 7.53 | 0 | 55 |
| Low MPG | Fuel economy less than 20 mpg | 0.220 | 0.415 | 0 | 1 |
| High MPG | Fuel economy greater than 30 mpg | 0.123 | 0.328 | 0 | 1 |
| Age | Respondent's age (years) | 35.44 | 15.79 | 18 | 83 |
| Gender | Indicator variable for males | 0.533 | 0.499 | 0 | 1 |
| Income | Household income before taxes ($/year) | 52,420 | 58,371 | 0 | 200,000 |
| Full-Time Student | Enrolled in 9 or more credit hours and working fewer than 35 hours/week | 0.416 | 0.493 | 0 | 1 |
| Employed | Employed Part- or Full-Time | 0.680 | 0.467 | 0 | 1 |
| College Educated | Attained at least Bachelor's degree | 0.488 | 0.500 | 0 | 1 |
| Household Size | Number of persons in household | 2.574 | 1.279 | 1 | 6 |
| Vehicles/Driver | Vehicles used by household 2+ times/week per driver in household | 0.533 | 0.516 | 0 | 2 |
| Local Population[11] | Population within 1 mile radius of TSZ | 60276 | 6367 | 30791 | 72393 |
| Residential Area | Residential Area in 1 mile radius of TSZ (in square miles) | 5.50 | 0.39 | 3.49 | 6.38 |
| Commercial Area | Commercial Area in 1 mile radius of TSZ (in square miles) | 0.43 | 0.03 | 0.27 | 0.51 |
| Basic Employment | Basic jobs in 1 mile radius of TSZ | 13952 | 3185 | 5860 | 25652 |
| Retail Employment | Retail jobs in 1 mile radius of TSZ | 5874 | 943.53 | 2618 | 7775 |
| Service Employment | Service industry jobs in 1 mile radius of TSZ | 16703 | 3647 | 7124 | 27325 |
| Total Employment | Total jobs in 1mile radius of TSZ | 75.06 | 2.61 | 65.07 | 86.05 |
| CBD Distance | Euclidean Distance from TSZ to CBD (mi.) | 4.37 | 3.74 | 0.685 | 17.78 |
| Bus Stop Density | Bus stops/square mile in TSZ | 46.97 | 52.42 | 0 | 212 |
| Zone Density | (Jobs + households)/square mile in TSZ | 6248 | 5103 | 293.86 | 67108 |

[10] "Trips" came directly from the survey where they were reported by respondents. Respondents were asked to report "On average, how many round-trip NON-WORK related trips do you make each week by car?"

[11] Population, employment, and area statistics were computed by Gupta et al. (2004) for each of Austin's Traffic Serial Zones (TSZs) using 1 mile radii. Each index reflects the total population, area (in square miles) or number of jobs within a 1 mile radius of the respondent's home TSZ centroid, or, in instances where a 1 mile radius contains the centroid of adjacent TSZ, the total population ,area, or number of jobs in the home TSZ plus those adjacent TSZs

## Table 3: Descriptive Statistics of Behavior During Spike

| Behavior | Mean | Standard Deviation | Percentage No Change | Percentage Increase | Percentage Significant Increase |
|---|---|---|---|---|---|
| Shopping around for gas | 3.38 | 1.23 | 32.11 | 67.44 | 24.70 |
| Reducing overall driving | 3.05 | 1.12 | 35.30 | 61.60 | 10.70 |
| Trip chaining | 3.07 | 1.15 | 40.20 | 58.60 | 13.90 |
| Greater attention to vehicle maintenance | 2.76 | 1.04 | 56.53 | 43.47 | 7.90 |
| Driving most fuel efficient vehicle[12] | 2.75 | 1.10 | 61.50 | 38.00 | 12.50 |
| Driving at steadier speeds | 2.61 | 0.98 | 64.41 | 35.22 | 6.30 |
| Driving at slower speeds | 2.53 | 0.95 | 66.40 | 32.40 | 5.90 |
| Walking trips | 2.42 | 0.84 | 69.40 | 29.00 | 4.20 |
| Buying partial tanks of gas | 2.46 | 1.02 | 72.13 | 24.83 | 8.00 |
| Carpooling | 2.30 | 0.85 | 73.69 | 21.45 | 3.90 |
| Transit use | 2.26 | 0.79 | 78.40 | 17.90 | 3.60 |
| Bicycle trips | 2.23 | 0.75 | 81.60 | 15.60 | 3.30 |
| Key: 1 = Decrease (in behavior), 2 = No change, 3 = Slight increase, 4 = Moderate increase, 5 = Significant increase | | | | | |

## Table 4: Descriptive Statistics of Behavior Post-Spike

| Behavior | Mean | Standard Deviation | Percentage Decrease | Percentage No Change | Percentage Increase |
|---|---|---|---|---|---|
| Shopping around for gas | 4.22 | 0.75 | 9.20 | 56.30 | 34.50 |
| Trip Chaining | 4.18 | 0.75 | 9.28 | 59.15 | 31.57 |
| Reducing overall driving | 4.13 | 0.84 | 11.73 | 57.10 | 31.16 |
| Driving most fuel efficient vehicle | 4.15 | 0.67 | 11.00 | 67.50 | 26.00 |
| Greater attention to vehicle maintenance | 4.14 | 0.62 | 6.10 | 71.50 | 22.40 |
| Walking trips | 4.10 | 0.64 | 6.30 | 73.90 | 19.80 |
| Buying partial tanks of gas | 3.98 | 0.74 | 9.20 | 75.60 | 15.10 |
| Transit use | 3.99 | 0.76 | 7.50 | 77.60 | 14.80 |
| Driving at steadier speeds | 4.04 | 0.59 | 6.80 | 78.50 | 14.60 |
| Driving at slower speeds | 4.02 | 0.61 | 8.00 | 77.90 | 14.20 |
| Carpooling | 3.95 | 0.75 | 8.75 | 78.99 | 12.26 |
| Bicycle trips | 3.88 | 0.76 | 9.90 | 81.60 | 8.50 |
| Key: 1 = Significant decrease (in behavior), 2 = Moderate decrease, 3 = Slight decrease, 4 = No change, 5 = Increase | | | | | |

[12] Statistics for Driving most fuel efficient vehicle are based on only households that reported owning more than one vehicle

### Table 5: Correlations of Behavioral Increases Reported During Spike

| | Driving Most Efficient Vehicle | Car-pooling | Trip Chaining | Reducing Overall Driving | Shopping Around for Gas | Attention to Main-tenance | Driving Slower | Driving at Steadier Speeds | Buying Partial Tanks | Transit Use | Walking Trips | Bicycle Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Driving Most Efficient Vehicle | 1.000 | | | | | | | | | | | |
| Carpooling | -0.012 | 1.000 | | | | | | | | | | |
| Chaining Activities | 0.197 | **0.234** | 1.000 | | | | | | | | | |
| Reducing Overall Driving | **0.200** | **0.257** | **0.555** | 1.000 | | | | | | | | |
| Shopping Around for Gas | 0.112 | 0.107 | **0.253** | **0.286** | 1.000 | | | | | | | |
| Greater Attention to Maintenance | 0.130 | 0.177 | **0.286** | **0.302** | **0.322** | 1.000 | | | | | | |
| Driving Slower | 0.169 | 0.155 | **0.299** | **0.304** | **0.240** | **0.382** | 1.000 | | | | | |
| Driving at Steadier Speeds | 0.133 | 0.142 | **0.277** | **0.309** | **0.283** | **0.400** | **0.734** | 1.000 | | | | |
| Buying Partial Tanks | 0.041 | 0.071 | **0.213** | **0.262** | **0.254** | **0.316** | **0.226** | **0.223** | 1.000 | | | |
| Transit Use | -0.099 | **0.412** | 0.136 | **0.279** | 0.062 | **0.207** | 0.189 | **0.234** | 0.135 | 1.000 | | |
| Walking Trips | 0.077 | **0.335** | **0.242** | **0.320** | 0.140 | **0.234** | **0.293** | **0.260** | 0.156 | **0.392** | 1.000 | |
| Bicycle Trips | 0.100 | 0.141 | 0.149 | 0.196 | 0.003 | 0.165 | 0.180 | 0.120 | 0.086 | 0.166 | **0.427** | 1.000 |

Note: Boldface entries are statistically significant at the $\alpha = 0.20$ level.

## Table 6: Explanatory Variables Excluding Students from Sample

| Explanatory Variable | Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| SOV | Drive alone to work 2+ times/week | 0.705 | 0.457 | 0 | 1 |
| Bus | Take bus to work 2+ times/week | 0.058 | 0.234 | 0 | 1 |
| Walk | Walk to work 2+ times/week | 0.018 | 0.134 | 0 | 1 |
| Bicycle | Bike to work 2+ times/week | 0.055 | 0.228 | 0 | 1 |
| Bike/Ped | Walk or bike to work 2+ times/week | 0.073 | 0.272 | 0 | 1 |
| Carpool | Carpool to work 2+ times/week | 0.049 | 0.215 | 0 | 1 |
| Work at Home | Work at home 2+ times/week | 0.131 | 0.453 | 0 | 1 |
| Multiple Modes | Commute to work using different modes 2+ times/week each | 0.134 | 0.134 | 0 | 1 |
| Children | Take children to school or daycare | 0.207 | 0.406 | 0 | 1 |
| HBW Travel Time | Home-to-work travel time (minutes) | 13.80 | 14.07 | 0 | 90 |
| HBNW Trips/Week | Number of non-work related driving trips/week | 7.15 | 4.39 | 2.5 | 20 |
| Gas Expenditures | Money ($) spent on gas/week | 90.17 | 56.67 | 25 | 250 |
| VMT/Week | Vehicle Miles Traveled/week | 96.66 | 68.13 | 25 | 250 |
| Fuel Economy | Average fuel economy of all households vehicles used 2+ times/week (mpg) | 23.85 | 6.46 | 0 | 55 |
| Low MPG | Fuel economy less than 20 mpg | 0.210 | 0.408 | 0 | 1 |
| High MPG | Fuel economy greater than 30 mpg | 0.109 | 0.313 | 0 | 1 |
| Age | Respondent's age (years) | 45.53 | 13.15 | 21 | 83 |
| Gender | Indicator variable for males | 0.422 | 0.495 | 0 | 1 |
| Income | Household income before taxes ($/year) | 89,688 | 49849 | 0 | 200,000 |
| Employed | Employed part- or full-time | 0.857 | 0.350 | 0 | 1 |
| College Educated | Attained at least Bachelor's degree | 0.836 | 0.371 | 0 | 1 |
| Household Size | Number of persons in household | 2.286 | 1.109 | 1 | 6 |
| Vehicles/Driver | Vehicles used by household 2+ times/week per driver in household | 0.912 | 0.331 | 0 | 2 |
| Local Population | Population within 1 mile radius from TSZ | 58457 | 6136 | 30791 | 66079 |
| Local Residential Area | Residential Area within 1 mile radius from TSZ (in square miles) | 5.57 | 0.41 | 3.49 | 6.37 |
| Local Commercial Area | Commercial Area within 1 mile radius from TSZ (in square miles) | 0.42 | 0.04 | 0.27 | 0.51 |
| Local Basic Employment | Basic jobs within 1 mile radius from TSZ | 12924 | 2785 | 5860 | 16876 |
| Local Retail Employment | Retail jobs within 1 mile radius from TSZ | 5742 | 1028 | 2618 | 7775 |
| Local Service Employment | Service industry jobs within 1 mile radius from TSZ | 15857 | 3581 | 7124 | 24330 |
| Local Employment | Total jobs with in 1 mile radius from TSZ | 75.32 | 2.57 | 65.07 | 84.87 |
| Distance to CBD | Distance from TSZ to CBD (mi.) | 5.10 | 3.72 | 0.86 | 16.20 |
| Bus Stop Density | Bus stops/square mile in TSZ | 28.16 | 23.25 | 0 | 118 |
| Zone Density | (Jobs + households)/square mile in TSZ | 4241 | 2877 | 293.9 | 16417 |

## Table 7: Ordered Probits for Trip Chaining and Reducing Overall Driving

| Variable | | Trip Chaining | | | Reducing Overall Driving | | |
|---|---|---|---|---|---|---|---|
| | | Final Estimates | | | Final Estimates | | |
| | | *β* | *t-stat* | *p* | *β* | *t-stat* | *p* |
| | Constant | 9.372 | 11.663 | 0.000 | 14.780 | 16.057 | 0.000 |
| Transportation Needs | Bus | 1.248 | 8.908 | 0.000 | 0.826 | 6.914 | 0.000 |
| | Bike/Ped | -0.380 | -4.653 | 0.000 | | | |
| | Work at Home | | | | 0.573 | 8.267 | 0.000 |
| | Multiple Modes | -0.634 | -4.113 | 0.000 | -0.754 | -6.392 | 0.000 |
| | HBNW Trips/Week | -0.044 | -6.595 | 0.000 | -0.046 | -6.548 | 0.000 |
| | VMT/Week | | | | -0.004 | -11.996 | 0.000 |
| | Fuel Economy | | | | -3.22E-02 | -8.946 | 0.000 |
| Demographics | Gender | -0.464 | -8.352 | 0.000 | | | |
| | Employed | -0.630 | -10.771 | 0.000 | -0.500 | -5.278 | 0.000 |
| | Age | | | | -0.019 | -6.308 | 0.000 |
| | College Educated | | | | 0.304 | 3.228 | 0.001 |
| | Income ($) | -3.38E-06 | -3.286 | 0.001 | -5.01E-06 | -4.280 | 0.000 |
| | Vehicles/Driver | -0.422 | -4.520 | 0.000 | -0.468 | -3.877 | 0.000 |
| Neighborhood Characteristics | Resid. Area | -9.59E-01 | -14.692 | 0.000 | | | |
| | Comm. Area | 6.797 | 5.468 | 0.000 | | | |
| | Basic Empl. | | | | 8.47E-05 | 4.058 | 0.000 |
| | Retail Empl | 3.87E-04 | 4.014 | 0.000 | 5.03E-04 | 6.125 | 0.000 |
| | Service Empl. | -1.87E-04 | -4.735 | 0.000 | -2.47E-04 | -7.690 | 0.000 |
| | Total Empl. | | | | -0.126 | -10.834 | 0.000 |
| | Zone Density | -3.42E-05 | -4.536 | 0.000 | | | |
| | Distance to CBD | -1.984 | -9.216 | 0.000 | | | |
| | Bus Stop Density | -1.49E-02 | -9.856 | 0.000 | | | |
| Thresholds | $\mu_0$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | $\mu_1$ | 2.417 | 25.570 | 0.000 | 1.81 | 16.934 | 0.000 |
| | $\mu_2$ | 3.204 | 33.164 | 0.000 | 2.572 | 24.116 | 0.000 |
| | $\mu_3$ | 4.240 | 35.632 | 0.000 | 3.599 | 24.600 | 0.000 |
| Log-Likelihood | | -394.837 | | | -420.673 | | |
| Constants Only Log-Likelihood | | -455.367 | | | -468.034 | | |
| Pseudo R-Squared | | 0.133 | | | 0.101 | | |

Note: Final model specifications include only variables significant at the 0.01 level.

**Table 8: Binary Logit Models for Driving Slower and Driving at Steadier Speeds Responses**

| Variable | | Driving Slower | | | | Driving at Steadier Speeds | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Final Estimates | | | | Final Estimates | | | |
| | | *β* | *t-stat* | *p* | *Elasticity* | *β* | *t-stat* | *p* | *Elasticity* |
| | Constant | -6.416 | -2.805 | 0.005 | -4.559 | -3.571 | -1.387 | 0.166 | -2.303 |
| Transportation Needs | Walk | -2.882 | -2.556 | 0.011 | -0.037 | -0.034 | -2.553 | 0.011 | -4.00E-04 |
| | HBW Time | -0.033 | -2.526 | 0.012 | -0.324 | | | | |
| | HBNW Trips/Week | -0.102 | -2.570 | 0.010 | -0.518 | | | | |
| | VMT/Week | | | | | 8.34E-03 | 3.661 | 0.000 | 0.520 |
| | Gas Expenditures | 6.77E-03 | 2.325 | 0.020 | 0.434 | | | | |
| | Fuel Economy | -0.083 | -3.002 | 0.003 | -1.407 | -5.60E-02 | -2.442 | 0.015 | -0.862 |
| Demographics | College Educated | 0.775 | 2.452 | 0.014 | 0.460 | | | | |
| | Income ($) | -1.29E-05 | -4.087 | 0.000 | -0.822 | -1.19E-05 | -3.964 | 0.000 | -0.688 |
| Neighborhood Characteristics | Population | | | | | -3.43E-04 | -4.024 | 0.000 | -12.933 |
| | Resid. Area | | | | | 1.72E+00 | 2.562 | 0.010 | 6.169 |
| | Comm. Area | 21.577 | 4.174 | 0.000 | 6.482 | 17.922 | 2.959 | 0.000 | 4.887 |
| | Basic Empl. | | | | | 5.31E-04 | 4.079 | 0.000 | 4.427 |
| | Zone Density | -1.15E-04 | -2.336 | 0.020 | -0.347 | | | | |
| | Bus Stop Density | | | | | 0.022 | 3.172 | 0.002 | 0.400 |
| Log-Likelihood | | -166.256 | | | | -175.502 | | | |
| Constants Only Log-Likelihood | | -205.077 | | | | -211.027 | | | |
| Rho-Squared | | 0.1893 | | | | 0.1683 | | | |

Note: Final model specifications include only explanatory variables significant at the 0.05 level. Elasticities are calculated assuming explanatory variables to be at means.

**Table 9: Comparison of Final Models**

| Explanatory Variables | Increased Trip Chaining | Reduced Overall Driving | Driving Slower | Driving at Steadier Speeds |
|---|---|---|---|---|
| Bus | + | + | | |
| Bike/Ped | - | | | |
| Work at Home | | + | | |
| Multiple Modes | - | - | | |
| HBNW Trips/Week | - | - | | |
| VMT/Week | | - | | + |
| Fuel Economy | | - | | |
| Gender | - | | | |
| Employed | - | - | | |
| Age | | - | | |
| Income | | - | - | - |
| Vehicles/Driver | - | - | | |
| Population AI | | | | – |
| Residential Area AI | - | | | |
| Commercial Area AI | + | | ++ | |
| Base Employment AI | | + | | ++ |
| Retail Employment AI | + | ++ | | |
| Service Employment AI | -- | -- | | |
| Total Employment AI | | - | | |
| CBD Distance | -- | | | |
| Bus Stop Density | - | | | |

Notes: This table includes variables from final models having *t-stats* > 3.5. Strong practical significance was considered to be an absolute elasticity value greater than 1 for attention to vehicle maintenance, driving slower, and driving at steadier speeds, or a marginal effect $\frac{\Delta y}{\Delta x_i} > .5$ for $\Delta x_i$ = one standard deviation of $x_i$

**Figure 1: Texas Retail Gas Prices During Spike and Data Collection Period**

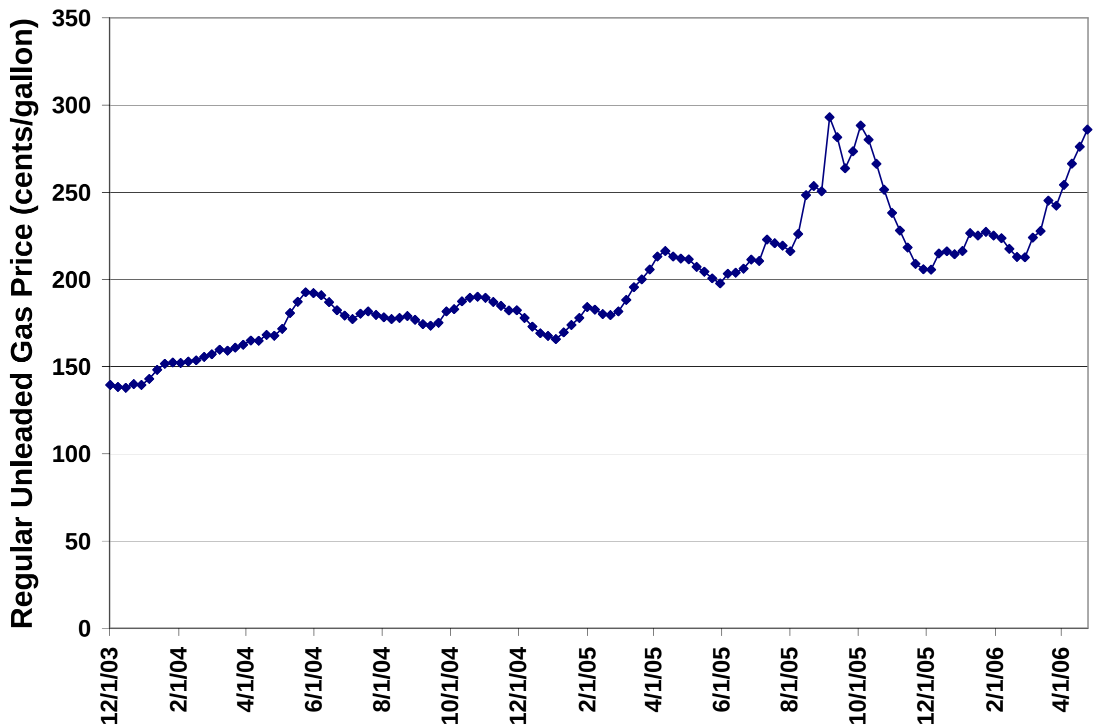
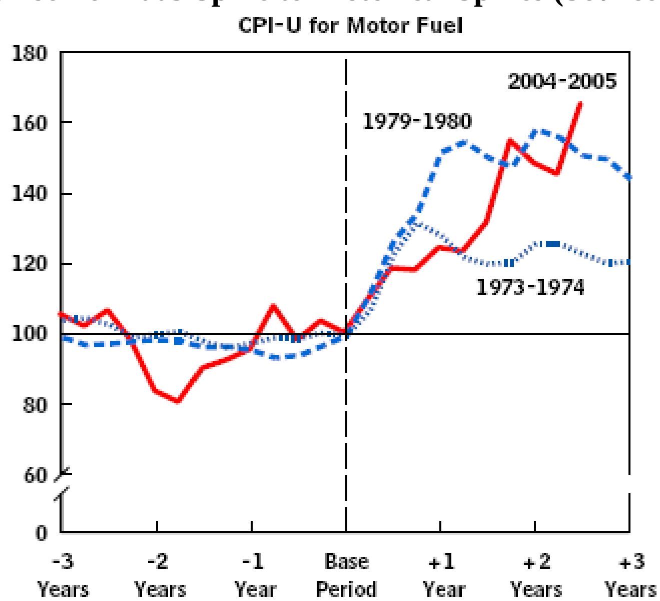



**Figure 2: Comparison of 2005 Spike to Historical Spikes (Source: Peterson 2006)**




Notes: In Figure 2, CPI-U is the consumer price index for all urban consumers. The base periods are the third quarter of 1973 for the 1973-1974 price shock, the first quarter of 1979 for the 1979-1980 price shock, and the fourth quarter of 2003 for the 2004-2005 price shock.