A Time Geography Approach to Understanding the Impact of Gasoline Price Changes on Traffic Safety

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ABSTRACT The impact of gasoline price changes on traffic safety has received increasing attention in empirical studies. However, this important relationship has not been explained within a conceptual or theoretical framework. In this study, we examine this relationship within a time geography framework in an attempt to understand the effect of time-varying fluctuations in gasoline prices and their relationship to traffic safety in a case study of Mississippi from April 2004 to December 2008. We further extend this work by examining the degree to which this relationship is differential in impact by age, gender, and race. The results suggest that changes in gasoline prices have immediate effects on reducing total traffic crashes and crashes of younger drivers, women, and whites. However, changes in gasoline prices do not affect total crashes of older drivers, men, or blacks. Within the theoretical framework of time geography, we understand gasoline prices as one type of capability constraint of the space-time path and space-time prism. As gasoline prices increase (that is, as the capability constraint becomes stronger), traffic crash rates will decrease. However, the effects vary by age, gender, and race because the capability constraint of gasoline prices differs across demographic groups.

INTRODUCTION

Recent surges in gasoline prices have resulted in complex social and spatial implications for individuals, the public, transportation and land use planners, and decision makers. Populations that are more vulnerable to gasoline price increases may drive fewer miles and reduce gasoline consumption by reducing driving frequency and distance, shifting from personal vehicles to public transport, driving in a more fuel-efficient manner (such as driving more slowly and reducing sudden speeding and braking), switching to fuel-efficient vehicles, and relocating closer to workplaces. These changes in commuting behaviors and residential location could eventually lead to improved traffic safety. Although a large body of literature has empirically examined the impact of gasoline price changes on traffic safety (see Chi et al. 2010 for a review of the literature), a conceptual or theoretical framework has not been offered to explain the impact.

In this study, we attempt to use time geography theory (Hägerstrand 1970) to understand the impact of gasoline price changes on traffic safety. Time geography theory has been utilized to study various perspectives of transportation accessibility, such as bus services (Lenntorp 1976), commute modes and times (Burns 1979), the transportation geographic information system (Miller 1991), disparities in gender accessibility (Kwan 1998), and information and communication technologies (Yu and Shaw 2007). It has also proven to be an important organizing principle for modeling travel behavior as a set of linked activity and travel decisions subject to constraints on resources such as time (Kitamura and Fujii 1996). We assert that the theory of time geography can also be useful for explaining the effects of gasoline price changes on traffic safety. Within the theoretical framework of time geography, we understand gasoline prices as one type of capability constraint. We expect that as gasoline prices increase (as the capability constraint becomes stronger), traffic crash rates will decrease. Furthermore, we expect that these capability constraints will be stronger for some and will manifest themselves in differential effects by age, gender, and race.

The next section summarizes existing studies of gasoline price effects on traffic safety. Immediately following that is a section that reviews time geography theory and proposes a conceptual framework for understanding the relationship between gasoline prices and traffic crashes within that context. Next, the data and methods section introduces the data that are related to traffic crashes by age, gender, and race in the state of Mississippi from April 2004–December 2008 and addresses the methods that direct our analyses. Finally, the results section reports our findings within the theoretical framework of time geography and is followed by a concluding section with a summary and discussion of our findings and their implications.

PRIOR RESEARCH OF GASOLINE PRICE EFFECTS ON TRAFFIC SAFETY

There exists an increasing body of literature that examines gasoline price effects on traffic safety (see Chi et al. 2010 for a review of the literature). Most of the studies, which have been undertaken with nearly a sole focus on fatal crashes (e.g., Grabowski and Morrisey 2004, 2006; Leigh and Geraghty 2008; Leigh and Wilkinson 1991; Wilson et al. 2009), found that increasing gasoline prices (or taxes) lead to higher traffic safety as measured by fewer traffic crashes. The effects were also found to vary by demographic characteristics of drivers and by crash types. These findings highlight a couple of important trends that have helped guide the current research.

First, existing literature on the subject has consistently shown that the effects of gasoline prices on traffic crashes differ by age, gender, and race. The effects tend to be larger on younger drivers than on older drivers, larger on male drivers than on female drivers, and larger on black drivers than on white drivers (Chi et al. 2010; Grabowski and Morrisey 2004; Leigh and Wilkinson 1991). Second, gasoline price effects on traffic crashes differ by fatal crashes, injury crashes, property-damage-only crashes, and drunk-driving crashes (Chi et al. 2011; Huang and Levinson 2010). When compared to overall crashes, gasoline prices have larger effects on less severe crashes and drunk-driving crashes. Although these studies found a statistically significant association between gasoline prices and traffic crashes, a conceptual or theoretical framework has not been given to explain their association. In this study, we attempt to use time geography theory to explain the effect of gasoline prices on traffic crashes.

UNDERSTANDING GASOLINE PRICE EFFECTS ON TRAFFIC SAFETY WITHIN TIME GEOGRAPHY THEORY

Time Geography Theory

Originally developed by Hägerstrand (1970), time geography theory studies the relationships between the behavioral possibilities of individuals and the various spatial and temporal constraints on those behaviors (Shaw and Yu 2009; Yu and Shaw 2007). The core notion of time geography is that an individual's existence and activities are constrained by spatial and temporal attributes (Pred 1977). Time geography theory asserts that an individual can only participate in activities in a single location in space at one single time (Miller 1991). Three types of constraints on the activities exist: capability constraints, authority constraints, and coupling constraints (Hägerstrand 1970). Capability constraints refer to biological (e.g., sleeping and eating) and physical (e.g., vehicle ownership, time availability, maximum speed of travel) limitations that restrict an individual from participating in activities. Authority constraints represent limitations to accessing particular areas (e.g., military bases) or individuals that are classified by certain people or institutions. Coupling constraints indicate limitations for two or more individuals to participate in an activity in the same location at the same time interval. These three types of constraints dictate the spatial and temporal patterns of an individual's movements. Cullen and Godson (1975) further refined the notion of constraints by noting that temporal constraints might vary in their rigidity by time of day, with constraints weakening later in the day as more discretionary activities are pursued.

Within this approach, an individual's movements in space over time generate a *space-time path*, which can be understood as a series of lines in a three-dimensional system in which space is represented by a two-dimensional plane and time is represented by the vertical axis. However, any space-time path is only one of many possible space-time paths that can be taken by an individual in a given time interval. All the points that an individual can reach from an origin location to a destination location at a given time interval comprise a *space-time prism*. The prism is determined by the intermediate locations between the origin and destination points, the time required for participation in activities at those locations, and the travel time between each point. The space-time path and space-time prism are the two most essential concepts of time geography, and they provide a valuable measure of an individual's accessibility within particular spatial and temporal constraints (Miller 1991).

Conceptual Framework

We understand gasoline prices as one type of capability constraint. Higher gasoline prices reduce an individual's ability to afford the same amount of gasoline as that consumed at lower prices, causing an individual to drive less distance and less frequently, in turn reducing exposure to traffic crashes. Gasoline price increases reduce transportation accessibility by reducing the lengths and frequencies of economically feasible space-time paths and sizes of space-time prisms, which in turn leads to fewer traffic crashes. However, the capability constraint of gasoline prices varies by income and private vehicle ownership. An individual with higher income tends to have a higher capability of gasoline consumption and is less vulnerable to gasoline price increases. Yet the income influence on the gasoline price constraint is conditional on private vehicle ownership—gasoline prices affect automobile usage only if an individual owns a private vehicle. For those who do not own private vehicles, gasoline price changes are less likely to affect driving. For those who own private vehicles but have low income, the effect is substantial. For example, blacks and Latinos, who have relatively lower private vehicle ownership rates (Raphael and Stoll 2001), are less likely to be affected by gasoline price increases. In contrast, young drivers who own cars but lack discretionary income are likely to be substantially affected by increases in gasoline prices.

We conceptualize gasoline prices as influencing traffic safety through at least five intermediate factors: trip frequency and distance for non-work trips, travel modes, driving behaviors, vehicle fuel efficiency, residential and work locations (Figure 1). First, rising gasoline prices could cause people to drive shorter distances by reducing trip frequency (fewer space-time paths) and distance (shorter space-time paths) as well as to make more multi-purpose (linked or chained) trips rather than single-purpose trips (for shorter total lengths of space-time paths) (Huang and Levinson 2010). Second, an increase in gasoline prices could cause some drivers to switch from personal vehicle use to other commuting modes, such as using public transportation (Lane 2010), carpooling, biking, or walking (fewer motor vehicle space-time paths and fewer destinations reached by motor vehicle). Third, surging gasoline prices could cause people to drive in a more fuel-efficient manner, such as driving more slowly and reducing sudden speeding and braking, which in turn likely lowers crash risk. These three paths through which gasoline prices affect traffic safety likely occur immediately after gasoline price increases. However, over the long term, gasoline prices may influence traffic safety through two additional factors—higher vehicle fuel efficiency and residential relocation or job change. An increase in gasoline prices could persuade some drivers to switch to fuel-efficient vehicles, which are generally lighter (and therefore more vulnerable if hit by a larger vehicle but likely to cause less damage to another vehicle or a pedestrian in a crash) and equipped with better safety technologies (the net effects of lightness and safety have been found to be insignificant; Leigh and Wilkinson 1991). Increased gasoline prices could also induce workers, especially low- and medium-income automobile commuters who live far from their workplaces, to relocate closer to their workplaces (shorter space-time paths), and may encourage low-wage, younger, and part-time workers to find jobs nearer their residence (shorter space-time paths).

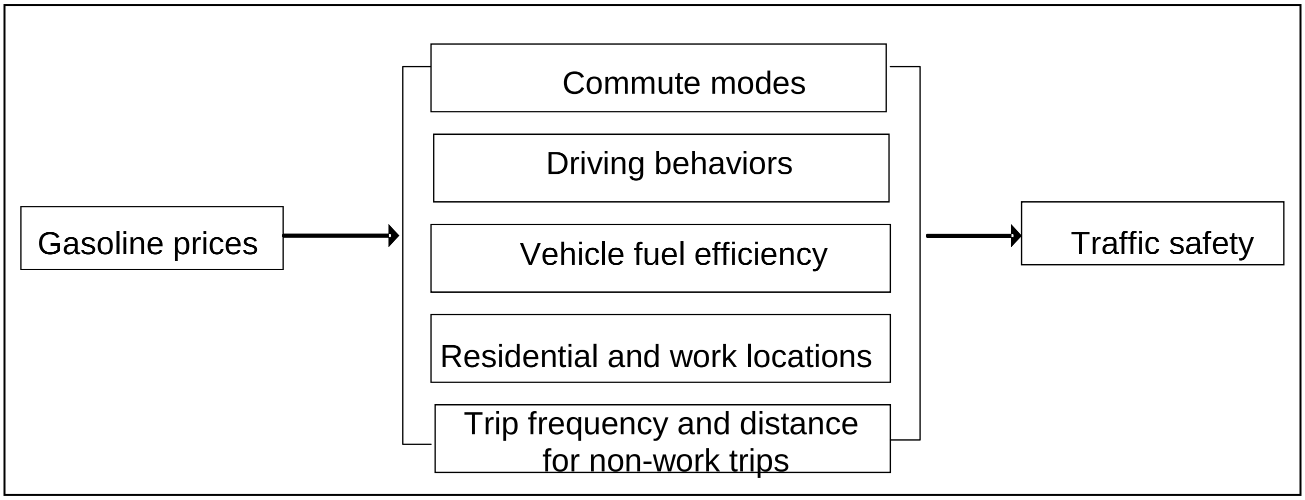

FIGURE 1 A conceptual framework.

The effects of gasoline prices on the intermediate factors eventually lead to greater traffic safety: rising gasoline prices reduce the total lengths of motor-vehicle-based space-time paths of an individual during a given time interval—i.e., an individual travels less and for shorter distances by car—which in turn reduces the likelihood of a traffic crash occurrence for that individual. Thus, we expect that as gasoline prices increase (as the capability constraint becomes stronger), traffic crash rates will decrease. Furthermore, as we expect capability constraints to be differentially impactful, we expect that significant variations will exist across demographic categorizations of the population.

These conceptual links through which gasoline prices affect traffic safety are complex. They have not been tested in existing studies; this study likewise does not attempt to test these conceptual links. Measurement of the intermediate links might have potentially large errors, and the conceptual links might be imprecise. Moreover, the data for studying these conceptual links are unavailable and may be difficult to collect. Therefore, instead of modeling the effects by these links, this research directly models the effects of gasoline prices on reducing traffic crashes. The conceptual links are used only for the purpose of introducing the framework through which we interpret our findings and highlight the underlying mechanisms driving the findings reviewed in the literature section above.

DATA AND METHODS

Data and Variables

This study makes use of data provided by the Mississippi Highway Patrol and analyzes monthly traffic crashes in the state of Mississippi from April 2004 until December 2008. Following the recent work of Chi et al. (2010), this analysis is unique in that most studies to date have only examined the effects of gasoline prices on traffic *fatalities* (e.g., Grabowski and Morrisey 2004; Leigh and Wilkinson 1991; Wilson et al. 2009) by making use of Fatal Accident Reporting System (FARS) data, which reports only information on fatal accidents. Our data is unique in that it contains information on vehicles, drivers, and passengers of all traffic accidents documented by the Mississippi Highway Patrol during the identified period. In addition, crashes per vehicle miles traveled (VMT) were computed using data collected from the Mississippi Department of Transportation.

Data for regular-grade gasoline prices were obtained from the U.S. Department of Energy's Energy Information Administration (EIA) (Figure 2). Given the location of Mississippi in the Gulf States region of the U.S., the data collected from the EIA were related to the average prices for all Gulf Coast states. Gasoline prices were also adjusted for inflation in June 2009 dollars.

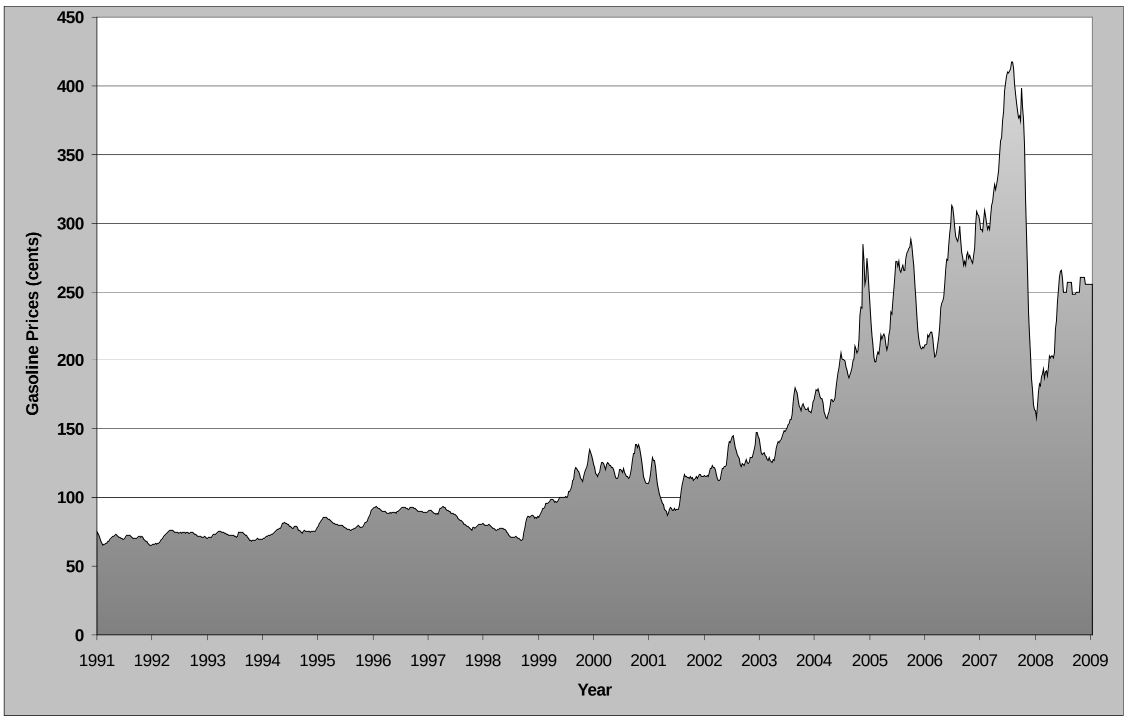

FIGURE 2 Average gasoline prices (in June 2009 dollars) in the U.S., 1991–2009.
Data source: Energy Information Agency, U.S. Department of Energy.

This study also controls for other factors that may affect traffic crashes. These factors are seat belt usage (Evan and Graham 1991), alcohol consumption (Chi et al. 2011), and state unemployment rate (Graham and Glaister 2003; Leigh and Wilkinson 1991; Quddus 2008). Data for these factors come from the Mississippi Department of Public Safety, the Beer Institute (2009), and the U.S. Bureau of Labor Statistics (2009). These factors are reviewed in Chi et al. (2010).

Methods

In this study, semi-log regression models are utilized for examining the effects of gasoline prices on traffic crashes per VMT. Semi-log models are often used to model traffic crash rates because of skewness (Dee 2001). Moreover, semi-log model estimates are more robust than grouped logistic models regarding magnitude and precision (Grabowski and Morrisey 2004). The specification for the semi-log models is:

$$ln(r) = \beta X + \lambda K + \mu$$

where
r refers to crashes per one million VMT;
X refers to gasoline prices and control variables;
β refers to coefficients of *X*;
K refers to month-fixed effects;
λ is the coefficient for month-fixed effects; and
μ is the randomly distributed error term.

The total crash rate is measured per million VMT. Crash rates are also measured by age (15–23 and 24+ years old), gender (male and female), and race (white and black).[1] Therefore, seven different traffic crash rates are studied. Each measure is used as a dependent variable in a semi-log model. Traffic crash rates are functions of gasoline prices, seat belt usage, alcohol consumption, and unemployment rate.

Existing studies suggest that the short-term and long-term effects of gasoline prices on reducing traffic crashes may be different (Chi et al. 2010; Dahl and Sterner 1991; Grabowski and Morrisey 2004). The gasoline price threshold, however, is ambiguous. In this study, we follow the Chi et al. (2010) and Grabowski and Morrisey (2004) studies to measure gasoline prices at the current time, a 1-year lag, a 2-year lag, a 3-year lag, and a 4-year lag; the first measure represents short-term effects while the latter four represent long-term effects. Month-fixed effects control for unobserved seasonal variation in traffic crash rates, such as weather conditions.

RESULTS

Gasoline Prices and Total Crashes per Million VMT

Figure 3 presents the association between average gasoline prices and traffic crashes per million VMT.[2] Here we see that quarterly average gasoline prices (adjusted for inflation) are temporally associated with the total number of traffic crashes per million VMT in Mississippi from April 2004 to December 2008. Both gasoline prices and the traffic crash rate are standardized on competing y-axes for comparative purposes. The average gasoline prices (in cents) are labeled on the left y-axis and traffic crashes per million VMT are labeled on the right y-axis.

The overall trend of the relationship highlights an association where traffic crashes fall as average gasoline prices rise. This is particularly evident at some specific points across the figure. For example, in quarters 2 and 3 of 2006, average gasoline prices were at a three-year peak and traffic crashes were at their lowest point in two years. Immediately following that, traffic crashes rose in the fourth quarter in 2006 in direct temporal proximity to falling gasoline prices. The most obvious point in this relationship concerns the relatively large spikes in average

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[1] Crashes of Latino drivers are not examined in this study as Latinos make up a very small proportion of the Mississippi population—only 2.2% of the population was of Hispanic origin in 2008 (U.S. Bureau of Census 2010).

[2] Quarterly data relate to standard calendar year quarters such that Q1 represents data from January to March, Q2 represents data from April to June, Q3 represents data from July to September, and Q4 represents data from October to December.

gasoline prices in the second and third quarters of 2008, which also saw the lowest rates of traffic crashes in four years. Again, immediately following these periods was a slight drop in average gasoline prices and a related upward swing in traffic crashes per million VMT in the fourth quarter of 2008.

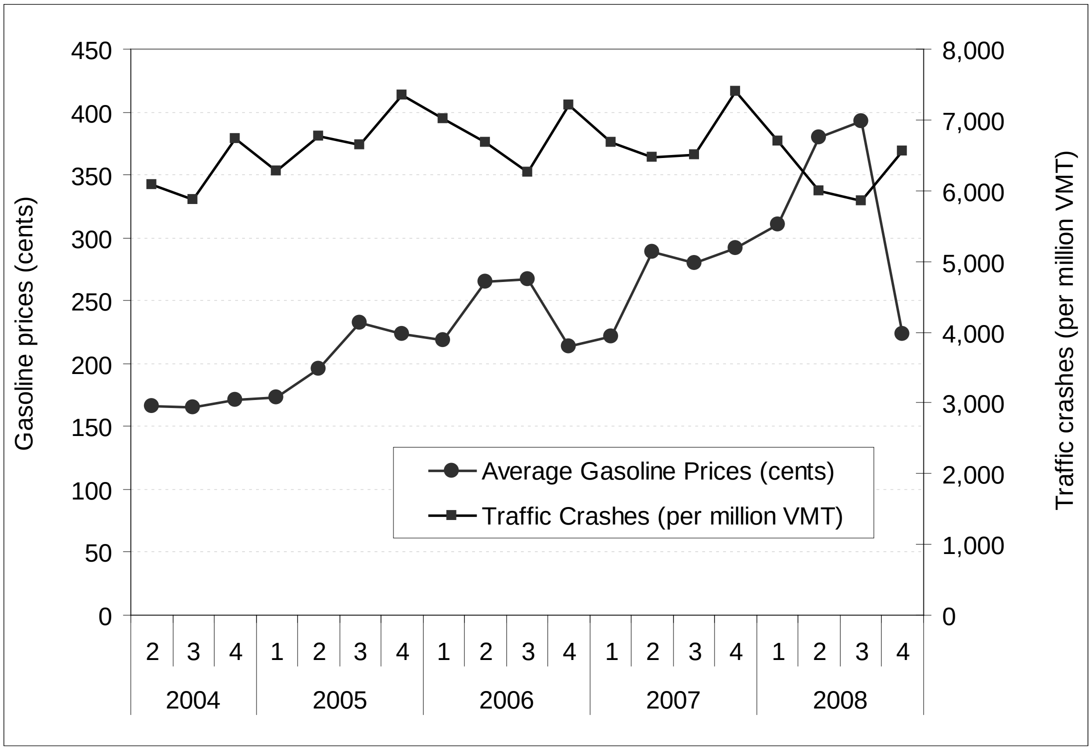

FIGURE 3 Average gasoline prices and total traffic crashes per million VMT by quarter in Mississippi, 2004–2008.

We then examined the effects of gasoline prices on total traffic crashes per million VMT at the monthly level by using semi-log regression models (Table 1). It was found that the gasoline price at the current time has effects on reducing traffic crashes per VMT—a one-cent increase in the inflation-adjusted gasoline price is associated with a 0.053% decrease in monthly total crashes per million VMT. Evaluated at the mean price of $2.40 (for the studied period), this coefficient implies an elasticity of –0.13. Gasoline prices at the 1-year, 2-year, 3-year, and 4-year lags were found to have no effects on traffic crashes per million VMT. Thus, the results suggest that gasoline prices have short-term but not long-term effects on reducing traffic crashes per million VMT. As discussed in the section on the time geography theory framework, gasoline prices act as one type of capability constraint. However the lack of significance on the long-term lags implies the short-term readjustments (changing non-work travel frequency and distance, changing mode of travel, and driving more efficiently) are more likely than long term adjustments (vehicle type, residential and work locations). Higher gasoline prices reduce the affordability of gasoline for middle- and low-income people. The total lengths of their space-time paths and sizes of their space-time prisms are reduced, which in turn decreases the probability of their being involved in traffic crashes.

TABLE 1 Least-Squares Estimates of Semi-Log Regression Models for Traffic Crashes per Million VMT, April 2004–December 2008, Mississippi

	Total	Age		Gender		Race	
		15–23 years	24+ years	Men	Women	White	Black
Gasoline price at current time	–0.00053* (0.00026)	–0.00108** (0.00036)	–0.00034 (0.00026)	–0.00036 (0.00025)	–0.00075* (0.00030)	–0.00059* (0.00027)	–0.00051 (0.00026)
Gasoline price at a 1-year lag	–0.00046 (0.00042)	0.00048 (0.00058)	–0.00079 (0.00043)	–0.00048 (0.00040)	–0.00042 (0.00049)	–0.00037 (0.00044)	–0.00073 (0.00043)
Gasoline price at a 2-year lag	0.00028 (0.00055)	0.00044 (0.00076)	0.00023 (0.00055)	–0.00006 (0.00052)	0.00057 (0.00063)	0.00023 (0.00057)	0.00025 (0.00056)
Gasoline price at a 3-year lag	–0.00022 (0.00054)	–0.00028 (0.00074)	–0.00021 (0.00054)	–0.00028 (0.00051)	–0.00014 (0.00062)	0.00005 (0.00056)	–0.00087 (0.00054)
Gasoline price at a 4-year lag	–0.00128 (0.00094)	–0.00237 (0.00130)	–0.00092 (0.00094)	–0.00130 (0.00089)	–0.00124 (0.00108)	–0.00146 (0.00098)	–0.00080 (0.00095)
Seat belt usage	–0.00444 (0.00676)	–0.02135* (0.00932)	0.00137 (0.00679)	–0.00496 (–0.00639)	–0.00372 (0.00778)	–0.01046 (0.00708)	0.00372 (0.00687)
Alcohol consumption	0.10918 (0.05841)	0.06488 (0.08054)	0.12742* (0.05869)	0.11493* (0.05521)	0.10153 (0.06722)	0.12643* (0.06123)	0.06054 (0.05935)
State unemployment	0.03819** (0.01153)	0.00058 (0.01590)	0.05187*** (0.01158)	0.03972*** (0.01090)	0.03628** (0.01327)	0.03846** (0.01208)	0.04180*** (0.01171)
Month-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	–1.44635 (1.475363)	–0.10767 (2.03463)	–2.75511 (1.48263)	–2.15076 (1.39468)	–2.10427 (1.69809)	–2.03188 (1.54664)	–1.70710 (1.49926)
Adjusted R^2	0.54	0.73	0.44	0.61	0.41	0.62	0.59

*Notes: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; standard errors in parentheses.*

Previous traffic safety studies suggest that driving behaviors vary among the younger and the older population, men and women, as well as whites and blacks, which in turn could produce different traffic safety outcomes among these groups (van den Bossche et al. 2007). Thus, we further partitioned the crash data by age, gender, and race to analyze gasoline price effects on the traffic crash rates of each of these groups.

Variations by Age

To examine variations by age, we ran semi-log regression models for the crash rate of the younger population (15–23 years old) and the older population (24+ years old) separately. As shown in Table 1, it was found that the gasoline price at the current time has substantial effects on reducing the traffic crash rate of the younger population: a one-cent increase in the inflation-adjusted gasoline price is associated with a 0.108% decrease in monthly total crashes per million VMT, which is twice the percentage point decrease in total traffic crash rates. Evaluated at the mean price of $2.40, this coefficient implies an elasticity of –0.26. The younger population tends to have lower income than the older population and thus is more vulnerable to gasoline price increases. In other words, the capability constraint of gasoline prices is stronger on the younger population. Therefore one would expect that when gasoline prices increase, the younger population is likely unable to consume as much gasoline as previously. Thus, the frequency and total lengths of their space-time paths and the sizes of their space-time prisms tend to be reduced, which in turn reduces their exposure to traffic crashes. Gasoline prices at the 1-year, 2-year, 3-

year, and 4-year lags were found to have no effects on reducing the traffic crash rate of the younger population.

The results also indicate that seat belt usage has an effect on reducing traffic crashes of the younger population but not on any other group (the older population, men, women, whites, and blacks). This finding is consistent with prior research results indicating that the driving behaviors of young people are riskier than those of other populations (e.g., Leigh and Wilkinson 1991; Roudsari et al. 2009).

In contrast to the findings on the effects of gasoline prices on the crash rate of the younger population, it was found that gasoline prices do not affect the crash rate of the older population, either in the short term or the long term. The older population may have more work and household responsibilities (more coupling constraints) limiting their willingness to reduce trips dramatically. Partly because of their greater responsibilities, the older population may react to gasoline price changes more conservatively; the older population is more experienced in dealing with gasoline price changes. In addition, they have relatively higher incomes than the younger population and thus their capability constraint of gasoline prices is lower.

However, the crash rate of the older population is affected by alcohol consumption and unemployment. The results indicate that alcohol consumption increases the crashes of the older population. This conclusion is consistent with the findings of other studies, which indicate that alcohol reduces driving skill and reaction speed, leading to a heightened crash rate (e.g., Bernat et al. 2004; Chi et al. 2011; Wagenaar et al. 2000). Our results also show that unemployment increases the crash rate of the older population. The reason may be that unemployment imposes a psychological effect—unemployment may cause people to live in a less structured fashion and to have lower self-esteem, which in turn leads to riskier driving behaviors (Wilson 1996). These findings, however, are contradictory to the findings of existing studies (e.g., Grabowski and Morrisey 2004). Thus, the explanation of unemployment effects on the crash rate of older drivers needs to be investigated further.

Variations by Gender

Prior research indicates that travel behaviors differ between men and women (Ren and Kwan 2009). Thus, gasoline prices may have different effects on traffic safety between men and women. To test this hypothesis, we ran semi-log regression models for the crash rates of men and women separately. The results in Table 1 indicate that gasoline prices have neither short-term nor long-term effects on the traffic crash rate of men. This suggests that driving behaviors of men are statistically unaffected by gasoline price changes. A larger proportion of men's trips are work related (Meyer 2004); because work-related trips are not optional, the number and frequency of men's trips are affected much less by gasoline price changes. Thus, men's space-time paths and prisms are less vulnerable to gasoline price changes. However, the crash rate of men is affected by alcohol consumption—higher alcohol consumption leads to a higher crash rate. This observation is in line with the findings of most existing driving under the influence (DUI) studies (e.g., Chi et al. 2011; Mayhew et al. 2003). In addition, men's crash rate is affected by the unemployment rate. As the unemployment rate increases, men's crash rate increases.

In contrast, gasoline prices have short-term effects on reducing women's crash rate; a one-cent increase in the inflation-adjusted gasoline price is associated with a 0.075% decrease in women's monthly total crashes per million VMT, which is a higher percentage point increase than the crash rate of the overall population. Evaluated at the mean price of $2.40, this coefficient implies an elasticity of –0.18. That gasoline prices have effects on the crash rates of women but not of men may be due to their gender differences. Women have different preferences, values, and concerns regarding traffic safety and are more sensitive to traffic safety than men (Woodcock et al. 2001). Women are likely to be responsible for more household activities in Mississippi, such as grocery shopping, taking children to school or other activities, and taking other adults to medical appointments. Accordingly, women make more frequent short-distance trips. In response to gasoline price increases, women could change frequent short-distance trips to less frequent multi-purpose trips. Although women do make more linked or chained trips than men (McGuckin and Nakamoto 2004), women could make further adjustments to make more multi-purpose trips. This may explain why women's space-time paths might reduce in response to gasoline price increases.

Variations by Race

To analyze variations by race, we ran semi-log regression models for the crash rates of whites and blacks separately. Gasoline prices have short-term but not long-term effects on reducing the crash rate of whites. A one-cent increase in the inflation-adjusted gasoline price is associated with a 0.059% decrease in whites' monthly total crashes per million VMT, which is close to the percentage point decrease in total traffic crash rates. Evaluated at the mean price of $2.40, this coefficient implies an elasticity of –0.14. Whites have relatively higher private vehicle ownership rates (Raphael and Stoll 2001) and thus are more exposed to the impact of gasoline price changes. When gasoline prices increase, whites who own vehicles but have low incomes might change their commuting behaviors by any of the mechanisms described above. Traffic crashes of whites are also affected by alcohol consumption and unemployment. This observation is similar to that found in the older population. As alcohol consumption increases, crash occurrence becomes more likely, and higher unemployment rates are associated with higher crash rates.

For blacks, however, gasoline prices have neither short-term nor long-term effects on reducing the crash rate. Blacks have on average lower incomes, which correspond to high capability constraints. Blacks also have relatively low private vehicle ownership rates, so they depend less on private vehicles (Raphael and Stoll 2001). Moreover, blacks are more likely to live in central city neighborhoods, which provide easier access to public transportation (Deka 2004; Massey and Denton 1993). When gasoline prices are low, blacks depend on public transportation because they have low private vehicle ownership rates; when gasoline prices are high, they still depend on public transportation. Therefore, gasoline price changes tend to have less effect on their commute modes. The only factor that affects the crash rate of blacks is the unemployment rate. As the unemployment rate increases, the crash rate increases.

SUMMARY AND DISCUSSION

The impact of gasoline price changes on traffic safety has been increasingly addressed in empirical studies. However, the impact has not been explained within a conceptual or theoretical framework. In this study, we use time geography theory to understand the effects of gasoline prices on traffic safety by age, gender, and race in a case study of Mississippi from April 2004–December 2008. The results show that gasoline prices do not have long-term effects on reducing traffic crash rates but do have immediate effects on reducing the crash rates of the total population, the younger population, women, and whites. It was found that a one-cent increase in gasoline prices is associated with a 0.053% decrease in monthly total crashes per million VMT, a

0.108% decrease in monthly crashes per million VMT of the younger population, a 0.075% decrease in monthly crashes per million VMT of women, and a 0.059% decrease in monthly crashes per million VMT of whites.

The findings can be explained within the framework of time geography theory. Gasoline prices can be seen as a capability constraint of the space-time path and space-time prism. Gasoline price increases tend to reduce gasoline affordability—an individual cannot purchase the same amount of gasoline as previously at lower prices. Therefore, people who are more vulnerable to gasoline price increases are more likely to reduce their space-time path lengths and space-time prism sizes. These ends might be achieved through at least five means: converting frequent short-distance trips to multi-purpose trips, switching from private vehicles to public transportation, driving in a more fuel-efficient manner, using more fuel-efficient vehicles, and relocating to be closer to valued destinations (such as workplaces). The first three mechanisms are likely to occur in a short time but the latter two mechanisms are likely to occur over a longer time horizon. However, the implementation of the mechanisms tends to differ by age, gender, and race. The younger population typically has higher capability constraints due to lower incomes, and thus their crash rates decrease as gasoline prices increase. In contrast, the older population and men have lower capability constraints due to relatively higher incomes and necessary family and work responsibilities, which limit the potential to reduce their space-time path lengths and space-time prism sizes. Women typically are more responsible for household activities and make more short-distance trips than men; women drivers can therefore adjust to multi-purpose trips in response to gasoline price increases, which reduces both their space-time path lengths and space-time prism sizes. Variations in the observed effects by race can be explained by differential private vehicle ownership. Whites are likely to own one or more private vehicles; whites who are more vulnerable to gasoline price increases could reduce their space-time path lengths and space-time prism sizes through the various means of travel adjustment. The space-time paths and prisms of blacks tend to be limited because they have lower vehicle ownership rates and are more likely to live in central city neighborhoods than whites; blacks tend to rely more on public transportation regardless of gasoline price fluctuations and thus their crash rate is less likely to be affected by gasoline price changes.

In conclusion, these findings highlight a complex relationship between temporal shifts in gasoline prices and their unique effects on traffic crashes that is further tempered by the availability of resources across specific demographic groups. Within a time geography framework, these findings point to the deterministic impact of external conditions that directly impact the space-time paths and space-time prisms of the different groups in our study. Thus, we expect systematic variations in one's space-time prism that are directly related to the unique conditions experienced at the intersections of age, gender, and race. In this sense, time geography provides a framework in which we can conceptualize the potential impact of shifts in gasoline prices on traffic crashes and their relationship to group-specific adjustments to space-time paths and the shape and size of the overall space-time prism.

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