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DOT Grant No. DTRT06-G-0044

The Short-Run Impact of Gas Prices on Toll Road Use

Final Report

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Performing Organization
University Transportation Center for Mobility™
Texas Transportation Institute
The Texas A&M University System
College Station, TX

Sponsoring Agency
Department of Transportation
Research and Innovative Technology Administration
Washington, DC

Texas Transportation Institute

UTCM Project #09-01-03
October 2011

Technical Report Documentation Page

1. Project No. UTCM 09-01-03	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle The Short-Run Impact of Gas Prices on Toll Road Use		5. Report Date October 2011
		6. Performing Organization Code Texas Transportation Institute
7. Author(s) Mark Burris and Chao Huang		8. Performing Organization Report No. UTCM 09-07-03
9. Performing Organization Name and Address University Transportation Center for Mobility™ Texas Transportation Institute The Texas A&M University System 3135 TAMU College Station, TX 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTRT06-G-0044
12. Sponsoring Agency Name and Address Department of Transportation Research and Innovative Technology Administration 400 7th Street, SW Washington, DC 20590		13. Type of Report and Period Covered Final Report September 2009–August 2011
		14. Sponsoring Agency Code
15. Supplementary Notes Supported by a grant from the US Department of Transportation, University Transportation Centers Program		

16. Abstract

One of the primary functions of transportation planning is to predict future travel behavior. Using estimated travel patterns, planners can then help decision makers select the array of projects that will best suit the needs of their community. Travel behavior is a function of many variables, with cost being among the most important. Recent fluctuations in the price of gas provide an excellent opportunity to observe the impact of the price of gas on travel behavior. This project goes a step beyond looking at the elasticity of travel with respect to gas price by examining how recent changes in gas prices have impacted travel on specific facilities: toll facilities. Data from around the US was used to examine how traffic levels on toll roads have been affected by fluctuations in gas prices over the last several years. This study developed models that account for the many other exogenous factors influencing toll road use (such as local economy, population, and toll rates), and provide an elasticity of toll road demand with respect to gas price independent of those other factors. This study will provide planners and toll road authorities with valuable information on how travelers react to increasing cost of travel when already selecting a mode with an added cost (the toll). The research findings indicated that travel demand elasticity estimates with respect to gas price were inelastic and mostly negative. Elasticities found here for the period from 2000 to 2010 ranged from −0.36 to +0.14, similar to those found in the literature for non-toll facilities. However, the average value of the elasticities found here were much smaller (closer to −0.06) than those found for non-toll facilities.

17. Key Word Gas prices, toll road use, travel demand elasticity	18. Distribution Statement Public distribution

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 119	22. Price n/a

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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UTCM 09-01-03

Project Title:
The Impact of Gas Prices on Toll Road Use

Sponsored by the
University Transportation Center for Mobility™

October 2011

TEXAS TRANSPORTATION INSTITUTE
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ACKNOWLEDGMENTS

Support for this research was provided in part by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the University Transportation Center for Mobility (DTRT06-G-0044).

The authors would like to thank the Texas Transportation Institute (TTI) and University Transportation Center for Mobility (UTCM) for providing support for this research. We also would like to extend our gratitude to the 13 agencies that provided traffic data for this research.

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EXECUTIVE SUMMARY

Travelers' responses to changes in the cost of travel provide key data to help predict future travel behavior. Recently, the price of gas has fluctuated dramatically—and therefore the cost of travel has fluctuated as well. Travelers' responses to this have been generally as expected. Initially there was relatively little change in behavior, but as prices continued to rise some travelers shifted to vehicles with higher fuel efficiencies and to alternative modes of travel (transit and bike/pedestrian). One thing that has not been examined is potential route shifts to or from toll roads.

Many toll facilities offer an uncongested and more direct route to a traveler's destination. Therefore, the traveler is willing to pay a toll to use the toll facility rather than a toll-free alternative. In theory, as gas prices increase the use of toll facilities should also increase. However, some toll facilities experienced the opposite effect. The cost of gas increased to a point where some travelers refused to pay any more for their trip, including paying a toll, despite the fact that the toll facilities may offer significant gas savings. Additionally, as more travelers shift modes, congestion of non-toll routes decreases, eroding the travel time savings offered by the toll facilities.

This research examined traffic trends on several toll facilities from 2000 to 2010. These data were used to estimate the impact of rising gas prices on travelers' choice of toll or non-toll route – furthering researchers' understanding of travel behavior in response to pricing. In addition to investigating the impact of gas price changes on the use of toll facilities, other factors that may have influenced the total use of the toll facility were also considered. These data included the toll rates, monthly unemployment rate, and population in the metropolitan area where the toll road is located.

The research findings indicated that travel demand elasticity estimates with respect to gas price were inelastic and mostly negative. Elasticities found here for the period from 2000 to 2010 ranged from −0.36 to +0.14, similar to those found in the literature for non-toll facilities. However, the average value of the elasticities found here were much smaller (closer to −0.06) than those found for non-toll facilities. This indicates that either (a) toll facility users are less impacted by changes in gas prices, or more likely, (b) although overall traffic volumes decrease some travelers switch to toll facilities as gas prices rise. Therefore, there was some evidence that toll facilities were more insulated from downturns in traffic volumes resulting from increases in gas prices than were toll-free facilities.

CHAPTER 1. INTRODUCTION

Travelers' responses to changes in the cost of travel provide key data to help predict future travel behavior. Recently (particularly in the year 2008), the price of gasoline increased dramatically – and, therefore, the cost of travel increased as well. Travelers' responses to this have been generally as expected. Initially there was relatively little change in behavior, but as prices continued to rise some travelers shifted to vehicles with higher fuel efficiencies and to alternative modes (transit and bike/pedestrian) [1-3]. One thing that has not been examined is potential route shifts to or from toll facilities.

Many toll routes offer an uncongested and more direct route to a traveler's destination. Therefore, the traveler is willing to pay a toll to use the toll facility rather than a toll-free alternative. A substantial amount of research finds this choice primarily depends on (1) travel time savings, (2) travel time reliability, and (3) toll cost [4-9]. However, as the price of gas increases, the difference in the cost of gas used on an uncongested, shorter, toll route versus a non-toll route may also influence route choice.

In theory, as gas prices increase the use of toll facilities should also increase. However, some toll roads are experiencing the opposite effect. The cost of gas increased to a point where many travelers refused to pay any more for their trip, including paying a toll, despite the fact that the toll route may offer significant savings in gas. Additionally, as more travelers shift modes due to higher gas prices, congestion of non-toll routes decreases, eroding the travel time savings offered by the toll facilities.

This study examined traffic trends on several toll facilities around the country over the last few years, and these traffic data were used to estimate the impact of rising gas prices on travelers' choice of toll facilities—furthering researchers' understanding of travel behavior in response to prices. This study collected monthly toll traffic data and gas price data for the period 2000 to 2010 from toll facilities operated by 13 agencies around the country. In addition to investigating the impact of changes in gas price on the use of toll facilities, this research also considered other factors that may have influenced the use of the toll facility. These data included the toll rates, monthly unemployment rate, and population in the metropolitan area where the toll facility was located.

Additionally, during the data collection process, this study also obtained the monthly number of toll violations from June 2003 to December 2009 for the Orlando-Orange County Expressway Authority (OOCEA) toll roads. The toll violation rate (obtained by dividing the number of toll violations by the total toll traffic volume) is very important to toll facility operation and may prove valuable to analyze. Using similar time series analysis techniques used for analysis of impact of gas prices on the use of toll road, this study examined the toll violation rate with respect to gas price and toll rate to see if there was a connection among the three.

This report is organized as follows: Chapter 2 presents the literature reviews and previous research on relevant/similar studies, and Chapter 3 describes data collection efforts. Chapter 4 presents a discussion of the formulation and estimation of an econometric model and some time series analysis techniques to deal with modeling these data. As the research team obtained toll traffic data for toll facilities operated by 13 agencies, the time series analyses results for these datasets were presented in Chapter 5. Chapter 6 describes the characteristics of toll violation data, methodology and results. Chapter 7 offers the conclusions, limitations of this study, and recommendations for future study.

CHAPTER 2. LITERATURE REVIEW

The price elasticity of travel demand provides information on travelers' responsiveness to changes in travel costs. For road transport, factors influencing the level of travel demand include vehicle operating costs, parking fees, travel time costs, ownership costs, accidents and insurance costs. In addition, toll facility users' travel costs include one extra component—the toll paid for using the facility. Empirical evidence on travel demand elasticity on toll roads is limited due to the relatively low number of toll roads in the world [7]. A World Bank study indicated that where there are toll roads the tolled network typically comprises less than 5 percent of the road network [10]. The objectives of this research included estimating the impact of rising gas prices on a traveler's choice of toll route. This study would further researchers' understanding of travel behavior in response to pricing. The examination of the literature found only one study that examined the price elasticity of toll road demand with respect to the price of gas, and that study was in Spain on a system of national toll roads. Therefore, this literature review examined the wealth of information available on how travelers react to price changes—primarily toll rate changes.

There has been increasing interest in using toll revenue to finance new road investment—to relieve ever increasing public budget constraints. An accurate estimate of traffic demand for toll roads is a vital part of planning for these roads. An accurate estimate of traffic demand for toll facilities is a vital part of planning for these facilities. Transportation planners and owners of toll facilities need accurate estimates of demand elasticity with respect to price, income, macroeconomic environment, etc. in order to develop traffic and revenue forecasts. To evaluate the impacts of transportation pricing strategies, it is necessary to understand drivers' response to changes in price. A price elasticity of demand measures the responsiveness of demand to a change in price. It is an empirical measure that summarizes demand for a given highway facility at a given time in a single number [11].

In the long run, drivers have more opportunities to change their travel behavior in response to a change in price than in the short run. This results in higher long-run elasticities than short-run elasticities[1]. As indicated by Burris, et al. [12], almost all available estimates in the literature suggest that the long-run elasticities were at least twice those of corresponding short-run elasticities. The distinction between long-run and short-run is arbitrary in most transport demand studies [13]. In general, short-run was considered within 1 year, and long-run was considered within a span of 3 to 5 years [11, 12]. As monthly data were used in this research, results from this study can generally be considered as short-run elasticity estimates.

Researchers have studied price elasticities of demand for various transport modes, and perhaps the most comprehensive surveys were conducted by Cervero [14], Goodwin [15], and Oum et al. [13]. Some of the most recent surveys include Graham and Glaister [16], Goodwin [17], and Odeck and Brathen [7]. Although this literature is extensive and some studies dealt with toll and fuel elasticities, only two studies examined the price elasticity of toll road demand with respect to the price of gas. One study was in Spain on a system of national toll roads. The other compared proportional changes in toll transactions in two months (May and June) in 2006, 2007,

[1] Period defined as long run was often left to the individual author's discretion.

and 2008 on the Dallas North Tollway Authority System (NTTA) system. This study, by Wilbur Smith Associates [18] indicated that the toll transactions were relatively inelastic to increases in the price of gas, but did not report the travel demand elasticity with respect to the price of gas.

Oum et al. [13] summarized empirical price elasticity estimates from over sixty studies that report estimates of own-price elasticities of both passengers and freight demand based on different databases and cover many countries and cities. Their summarized *own-price* elasticity estimates of demand for transport (automobile usage) with respect to price range from −0.52 to +0.09. This estimate indicates that the demand for automobile usage is fairly inelastic[2]. Odeck and Brathen [7] summarized existing literature and found that transport demand with respect to tolls is fairly inelastic—most of previous studies found values in the range of −0.5 to 0.0. Burris [19] found that the fixed-toll price elasticity of travel demand varied from −0.30 to −0.03.

Graham and Glaister [16] reviewed 387 short-run and 213 long-run road traffic demand elasticities with respect to fuel costs, and they reported that the mean of the 387 short-run price elasticities was −0.25 with a range of −2.13 to +0.59. The mean of 213 long-run estimates was −0.77, with a range of -22.00 to +0.85. Approximately 2 percent of each of the studied cases had positive elasticities. Lee and Burris [20] used a value of −0.16 for short-run travel impacts of fuel price changes and -0.33 for long-run impacts in the calculation of the implied travel demand elasticity with respect to fuel price changes. Crotte et al. [21] reported an estimated medium-run traffic elasticity with respect to fuel prices of −0.12 for Mexico City, Mexico.

Matas and Raymond [22] studied the elasticities of demand for various Spanish tolled motorways. The authors used a dynamic model to identify short-term and long-term responses to changes in some key variables with an emphasis on toll costs. They found that the demand was elastic with respect to the level of economic activity—represented by real national gross domestic product (GDP). The study results also indicated that travel demand was less sensitive to gas prices and tolls than it was to GDP. Their study indicated that demand elasticity with respect to gas prices for Spanish toll roads was about −0.30. Demand elasticity with respect to toll prices varied from −0.83 to −0.21. The authors indicated that differences in elasticities for various tolled roads were related to the availability and quality of the alternative free routes, length of the toll road segment, and location of the road in the neighborhood of a tourist destination.

It is often assumed that the demand for road freight was less elastic than general traffic. Goodwin et al. [17], in their review on price and income elasticities of road traffic and fuel consumption, did find that goods traffic was less sensitive to price than private cars. However, Graham and Glaister [16] found that this may not be the case. The studies they reviewed mostly produced negative, and in many cases above unity, price demand elasticity estimates for freight traffic. From the studies they reviewed, they emphasized that the price elasticity of demand for freight, with a variety of different commodities and countries, was negative and relatively elastic.

As Hirschman et al. [23] indicated, elasticities can change from one year to another, and their value may even change from one specific site to another within the same city. Our results

[2] Even though these studies were conducted for datasets from different countries, the estimates summarized are quite similar.

indicate that gas price elasticity estimates can be significantly different for different months on one toll facility.

Based on the literature, one might expect short-run elasticity of travel demand on non-toll facilities with respect to gas prices to be around −0.25. If the elasticity of travel demand on toll facilities with respect to gas prices is significantly different, then one of two things is happening:

1) If it is significantly more elastic, then the hypothesis that drivers avoid toll facilities as gas prices rise (despite this being counterproductive) is correct;

2) If it is significantly less elastic, then drivers are using toll facilities more (relatively speaking) as gas prices rise, which makes sense as most toll routes will save drivers gas.

CHAPTER 3. DATA COLLECTION AND DESCRIPTION

To estimate the price elasticity of toll road demand with respect to gas prices, this research obtained monthly/quarterly toll traffic data for the period 2000 to 2010 from toll facilities operated by 13 agencies[3] around the United States (see Table 3-1). Except for the Macquarie Atlas Roads,[4] all other traffic data were obtained directly from the toll road operating agencies. Some operating agencies had monthly traffic data covering the whole study period, while others did not have ready access to the full 10 years of data. However, datasets for all roads in this study covered at least the period 2005 to 2009. Fortunately, this included the year 2008, which is of particular interest since it is the year when the greatest fluctuation in gas prices occurred. Therefore, the sample sizes of collected toll traffic data for each toll facilities were sufficient and appropriate for further analyses. The monthly average gas price was obtained from the LexisNexis Statistical DataSets (www.lnstatistical.com).

Other data were included in an attempt to isolate the impact of gas price from other exogenous factors impacting the use of toll roads. Historical toll rates were collected from the website of each operating agency, and then adjusted by inflation to real dollars using the Consumer Price Index (CPI) for all urban consumers to reflect the real value of these costs to the travelers. Inflation adjustment is a process of adjusting the prices of goods and services from different time periods to the "constant dollars." For instance, a toll rate of 2 dollars in the 1990s was of much greater value to travelers than it is today. The inflation adjustment is accomplished by dividing a monetary time series by a price index, such as the CPI. The CPI program in the Bureau of Labor Statistics produces monthly data on changes in the prices paid by urban consumers for a representative basket of goods and services. The CPI for all urban consumers and the monthly unemployment rates were available from the website of the Bureau of Labor Statistics (www.bls.gov). In addition, recent data on number of registered vehicles were unavailable—so population was used as a surrogate measure. Because there are no available monthly data on population, linear interpolation and extrapolation of yearly data was conducted to estimate the monthly population.

Unfortunately, this study did not obtain access to the average travel time on the toll facility and any nearby toll-free facilities. The availability and attractiveness of alternate routes would have been beneficial to include, but the use of a lagged traffic volume term in the time series model helped to account for the lack of travel time data. The next chapter discusses the time series model.

[3] As noted in Table 3.1, the traffic data obtained from Illinois State Toll Highway Authority could not be analyzed due to large-scale continuous reconstruction. This resulted in using data from 12 agencies.

[4] For yearly and quarterly traffic data for the Indiana Toll Road, this study used the Revenue and Traffic Statistics published in the Macquarie Atlas Roads website (http://www.macquarie.com/mgl/com/mqa).

Table 3-1: Description of Tolled Traffic Volume Data Obtained

State	Operating Agency	Toll Road/Bridge	Traffic Data Description
California	Bay Area Toll Authority (BATA)	• Seven toll bridges in the San Francisco Bay Area	Monthly historical total traffic for July 2000 − December 2009
California	Transportation Corridor Agencies	• State Route 261 • State Route 241 • State Route 73	Monthly historical traffic by vehicle class for January 2000 − December 2009
Florida	Florida Turnpike Enterprise (FTE)	• Turnpike System Roads	Monthly historical total traffic at toll plazas for July 2001 − December 2009
Florida	Miami-Dade Expressway (MDX) Authority	• State Route 112 • State Route 836 • State Route 874 • State Route 924	Monthly historical traffic by vehicle class for July 2000 − April 2010
Florida	Orlando-Orange County Expressway Authority	• State Route 408 • State Route 417 • State Route 429 • State Route 528	Monthly historical total traffic at toll plazas for June 2003 − December 2009
Georgia	State Road & Tollway Authority	• State Route 400	Monthly total traffic for August 1993 – August 2010
Illinois	Illinois State Toll Highway Authority	• Veterans Memorial Tollway	Data could not be analyzed due to large-scale continuous reconstruction
Indiana	Macquarie Atlas Roads	• Indiana East-West Toll Road	Quarterly historical traffic by toll collection method for Q3 2006 – Q4 2009
Kansas	Kansas Turnpike Authority (KTA)	• Kansas Turnpike	Monthly historical traffic by vehicle class for January 2000 − July 2010
Maryland	Maryland Transportation Authority (MdTA)	• Harbor Tunnel Thruway	Monthly total traffic data by vehicle class for January 2003 − August 2010
New York	New York State Thruway Authority	• New York State Thruway	Monthly historical traffic by vehicle class for January 2000 − December 2009
Oklahoma	Oklahoma Turnpike Authority (OTA)	• Oklahoma Turnpike System	Monthly historical traffic (Miles Driven) by vehicle class for January 2000 – September 2010
Texas	Harris County Toll Road Authority (HCTRA)	• Hardy • Sam Houston	Monthly historical traffic by toll plaza for January 2000 – December 2009

CHAPTER 4. EMPIRICAL TIME SERIES ECONOMETRIC MODEL

To build a model that is applicable for multiple datasets from different toll facilities, this study first used the dataset from the San Francisco Bay Area as the test of the modeling procedures. Due to the properties of this time series data, modeling with this dataset made an excellent example of how potential spurious regression and serial correlations in the residuals were handled. The model generated from this specific dataset was tested to see if it could serve as a master model for the datasets collected from other toll roads. In this chapter, the properties of the collected time series data from San Francisco are introduced first, followed by a discussion of empirical econometric models based on two modeling techniques: conventional time series analysis and genetic algorithm (GA) modeling methods. Comparisons of the performance of these two methodologies indicate that the conventional time series analysis performed as good as the GA with the additional advantage of being much easier to interpret the results. Therefore, this study chose to use conventional time series modeling on all datasets. The next chapter includes the results of conventional time series modeling on all datasets using the model developed in this chapter.

4.1 Time Series Properties of the Data (San Francisco)

Monthly traffic volume data for the period July 2000 to December 2009 in the San Francisco Bay Area were used for the preliminary analysis and model development. It is the total toll traffic volume of 2-axle vehicles for seven toll bridges in the area. Upon examination, a plot of the data (see Figure 4-1) reveals strong seasonality in the monthly traffic volume data. Since this study investigates the impact of variation of gas prices on toll facility traffic volume, seasonal factors influencing the use of toll bridges needs to be accounted for before causality analyses. Seasonal Adjustment Methods X11was developed by the U.S. Census Bureau and was initially used in the United States in 1965 [24] to estimate the seasonal component of the time series data. The deseasonalized monthly traffic volume was then used in model estimation[5]. Figure 4-1 also presents the seasonal component and deseasonalized monthly traffic volume. Other data collected for the period July 2000 to December 2009 include: monthly gas price averages for the San Francisco-Oakland-San Jose metropolitan statistical area (MSA) (Figure 4-2, source: www.lnstatistical.com); CPI for All Urban Consumers[6] (Figure 4-3, source: www.bls.gov); nominal toll rates (source: http://bata.mtc.ca.gov/) and the CPI-adjusted toll rates in real dollars[7] (Figure 4-4); and unemployment rates (Figure 4-5, source: www.lnstatistical.com) in the San Francisco Metropolitan Area. There is a clear upward trend in gas prices for the period between the end of 2001 and the middle of 2008, followed by a big drop, and then another rise. There were two toll increases during the study period, as shown in the plot of nominal toll rates (Figure 4-4), and the toll rates in real dollars were obtained by dividing nominal toll rates by the CPI. It is obvious that the San Francisco-Oakland-Fremont area in California lost many jobs during the period 2007 to 2009 (Figure 4-5).

[5] Some time series regressions used the unadjusted traffic data due to a serial correlation problem in the residuals or/and extremely low Goodness-of-Fit. Techniques introduced in this chapter may not be able to eliminate the serial correlation; in that case modeling on the original traffic data with monthly dummy variables was used.

[6] As the CPI provided by the Bureau of Labor Statistics was available for only the even months in each year, the CPI for odd months were obtained by taking the means of two neighboring even months.

[7] CPI for period 1982-84 (1982-84 = 100) was used as the base period for calculating the values in real dollars.

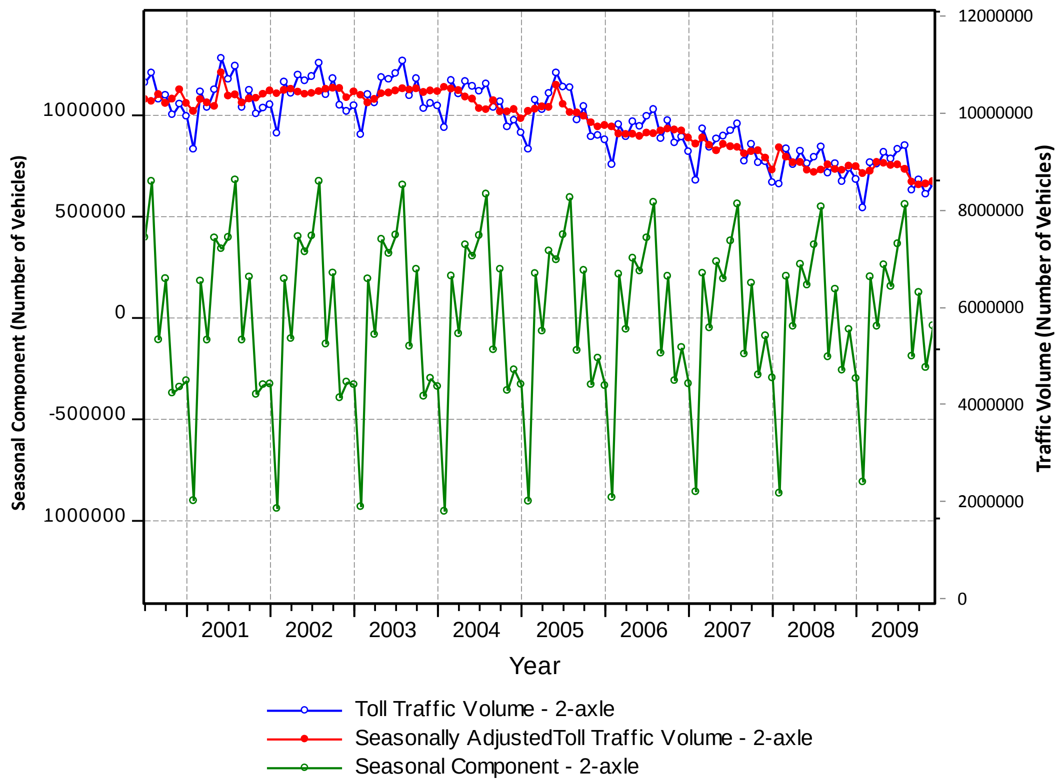

Figure 4-1: Monthly Toll Traffic Volume for 2-Axle Vehicles (Seven Bridges in San Francisco)

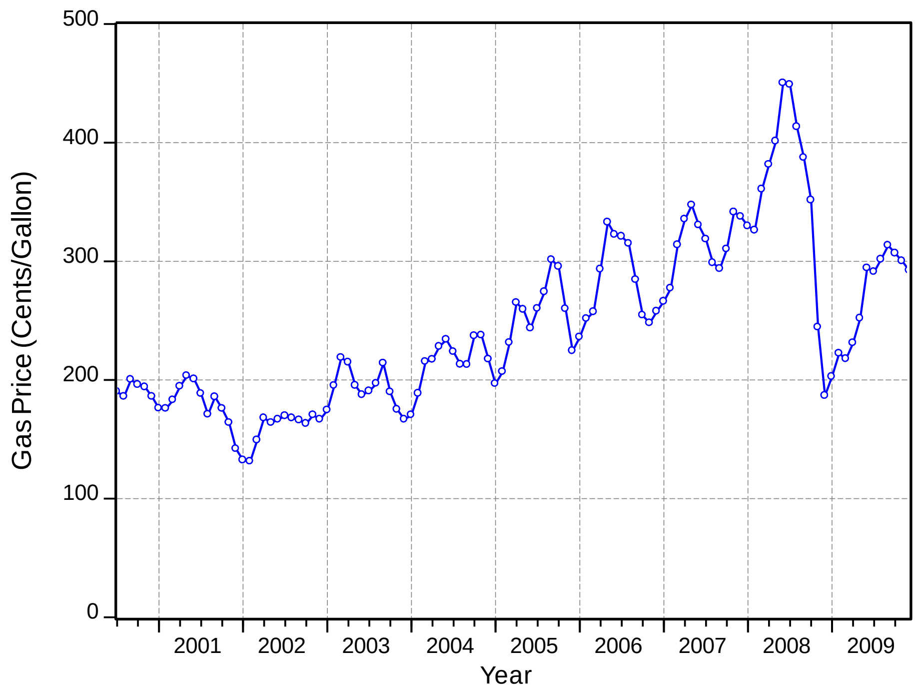

Figure 4-2: CPI-Adjusted Monthly Average Gas Price (All Types, MSA: San Francisco-Oakland-San Jose)

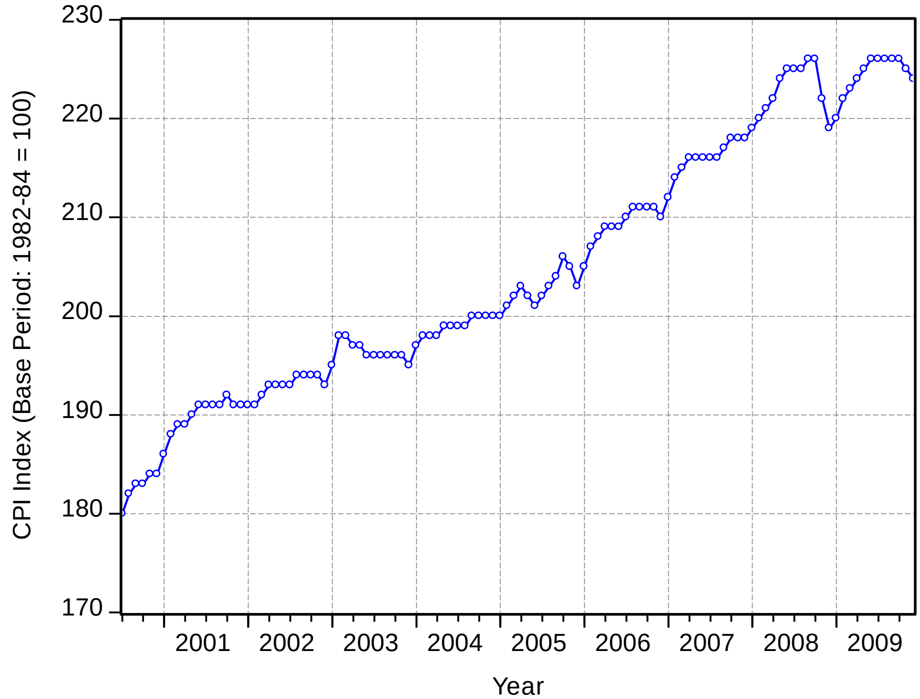

Figure 4-3: Unadjusted CPI All Urban Consumers (MSA: San Francisco-Oakland-San Jose)

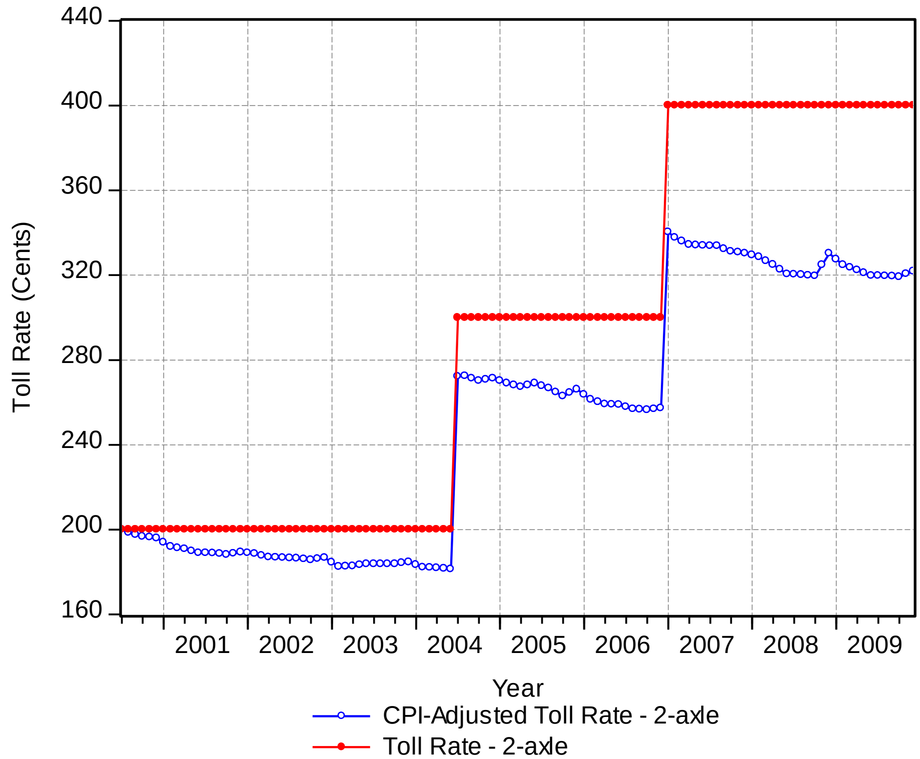

Figure 4-4: Nominal Toll Rates (2 Axles) and CPI-Adjusted Toll Rates (San Francisco Toll Bridges)

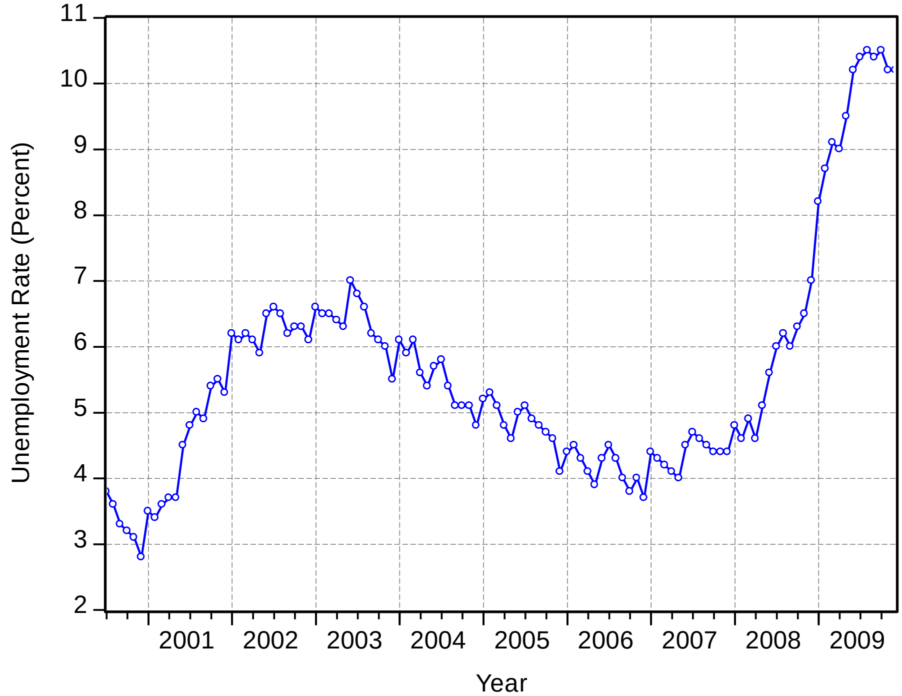

Figure 4-5: Monthly Unemployment Rates (MSA: San Francisco-Oakland-Fremont, California)

The autocorrelation plots (see Figure 4-6) of toll traffic volume (Series LogTollVol for the logarithm of the original series and Series LogTollVolSA for the logarithm of the seasonally adjusted series), gas prices (Series LogGAS for the logarithm of gas prices), toll rates (Series LogTollRate for the logarithm of CPI-adjusted toll rates in cents), and unemployment rates (Series UEMP) in the metropolitan area suggest the presence of a unit root in each series. If a process has a unit root, then it is a non-stationary time series indicating the moments of the stochastic process depend on time. Use of ordinary least squares (OLS) requires data being stationary stochastic processes. If the stochastic process is non-stationary, then use of OLS can produce invalid estimates. The Elliott-Rothenberg-Stock unit root test [25] statistics failed to reject a unit root for each series.

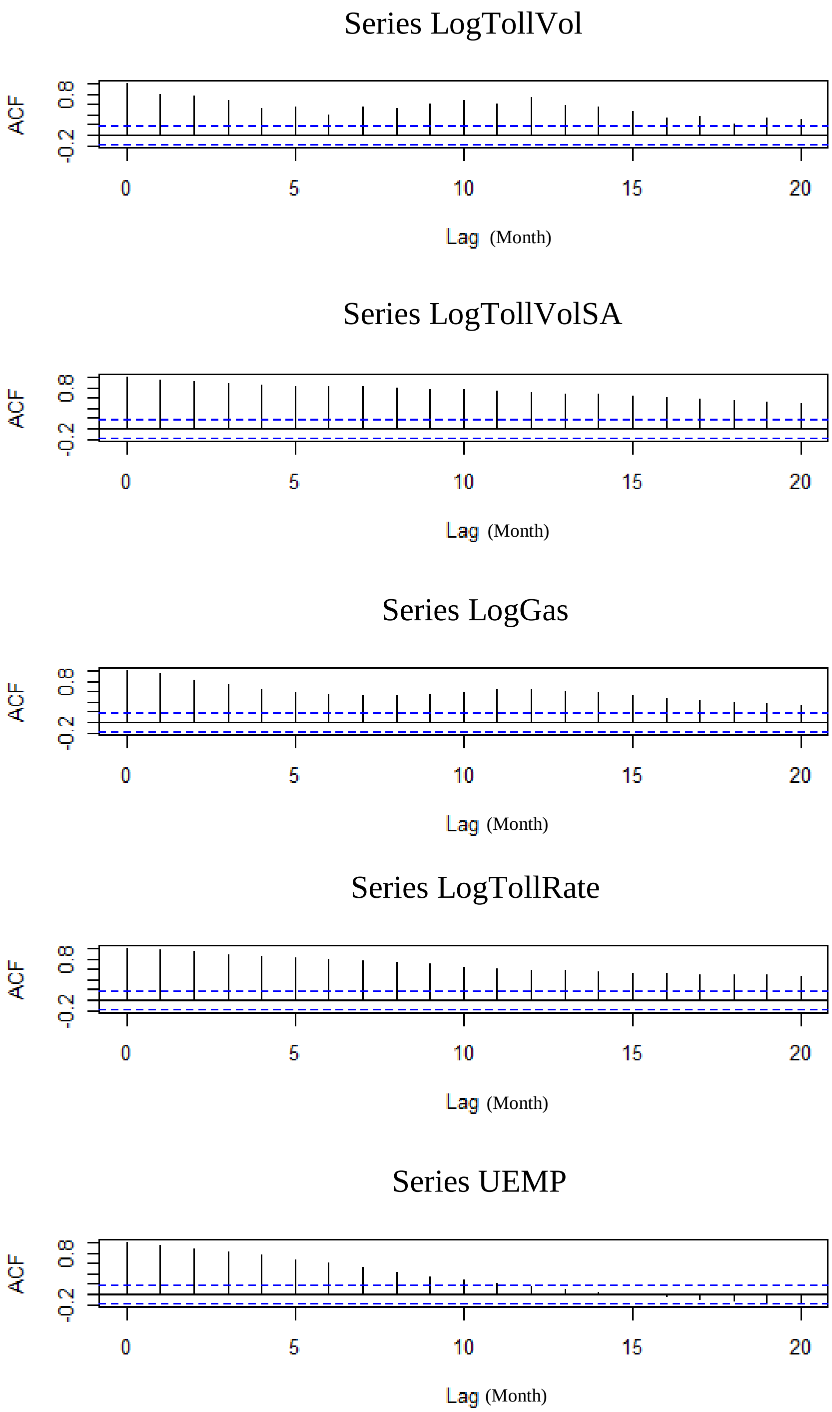

Figure 4-6[8]: Autocorrelation Plots of the Logarithm of Toll Traffic Volume, Logarithm of Gas Price, Logarithm of Toll Rates, and Unemployment Rates (San Francisco, California)

[8] ACF: Autocorrelation Function. Blue dotted lines are the tolerance levels for autocorrelation of the series. For example, to consider a series stationary, the ACF values of all order lags need to be within the tolerance intervals.

4.2 Autoregressive Distributed Lag (ADL) Model

Lagged effects of economic variables are well identified and are the primary reason for the use of an autoregressive distributed lag (ADL) model in this study. For instance, the increase in gas price in the short term, say one or two weeks, might not change the travelers' behavior immediately following the price change. It might take a month or longer for travelers to adjust their travel route or use an alternate transport mode such as switching to public transit. The same lagged effect also applies to the change in the toll rate. The lagged effect could also be partially caused by the consumer's inertia. For example, the toll facility users might get used to using the toll facility for the convenience and time savings it provides. Even in a situation with increasing toll cost, the consumer's inertia might keep the toll facility users on the toll facility even when another alternative becomes a better option. Consumers' inertia has been widely discussed in the field of behavioral operations [26-30]. The lagged impact of changing costs can be measured by inclusion of lagged gas price and toll rate in the model.

Many factors, for example, psychological, income level, vehicle occupancy level, urgency of the trip, traffic congestion level, etc. may have a significant impact on the decision to use the toll facility. However, information on many of those factors is difficult to collect and quantify. Excluding these factors in the analysis may generate inaccurate estimation of elasticity of toll road use with respect to the change in gas price. By introducing the lagged dependent variable (toll traffic volume) in the equation, the impact of most excluded factors could be captured as the coefficient of previous traffic volume for near-term future time periods. This specification (model with a lagged dependent variable) also provides estimates of short-run and long-run elasticities as long as the coefficient for the lagged dependent variable is less than 1.0.

The autoregressive lag model of order p and n, ADL(*p*,*n*) (see Equation 4-1), is defined as:

$$y_t = c + \sum_{i=1}^{p} a_i y_{t-i} + \sum_{j=0}^{n} \beta_j x_{t-j} + u_t$$

$$E(u_t) = 0, (t = 1, ..., N)$$

$$Cov(u_t, u_s) = \delta_{st}\sigma^2, (s, t = 1, ..., N)$$

Equation 4-1

Where:

- y_t = a scalar variable (such as the traffic volume);
- c = the regression intercept;
- u_t = a scalar zero mean error term;
- x_t = a vector of explanatory variables observed at time t (such as the price of gas);
- p and n = the number of order of lags for y and x;
- u_t and u_s = the error term at time t and s, respectively;
- a_i and β_j = coefficient estimates; and
- σ = the standard deviation.

This class of rational distributed lag function was first defined by Jorgenson [31]. The autoregressive lag model is a dynamic single-equation regression and is a member of the class of rational distributed lag functions. This model is particularly attractive for its error-correction (EC) in applied time series econometrics; for instance, an ADL(*1*,*1*) model as shown below:

$$y_t = c + \alpha_1 y_{t-1} + \beta_1 x_t + \beta_2 x_{t-1} + \varepsilon_t \qquad \text{Equation 4-2}$$

After rearranging, we obtain:

$$\Delta y_t = c + \beta_1 \Delta x_t + (\alpha_1 - 1)\left(y - \frac{\beta_1 + \beta_2}{1 - \alpha_1} x \right)_{t-1} + \varepsilon_t \qquad \text{Equation 4-3}$$

In this form, we have an equilibrium relationship, $\Delta y_t = c + \beta_1 \Delta x_t + \varepsilon_t$, and the equilibrium error, $\left(y - \frac{\beta_1 + \beta_2}{1 - \alpha_1} x \right)_{t-1}$, which account for the deviation of the pair of variables from that equilibrium. The change in y_t from previous period consists of the change associated with movement along the long-run equilibrium path plus a part $(\alpha_1 - 1)$ of the deviation $\left(y - \frac{\beta_1 + \beta_2}{1 - \alpha_1} x \right)_{t-1}$ from the equilibrium [32]. 0 shows the mechanism of how the EC model works.

The autocorrelation plots of all the collected time series suggest that the time series data were not stationary, and regression with non-stationary processes violates the OLS assumptions and is subject to spurious regression [33]. Durlauf and Phillips [34] indicated that "*Traditional Analyses of Economic time series frequently rely on the assumption that the time series in question are stationary,…….*" However, it turned out for non-stationary variables that cointegration is equivalent to an EC mechanism as formalized by Engle and Granger [35]. Non-stationary series are called *integrated of order n* if the series become stationary when differenced *n* times. A set of series, all integrated of order *n*, are cointegrated if and only if a linear combination of the non-stationary series (with nonzero weights only) is integrated of order less than *n*. Preliminary data statistics revealed that the monthly toll traffic volume, gas price, toll rates and unemployment rates are integrated of order one *I(1)*, and a cointegration test indicated that there was a cointegrating relationship between the dependent (toll traffic time series data) and independent variables. As a consequence, our model could use the non-stationary series in the ADL model due to the cointegrating relationship between included variables.

Serial correlation in time series regression is not an unusual problem. The presence of serial correlation in regression residuals violates the standard assumption of regression theory that disturbances are not correlated with other disturbances. If serial correlation is present, then the following occur: the OLS is no longer efficient among linear estimators; standard errors computed using OLS are generally understated and OLS estimates in Equation 4-1 are biased and inconsistent with the inclusion of lagged dependent variables on the right-hand side. The Durbin-Watson statistic is not appropriate as a test for serial correlation in this case and the correct tests to check for serial correlation are Ljung-Box Q Test and Breusch-Godfrey Serial Correlation LM Test [36]. To account for the presence of serial correlation, as a preliminary treatment, the regression with autoregressive process of order p error is added in the regression, as given by Equation 4-4.

$$y_t = c + \sum_{i=1}^{p} a_i y_{t-i} + \sum_{j=0}^{n} \beta_j x_{t-j} + u_t \quad \text{Equation 4-4}$$
$$u_t = \sum \rho_i u_{t-i} + \varepsilon_t \ \ (i = 0,1,2,3,.....n)$$

Where:

- $\rho_i u_{t-i}$ = the autoregressive process of order i (AR(i)),
- u_t = a disturbance term with zero mean, and
- ε_t = the innovation in the disturbance.

With all other terms as described previously, $\rho_1 u_{t-1}$ is defined as AR(*1*), $\rho_2 u_{t-2}$ AR(*2*), and $\rho_p u_{t-p}$ AR(p), etc. u_t is a disturbance term with zero mean, and ε_t is the innovation in the disturbance. The disturbance, u_t, is termed the unconditional residual that is based on the structural component ($a_i y_{t-i} + \beta_i x_{t-j}$) but not using the information contained in u_{t-i}. The innovation is also known as the *one-period ahead forecast error* or the *prediction error*. It is the difference between the actual value of the dependent variable and a forecast made on the basis of the independent variables and the past forecast errors [36]. The autocorrelations of the stationary autoregressive process of order p gradually die out to zero and the partial autocorrelations for a lag larger than p are zero. Each AR term corresponds to the use of a lagged value of the residual in the forecasting equation for the unconditional residual. An AR model will be estimated using nonlinear regression techniques that will generate nonlinear least squares estimates that are asymptotically equivalent to maximum likelihood estimates and asymptotically efficient [36]. For instance, an AR(*1*) model (see Equation 4-5) will be transformed into the nonlinear model (see Equation 4-6). The coefficients ρ and β are estimated simultaneously by applying a Marquardt nonlinear least squares algorithm to the transformed equation [36]. Higher order AR specifications are handled analogously.

$$y_t = x_t \beta + u_t \quad \text{Equation 4-5}$$
$$u_t = \rho_1 u_{t-1} + \varepsilon_t$$

$$y_t = \rho y_{t-1} + (x_t - \rho x_{t-1})\beta + \varepsilon_t \quad \text{Equation 4-6}$$

The presence of serial correlation might also indicate signs of misspecification. If the inclusion of an AR(p) process does not fix the problem, including additional, improperly excluded variables to the regression might help eliminate the serial correlation.

4.2.1 Conventional Time Series Analyses

For this section the data from San Francisco were used in the ADL model discussed in the previous section. The lagged effect of the change in gas price, toll increases, and unemployment rate were not statistically significant in an interpretable sense, as indicated by including various combinations of different order of lags for the four independent variables. This led to the final model, as shown in Equation 4-7:

$$\text{Log}(\text{TollVol}_t) = c + a_1\text{Log}(\text{TollVol}_{t-1}) + \beta_1\text{Log}(\text{Gas}_t) + \beta_2\text{Log}(\text{TollRate}_t) + \beta_3\text{UEMP}_t + \beta_4\text{Log}(\text{Pop}_t) + u_t \quad \text{Equation 4-7}$$

Where:

- *Log*($TollVol_t$) denotes the logarithm of seasonally adjusted toll traffic volume in month t (note that in two cases, the Indiana Toll Road and Oklahoma Turnpike System, the quarterly number of toll transactions and miles driven, respectively, were used in above equation);
- *Log*($TollVol_{t-1}$) denotes the 1^{st} lag of *Log*($TollVol_t$);
- *Log*(Gas_t) denotes the logarithm of retail price of gas in month t for the specific metropolitan area/state/region;
- *Log*($TollRate_t$) denotes the logarithm of the CPI-adjusted toll rate in month t for the toll facilities;
- $UEMP_t$ denotes the unemployment rate in month t for the specific metropolitan area/state/region;
- *Log*(Pop_t) denotes the logarithm of the population of the metropolitan area/state/region where the toll facility is located in period t; and
- u_t denotes an error term with a mean of zero.

Equation 4-8 shows regression results. Numbers in the parentheses are standard errors. The adjusted R^2 is relatively high: 0.96, which indicates that the model explained about 96 percent of the variation of the toll traffic volume. All coefficients except unemployment rate are statistically significant at a 1 percent level.

$$\begin{aligned}\text{Log}(\text{TollVolSA}_t) = \underset{(7.44)}{39.38} + \underset{(0.08)}{0.46}\times\text{Log}(\text{TollVolSA}_{t-1}) - \underset{(0.01)}{0.03}\times\text{Log}(\text{Gas}_t) \quad \text{Equation 4-8}\\ - \underset{(0.01)}{0.05}\times\text{Log}(\text{TollRate}_t) - \underset{(0.001)}{0.001}\times\text{UEMP}_t - \underset{(0.40)}{1.92}\times\text{Log}(\text{Pop}_t) + u_t\end{aligned}$$

$$n = 114, \text{Adjusted-}R^2 = 0.96, \text{AIC: } -5.44$$

The adjusted R^2 is relatively high: 0.96, which indicates that about 96 percent of the variation of the toll traffic volume has been explained by the model. All coefficients are statistically significant at a 5 percent level.

The inclusion of population as an explanatory variable in the model served as an instrument for general traffic growth in the area where the toll facility was located. Including population in the equation, as its coefficient was statistically significant, helped improve the overall goodness-of-fit (GOF) of many models. However, for the model above the elasticity estimate with respect to population was −1.92. This is counterintuitive since this would indicate that as population grew the use of the toll bridges decreased.

Another example of this problem, one that may be more illustrative than the San Francisco example, was from SR 112 in Miami (see Chapter 5.5 for details of this facility). On SR 112, the elasticity of demand with respect to population for 2-axle vehicle cash-paying customers was statistically significant and negative (−2.08), while it was significant and positive for electronic toll collection (ETC) customers (+9.04). This is an example of spurious regression as the large positive estimate generated from the model for ETC customers is very misleading. The model is attributing the increase in ETC patrons to the growth in population instead of the actual primary force – a large amount of customers switched payment method from cash to ETC during the sample period[9] (see Figure 4-7). Similarly, the decrease in cash-paying customers was obviously not due to a growth in population. For any of the analyses of the different toll facilities, if the population was suspected of providing a spurious regression then the population was then excluded from Equation 4-8, resulting in Equation 4-9.

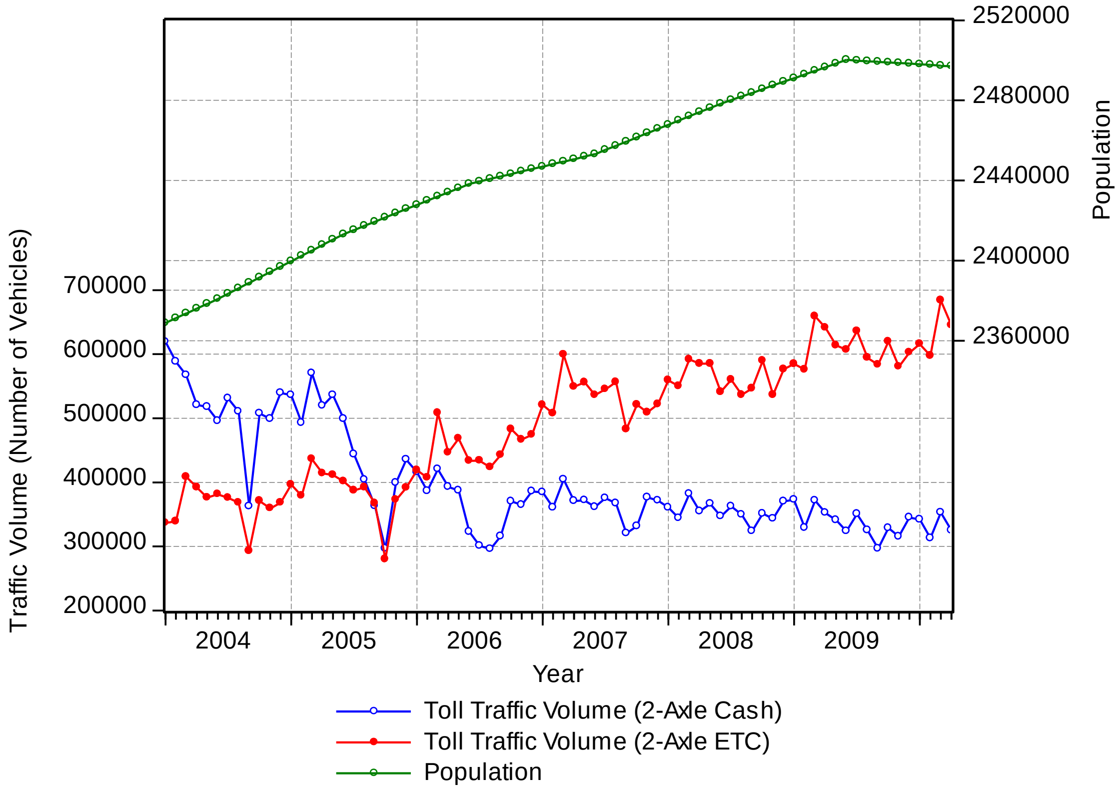

Figure 4-7: Population, Traffic Volume of 2-Axle Vehicle (Cash and ETC) for SR112 in Miami-Dade County, Florida

[9] Mr. Chad Huff, the public information manager for Florida's Turnpike, indicated that a 2004 toll rate increase that was only for cash paying customers resulted in a significant increase in ETC participation in subsequent years.

$$\text{Log}(\text{TollVolSA}_t) = \underset{(0.92)}{3.71} + \underset{(0.05)}{0.79} \times \text{Log}(\text{TollVolSA}_{t-1}) - \underset{(0.01)}{0.02} \times \text{Log}(\text{Gas}_t)$$ Equation 4-9

$$- \underset{(0.02)}{0.04} \times \text{Log}(\text{TollRate}_t) - \underset{(0.001)}{0.003} \times \text{UEMP}_t$$

$$n = 113, \text{ Adjusted-}R^2 = 0.95, \text{ AIC: } -5.26$$

A plot of the regression residuals reveals that it is a stationary process that is confirmed by the Elliott-Rothenberg-Stock (ERS) Point-Optimal Unit Root Test [36]. The White Heteroskedasticity test statistics (F-statistics: 0.88 with probability 0.87, Obs*R-squared: 3.20 with probability 0.87) cannot reject the null hypothesis that there is no heteroskedasticity in the regression residuals. Since the Durbin-Watson statistic is invalid in the presence of lagged dependent variables on the right side of the regression equation, the more general Ljung-Box Q-statistics and/or Breusch-Godfrey LM test is needed to test for serial correlation in the residuals. The Ljung-Box Q-statistics and Breusch-Godfrey LM test for high-order serial correlation at lag 1 through lag 10 reject the null hypothesis of no serial correlation and the corresponding p-value indicates the presence of serial correlation in the residuals.

As discussed in the beginning of Section 4.2, the introduction of an AR(*p*) might correct for residual serial correlation. The Ljung-Box statistics indicate that the introduction of an AR(*3*) into Equation 4-9 helped reduce, if not eliminate, the serial correlation in the regression residuals. Equation 4-10 includes the regression results with AR(*3*) that indicates that the current disturbance is correlated with the disturbance three time periods ahead. u_{t-3} is the regression disturbance from previous period, as defined in Equation 4-4. The adjusted R^2 is 0.95, and all coefficients are statistically significant at a 5 percent level with smaller Akaike info criterion (AIC) value. The AIC provides a means for comparison among models—a tool for model selection. The AIC includes a penalty discouraging over fitting and attempts to find the model, among a candidate set of models that best explains the data with the fewest parameters. The smaller the AIC the better the model is.

$$\text{Log}(\text{TollVolSA}_t) = \underset{(1.03)}{4.01} + \underset{(0.06)}{0.78} \times \text{Log}(\text{TollVolSA}_{t-1}) - \underset{(0.03)}{0.08} \times \text{Log}(\text{Gas}_t)$$ Equation 4-10

$$- \underset{(0.04)}{0.11} \times \text{Log}(\text{TollRate}_t) - \underset{(0.001)}{0.003} \times \text{UEMP}_t + u_t$$

$$u_t = 0.20 \times u_{t-3} + \varepsilon_t$$

$$n = 113, \text{ Adjusted-}R^2 = 0.95, \text{ AIC: } -5.28$$

A comparison of Equation 4-9 and Equation 4-10 shows that the inclusion of AR(*3*) term improves the model in terms of the adjusted R^2 and the Akaike info criterion. The Ljung-Box Q-statistics (with P-values of up to 3 to 36 lags not statistically significant at 10 percent level) indicate that the serial correlation in regression residuals was alleviated by introducing the AR term.

Given the presence of a unit root for each series of data (see Figure 4-6), this ADL model (Equation 4-10) may be considered a cointegrating regression model. If no cointegration relationship exists, then estimates with non-stationary series using OLS can be invalid. Granger and Newbold [33] called such estimates 'spurious regression' results. The cointegration test shows that there is a cointegration relationship at a 5 percent significance level. As all included variables are integrated of order one, *I(1)*, then our model could just use the non-stationary series in the OLS regression due to the cointegrating relationship between included variables. A residual plot (Figure 4-8) and Elliot-Rothenberg-Stock tests (P-Statistic: 2.27) of the residuals suggest that the residuals are stationary at a 5 percent significance level. The revised model (Equation 4-10) is, therefore, better in explaining variations (higher adjusted R^2). A lower AIC value also suggests the superiority of this model. As a consequence, Equation 4-11 (same as Equation 4-10, but without the estimated coefficients) was an appropriate model for further use, where *n* is the number of observations. This model will be the time series model for all toll traffic data gathered from all 12 toll agencies. The value of *i* in Equation 4-11 is determined by the order of the included AR term that would help reduce serial correlations in the residuals.

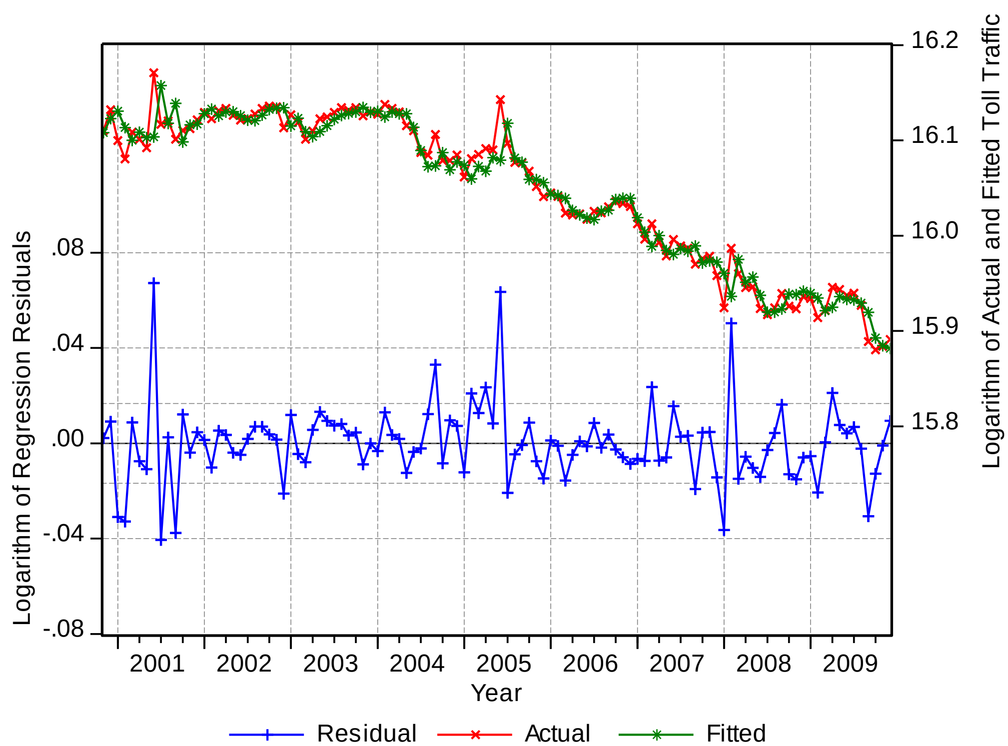

Figure 4-8: Actual (Seasonally Adjusted), Fitted Toll Traffic Volume and Regression Residual for ADL AR(3) Model

$$\begin{aligned} \text{Log(TollVolSA}_t) &= c + a_1\text{Log(TollVolSA}_{t-1}) + \beta_1\text{Log(TollGas}_t) \\ &+ \beta_2\text{Log(TollRate}_t) + \beta_3\text{UEMP}_t + \beta_4\text{Log(Pop}_t) + u_t \\ u_t &= \sum \rho_i u_{t-i} + \varepsilon_t \quad (i = 0,1,2,3,.....n) \end{aligned}$$

Equation 4-11

4.2.2 Genetic Algorithm

The genetic algorithm is a search heuristic that mimics the process of natural evolution and was invented by Holland [37]. Holland presented a mathematical model that allows for the nonlinearity of complex interactions such as adaption of a biological process where organisms evolve by rearranging genetic material to survive in environments confronting them [37]. The adaptation incorporates combinations of selection, recombination and mutation to evolve a solution to a problem. The genetic algorithm starts from an initial population of potential solutions consisting of elementary equation strings. Within each generation level, the strongest strings choose a mate for reproduction whereas the weaker strings become extinct. The newly generated population is subjected to mutations that change fractions of information. The evolutionary steps are repeated with the new generation. The process ends either when reaching the target fitness (e.g., to reduce a model's sum of squared errors or root mean squared error on a dataset to a certain preset value) or other stopping criterion (e.g., the change in coefficients is less than 0.1 percent) specified by the user.

Genetic programming (GP) is a GA-based machine learning method that implements random population generation of tree structures (see Figure 4-9 for a function represented as a tree structure) and then develops mutations and crossovers for the best performing trees to create a new population. This process is iterated until the evolved population contains programs that reached the preset target fitness. Instead of specifying the structure of the mathematical model as required by traditional regression analyses, the GP automatically evolves both the structure and the parameters of the mathematical model. However, the structure of the model in this study was constrained to be a linear one which has been adopted by other similar empirical studies [38, 39]. Only two basic arithmetic operators (addition and subtraction) and real number constants were included in the symbolic linear regression to compare with the conventional time series analyses techniques and so that the resulting parameters would have clear real-world meanings as to their impact on toll road use. The criterion that measures how well the equation strings perform on a training set of the data is its fitness to the data, defined as root mean squared error (RMSE) (see Equation 4-12) between the predicted value ($\hat{y}_i$) and the actual value (y). The objective of the GP is in fact an error minimization problem.

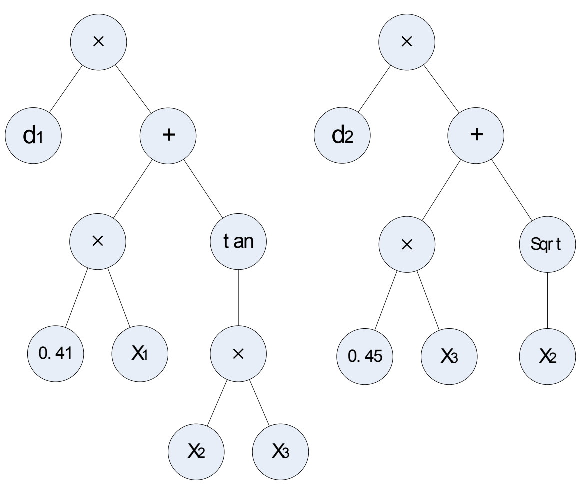

Figure 4-9: Example of Tree Structure and a Multigene Symbolic Model

Source: Searson, et al. [40]

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}$$ Equation 4-12

Where:

- $\hat{y}_i$ = the estimated value at time point *i*,
- y_i = the actual value at time point *i*, and
- n = the number of observations.

The GA in this study is implemented in a modeling tool called GPTIPS, which is developed by Searson et al. [40]. It is a free, open source MATLAB toolbox for performing symbolic regression by genetic programming. "GPTIPS is specifically designed to evolve mathematical models of predictor response data that are "multigene" in nature" [40]. A multigene individual consists of two or more genes, each of which is a "traditional" GP tree [41]. In GPTIPS, genes are acquired incrementally by individuals in order to improve fitness (e.g., to reduce a model's RMSE on a dataset). For example, the multigene model shown in Figure 4-9 predicts an output variable using input variables x_1, x_2 and x_3. The resulting prediction equation is, therefore, of this form (the weights d_1 and d_2 are automatically obtained by least squares), as in Equation 4-13:

$$y = d_0 + d_1(0.41x_1 + \tanh(x_2x_3)) + d_2(0.45x_3 + sqrt(x_2))$$ Equation 4-13

The overall model is a weighted linear combination of each gene. In GPTIPS, "the optimal weights for the genes are automatically obtained using ordinary least squares to regress the genes against the output data" [40]. The predicted formula will depend on the number of genes used so that the form of the estimated model, in the case of 2 genes, will be as shown in Equation 4-14, where d_0 is the bias term and d_1 and d_2 are the weights. According to Searson et al. [40], the bias and weights (regression coefficients) are automatically determined by a least squares procedure for each multigene individual. A single final function that predicts the output using the selected inputs is generated from combining the gene expressions with the gene weights (regression coefficients). Measurements of goodness-of-fit of the model: R^2 (see Equation 4-15) and adjusted R^2 (see Equation 4-16) can be calculated for each individual run.

$$\hat{y}_i = \mathrm{d}_0 + \mathrm{d}_1 \times \mathrm{tree}_1 + \mathrm{d}_2 \times \mathrm{tree}_2$$ Equation 4-14

$$R^2 = 1 - \frac{\sum_{1}^{n}(\hat{y} - y_i)^2}{\sum_{1}^{n}(\bar{y} - y_i)^2}$$ Equation 4-15

$$Adjusted - R^2 = 1 - (1 - R^2)\left(\frac{n-1}{n-k-1}\right)$$ Equation 4-16

Where:

- d_0 = bias term,

- $d_{(1,2)}$ = weights of individual gene tree,
- $\hat{y}_i$ = the estimated value at time point *i*,
- y_i = the actual value at time point *i*,
- $\bar{y}$ = average value of all y_i ,
- *n* = the number of observations, and
- *k* = number of independent variables.

Due to the grid search characteristic for an optimal solution of the GP, the outcomes of each individual run generated by the program are different but eventually converge in a relatively small interval. One estimated result from GPTIPS is shown in Figure 4-10 with plots of actual, fitted tolled traffic volume. The estimated formula for tolled traffic volume is as shown in Equation 4-17. Figure 4-11 shows the plots of the best (log values) and mean fitness over the course of a GPTIPS run. The best fitness with 0.0161 was found at generation 94. The goodness-of-fit indicators (R^2 and adjusted R^2 in this case) indicate that the GP generated a linear model comparable to the one estimated by conventional time series analyses (ADL model in this study).

$$\text{Log}(\text{TollVolSA}_t) = 3.27 + 0.81 \times \text{Log}(\text{TollVolSA}_{t\text{-}1}) - 0.09 \times \text{Log}(\text{Gas}_t) - 0.10 \times \text{Log}(\text{TollRate}_t) - 0.003 \times \text{UEMP}_t \quad \text{Equation 4-17}$$

$$n = 113,\ R^2 = 0.96\ \text{Adjusted-}R^2 = 0.95$$

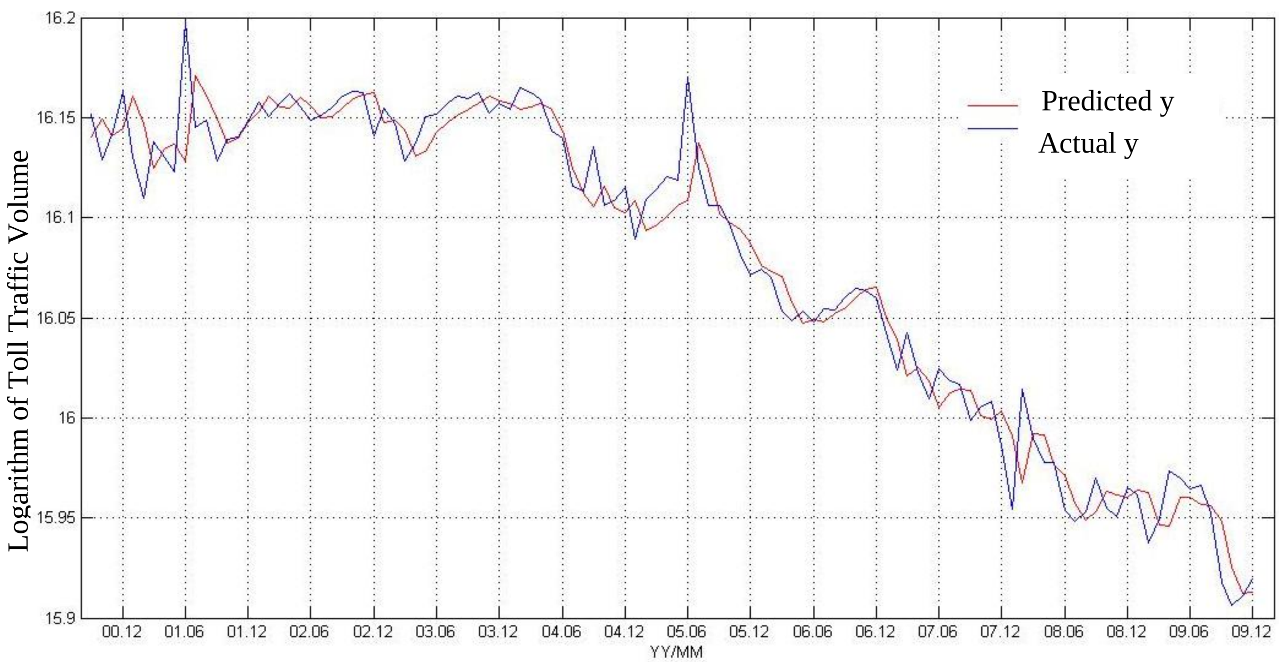

Figure 4-10: Actual, Fitted Toll Traffic Volume (in logarithm) from Estimation Using GPTIPS

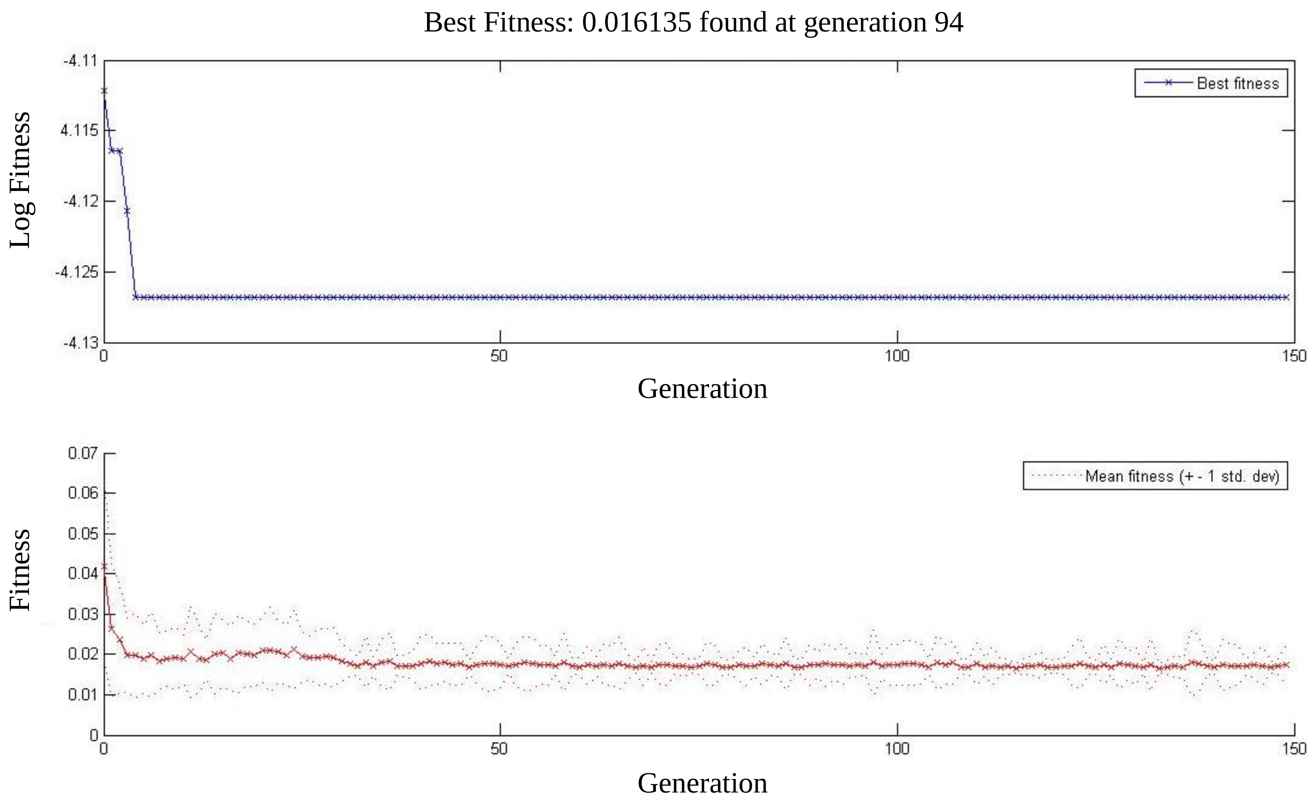

Figure 4-11: The Best (log Values) and Mean Fitness over the Course of a Run

4.2.3 Comparison of the Two Modeling Techniques

As mentioned previously, the GP generated a linear model comparable to the one estimated by conventional time series analyses (ADL model in this study). However, the variation of the GOF and estimates for each GP result makes it arbitrary to decide which estimates would be the final model to use. Also, the revised ADL model actually has higher GOF indicators. Appendix B presents estimated solutions for 100 trials for the fitted model using the dataset of San Francisco. For those two reasons with the additional advantage of being much easier to interpret the results, and for easier comparison to previous research, this study chose to use the conventional time series analyses.

CHAPTER 5. RESULTS AND ANALYSES OF EMPIRICAL TIME SERIES MODELS

This chapter includes the time series analyses results for datasets collected from all toll facilities listed in Table 3-1. Toll traffic data were obtained for toll facilities operated by 13 agencies. However, the traffic data were not in a uniform format: some were simply the summation of traffic volumes for all vehicles on a specific toll road, some were traffic volume differentiated by vehicle class for all toll facilities operated by a single agency, and others were toll traffic for different toll collection booths along a corridor. Therefore, the model developed in Chapter 4 was applied based on the characteristics of each agency's traffic data. For example, if the traffic data were differentiated by vehicle class, then the model was applied on individual classes and compared the elasticity estimates among different vehicle classes. Based on the extremely low GOF in some regression equations, the actual toll traffic data, not the seasonally adjusted data, were used to verify the validity of the ADL model. In these cases, an ADL model with 11 dummy variables representing 11 months of the year were used to take care of any seasonal effects.

This chapter starts with an introduction of the concept of elasticity, followed by 12 sections plus one concluding section. Each section starts with a description of the data collected from that toll agency, followed by the model estimates for the toll facilities operated by a specific agency. Toll traffic consisted primarily of 2- and 5-axle vehicles for nineteen toll roads/bridges operated by six agencies[10] and generally comprises the majority of vehicles. Demand elasticity estimates of toll road use (for 2- and 5-axle vehicles for the entire sample period) with respect to gas price, toll rate, unemployment rate and population are summarized and discussed in the concluding section. For facilities where traffic was not differentiated by vehicle class, results are for all vehicles combined.

To achieve our research objective—estimate the impact of rising gas prices, in particular for the two-year period from 2006 to 2008 when the gas price rapidly increased (see Figure 5-1)—we also estimated the time series regression on only a portion of the dataset (October 2006 to July 2008). By comparing elasticity estimates for the entire sample period versus this 2-year period, it was possible to check if toll facility users' behavior changed during the period when the price of gas rapidly increased. The results are also discussed at the end of this chapter.

[10] This study obtained traffic volume data by vehicle classes from six operating agencies. Data from the other six agencies were combined traffic volume for all vehicle classes.

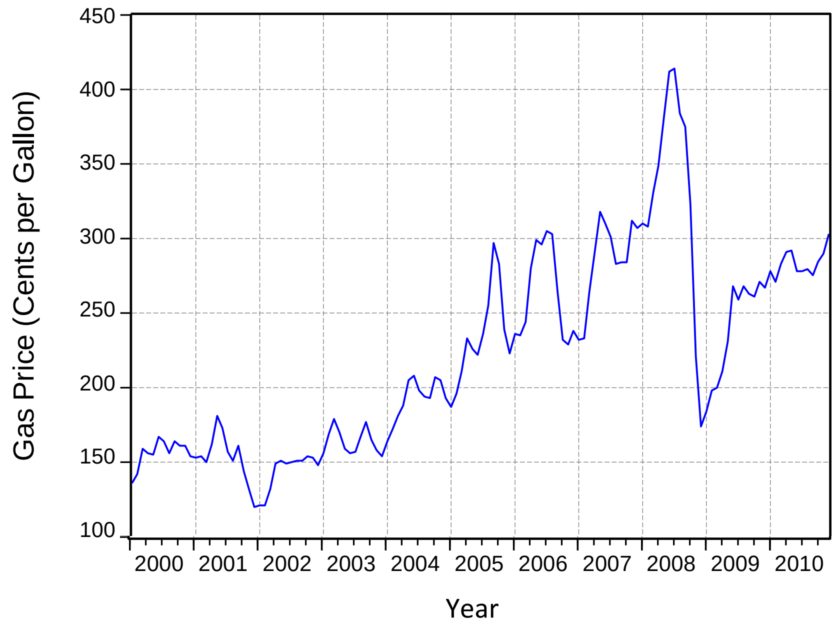

Figure 5-1: Monthly CPI-Adjusted Average Gas Price (All Types, the United States)

5.1 Concept of Elasticity

Before examining the time series regression results, this section first introduces the price elasticity of travel demand, as shown in Equation 5-1. This equation relates the changes in overall price of travel ($Price_2 - Price_1$) to a corresponding change in traffic volume ($TollVol_2 - TollVol_1$) caused by the price change. Coefficient estimates (β_1, β_2, β_3, and β_4) from Equation 4-11 all are elasticities of travel demand with respect to change in gas price, toll rates, unemployment rates[11] and population, respectively. For example, the coefficient for $LogGas_t$ is the estimated elasticity of toll traffic volume with respect to changes in gas price. It implies that a 1 percent increase in gas price increases/decreases the toll traffic by β_1 percent – the usual interpretation of elasticity.

$$E = \frac{(TollVol_2 - TollVol_1) / TollVol_1}{(Price_2 - Price_1) / Price_1} \qquad \text{Equation 5-1}$$

Where:

- $TollVol_1$ = toll traffic volume at period *1*,
- $TollVol_2$ = toll traffic volume at period *2*,
- $Price_1$ = travel cost at period *1*, and
- $Price_2$ = travel cost at period *2*.

[11] As the unemployment rates, being in percentage form, used in the equations were not in logarithm, so this is called semi-elasticity.

5.2 Toll Bridges in San Francisco, California

For the period July 2000 to December 2009, monthly traffic volume data (by bridge and vehicle class) were available for seven toll bridges (see list below and Figure 5-2) in the San Francisco Bay Area. Additionally, the CPI-adjusted monthly average of gas price, toll rates for different vehicle classes, unemployment rates and population[12] were also collected. Since the time series analysis on the total traffic volume of 2-axle vehicles for all seven bridges, as an illustration, was performed in Chapter 4, this section first presentssummary results on the aggregated toll traffic volume of all vehicle classes for all seven bridges, followed by the regression results for toll traffic volumes by vehicle classes. The seven bridges were the:

- Antioch Bridge,
- Benicia-Martinez Bridge,
- Carquinez Bridge,
- Dumbarton Bridge,
- Richmond-San Rafael Bridge,
- San Francisco-Oakland Bay Bridge, and
- San Mateo-Hayward Bridge.

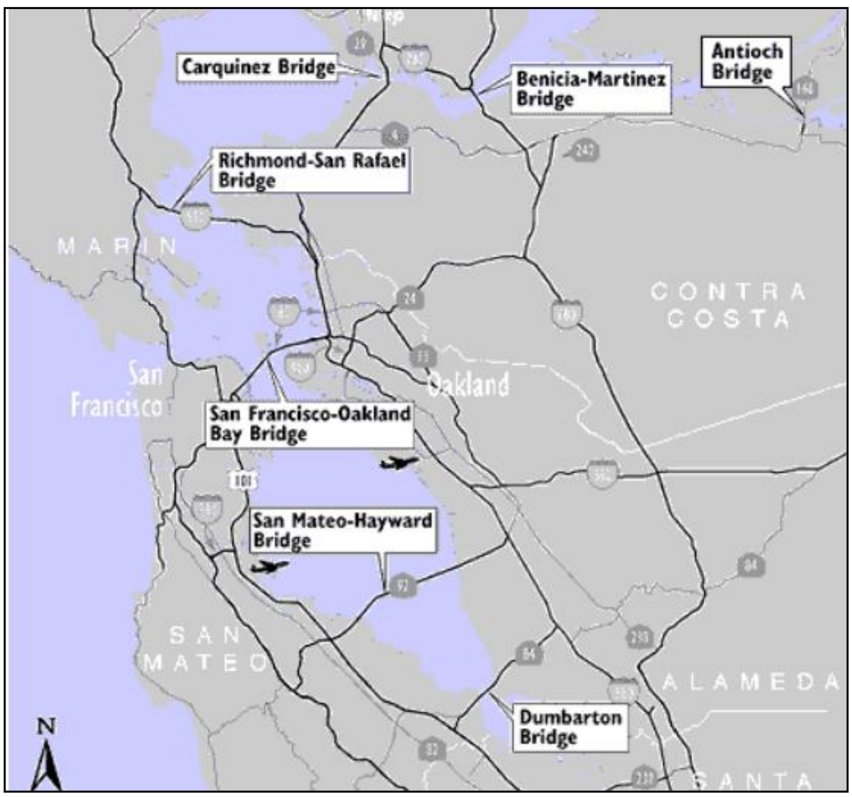

Figure 5-2: Locations of the Seven Toll Bridges in San Francisco, California
Source: http://bata.mtc.ca.gov/bridges/index.htm

[12] The population was a summation of nine counties in California: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma.

5.2.1 Data Description

Figure 5-3 shows toll traffic volumes for 2-axle vehicles and all vehicle classes combined (2-, 3-, 4-, 5-, 6- and 7+-axle). It is evident that a large portion of the toll traffic is composed of 2-axle vehicles. Plots of the data also reveal strong seasonality in the monthly traffic volume.

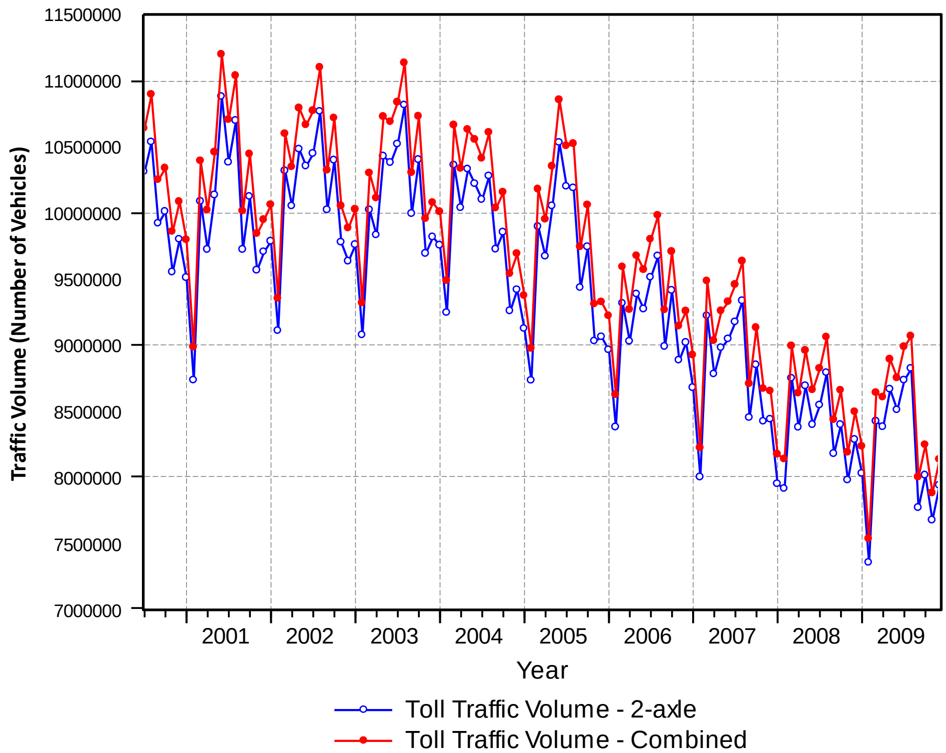

Figure 5-3: Toll Traffic Volume for 7 Toll Bridges in the San Francisco Area, California (All Classes and 2-Axles)

The plots of CPI-adjusted monthly gas price (Figure 5-4), nominal toll rates and CPI-adjusted toll rates for different vehicle classes (Figure 5-5), unemployment rates (Figure 5-6) in the San Francisco-Oakland-San Jose Metropolitan Area, and interpolated/exterpolated monthly population (Figure 5-7) are for the period July 2000 to December 2009. There is a clear upward trend in gas prices for the period between the end of 2001 and the middle of 2008, followed by a large decrease. The gas prices then started increasing again at the end of 2008. There were two toll increases during the study period, as shown in the plot of nominal toll rates (see Figure 5-5), and the multi-axle vehicles pay a higher toll with the toll determined by the total number of axles. From the plots (Figure 5-5), it is apparent that the toll rose more rapidly for 2-axle, 3-axle and 4-axle vehicles than for 5-axle, 6-axle and 7+-axle vehicles. During the period 2007 to 2009, there was a large increase in the unemployment rate and Figure 5-6 shows that there was a significant, huge loss of jobs during the period 2007 to 2009.

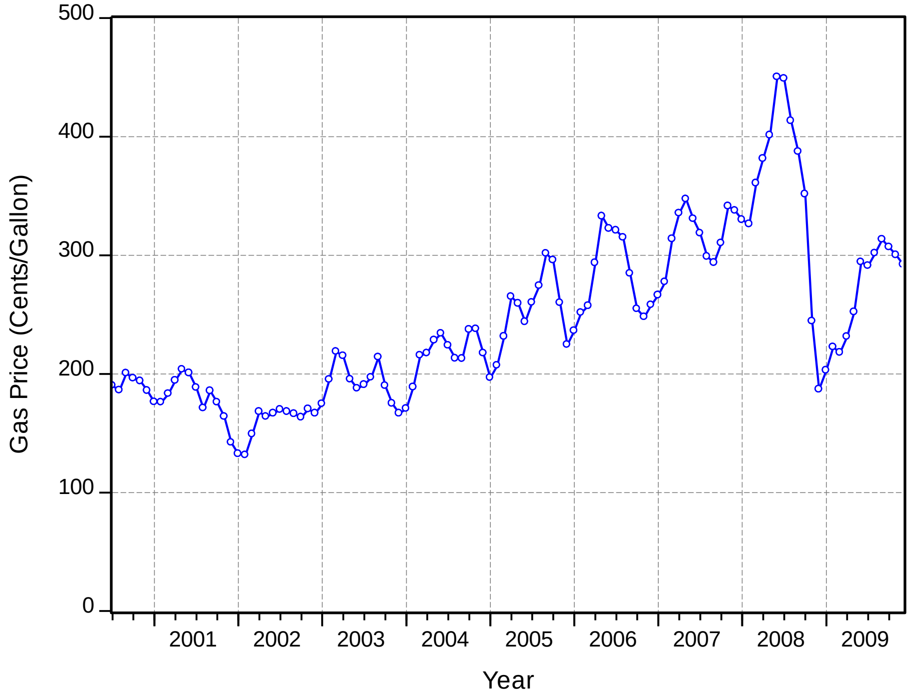

Figure 5-4: CPI-Adjusted Monthly Average Gas Price (All Types, MSA: San Francisco-Oakland-San Jose)

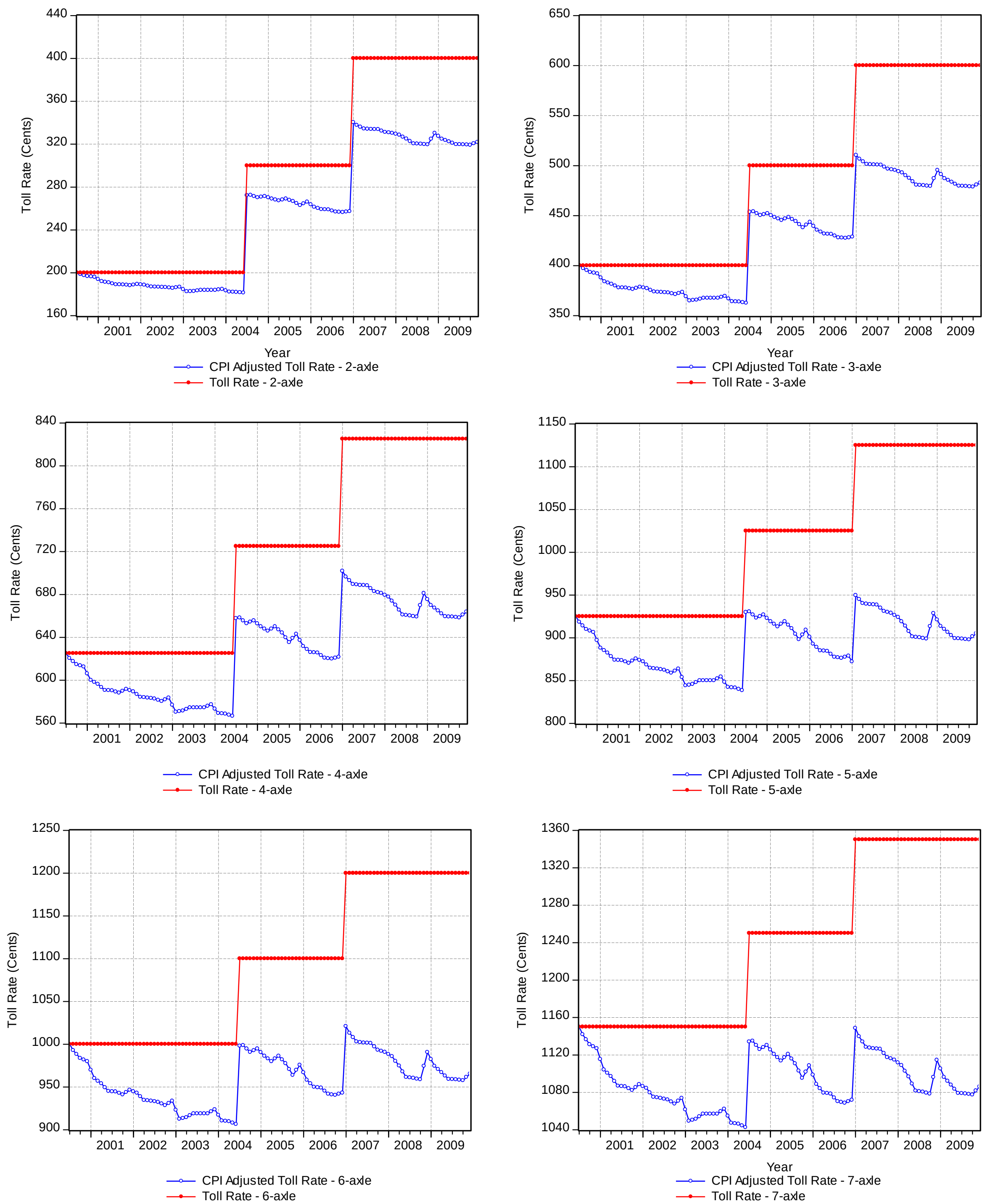

Figure 5-5: Nominal Toll Rates and CPI-Adjusted Toll Rates for Different Vehicle Classes in the San Francisco Bay Area, California

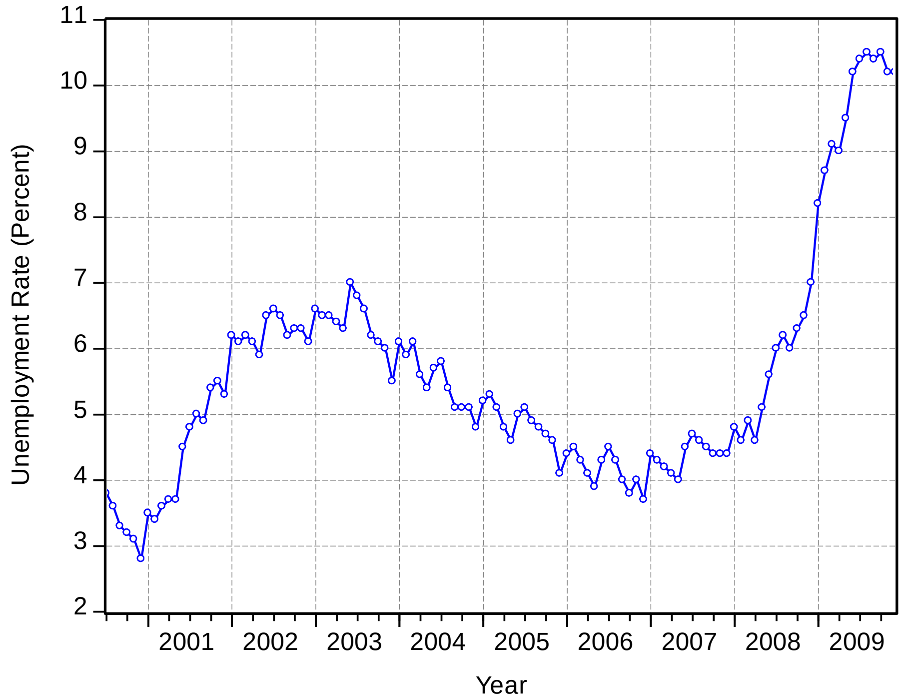

Figure 5-6: Monthly Unemployment Rates (MSA: San Francisco-Oakland-Fremont, California)

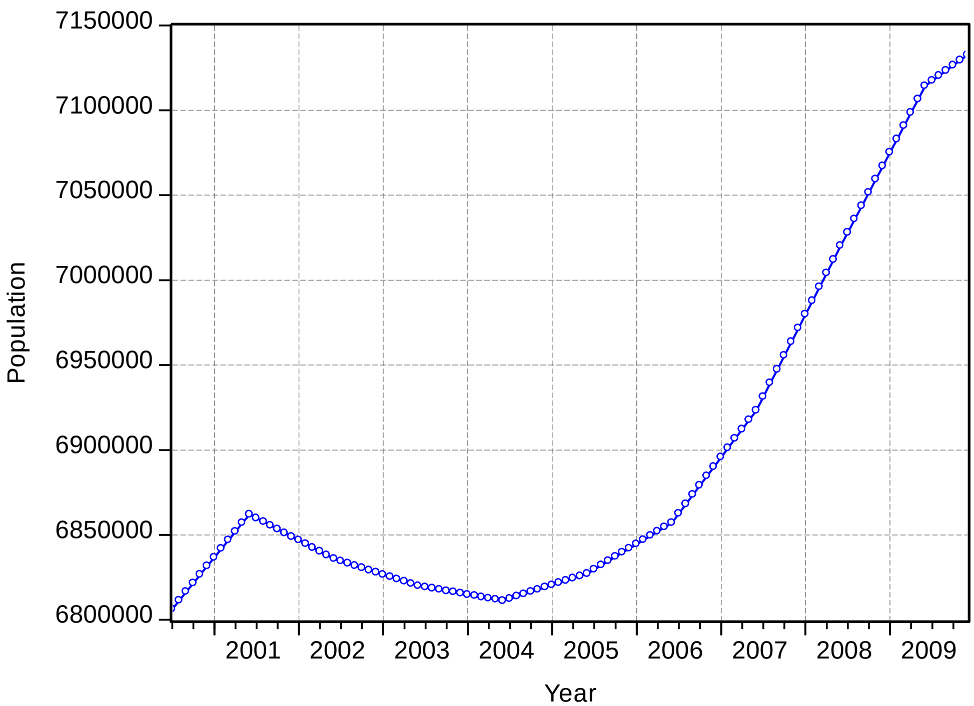

Figure 5-7: Inter/extrapolated Monthly Population (San Francisco Bay Area, California)

5.2.2 Time Series Analyses on Aggregated Traffic Volume for All Seven Toll Bridges

Regression results of the ADL model with an AR(*3*) included using the aggregated toll traffic for the seven toll bridges are shown in Equation 5-2.[13] Numbers in parentheses are standard errors. The adjusted R^2 is 0.96, and all coefficients are statistically significant at a 5 percent level with AIC equal to −5.29. The elasticity of travel demand with respect to gas price was −0.02 at a 1 percent significance level, which implies that as gas prices increase the use of toll bridges will decrease. From a macroeconomic perspective, this is understandable since higher fuel prices give rise to a higher operating cost for all vehicles, regardless of toll road or toll-free road. Higher operating costs generally would discourage travel. The reduced use of the toll bridges is only a portion of the total reduction in mileage driven. The elasticity of travel demand with respect to toll rate was −0.05 at a 1 percent significance level. The negative elasticity implies that as the toll rate increases the total use of toll bridges decreases. Negative elasticity of travel demand with respect to unemployment rates indicates that as unemployment rises then the use of the toll bridges decreases.

$$\underset{}{\text{Log}(\text{TollVolSA}_t)} = \underset{(1.06)}{4.45} + \underset{(0.06)}{0.75} \times \text{Log}(\text{TollVolSA}_{t\text{-}1}) - \underset{(0.01)}{0.02} \times \text{Log}(\text{Gas}_t) \qquad \text{Equation 5-2}$$

$$- \underset{(0.02)}{0.05} \times \text{Log}(\text{TollRate}_t) - \underset{(0.001)}{0.004} \times \text{UEMP}_t + u_t$$

$$u_t = 0.23 \times u_{t\text{-}3} + \varepsilon_t$$

$$n = 114,\ \text{Adjusted-}R^2 = 0.96,\ \text{AIC: } -5.29$$

5.2.3 Time Series Analyses on Tolled Traffic by Vehicle Classes

Table 5-1 shows regression results by individual vehicle classes. The elasticity estimates with respect to gas price for 2- to 6-axle vehicles are negative at a 5 percent significance level, while the elasticity for 7+-axle vehicles is not statistically significant. The negative elasticity estimates imply that as gas prices increase the use of the toll bridges decreases. This result indicates that drivers of 2- to 6-axle vehicles were sensitive to changes in gas price, while drivers of 7+-axle vehicles were not as sensitive to gas prices.

Elasticity estimates with respect to toll rates were negative at a 5 percent significance level with the exception of the elasticity estimate for 7+-axle vehicles being not statistically significant. Elasticity estimates with respect to toll rates for larger vehicles were generally higher than those for smaller vehicles. Further, it is interesting to see that the toll elasticity for 6-axle vehicles is −0.55, which is substantially higher than others. Elasticity estimates of toll road use with respect to unemployment rates were negative, which is consistent with the hypothesis that as more people are unemployed they require fewer trips across the bridge and buy fewer things – negatively impacting the number of larger (3+-axle) vehicle trips. Note that the adjusted R^2 value for the equation estimating the value of tolled 7-axle vehicles is very low (adjusted R^2 = 0.07). Examining a traffic volume plot of 7-axle vehicles, it is evident that this series is relatively flat except for three months where the volume spikes for unknown reasons. With this

[13] 2-axle vehicles comprise about 97 percent of the total traffic volume and a general toll rate index for all vehicle classes was not available for the study period. Therefore, in this regression on aggregated toll traffic volume the CPI-adjusted toll rates for 2-axle vehicles were used.

in mind, then it is not surprising to see that coefficients of gas price and toll rates for 7+-axle vehicles were not statistically significant.

Table 5-1: Summarized Regression Results for Individual Vehicle Classes (San Francisco)

Vehicle Class	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
2-Axle	0.91*** (0.03)	-0.002*** (0.01)	-0.01*** (0.01)	0.00 (0.00)	×	0.96	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
3-Axle	0.41*** (0.08)	-0.12*** (0.02)	-0.32*** (0.06)	-0.02*** (0.00)	×	0.89	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
4-Axle	0.50*** (0.08)	-0.07*** (0.02)	-0.18** (0.08)	-0.01*** (0.00)	×	0.80	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
5-Axle	0.75*** (0.07)	-0.05** (0.02)	-0.21** (0.09)	-0.01** (0.00)	×	0.86	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
6-Axle	0.74*** (0.07)	-0.15*** (0.05)	-0.55*** (0.20)	-0.01* (0.00)	×	0.79	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
7+-Axle	0.19** (0.09)	0.03 (0.23)	-0.98 (1.48)	-0.05* (0.03)	×	0.07	**Sample Period**: 2000:07-2004:04, 2004:09-2009:12 **Sample Size**: 110

Notes:
- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a ×) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.
- Standard errors in brackets ().
- Data of three months for 7+-axle vehicles were excluded because the volume spikes for the three months for unknown reasons.

5.3 Transportation Corridor Agencies (TCA) Toll Roads, California

Transportation Corridor Agencies (TCA) are two joint power authorities operating Orange County's toll roads. TCA consists of two local government agencies: the San Joaquin Hills Transportation Corridor Agency that oversees the San Joaquin Hills Toll Road (State Route(SR)73), and the Foothill/Eastern Transportation Corridor Agency that runs both the Foothill Toll Road (SR241) and the Eastern Toll Road (SR261). For a map of the toll roads, see Figure 5-8. The San Joaquin Hills Toll Road, which is about 12 miles long, is part of SR 73. The Foothill Toll Road is a 12-mile tollway in Orange County, California. The Eastern Toll Road comprises the entire length of SR 261 in Orange County, California.

Figure 5-8: Location of the TCA Toll Roads in Orange County, California
Source: https://www.thetollroads.com/home/pdf/F10_visor_map_6_22_09.pdf

5.3.1 Data Description

Toll traffic data were available for different vehicle classes (2-axle, 3-axle, 4-axle, 5-axle, and 6-axle as defined by the TCA) for different time periods. The toll traffic volume for 2-axle vehicles was available for January 2000 to December 2009, while the traffic volumes for 3+-axle vehicles were only available for June 2005 to December 2009 (see Figure 5-9). We then analyzed each dataset based on its corresponding time period. Monthly toll traffic volume data and historical nominal toll rates average for all vehicle classes were obtained from the TCA. The monthly all type gasoline price average and CPI for all urban consumers for Los Angeles-Riverside-Orange County MSA and monthly unemployment rates for Orange County, California, were obtained from the LexisNexis Statistical Datasets. The CPI-adjusted toll rates were obtained by dividing the toll rates by the CPI for the study period.

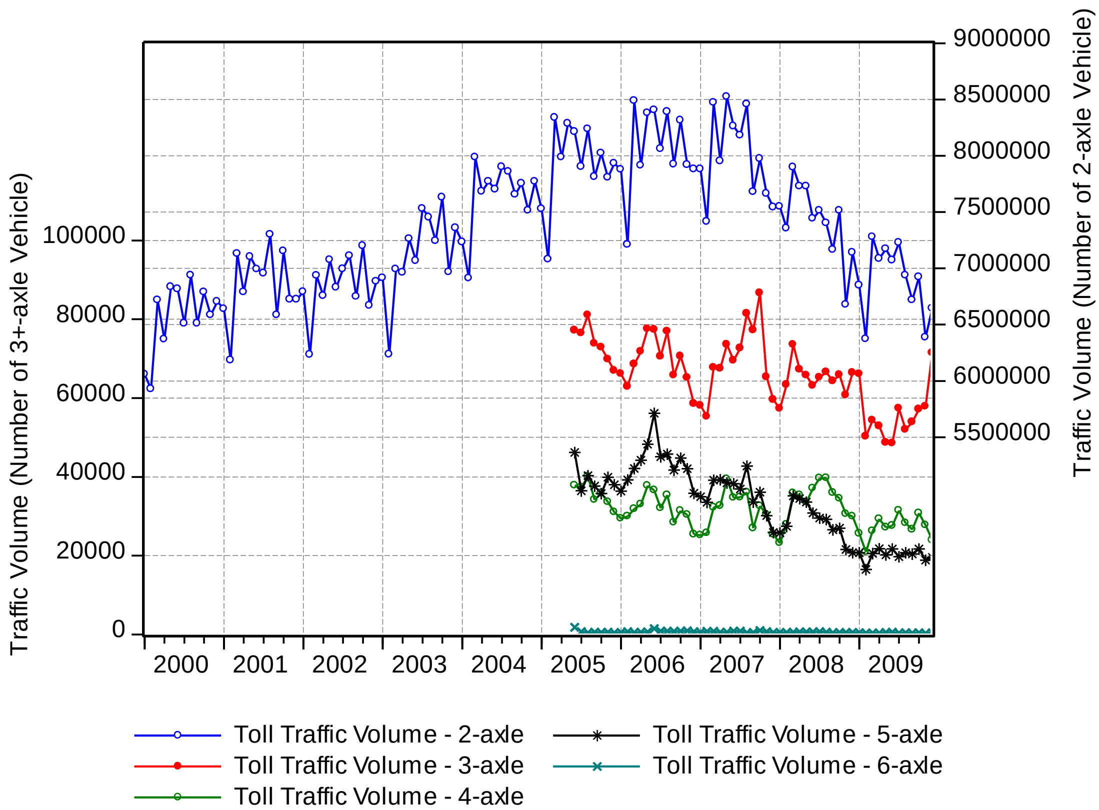

Figure 5-9: Toll Traffic Volume for the Three TCA Toll Roads

5.3.2 Time Series Analyses on Aggregated Traffic Volume for the Three Toll Roads

Table 5-2 shows the regression results by individual vehicle classes. Two elasticity estimates with respect to gas price were statistically significant: 2-axle vehicles in the SR 73 and 4-axle vehicles in SR 241 and SR 261. Statistically significant elasticity estimates with respect to unemployment rates were negative and inelastic.

Table 5-2: Summarized Regression Results (TCA)

Vehicle Class **Toll Road**	**$LogTollVol_{t-1}$**	**$LogGas_t$**	**$LogTollRate_t$**	**$UEMP_t$**	**$LogPop_t$**	**Adjusted R^2**	**Notes**
2-Axle SR73	0.96*** (0.04)	-0.02*** (0.02)	-	-0.005** (0.002)	0.51** (0.21)	0.92	**Sample Period**: 2000:01-2009:12 **Sample Size**: 120
2-Axle SR241 + SR261	0.93*** (0.04)	-0.01 (0.005)	-0.01 (0.04)	-0.005** (0.002)	0.41 (0.28)	0.94	**Sample Period**: 2000:01-2009:12 **Sample Size**: 120
3-Axle SR73	0.82*** (0.17)	0.09 (0.12)	-	0.02 (0.01)	×	0.82	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
3-Axle SR241 + SR261	0.49*** (0.12)	-0.09 (0.06)	0.18 (0.30)	-0.04*** (0.01)	×	0.80	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
4-Axle SR73	0.85*** (0.06)	0.07 (0.06)	-	-0.01** (0.004)	×	0.86	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
4-Axle SR241 + SR261	0.88*** (0.09)	0.08** (0.03)	0.06 (0.20)	-0.002 (0.003)	×	0.54	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
5-Axle SR73	0.49*** (0.13)	0.06 (0.15)	-	-0.08*** (0.02)	×	0.78	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
5-Axle SR241 + SR261	0.71*** (0.13)	-0.03 (0.06)	0.52 (0.32)	-0.04** (0.02)	×	0.93	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
6-Axle SR73	0.60*** (0.20)	-0.05 (0.22)	-	-0.08* (0.04)	×	0.76	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
6-Axle SR241 + SR261	0.03 (0.13)	-0.01 (0.14)	0.68 (0.70)	-0.07*** (0.01)	×	0.39	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a ×) were subject to “spurious regression” problem associated with inclusion of the “population” as a variable in the regression equations.
- Standard errors in brackets ().

5.4 Florida Turnpike Toll Roads, Florida

Florida's Turnpike Enterprise (FTE) is an agency owned and operated by the Florida Department of Transportation (FDOT), which manages all toll roads in the state of Florida. This study obtained the combined toll traffic volume data for the whole Turnpike System (see Figure 5-10 for a map of the turnpike system) including:

- Turnpike Mainline,
- Homestead Extension of Florida's Turnpike (HEFT),
- Veterans Expressway/Suncoast Parkway (Toll 589),
- Seminole Expressway/Central Florida GreeneWay/Southern Connector Extension (Toll 417),
- Beachline West Expressway (SR 528),
- Polk Parkway (SR 570),
- Sawgrass Expressway (SR 869), and
- Western Beltway (SR 429).

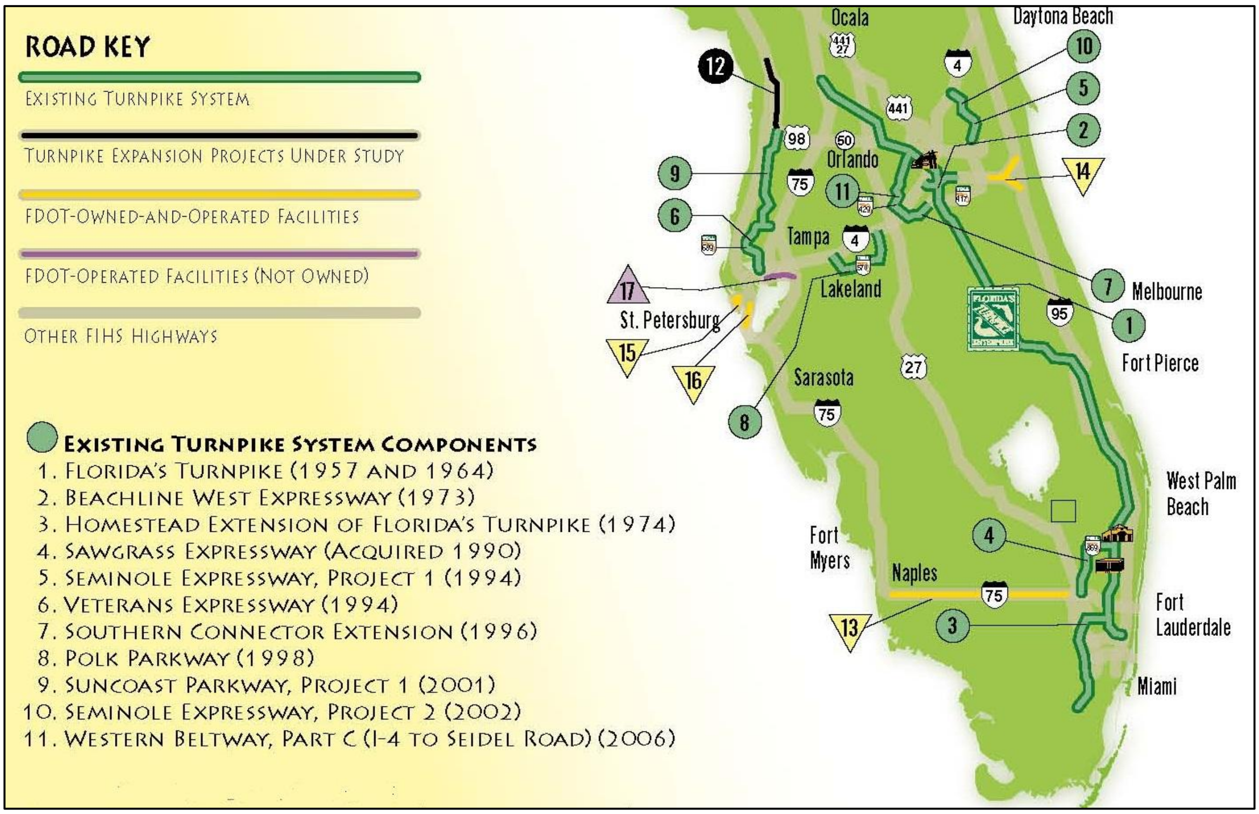

Figure 5-10: Location of the Florida Turnpike Toll Roads in Florida
Source: http://www.floridasturnpike.com/downloads/50thBookFinal.pdf

5.4.1 Data Description

Toll traffic data were available for ETC and cash-paying customers for the period from July 2007 to June 2009 (Figure 5-11). Monthly gas prices and unemployment rates in Florida were for the period July 2000 to June 2009. Gas price trends are similar to those described for San Francisco: a clear upward trend in the price of gas between the end of 2001 and the middle of

2008, followed by a big drop. The gas price then started increasing again at the end of 2008. The toll rate for cash-paying customers changed only once—in March 2004. In essence, the toll increase affected cash-paying customers only, and the ETC customers enjoy a 25 percent discount at most toll plazas, while cash-paying customers pay the higher rate following the increase. The higher rate for cash customers resulted in a significant jump in ETC participation. The toll rates were adjusted with the CPI for all urban consumers for the Miami-Fort Lauderdale area. Similar to San Francisco, the Florida economy suffered from a large increase in the unemployment rate during the period 2007 to 2009.

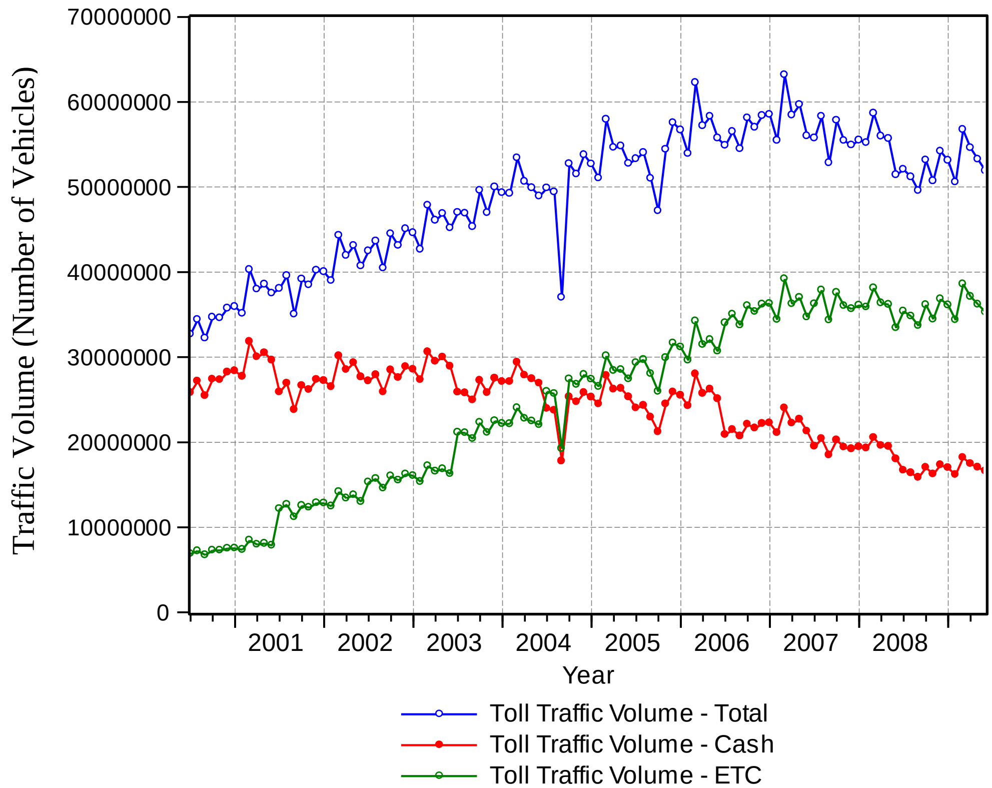

Figure 5-11: Monthly Traffic Volume for Total, Cash-Paying and ETC Customers on Florida Turnpike Toll Roads, Florida

5.4.2 Time Series Analyses on Tolled Traffic by Payment Method

Since the Florida Turnpike toll roads were located in an area which experienced active hurricane seasons in 2004 and 2005, traffic data for months that may have been significantly impacted by hurricanes and inclement weather were then removed from analyses. Table 5-3 shows regression results for cash-paying and ETC customers. The elasticity estimates of toll road use with respect to gas price for cash-paying customers is −0.08 at a 1 percent significance level, while the result was not statistically significant for ETC customers. The negative elasticity implies that as gas prices increased the use of the toll roads decreased. The elasticity estimates of toll road use with respect to toll rate for cash-paying customers is +0.02 at a 10 percent significance level. A positive elasticity estimate of travel demand with respect to toll rate indicates that as toll rates increased the use of the toll roads increased as well. Plots of the traffic volume for cash-paying vehicles and the CPI-adjusted toll rate (see Figure 5-12) indicate that the increase in toll rate in March 2004 did not significantly affect the use of toll road by cashing-paying customers. The extremely inelastic elasticity estimate (+0.02) might be evidence for this observation. Population was not included in the analysis due to the high correlation with gas price.

Table 5-3: Regression Results by Payment Method (Florida Turnpikes)

Payment Method	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Cash	0.85*** (0.04)	-0.08*** (0.03)	0.02* (0.01)	-0.01** (0.005)	-	0.96	**Sample Period**: 2000:07-2004:08, 2004:10-2005:09, 2005:11-2009:06 **Sample Size**: 106
ETC	0.98*** (0.01)	0.01 (0.02)	-	-0.002 (0.003)	-	0.99	**Sample Period**: 2000:07-2004:08, 2004:10-2005:09, 2005:11-2009:06 **Sample Size**: 106

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification.
- Standard errors in brackets ().

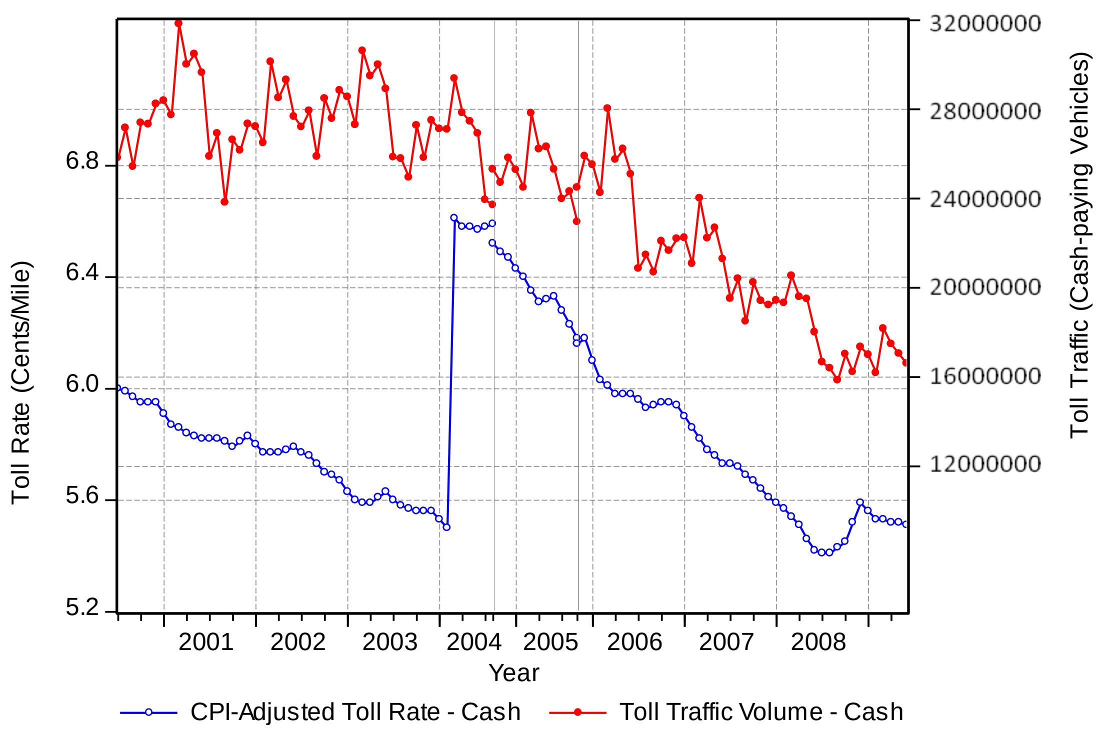

Figure 5-12: Traffic Volume for Cash-Paying Vehicles and the CPI-Adjusted Toll Rate (Florida Turnpikes)

5.5 Miami-Dade Expressway Authority Toll Roads, Florida

MDX has been operating and maintaining five expressways: Gratigny Parkway (SR 924), Airport Expressway (SR 112), Dolphin Expressway (SR 836), Don Shula Expressway (SR 874) and Snapper Creek Expressway (SR 878). The Gratigny Parkway, Don Shula Expressway and Snapper Creek Expressway are currently electronic toll roads requiring the use of SunPass or a "toll-by-plate" program and do not accept cash. Monthly traffic volume data were obtained for four of the five expressways (see Figure 5-13 for a map of the roadway system):

- Airport Expressway (SR112),
- East-West (Dolphin) Expressway (SR836),
- Don Shula Expressway (SR874), and
- Gratigny Expressway (SR924).

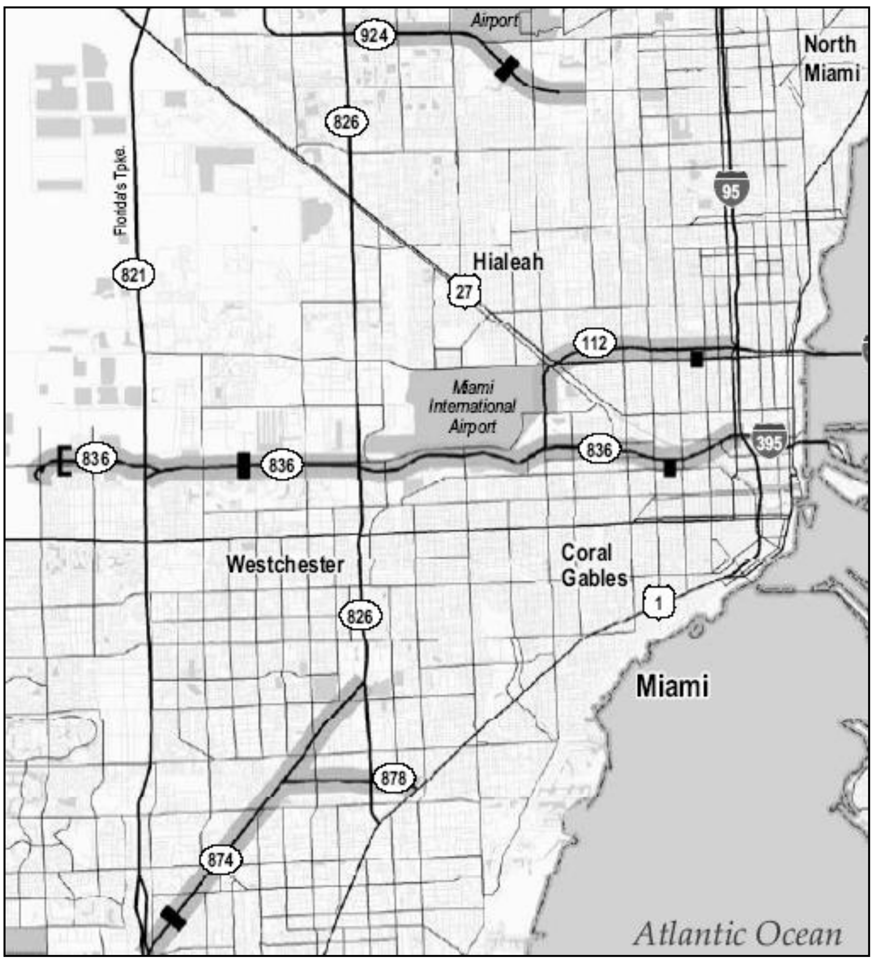

Figure 5-13: Location of the MDX Toll Roads in Miami-Dade County, Florida
Source: Miami-Dade County Expressway Authority (MDX) System-wide Traffic and Revenue Study (Wilbur Smith Associates, 2010)

5.5.1 Data Description

Toll traffic volume data were available for different vehicle classes (2-axle, 3-axle, 4-axle, 5-axle, and 6-axle) for different time periods.[14] Large decreases in traffic volumes in active hurricane seasons in 2004 and 2005 caused a significant drop in counted traffic. Data for months that may have been significantly impacted by hurricanes and inclement weather were then removed prior to further regression analyses. Combined monthly toll traffic volume of all vehicle classes (Figure 5-14), and historical nominal toll rates average for all vehicle classes were obtained from the TCA. Monthly gasoline price average and CPI for all urban consumers for Miami-Fort Lauderdale MSA and monthly unemployment rates for Miami Dade County, Florida, were obtained from the LexisNexis Statistical Datasets. For SR 874 and SR 924, tolls were collected in both directions at their mainline toll plaza, while for SR 112 and SR 836 tolls were collected in the eastbound direction only. The CPI-adjusted toll rates for the four toll roads were obtained by dividing the toll rate by the CPI of their corresponding sample period.

[14] The toll traffic volume data for cash-paying customers on SR 112, SR 836 and SR 924 were available for July 2000 to April 2010, while for ETC customers the data covered the period from December 2003 to April 2010. The traffic volume data for SR 874 for both cash-paying and ETC customers were available for December 2003 to April 2010. Traffic volume data from March to November 2003 were missing. However, seasonal adjustment requires a continuous dataset and inter/extrapolation of data (for seasonal adjustment purposes) for the missing points may introduce some unnecessary biases in the time series data. Therefore, for simplicity, the time series analyses were implemented on all datasets for a period beginning January 2004, unless otherwise specified in the results summary table.

Figure 5-14: Toll Traffic Volume (Number of Vehicles) for All Vehicle Classes for MDX Toll Roads in Miami-Dade County, Florida

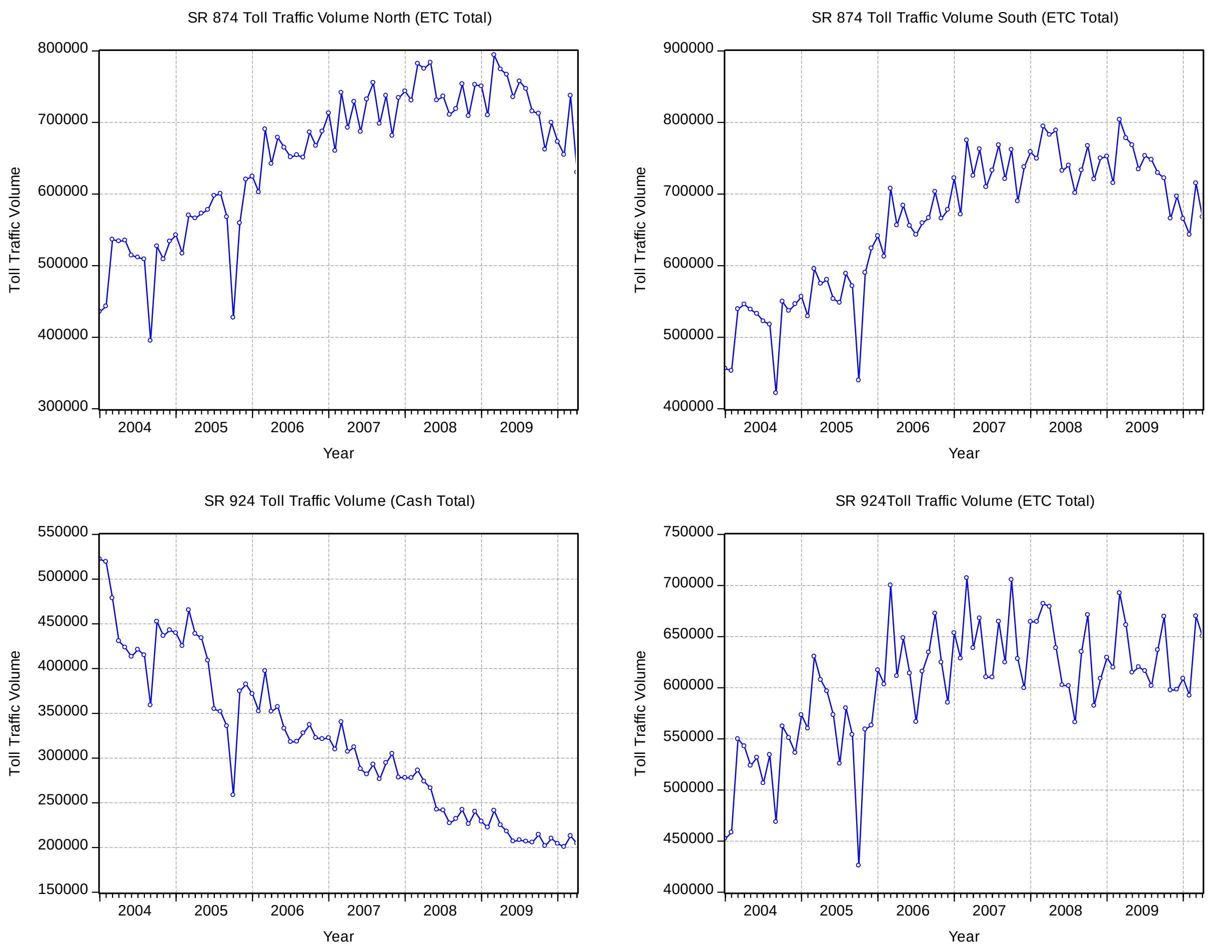

Figure 5-14: Toll Traffic Volume (Number of Vehicles) for All Vehicle Classes for MDX Toll Roads in Miami-Dade County, Florida (continued)

5.5.2 Time Series Analyses on Tolled Traffic by Vehicle Class

Table 5-4 shows the time series analysis results by individual vehicle class. As discussed previously, the toll traffic consisted primarily of 2- and 5-axle vehicles for the MDX toll roads. Since the results are by vehicle class the discussion of those results is left to Section 5.14.1 and 5.14.2 (for 2-axle vehicles) and Section 5.14.3 and 5.14.4 (for 5-axle vehicles). Those sections summarize the results of the MDX toll roads along with the other 5 agencies where data were differentiated by vehicle class.

Table 5-4: Summarized Regression Results for Individual Vehicle Class (MDX)

Vehicle Class	Toll Road	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
2-Axle	SR112 (Cash)	0.57*** (0.10)	-0.11** (0.05)	-0.28*** (0.07)	-0.01** (0.00)	×	0.92	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
	SR112 (ETC)	0.70*** (0.07)	0.003 (0.03)	0.01 (0.04)	-0.001 (0.001)	2.94** (1.20)	0.96	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
	SR836 (Cash)	0.77*** (0.07)	-0.11** (0.04)	-0.24** (0.12)	-0.01** (0.00)	×	0.89	**Sample Period**: 2004:01-2010:04 **Sample Size**: 76
	SR836 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	SR874 North (Cash)	0.88*** (0.08)	-0.03* (0.02)	-	-0.004* (0.002)	-	0.87	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 North (ETC)	0.96*** (0.05)	-0.01 (0.02)	-	-0.002** (0.001)	-	0.80	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 South (Cash)	0.81*** (0.10)	-0.02 (0.02)	-	-0.01** (0.00)	-	0.88	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 South (ETC)	0.96*** (0.04)	-0.01 (0.01)	-	-0.002*** (0.001)	-	0.84	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR924 (Cash)	0.84*** (0.07)	-0.10* (0.05)	-0.20 (0.14)	-0.01** (0.004)	-	0.94	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
	SR924 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
3-Axle	SR112 (Cash)	0.48*** (0.09)	-0.20** (0.07)	-0.42*** (0.10)	-0.03*** (0.01)	×	0.90	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71

Table 5-4: Summarized Regression Results for Individual Vehicle Class (MDX) (continued)

Vehicle Class	Toll Road	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	SR112 (ETC)	0.12 (0.18)	0.15*** (0.05)	-0.02 (0.06)	-0.02*** (0.01)	0.16 (1.01)	0.77	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2006:05, 2007:09-2010:04 **Sample Size**: 56 Traffic severely impacted by unknown factors.
	SR836 (Cash)	0.89*** (0.07)	-0.06 (0.06)	0.003 (0.16)	-0.01 (0.01)	×	0.90	**Sample Period**: 2004:01-2010:04 **Sample Size**: 76
	SR836 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	SR874 North (Cash)	0.95*** (0.03)	-0.03 (0.02)	-	-0.001 (0.002)	-	0.96	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 North (ETC)	0.52*** (0.17)	-0.21* (0.11)	-	-0.02** (0.01)	-	0.50	**Sample Period**: 2007:09-2010:04 **Sample Size**: 32
	SR874 South (Cash)	0.96*** (0.04)	-0.02 (0.03)	-	-0.0003 (0.002)	-	0.95	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 South (ETC)	0.70*** (0.16)	-0.05 (0.06)	-	-0.01* (0.01)	-	0.75	**Sample Period**: 2007:11-2010:04 **Sample Size**: 30
	SR924 (Cash)	0.89*** (0.05)	-0.10 (0.09)	-0.27* (0.15)	-0.01 (0.01)	-	0.95	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
	SR924 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
4-Axle	SR112 (Cash)	0.53*** (0.09)	-0.18 (0.08)	-0.28*** (0.08)	-0.02** (0.01)	×	0.79	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71

Table 5-4: Summarized Regression Results for Individual Vehicle Class (MDX) (continued)

Vehicle Class	Toll Road	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	SR112 (ETC)	0.31** (0.22)	0.22 (0.14)	0.23 (0.19)	-0.04* (0.02)	-2.86 (2.82)	0.61	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2006:05, 2007:09-2010:04 **Sample Size**: 56 Traffic severely impacted by unknown factors.
	SR836 (Cash)	0.86*** (0.06)	-0.07 (0.06)	-0.05 (0.08)	-0.01 (0.01)	×	0.93	**Sample Period**: 2004:01-2005:09, 2005:12-2010:04 **Sample Size**: 74
	SR836 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	SR874 North (Cash)	0.85*** (0.07)	-0.04 (0.05)	-	-0.01 (0.01)	-	0.89	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 North (ETC)	0.39** (0.16)	-0.19 (0.13)	-	-0.02 (0.01)	-	0.38	**Sample Period**: 2007:09-2010:04 **Sample Size**: 32
	SR874 South (Cash)	0.88*** (0.05)	-0.02 (0.03)	-	-0.01* (0.003)	-	0.90	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 South (ETC)	0.37* (0.20)	-0.06 (0.07)	-	-0.01* (0.01)	-	0.30	**Sample Period**: 2007:11-2010:04 **Sample Size**: 30
	SR924 (Cash)	0.77*** (0.07)	-0.16 (0.10)	-0.44*** (0.14)	-0.02** (0.01)	-	0.90	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
	SR924 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
5-Axle	SR112 (Cash)	0.47*** (0.07)	-0.06 (0.07)	-0.46*** (0.09)	-0.03*** (0.01)	5.67*** (1.67)	0.79	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11 - 2010:04 **Sample Size**: 71

Table 5-4: Summarized Regression Results for Individual Vehicle Class (MDX) (continued)

Vehicle Class	Toll Road	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	SR112 (ETC)	-0.10 (0.11)	0.14*** (0.05)	0.12 (0.05)	-0.02*** (0.01)	4.05*** (1.26)	0.77	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2006:05, 2007:09-2010:04 **Sample Size**: 56 Traffic severely impacted by unknown factors.
	SR836 (Cash)	0.42*** (0.06)	0.01 (0.05)	-0.31** (0.16)	-0.04*** (0.01)	-1.13 (0.97)	0.93	**Sample Period**: 2004:03-2005:09, 2006:01-2010:04 **Sample Size**: 71
	SR836 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	SR874 North (Cash)	0.82*** (0.08)	-0.01 (0.04)	-	-0.01 (0.004)	-	0.90	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 North (ETC)	0.36* (0.18)	-0.22* (0.12)	-	-0.02** (0.01)	-	0.37	**Sample Period**: 2007:09-2010:04 **Sample Size**: 32
	SR874 South (Cash)	0.82*** (0.08)	-0.01 (0.04)	-	-0.01 (0.004)	-	0.80	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 South (ETC)	0.85*** (0.14)	-0.04 (0.06)	-	-0.01 (0.01)	-	0.66	**Sample Period**: 2007:11-2010:04 **Sample Size**: 30
	SR924 (Cash)	0.64*** (0.09)	-0.17** (0.06)	-0.31 (0.22)	-0.02*** (0.01)	-	0.84	**Sample Period**: 2004:04-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 68
	SR924 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
6-Axle	SR112 (Cash)	0.51*** (0.11)	0.13 (0.19)	-0.07 (0.19)	-0.07*** (0.02)	7.49 (4.67)	0.65	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71

Table 5-4: Summarized Regression Results for Individual Vehicle Class (MDX) (continued)

Vehicle Class	Toll Road	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	SR112 (ETC)	0.42*** (0.15)	0.05* (0.19)	-0.12 (0.19)	0.003 (0.02)	11.53*** (4.89)	0.77	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2006:05, 2007:09-2010:04 **Sample Size**: 56 Traffic severely impacted by unknown factors.
	SR836 (Cash)	0.18 (0.13)	0.09 (0.16)	-0.25 (0.42)	-0.08*** (0.02)	3.84 (2.69)	0.64	**Sample Period**: 2004:01-2010:04 **Sample Size**: 76
	SR836 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	SR874 North (Cash)	-0.01 (0.15)	-0.21** (0.20)	-	-0.08*** (0.02)	-	0.55	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 North (ETC)	0.21 (0.13)	-0.09 (0.12)	-	-0.04*** (0.01)	-	0.49	**Sample Period**: 2005:10-2010:04 **Sample Size**: 55
	SR874 South (Cash)	0.42** (0.20)	-0.18 (0.17)	-	-0.02 (0.02)	-	0.09	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
	SR874 South (ETC)	0.72*** (0.08)	0.38* (0.19)	-	-0.01 (0.01)	-	0.70	**Sample Period**: 2007:06-2010:04 **Sample Size**: 35
	SR924 (Cash)	0.13 (0.12)	-0.45** (0.19)	-1.56** (0.61)	-0.01 (0.01)	-	0.19	**Sample Period**: 2004:04-2010:04 **Sample Size**: 73
	SR924 (ETC)	-	-	-	-	-	-	Traffic severely impacted by unknown factors.

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a ×) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.
- a: Modeled on unadjusted data with seasonal dummy variables.
- Standard errors in brackets ().

5.6 Orlando-Orange County Expressway Authority Toll Roads, Florida

The current toll road system operated by the OOCEA is a 105-mile transportation network that consists of five individual toll roads: SR 408, SR 414, SR 417, SR 429 and SR 528 (see Figure 5-15). Toll traffic volume data were obtained for eleven main toll plazas on four toll roads for the period June 2003 to December 2009 (missing data from SR 414). The eleven toll plazas were:

- SR 408: Hiawassee Plaza, Pine Hill Plaza, Conway Plaza, and Dean Plaza;
- SR 417: John Young Plaza, Boggy Creek Plaza, Curry Ford Plaza, and University Plaza;
- SR 429: Forest Lake Plaza; and
- SR 528: Airport Plaza and Beachline Plaza.

5.6.1 Data Description

Figure 5-16 shows the combined monthly toll traffic volumes for the eleven plazas. For the years 2000 through 2006, the use of toll roads had been continuously increasing at a slow pace, excluding the months impacted by hurricanes. In the spring 2007, the toll traffic volume began a slight downward trend. Large decreases in counted traffic volumes in August and September 2004 were due to Hurricanes Charley, Frances, Ivan, and Jeanne that led to the suspension of tolls at all toll plazas within the toll road system. Other influential hurricanes also occurred in August and October 2005, and tolls were suspended then as well. Tropical storm Faye occurred in August 2008. To reduce the impact of hurricanes and inclement weather on the use of toll roads, data for months that may have been significantly impacted by hurricanes were then removed prior to further regression analyses.

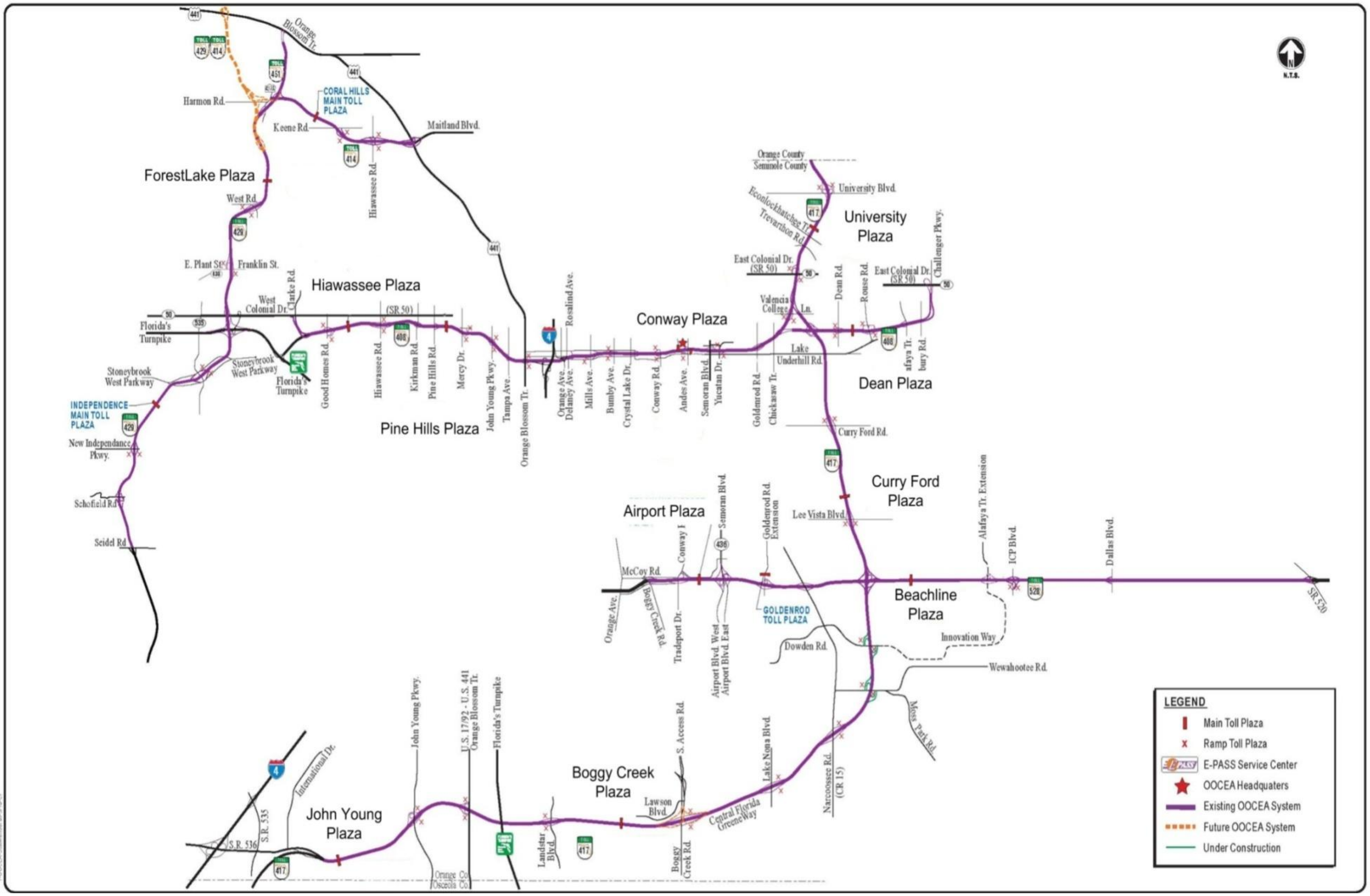

Figure 5-15: Toll Plaza Location Map (OOCEA Expressway System)

Source: http://www.expresswayauthority.com/Corporate/oursystem/assets/TollFacilitiesReferenceManual.pdf

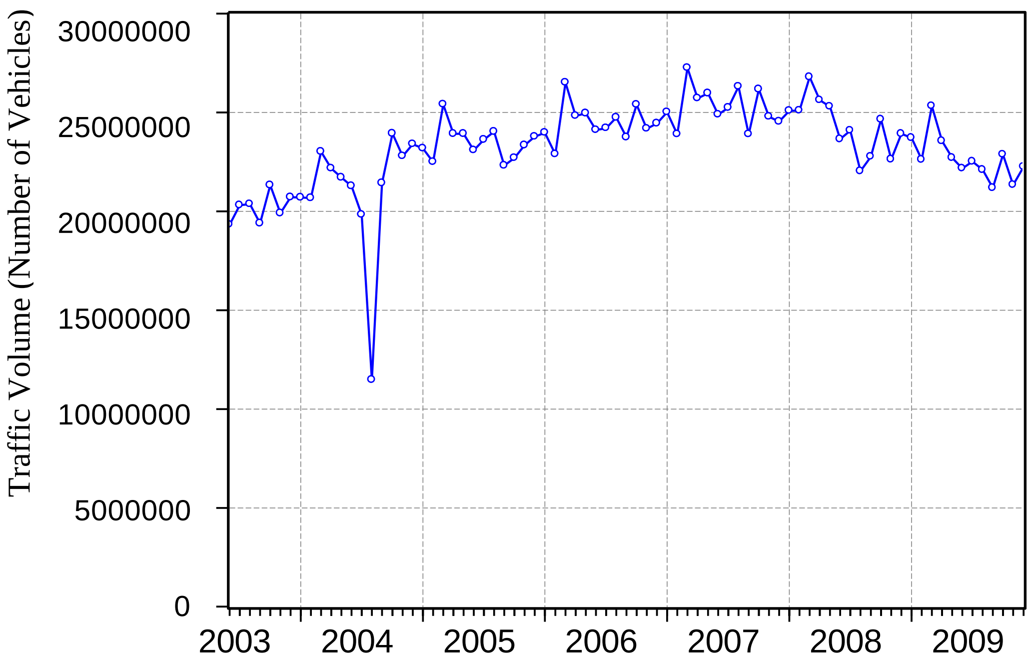

Figure 5-16: Total Monthly Traffic Volume (OOCEA Expressway System)

The CPI for all urban consumers in Orange County, Florida, where the OOCEA toll road system is located, was not available,[15] so the CPI of the South Region[16] was used as a substitute. The CPI-adjusted monthly average gas price was not available for the county-specific level, so the state average gas price for Florida was used.[17] Nominal toll rates for different vehicle classes were available for the eleven plazas. However, since the traffic volume data obtained was the summation of all vehicles and no general toll rate index for all vehicle classes was available for the study period, only the toll rates for 1-2 axle vehicles were then used since they compose most of the traffic. The rates for 1-2 axle vehicles are different at different toll plazas and they were adjusted with CPI for all urban consumers. There was one toll increase, in April 2009, during the study period. Unemployment rates were obtained for the Orlando-Kissimmee-Sanford (OKS), Florida Metropolitan Statistical Area.[18] The unemployment rate in the Orlando region was also very high (almost 12 percent in 2009), just as the rates were in San Francisco (10.5 percent) and the Miami region (11 percent).

5.6.2 Time Series Analyses on Data from the Eleven Toll Plazas

Table 5-5 shows time series analysis results by toll plaza. Two elasticity estimates with respect to gas price were statistically significant and negative. This implies that use of the toll roads would decrease slightly due to a gas price increase. Statistically significant elasticity estimates with respect to toll rates ranged from −0.28 to −0.17. Statistically significant elasticity estimates with respect to unemployment rates ranged from −0.03 to −0.01.

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[15] CPI in the state level was not available.
[16] As defined by the U.S. Census Bureau, the Southern region of the U.S. includes sixteen states.
[17] Weekly unadjusted all grades, all formulations, retail gas prices were obtained from the Energy Information Administration: http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html.
[18] This is a metropolitan area in the central part of Florida. Its principal cities are Orlando and the smaller municipalities of Kissimmee and Sanford. The U.S. Office of Management and Budget defines it as consisting of Lake County, Orange County (including Orlando), Osceola County (including Kissimmee), and Seminole County (including Sanford). The OOCEA toll road system is primarily located in Orange County, Florida.

Table 5-5: Summarized Regression Results for Individual Toll Plazas (OOCEA)

Toll Plaza	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Hiawassee	0.31*** (0.09)	-0.02 (0.05)	-0.18*** (0.05)	-0.004 (0.003)	1.06*** (0.28)	0.82	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Pine Hills	0.08 (0.25)	-0.02 (0.05)	-0.20*** (0.08)	-0.01*** (0.004)	0.53* (0.28)	0.82	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Conway	-0.04 (0.41)	-0.08* (0.04)	0.02 (0.04)	-0.02** (0.01)	0.89** (0.20)	0.80	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Dean	-0.03 (0.40)	-0.09* (0.04)	0.004 (0.03)	-0.02*** (0.01)	1.74** (0.69)	0.90	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
John Young	0.21 (0.09)	-0.09 (0.08)	-0.28** (0.11)	-0.02*** (0.003)	2.34*** (0.54)	0.91	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Boggy Creek	0.25** (0.11)	-0.01 (0.06)	-0.17* (0.09)	-0.02*** (0.003)	2.71*** (0.49)	0.95	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Curry Ford	0.02 (0.36)	-0.04 (0.05)	-0.02 (0.06)	-0.03*** (0.01)	3.14** (1.25)	0.95	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
University	-0.02 (0.53)	-0.03 (0.05)	-0.01 (0.05)	-0.03** (0.01)	1.59* (0.88)	0.92	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Forest Lake	0.11* (0.15)	0.02 (0.04)	0.10 (0.05)	-0.03*** (0.01)	3.93*** (0.74)	0.98	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Beachline Airport	-0.04 (0.60)	0.07 (0.05)	0.06 (0.06)	-0.02* (0.01)	2.02 (1.28)	0.93	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Beachline Main	-0.07 (0.24)	-0.06 (0.05)	-	-0.02*** (0.004)	1.28*** (0.35)	0.76	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Notes:	• *=10% significance level, **=5% significance level, ***=1% significance level. • Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. • All regressions were modeled on unadjusted data with seasonal dummy variables. • Standard errors in brackets ().						

5.7 Georgia State Route 400, Georgia

Georgia SR 400 begins at Interstate 85 just north of Downtown Atlanta and runs through Buckhead, Sandy Springs, Roswell, Alpharetta, Cumming, Dawson County, and Dahlonega (see Figure 5-17). At Interstate 285, the road becomes a toll-free road, heading north into the northern Atlanta suburbs. Tolls are collected in both directions. Currently the toll is 50 cents for a 2-axle vehicle, and $1.50 for 3-axle vehicles, plus 50 cents for each additional axle.

5.7.1 Data Description

Combined monthly toll traffic for all vehicles was obtained for the period January 1998 to August 2010 (Figure 5-18). This toll road experienced a considerable drop in traffic during 2008. During the sample period the nominal toll rates did not change for all vehicle classes. Gas prices and CPI for the Atlanta MSA peaked in 2008. Unemployment rates were obtained for the Atlanta-Sandy Springs-Marietta MSA, Georgia.

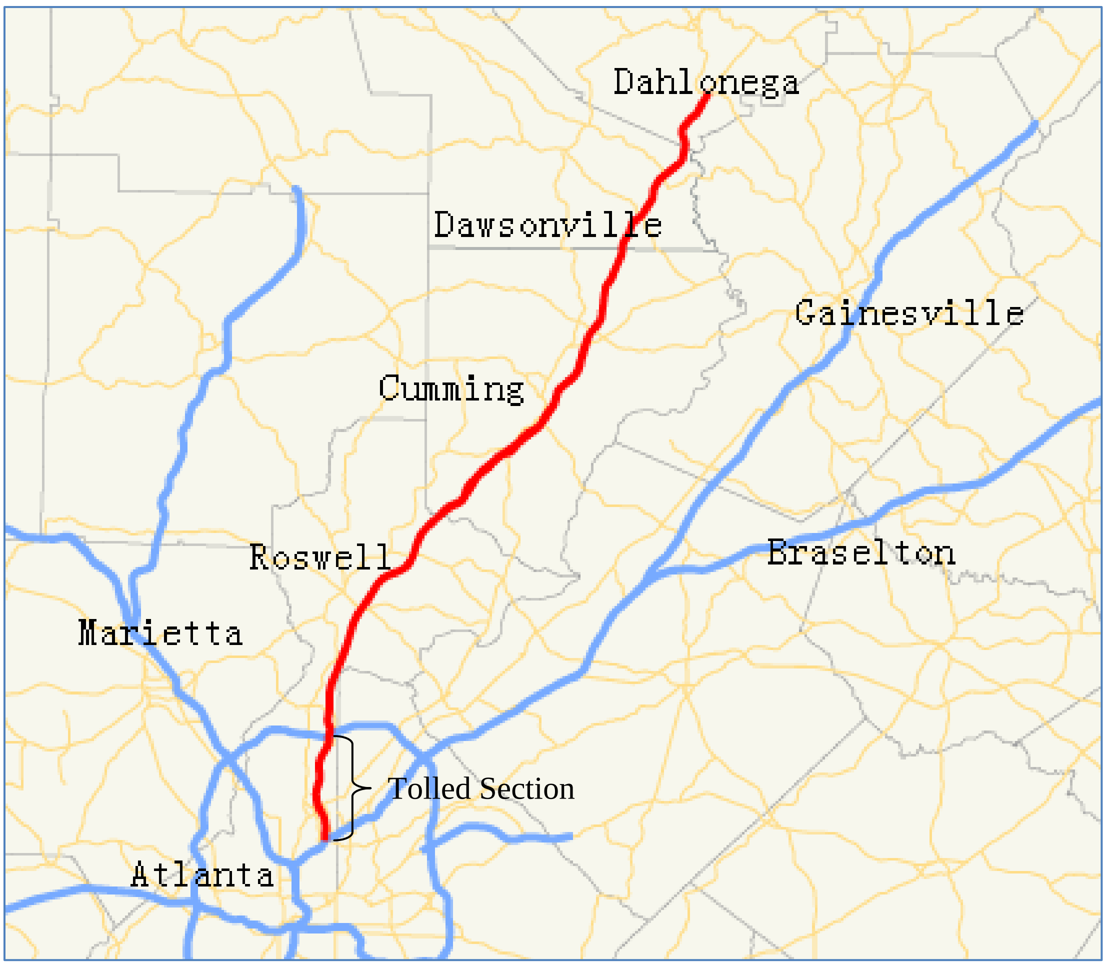

Figure 5-17: Georgia SR400 Route Map
Source: http://en.wikipedia.org/wiki/File:Georgia_state_route_400_map.png

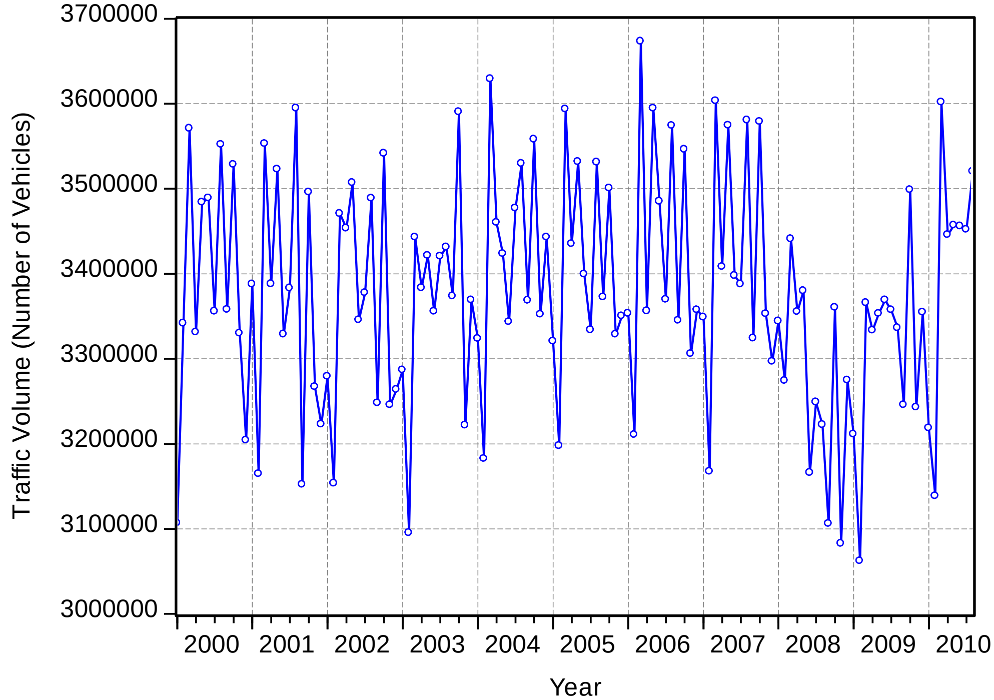

Figure 5-18: Combined Toll Traffic Volume for Georgia SR400, Georgia

5.7.2 Time Series Analyses on Combined Traffic (SR400)

Since there was no monthly traffic volume data available for each vehicle class for the entire sample period, and there was no average index of toll rates for the all vehicle classes, therefore, the CPI-adjusted toll rate for 2-axle vehicles was used in the time series analysis. The adjusted toll rate for 2-axle vehicles could essentially approximate the proportional change of the toll rate for all vehicle classes as the toll rates were maintained constant for all vehicle classes during the sample period.

Table 5-6 shows time series analysis results for Georgia SR 400. For the entire sample period (January 2000 to August 2010), the elasticity estimate of toll road use with respect to gas price was not statistically significant, and the elasticity estimate with respect to unemployment rate is −0.002 at a 10 percent significance level. Exclusion of the toll rate and population in the specification was due to the high correlation among gas price, toll rate, and population. A plot of the traffic volume (Figure 5-18) shows a sharp decrease in toll road use at the beginning of 2008, and this may suggest a structural change of specification of the linear equation (Equation 4-11). The Chow Test was used to examine whether the demand function for the toll road was the same before and after the rapid rise in the price of gas in 2008. The breakpoint Chow Test[19] showed a structural change (at a 1 percent significance level) in the relationship for each subsample. The Chow Test results indicated that two subsamples (January 2002 to December 2007 as the pre-period, and December 2008 to August 2010 as the post-period) could be used to examine the demand functions for each sub-period. The regression results for the two subsamples indicated that there was a significant change in the elasticity of gas price to the use of toll road: for the pre-

[19] The idea of the breakpoint Chow Test is to fit the equation separately for each subsample and to see whether there are significant differences in the estimated equations. A significant difference indicates a structural change in the relationship.

period the elasticity is negative (−0.01 at 5 percent significance level), while it changed to positive (+0.09 at a 1 percent significance level) in the post-period.

Table 5-6: Regression Results (Georgia SR400)

$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
0.31*** (0.09)	-0.0002 (0.09)	-	-0.002* (0.001)	-	0.68	**Sample Period**[a]: 2000:01-2010:08 **Sample Size**: 128
0.38*** (0.11)	-0.01** (0.01)	-	0.00 (0.00)	-	0.32	**Sample Period**: 2000:01-2007:12 **Sample Size**: 96
-0.08 (0.30)	0.09*** (0.03)	-	-0.03** (0.01)	-	0.43	**Sample Period**: 2008:12-2010:08 **Sample Size**: 21

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification.
- a: Modeled on unadjusted data with seasonal dummy variables.
- Standard errors in brackets ().

5.8 The Indiana East-West Toll Road

The Indiana Toll Road, officially the Indiana East-West Toll Road, is a 157-mile (253 km) toll road that runs east-west across northern Indiana from the Illinois state line to the Ohio state line (Figure 5-19). It is owned by the Indiana Finance Authority and operated by the Indiana Toll Road Concession Company, a joint-venture between Spanish Cintra Concesiones de Infraestructuras de Transporte and Australian Macquarie Atlas Roads.

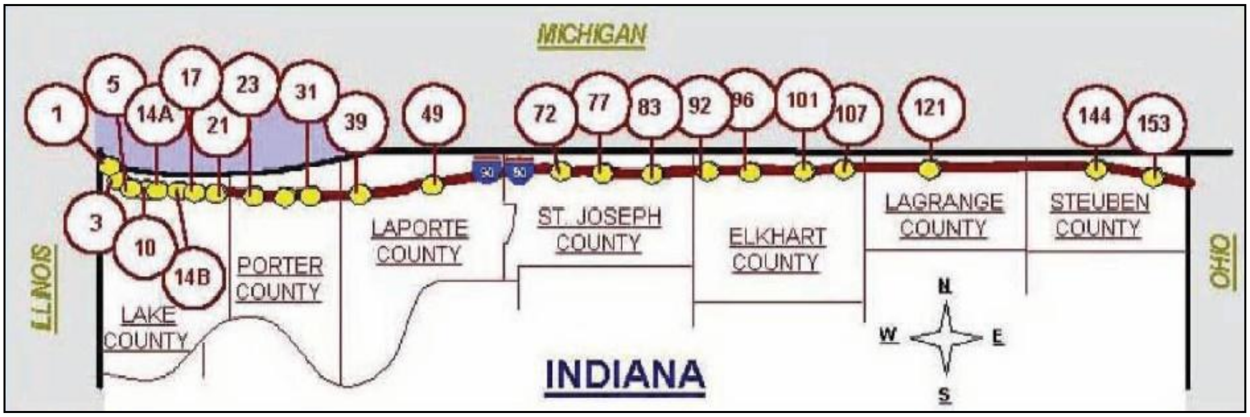

Figure 5-19: Location Map for the Indiana Toll Road[20]
Source: https://www.getizoom.com/rates/docs/trmap.pdf

5.8.1 Data Description

Quarterly toll traffic volume (Figure 5-20), and historical nominal toll rates for passenger cars were obtained from the Management Information Report published by the Macquarie Infrastructure Group.[21] Quarterly all type gasoline price average and CPI for all urban

[20] Numbers in the circles are the mile markers for toll plazas along the roadway.
[21] Reports can be found at: http://www.macquarie.com/mgl/com/mqa/investor-centre/investor-reports.

consumers for Chicago-Gary-Kenosha metropolitan statistical area and quarterly unemployment rates for the State of Indiana were obtained from the LexisNexis Statistical Datasets.[22] The CPI-adjusted toll rates were obtained by dividing the nominal toll rate by the CPI for the study period.

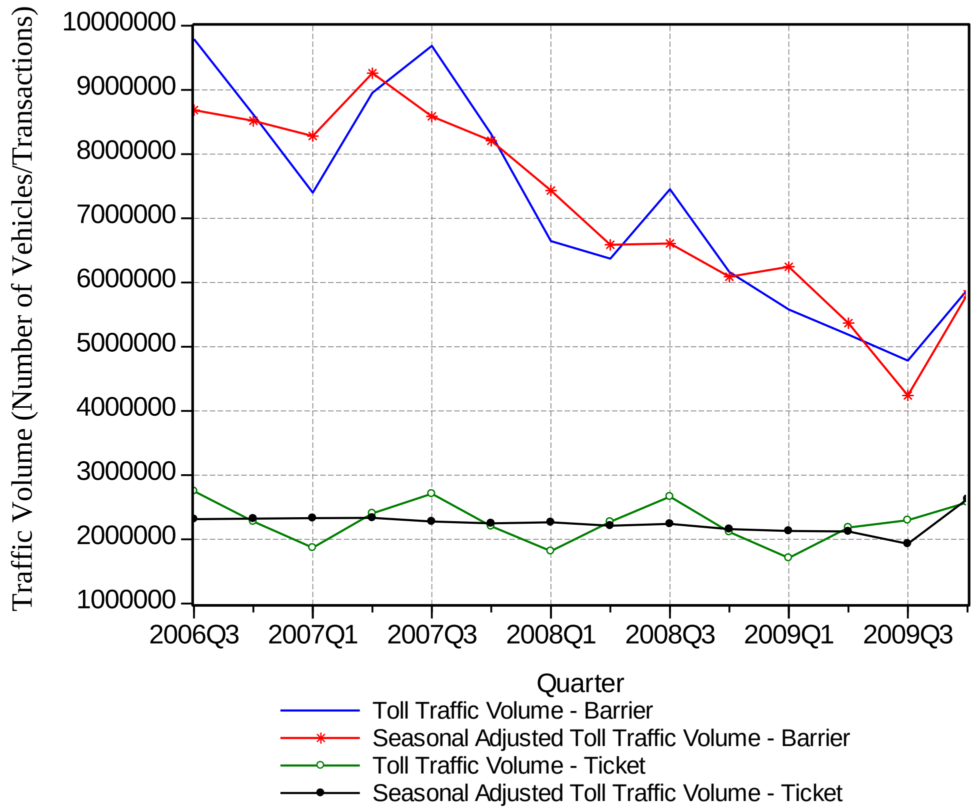

Figure 5-20: Quarterly Traffic Volume (Indiana Toll Road)[23]

5.8.2 Time Series Analyses of Toll Traffic

Table 5-7 shows time series analysis results for the combined toll traffic on the Indiana Toll road. Statistically significant elasticity estimate with respect to gas price was −0.36 at a 10 percent significance level for the Barrier System. No elasticity estimates with respect to toll rate for both Barrier and Ticket System were statistically significant. Statistically significant elasticity estimates with respect to unemployment rates was −0.09 at a 1 percent significance level for the Barrier System.

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[22] The west end of the Indiana Toll Road is located within the Chicago-Gary-Kenosha MSA. As there were no monthly gas price and CPI available for the general region where the Toll Road crosses, we used the corresponding gas price and CPI for Chicago-Gary-Kenosha as an approximation. The unemployment rates were not available for the region either, so the State level unemployment rate was used as an approximation. We then converted the monthly data into quarterly data by averaging corresponding months of each quarter.

[23] Note: ticket system traffic is reported in terms of full-length equivalent trips, and the barrier system traffic is reported in terms of total transactions.

Table 5-7: Regression Results (Indiana Toll Road)

Tolling System	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Barrier System	-	-0.36* (0.17)	-0.18 (0.22)	-0.09*** (0.01)	-	0.78	**Sample Period**: 2006:Q3 - 2009:Q4 **Sample Size**: 14
Ticket System	-	-0.02 (0.12)	-0.03 (0.15)	-0.01 (0.01)	-	-0.14	

Notes:
- *=10% significance level, **=5% significance level, ***=1% significance level.
- The ticket system is reported in terms of full-length equivalent trips. The barrier system is reported in terms of total transactions.
- Missing coefficient estimates for $LogTollVol_{t-1}$ were due to use of quarterly data, which do not capture much information for the near-term future time periods.
- Standard errors in brackets ().
- A negative R^2 suggests that the model fits worse than a model consisting only of the sample mean.

5.9 Kansas Turnpike, Kansas

The Kansas Turnpike is a 236-mile (380 km) toll road that runs in a general southwest-northeast direction from the Oklahoma border, and passes through several major Kansas cities, including Wichita, Topeka, Lawrence and Kansas City (see Figure 5-21). The Kansas Turnpike Authority owns and maintains the turnpike.

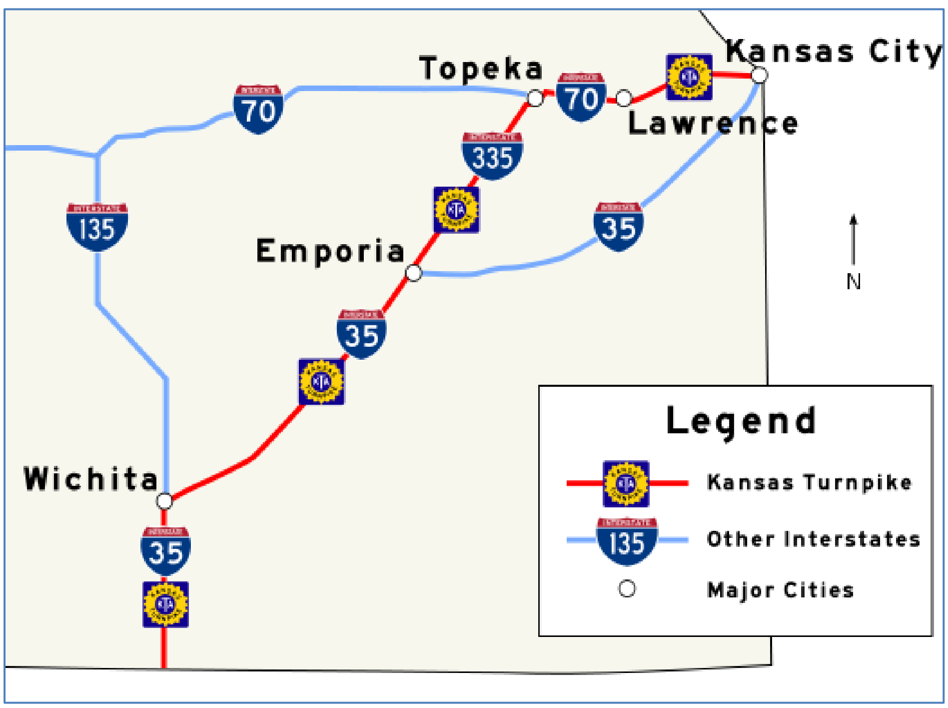


Figure 5-21: Location of the Kansas Turnpike in Kansas
Source: http://en.wikipedia.org/wiki/Kansas_Turnpike

5.9.1 Data Description

Toll traffic volume data were available for different vehicle classes (2- to 9-axle) for the period January 2000 to July 2010. As the state-specific gas price and CPI information were not available, corresponding monthly all-type gasoline price average and CPI for all urban consumers for the Midwest Region were used to approximate the data for regions along the Turnpike corridor.

Gas price and CPI for the Midwest Region peaked in the year 2008. Unemployment rates were obtained for the state of Kansas.[24] The peak unemployment rate in Kansas (7.8 percent) was lower than in San Francisco (10.5 percent) and the Miami region (11 percent).

The toll rates for different vehicle classes were adjusted with the CPI. Historical toll rates for different vehicle classes were obtained by dividing the total revenue collected by the total mileage driven on the toll roads for each vehicle category.[25] There were several toll adjustments during the 127-month study period.

5.9.2 Time Series Analyses of Kansas Turnpike Traffic

Table 5-8 shows time series analysis results. None of the elasticity estimates of toll road use with respect to gas price were statistically significant. One elasticity estimate with respect to toll rate was statistically significant (−0.08 for 2-axle vehicles). None of the elasticity estimates with respect to unemployment rates were statistically significant.

[24] The state unemployment rate was used because the Kansas Turnpike goes cross the borders of several cities, and there was no data for the general area covering whole segment of the Turnpike.
[25] So the toll rates were expressed in cents/mile.

Table 5-8: Regression Results (Kansas Turnpike)

Vehicle Class	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
2-Axle	0.91*** (0.05)	-0.01 (0.01)	-0.08* (0.05)	0.001 (0.002)	0.30* (0.17)	0.79	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
3-Axle	0.92*** (0.04)	-0.0002 (0.02)	-0.02 (0.10)	0.003 (0.004)	-0.27 (0.39)	0.73	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
4-Axle	0.89*** (0.05)	-0.002 (0.02)	-0.09 (0.09)	0.01 (0.004)	-0.08 (0.37)	0.62	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
5-Axle	0.31** (0.12)	0.03 (0.03)	-0.01 (0.11)	-0.01 (0.003)	×	0.87	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
6-Axle	0.99*** (0.02)	-0.001 (0.01)	0.04 (0.11)	0.001 (0.002)	×	0.95	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
7-Axle	0.95*** (0.03)	-0.004 (0.008)	-0.07 (0.10)	0.001 (0.002)	×	0.69	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
8-Axle	0.87*** (0.09)	0.04 (0.04)	0.26 (0.27)	0.004 (0.008)	-0.29 (0.72)	0.73	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
9-Axle	0.30*** (0.09)	0.07 (0.05)	-0.50 (0.35)	-0.01 (0.01)	2.22* (1.14)	0.61	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
All Classes	0.93*** (0.04)	-0.002 (0.008)	-	0.001 (0.002)	0.15 (0.15)	0.79	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a ×) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.
- Standard errors in brackets ().

5.10 Harbor Tunnel Thruway, Maryland Transportation Authority, Maryland

The Harbor Tunnel Thruway (I-895) is a 14.87-mile (23.93 km) toll road that crosses the Patapsco River estuary via the Baltimore Harbor Tunnel (see Figure 5-22). The highway, maintained by the Maryland Transportation Authority, is designed for through traffic by having partial interchanges that require vehicles from almost all starting points to pass through the tunnel and the tunnel toll plaza before exiting the facility.

5.10.1 Data Description

Total monthly toll traffic volume data (Figure 5-23) were available for different vehicle classes[26] (2- to 6+-axle) for the period January 2003 to August 2010. A plot of the 2-axle vehicles traffic volume, which comprised a large portion of the total traffic, showed no apparent trend except for seasonality, for the sample period (Figure 5-24).

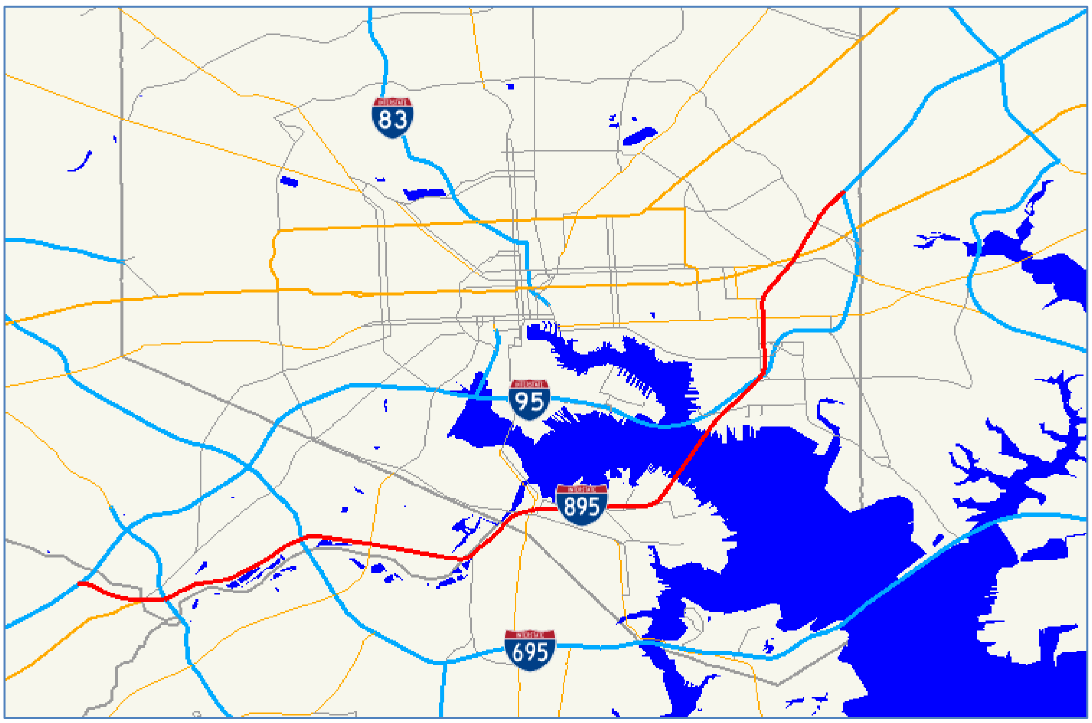


Figure 5-22: Location of the Harbor Tunnel Thruway (I-895) in Baltimore, Maryland
Source: http://en.wikipedia.org/wiki/Harbor_Tunnel_Thruway

[26] Motorcyclists pay the two-axle rate when using a side-car, or towing a light trailer. However, traffic data for motorcyclists were only available for May 2009 to August 2010, which was too short a period for analysis, so motorcyclists were not included in the time series analysis. Some traffic data for an extra category defined as "Unusual Axle" were also available for January 2003 to August 2010, but there were many missing data points, so they were also excluded this vehicle class from analysis.

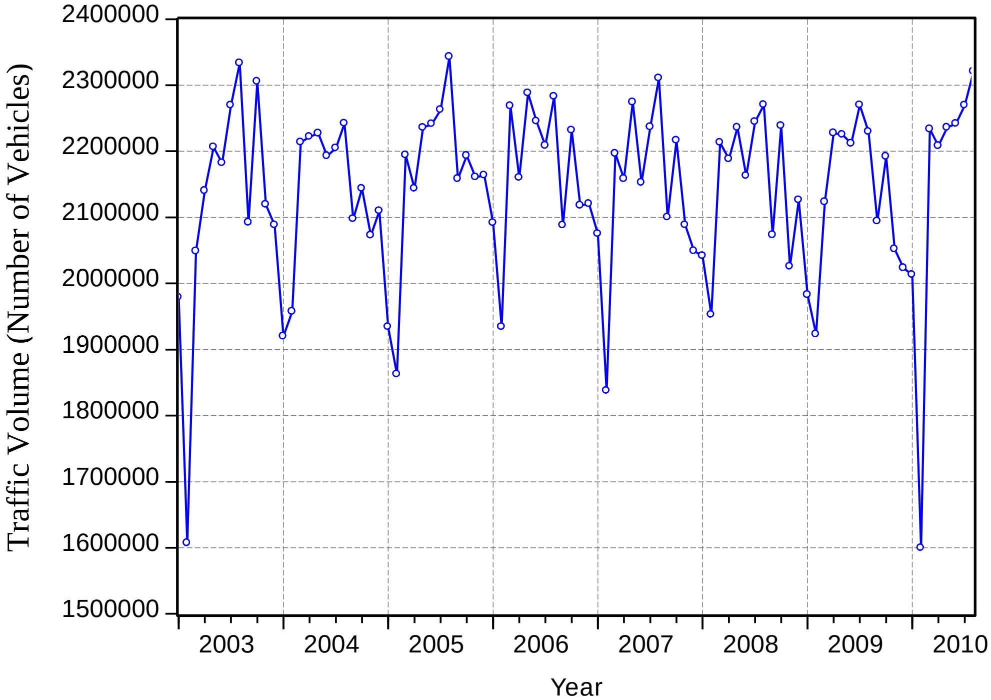


Figure 5-23: Harbor Tunnel Thruway Traffic Volume (All Vehicle Classes)

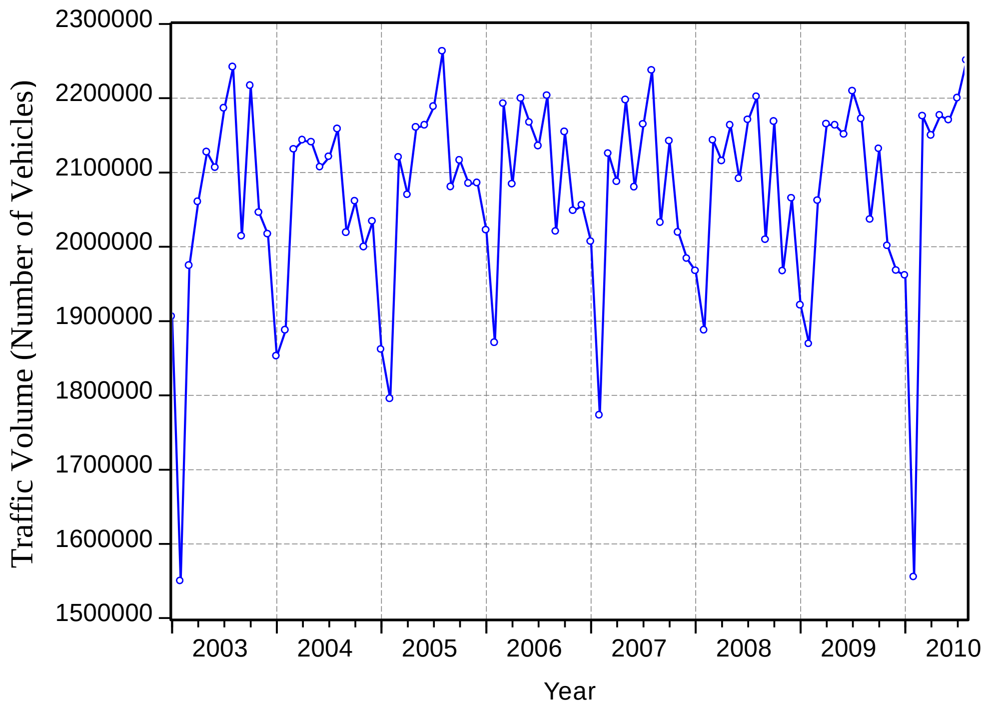


Figure 5-24: Harbor Tunnel Thruway Toll Traffic Volume (2-Axle Vehicles)

Monthly gasoline price averages and CPI for all urban consumers for the Washington-Baltimore MSA were obtained from the LexisNexis Statistical Datasets. Gas prices and CPI for this MSA peaked in the year 2008. Monthly unemployment rates were for the Baltimore-Towson MSA. The peak unemployment rates for the study period in this MSA were a little lower (8.6 percent was the highest) than in San Francisco (highest at 10.5 percent) and the Miami region (highest at 11 percent).

The toll rates for different vehicle classes were adjusted using the CPI. During the 92-month study period there were two toll increases for 3- to 6+-axle vehicles and only one for 2-axle vehicles.

5.10.2 Time Series Analyses on Harbor Tunnel Thruway Traffic

Table 5-9 shows time series analysis results. Results for the 2-axle vehicles deserve some discussion: two regressions[27] were run on the actual toll traffic volume and its seasonally adjusted counterpart (see Figure 5-24 for the plots of toll traffic volume and seasonally adjusted volume for 2-axle vehicles). This was due to the extremely low goodness-of-fit (adjusted R^2: 0.06) obtained from regression on seasonally adjusted traffic volume (see Figure 5-25 for the plots of seasonally adjusted and fitted traffic volume for 2-axle vehicles). The second regression analysis was on the actual traffic volume but with eleven seasonal dummy variables. The goodness-of-fit generated from this model was reasonably high (adjusted R^2: 0.84, see Figure 5-26 for the plots of actual and fitted traffic volume for 2-axle vehicles). The difference in the goodness-of-fit was apparently due to the inclusion of seasonal dummy variables in the regression on the actual traffic volume. Seasonal shift could account for the variation of traffic in the toll tunnel as the primary force, while gas price, toll rate and unemployment rate did not significantly exert influence on the use of the toll tunnel.[28] This is consistent with the fact that drivers in this area (in particular passenger and commuter vehicles) might not have too many alternative routes to switch to other than using the tunnel.

[27] Regressions were on the subsamples of 2-axle traffic volume with the following extreme outliers excluded: January 2004, February 2010 to August 2010.
[28] During this period, total 2-axle vehicle traffic remained consistent, apart from the seasonal variation.

Table 5-9: Regression Results (Harbor Tunnel Thruway)

Vehicle Class	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
2-Axle[a]	0.02 (0.27)	-0.03 (0.02)	-0.02** (0.01)	-0.01* (0.004)	0.69 (0.48)	0.06	**Sample Period**: 2003:03-2010:01 **Sample Size**: 92
2-Axle[b]	-0.14 (0.52)	-0.02 (0.03)	-0.03 (0.03)	-0.01 (0.005)	0.57 (0.67)	0.85	**Sample Period**: 2003:03-2010:01 **Sample Size**: 92
3-Axle	0.56*** (0.10)	-0.02*** (0.05)	-0.003 (0.027)	-0.01 (0.01)	-0.03 (1.35)	0.36	**Sample Period**: 2003:01-2010:08 **Sample Size**: 92
4-Axle	0.48*** (0.09)	0.004 (0.07)	0.06 (0.04)	-0.01** (0.02)	-2.89 (1.83)	0.59	**Sample Period**: 2003:01-2010:08 **Sample Size**: 92
5-Axle	0.73*** (0.05)	-0.07*** (0.02)	-0.01 (0.01)	-0.02*** (0.00)	×	0.94	**Sample Period**: 2003:01-2010:08 **Sample Size**: 92
6-Axle	0.43*** (0.09)	0.32 (0.22)	-0.22* (0.12)	-0.05 (0.04)	-0.70 (5.32)	0.47	**Sample Period**: 2003:01-2010:08 **Sample Size**: 92
All Classes	0.06 (0.11)	-0.04* (0.02)	-	-0.02*** (0.004)	1.31** (0.52)	0.09	**Sample Period**: 2003:01-2010:08 **Sample Size**: 92

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- a: This regression is on the seasonally adjusted traffic volume.
- b: This regression is on the actual traffic volume. Eleven monthly dummy variables were included.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a ×) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.
- Standard errors in brackets ().

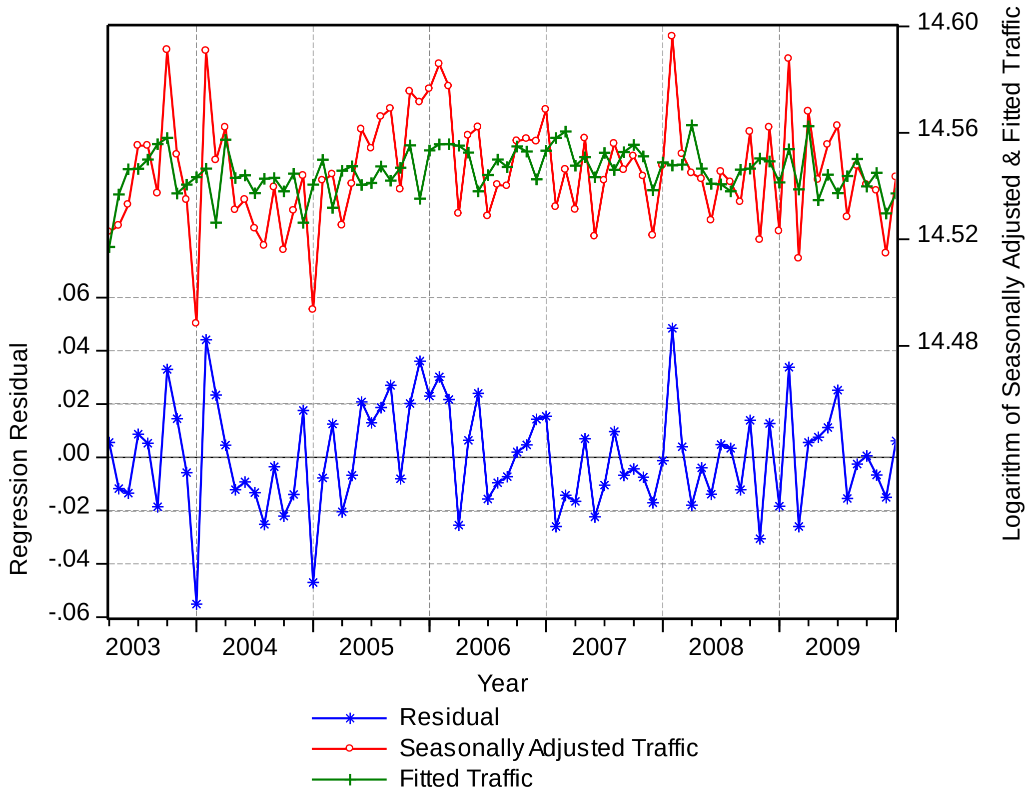


Figure 5-25: Seasonally Adjusted, Fitted Tolled Traffic Volume and Regression Residual for 2-Axle Vehicles (Harbor Tunnel Thruway)

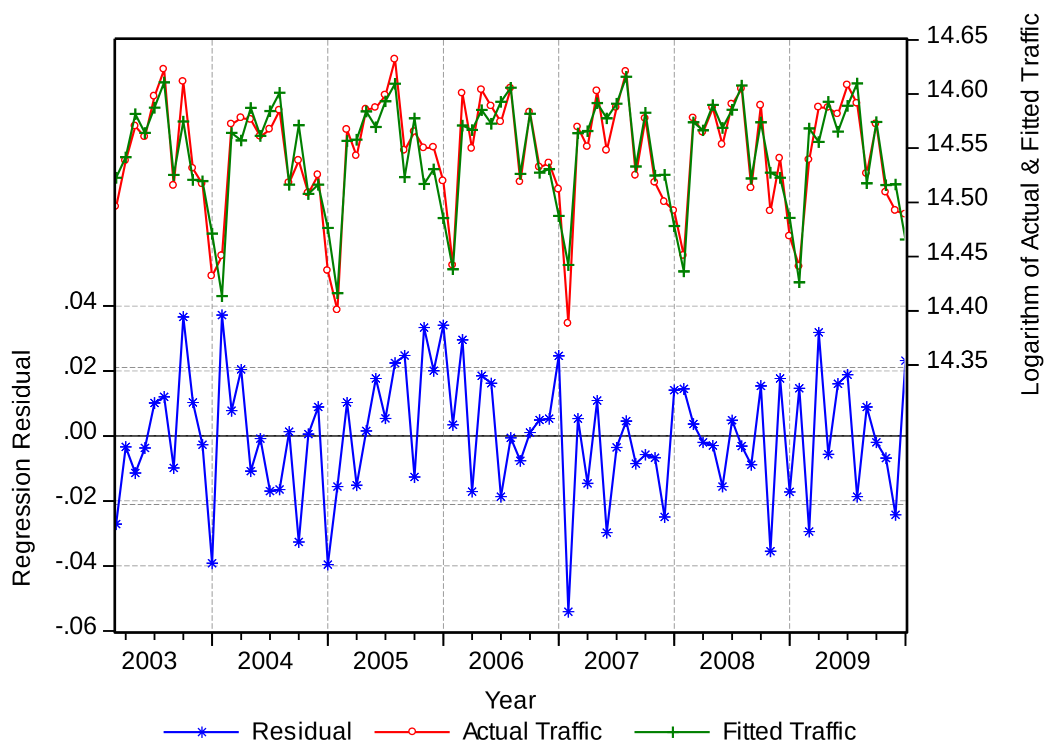


Figure 5-26: Actual, Fitted Tolled Traffic Volume and Regression Residual for 2-Axle Vehicles (Harbor Tunnel Thruway)

5.11 New York State Thruway, New York

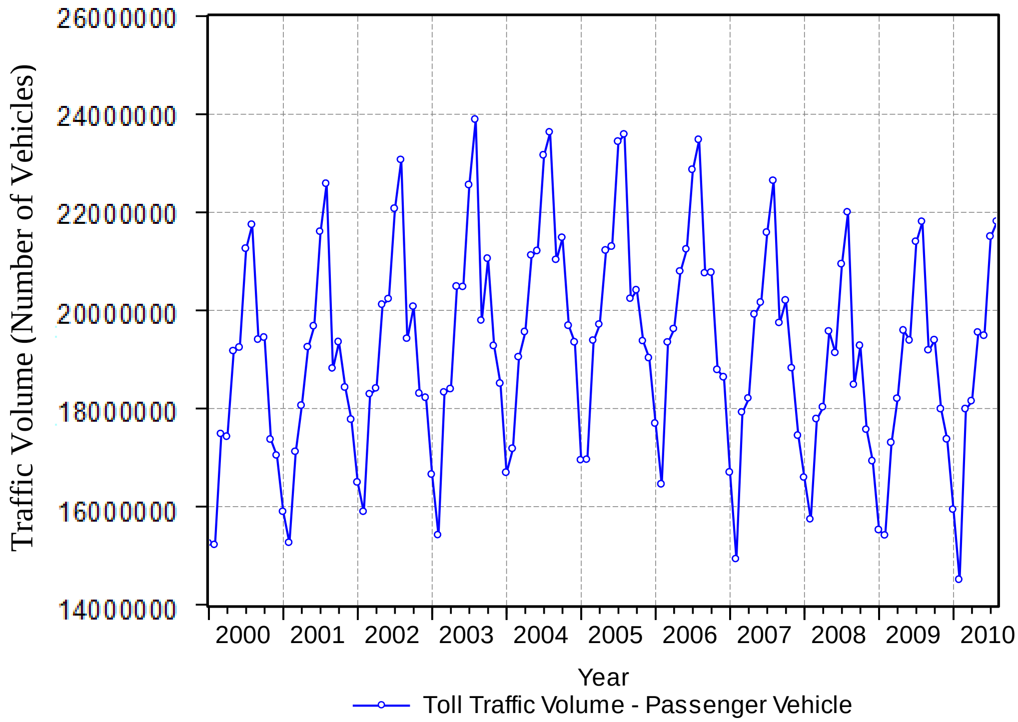
One of the longest toll highway systems in the United States, the New York State Thruway is a 570-mile highway system crossing the state. The Thruway route from the New York City line to the Pennsylvania line at Ripley is 496 miles long and includes the 426-mile mainline connecting the state's two largest cities, New York City and Buffalo (see Figure 5-27). This study obtained the monthly toll traffic volume data for both passenger and commercial vehicles.[29]

Figure 5-27: New York State Thruway Corridor in New York
Source: Google Map

5.11.1 Data Description

Monthly toll traffic volume data (Figure 5-28) were available for passenger and commercial vehicles for the period January 2000 to August 2010. Traffic plots (Figure 5-28) show that seasonality exerted a strong influence on the total traffic volumes. Traffic had generally increased during the period 2000 to 2004. Then, in the middle of 2004, total traffic began to decrease. This is particularly true for the commercial vehicle traffic that experienced a sudden large decrease in 2005.

[29] The New York State Thruway Authority defines passenger vehicles as a 2-axle passenger vehicle or 2-axle passenger vehicle towing a 1- to 3-axle trailer. Commercial vehicles are defined as 2- to 7-axle trucks greater than 7'6" high.



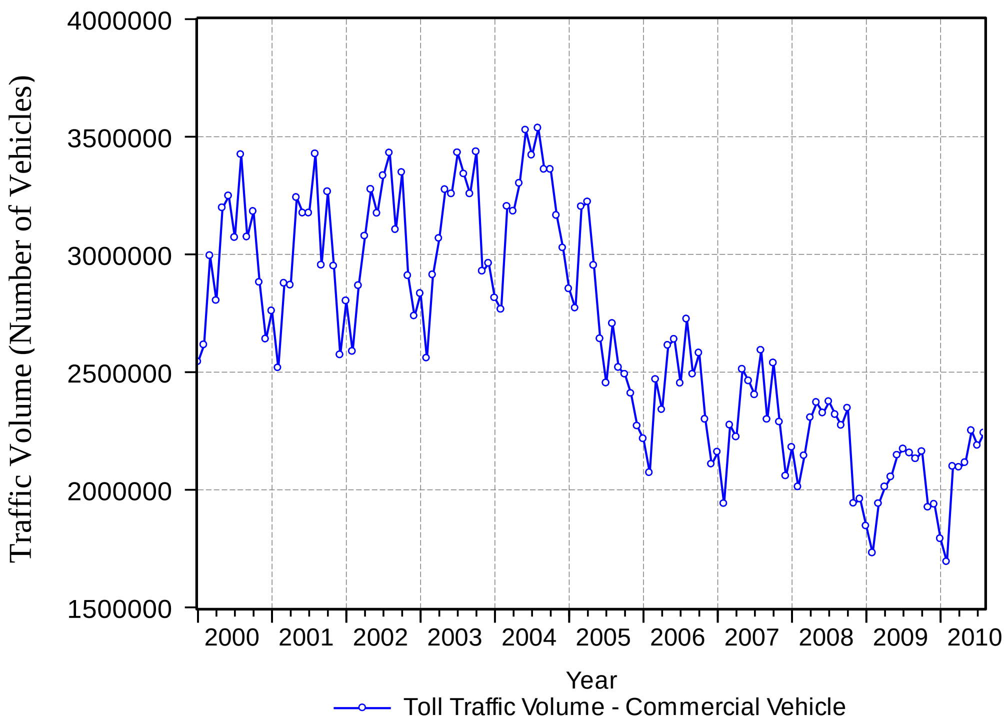


Figure 5-28: Toll Traffic Volume (Number of Vehicles) for New York State Thruway, New York

Monthly gasoline price averages and CPI for all urban consumers for the New York-Northern New Jersey-Long Island MSA were obtained from the LexisNexis Statistical Datasets. Gas price and CPI for this MSA peaked in the year 2008. Monthly unemployment rates were for the state of New York. The nominal toll rates for passenger and commercial vehicles were adjusted using the CPI. During the 120-month study period there were five toll increases for all vehicle classes.[30]

5.11.2 Time Series Analyses on Vehicle Types

Table 5-10 shows time series analysis results. Remember that the commercial vehicle traffic experienced a sudden large decrease in 2005—this may suggest a structural change in the demand function for toll roads before and after 2005. Therefore, the elasticity of toll road use by commercial vehicles was first estimated for the entire 10-year period followed by two sub-periods—one prior to 2005 and the other after 2005. Elasticity estimates of toll road use with respect to gas price were insignificant for both passenger and commercial vehicles in the 10-year period. However, the gas price elasticity estimate was statistically significant for commercial vehicles in the period prior to 2005. Elasticity estimate with respect to toll rate for commercial vehicle traffic was negative and inelastic (at a 10 percent significance level) in both the 10-year period and the after-2005 periods. Elasticity estimate with respect to unemployment rate for commercial vehicle traffic was negative in the post-2005 period (at a 1 percent significance level).

[30] The New York State Thruway Authority provided the percentage change (five observations) in toll rates for all vehicles. The five toll rate adjustments are listed below:

- In 2005, toll rates went up approximately 25 percent for passenger vehicles and 35 percent for commercial vehicles (E-ZPass was discounted 10 percent for passenger vehicles and 5 percent for commercial vehicles);
- In 2006, approximate 15 percent increase for passenger vehicles and 25 percent increase for commercial vehicles;
- January 2008, 10 percent overall increase;
- July 2008, the E-ZPass discount for passenger vehicles dropped from 10 percent to 5 percent;
- January 2009, general 5 percent increase.

As we did not obtain actual toll rates for both passenger and commercial vehicles (no E-ZPass participation information either), the above toll rate changes were not used in deriving the toll rate information. Toll rates were derived from New York State Thruway Authority's annual reports (2000 to 2009) – dividing the annual toll revenue by the number of transactions for a specific year for passenger and commercial vehicles, respectively. The average toll rates were then used for that entire year. Graphing these volumes shows that there were exactly five toll increases, which was consistent with the information provided by the New York State Thruway Authority. Approximation of toll rates in this way may generate bias when the toll adjustments did not occur at the start of a new year. However, there is only one such instance in the five toll adjustments and only the year 2008 was impacted. Therefore, an additional time series regression was run on the dataset with the year 2008 excluded to compare with the results of the regression on the dataset with whole range and there was no significant difference between elasticity estimates from models with and without data from the year 2008 included.

Table 5-10: Regression Results (New York State Thruway)

Vehicle Class	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Passenger Vehicle	0.94*** (0.03)	-0.01 (0.01)	-0.02 (0.02)	0.0004 (0.001)	0.30 (0.31)	0.97	**Sample Period**: 2000:01-2010:08 **Sample Size**: 128
Commercial Vehicle	0.82*** (0.05)	0.02 (0.02)	-0.14*** (0.04)	0.001 (0.003)	-1.32 (0.88)	0.96	**Sample Period**: 2000:01-2010:08 **Sample Size**: 128
	-0.23* (0.13)	0.13** (0.05)	-0.06 (0.06)	0.003 (0.008)	3.56 (1.60)	0.57	**Sample Period**: 2000:01-2005:02 **Sample Size**: 62
	0.34*** (0.12)	-0.0003 (0.03)	-0.16* (0.09)	-0.02*** (0.006)	×	0.77	**Sample Period**: 2005:06-2010:08 **Sample Size**: 63

Notes:
- *=10% significance level, **=5% significance level, ***=1% significance level.
- Standard errors in brackets ().
- Missing estimates (if symbolized with a ×) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.

5.12 Oklahoma Turnpike Toll Road System, Oklahoma

Oklahoma's extensive turnpike system is maintained by the state government through the Oklahoma Turnpike Authority. We obtained monthly traffic volume data for the period January 2000 to September 2010 for each of the ten turnpikes operated by the OTA. These ten turnpikes are listed below (see Figure 5-29 for a map of the OTA turnpike system):

- Cherokee Turnpike (part of the U.S. Highway 412),
- Chickasaw Turnpike,
- Cimarron Turnpike (part of the U.S. Highway 412),
- Creek Turnpike,
- H.E. Bailey Turnpike (Part of Interstate 44),
- Indian Nation Turnpike,
- Kilpatrick Turnpike,
- Muskogee Turnpike,
- Turner Turnpike, and
- Will Rogers Turnpike.

Figure 5-29: Map of the Oklahoma Turnpike System Toll Roads, Oklahoma
Source: http://pikepass.com/

5.12.1 Data Description

Monthly toll traffic data (by miles driven on the toll roads) were available for different vehicle classes[31] (2-axle through 6-axle, as defined by the OTA) for the period January 2000 to September 2010 for the 9 turnpikes operated by the OTA[32]. Figure 5-30 shows the total monthly toll traffic data for the Turnpike system. Monthly all-type gasoline price average and CPI for all urban consumers for the Midwest Region and monthly unemployment rates for the state of Oklahoma were obtained from the LexisNexis Statistical Datasets. Toll rate averages for different vehicle classes were obtained by dividing the total revenue by the total miles travelled on the turnpikes. The CPI-adjusted toll rates were obtained by dividing the toll rate by the CPI for the sample period.

[31] On January 1, 2001, the OTA consolidated its vehicle classes into five separate classes based on axle counts (2-axle through 6-axle). According to the OTA, vehicles were reclassified for comparison purposes:

Pre 01/01/01	After
Class 1	2-axle
Class 2	3-axle
Class 3	4-axle
Class 4	2-axle
Class 5	3-axle
Class 6	4-axle
Class 7	5-axle
Class 8	6-axle

[32] For the periods December 2001 to January 2003 and March 2006 to September 2006, traffic in the Chickasaw Turnpike was significantly interrupted for an unknown reason, so the Chickasaw Turnpike was not included in the combined toll traffic data and not further analyzed.

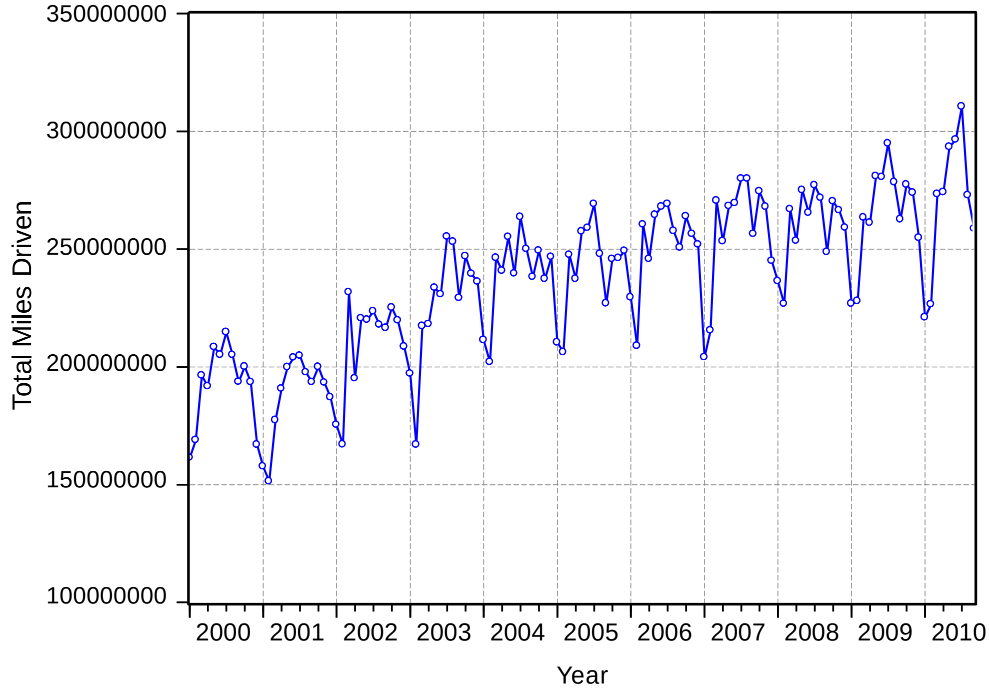


Figure 5-30: Total Miles Driven by Tolled Vehicles on the Oklahoma Turnpike System

5.12.2 Time Series Analyses on Vehicle Classes

For 2-axle vehicles, two elasticity estimates of travel demand on the toll road with respect to gas price were statistically significant (see Table 5-11). Statistically significant estimates of the elasticity of traffic volume with respect to toll rate ranged from -0.79 to -0.27, and estimates of the elasticity of traffic volume with respect to unemployment rates were much smaller, ranging from 0.01 to 0.03. Discussion of results for other vehicle classes is summarized in the concluding section of this chapter.

Table 5-11: Regression Results (OTA)

Vehicle Class	Turnpike	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
2-Axle	Cherokee	-0.09 (0.07)	-0.07* (0.04)	-0.79*** (0.06)	0.02* (0.01)	-0.10 (0.61)	0.72	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Chickasaw	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	Cimarron[b]	0.28*** (0.09)	-0.02 (0.03)	-0.27*** (0.07)	0.01*** (0.005)	0.67* (0.35)	0.89	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Creek[b]	0.39*** (0.09)	0.001 (0.03)	-0.36*** (0.08)	0.0001 (0.007)	2.87*** (0.61)	0.94	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91
	H.E. Bailey[b]	0.74*** (0.07)	0.02 (0.02)	-0.11* (0.06)	0.01** (0.01)	0.21 (0.25)	0.91	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Indian Nation	-0.31*** (0.08)	-0.05** (0.06)	-0.64*** (0.18)	0.02 (0.01)	0.07 (0.91)	0.62	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Kilpatrick[a,b]	0.80*** (0.07)	-0.003 (0.02)	-0.14** (0.06)	-0.001 (0.003)	0.85** (0.35)	0.94	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
	Muskogee	0.48*** (0.06)	0.02 (0.02)	-0.33*** (0.07)	0.02*** (0.004)	0.10 (0.28)	0.89	**Sample Period**[c]: 2000:01-2010:09 **Sample Size**: 129
	Turner	0.29*** (0.08)	-0.01 (0.02)	-0.41*** (0.06)	0.02*** (0.004)	1.02** (0.42)	0.91	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Will Rogers	0.46*** (0.07)	0.02 (0.03)	-0.38*** (0.07)	0.03*** (0.01)	-0.42 (0.37)	0.87	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
3-Axle	Cherokee	-0.13 (0.09)	-0.07 (0.07)	-0.81*** (0.12)	0.01 (0.01)	1.72 (1.43)	0.77	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Chickasaw	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	Cimarron[b]	0.81*** (0.08)	0.003 (0.05)	-0.20 (0.14)	0.01 (0.01)	0.06 (0.59)	0.91	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Creek[b]	-0.21 (0.13)	-0.24** (0.11)	-0.30 (0.22)	-0.11*** (0.03)	12.50*** (1.93)	0.87	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91
	H.E. Bailey[b]	0.59*** (0.08)	0.04 (0.07)	-0.30 (0.26)	0.03** (0.01)	1.08 (1.03)	0.83	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129

Table 5-11: Regression Results (OTA) (continued)

Vehicle Class	Turnpike	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	Indian Nation	0.46*** (0.08)	-0.05 (0.04)	-0.40*** (0.12)	-0.01* (0.01)	2.06*** (0.57)	0.82	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Kilpatrick[a,b]	0.59*** (0.09)	-0.05 (0.11)	-0.41 (0.29)	-0.06** (0.03)	3.18** (1.52)	0.77	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
	Muskogee	0.93*** (0.03)	-0.04 (0.03)	-0.04 (0.08)	0.01** (0.005)	0.57* (0.31)	0.86	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Turner	0.49*** (0.07)	0.05* (0.03)	-0.29*** (0.08)	0.003 (0.005)	0.16 (0.39)	0.82	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Will Rogers	0.63*** (0.06)	0.05* (0.03)	-0.36*** (0.07)	0.01*** (0.005)	-0.43 (0.33)	0.87	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
4-Axle	Cherokee	0.66*** (0.07)	-0.09*** (0.03)	-0.30** (0.13)	-0.003 (0.005)	×	0.57	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Chickasaw	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	Cimarron[b]	0.39*** (0.09)	-0.04 (0.05)	-0.37*** (0.12)	0.001 (0.008)	1.04* (0.61)	0.95	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Creek[b]	0.46*** (0.10)	-0.22** (0.09)	-0.84*** (0.16)	-0.03 (0.02)	5.92 (1.44)	0.89	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91
	H.E. Bailey[b]	0.38*** (0.09)	-0.01 (0.04)	-0.07 (0.12)	0.01* (0.01)	0.36 (0.50)	0.81	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Indian Nation	-0.13 (0.09)	0.03 (0.05)	-0.36*** (0.10)	-0.01 (0.01)	1.06 (0.66)	0.45	**Sample Period**: 2000:01-2002:12, 2003:02-2010:09 **Sample Size**: 128
	Kilpatrick[a,b]	0.57*** (0.09)	-0.10 (0.09)	-0.56*** (0.20)	-0.04* (0.02)	4.21*** (1.37)	0.85	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
	Muskogee	0.26*** (0.08)	-0.06** (0.03)	-0.52*** (0.11)	0.001 (0.006)	1.36*** (0.44)	0.59	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Turner	0.63*** (0.07)	0.002 (0.03)	-0.16* (0.08)	-0.004 (0.06)	-0.67 (0.40)	0.50	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Will Rogers	0.86*** (0.05)	-0.04** (0.02)	-0.13** (0.06)	0.002 (0.003)	×	0.70	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
5-Axle	Cherokee	0.67*** (0.07)	0.06* (0.03)	-0.22*** (0.07)	0.02** (0.01)	-1.82 (0.50)	0.73	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129 Pop-Gas correlation 0.74

Table 5-11: Regression Results (OTA) (continued)

Vehicle Class	Turnpike	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	Chickasaw	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	Cimarron[b]	0.33*** (0.09)	0.05* (0.03)	-0.21*** (0.07)	-0.01 (0.01)	0.18 (0.50)	0.82	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Creek[b]	0.27** (0.13)	-0.07 (0.05)	-0.11 (0.13)	-0.03*** (0.01)	2.11*** (0.78)	0.48	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91 ARCH Model
	H.E. Bailey[b]	0.25*** (0.09)	0.10*** (0.03)	0.12* (0.10)	-0.02*** (0.01)	0.15 (0.44)	0.64	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Indian Nation	0.39*** (0.08)	0.08*** (0.02)	-0.02 (0.06)	-0.01 (0.01)	-0.02 (0.39)	0.55	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Kilpatrick[1,a,b]	0.70*** (0.09)	0.05 (0.05)	-0.08 (0.13)	-0.02 (0.01)	0.56 (0.61)	0.87	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
	Muskogee	0.31*** (0.08)	0.03 (0.02)	0.02 (0.06)	-0.02*** (0.01)	-0.05 (0.34)	0.49	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Turner	-0.10*** (0.03)	-0.02 (0.04)	-0.85*** (0.05)	-0.01 (0.01)	-0.27 (0.80)	0.76	**Sample Period**: 2000:01-2002:02, 2002:04-2010:09 **Sample Size**: 128
	Will Rogers	0.88*** (0.07)	0.03* (0.02)	0.09 (0.06)	-0.001 (0.005)	-0.28 (0.21)	0.85	**Sample Period**: 2003:07-2010:09 **Sample Size**: 87
6-Axle	Cherokee	0.90*** (0.04)	0.01 (0.04)	-0.15 (0.12)	-0.001 (0.01)	×	0.76	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Chickasaw	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	Cimarron[b]	0.93*** (0.04)	0.04 (0.06)	-0.05 (0.09)	0.01 (0.01)	-1.11 (0.84)	0.76	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Creek[b]	0.79*** (0.06)	0.19 (0.14)	-0.09 (0.33)	-0.02 (0.04)	-2.32 (1.88)	0.78	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91
	H.E. Bailey[b]	0.74*** (0.06)	0.33*** (0.08)	-0.24 (0.18)	0.02 (0.01)	-0.85 (0.91)	0.91	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Indian Nation	0.74*** (0.07)	0.02 (0.04)	0.02 (0.10)	-0.02** (0.01)	1.70** (0.80)	0.77	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Kilpatrick[2,a,b]	0.72*** (0.06)	-0.05 (0.06)	-0.53*** (0.16)	-0.05*** (0.02)	1.72* (0.96)	0.90	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90

Table 5-11: Regression Results (OTA) (continued)

Vehicle Class	**Turnpike**	**$LogTollVol_{t-1}$**	**$LogGas_t$**	**$LogTollRate_t$**	**$UEMP_t$**	**$LogPop_t$**	**Adjusted R^2**	**Notes**
	Muskogee	0.98*** (0.03)	0.05 (0.06)	0.15 (0.13)	0.01 (0.01)	-0.83 (0.75)	0.94	**Sample Period**: 2000:01-2010:09 **Sample Size**: 96
	Turner	0.49*** (0.07)	0.05* (0.03)	-0.29*** (0.08)	0.003 (0.006)	0.16 (0.39)	0.82	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Will Rogers	0.91*** (0.04)	0.05* (0.03)	-0.06 (0.05)	0.007 (0.005)	-0.01 (0.46)	0.96	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
All Classes	Cherokee	0.40*** (0.08)	0.05 (0.04)	-	0.01 (0.01)	-0.13 (0.67)	0.27	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Chickasaw	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
	Cimarron[b]	0.84*** (0.07)	0.003 (0.02)	-	0.002 (0.003)	0.21 (0.19)	0.89	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Creek[b]	-0.31 (0.29)	-0.07 (0.04)	-	-0.05*** (0.01)	7.19*** (1.65)	0.94	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91
	H.E. Bailey[b]	0.76*** (0.07)	0.02 (0.02)	-	0.01* (0.004)	0.34 (0.23)	0.90	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Indian Nation	0.17* (0.09)	0.03 (0.02)	-	0.01** (0.01)	0.75** (0.35)	0.49	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Kilpatrick[1,a,b]	0.80*** (0.07)	-0.005 (0.02)	-	-0.005 (0.003)	0.91** (0.38)	0.93	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
	Muskogee	0.64*** (0.06)	0.05** (0.02)	-	0.01*** (0.004)	0.16 (0.29)	0.84	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Turner[b]	0.55*** (0.16)	0.01 (0.03)	-	-0.01 (0.008)	1.74** (0.77)	0.80	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
	Will Rogers	0.87*** (0.05)	0.03 (0.02)	-	0.006 (0.004)	-0.13 (0.25)	0.84	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- a: traffic significantly interrupted for unknown reason -->results may not be accurate.
- b: Modeled on unadjusted data with seasonal dummy variable.
- 1: due to high correlation (-0.81) between the Gas Price and Toll Rate, the Toll Rate was excluded in the specification.
- 2: due to high correlation (-0.74) between the Gas Price and Toll Rate, the Toll Rate was excluded in the specification.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a ×) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.
- Standard errors in brackets ().

5.13 Harris County Toll Road System, Texas

The Harris County Toll Road Authority system consists of approximately 120 miles of roadway in the Houston/Harris County area and 12 miles in Ft. Bend County, for a total of 132 miles. Monthly traffic volume data by toll plazas were obtained for the period January 2000 to December 2009 for the Hardy Toll Road and the Sam Houston Tollway (see Figure 5-31 for the map of the HCTRA system). These nine toll plazas are:

- Hardy North,
- Hardy South,
- Sam Houston South,
- Sam Houston Central,
- Sam Houston North,
- Sam Houston East,
- Sam Houston SouthEast,
- Sam Houston SouthWest, and
- Ship Channel Bridge.

5.13.1 Data Description

Figure 5-32 shows monthly toll traffic volume for the HCTRA system. Hurricane Ike caused large decreases in counted traffic volumes in August and September 2008. Monthly all-type gasoline price average, CPI for all urban consumers for the Houston-Galveston-Brazoria MSA, and monthly unemployment rates for the Houston-Sugar Land-Baytown MSA were obtained from the LexisNexis Statistical Datasets.

The monthly traffic data were the combined volumes for all vehicle classes, while the historical toll rates were for each vehicle class. This conflict made including toll rate as a factor in the regression difficult. However, proportional changes of the three toll adjustments during the period January 2000 to September 2009 show that for each toll adjustment the proportional change for each different vehicle class was not substantially different [33](see Table 5-12). For the above reason, the toll rate remained as a factor in the regression analysis through using an (approximately) proportional change index[34] for all vehicle classes. The caveat is that the coefficient estimates may not accurately reflect the actual elasticity of toll traffic volume with respect to toll rates.

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[33] Notice the proportional changes for 2003 range from 25 percent to 39 percent for all toll plazas except the Ship Channel Bridge toll plaza. This is similar to the adjustment in 2007. For the adjustment in 2009, only toll rates for electronic Class 2 customers (4 percent) and Class 4 customers (13 percent for both cash and ECT customers) were increased.

[34] A roughly weighted average of the range was used to approximate the proportional change in toll rates for the combined toll traffic volume. For instance, the proportional change in toll adjustment for cash-paying customers driving Class 2, 3, 4, 5 and 6 vehicles in Hardy North Toll Plaza were 25%, 22%, 25%, 33%, and 39%, respectively. Therefore, considering Class 2 vehicles comprised the majority of the total traffic, we considered 25% as a proportional increase for the entire vehicle classes.

Figure 5-31: Map of the HCTRA Toll Roads System, Texas
Source: https://www.hctra.org/tollroads_map/

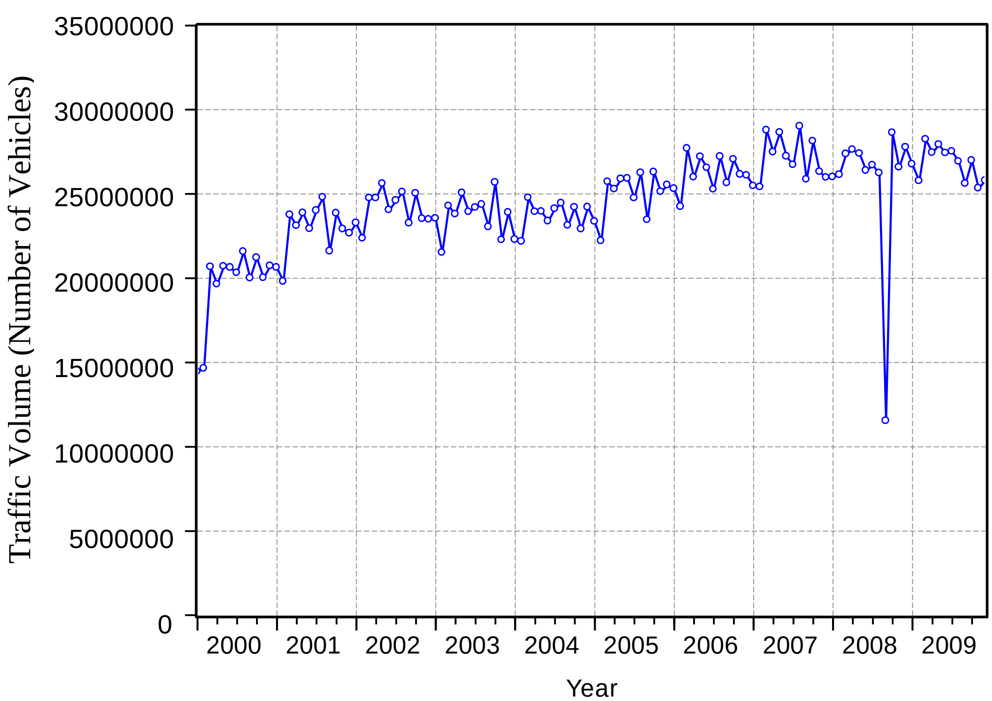

Figure 5-32: Toll Traffic Volume (Total) for the HCTRA System

Table 5-12: Proportional Changes of Toll Adjustment during the Study Period (HCTRA System)

Proportional Changes in Toll Adjustment (November 2003)

Hardy North	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Hardy South	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Sam South	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Sam Central	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Sam North	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Bridge	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	9%	29%	33%	36%
Mainline - EZ Tag	0%	9%	29%	33%	36%
Sam East	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Sam Southeast	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%
Sam Southwest	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	25%	22%	25%	33%	39%
Mainline - EZ Tag	33%	22%	25%	33%	39%

Proportional Changes in Toll Adjustment (September 2007)

Hardy North	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	9%	7%	20%	20%
Mainline - EZ Tag	25%	9%	7%	20%	20%
Hardy South	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	9%	7%	20%	20%
Mainline - EZ Tag	25%	9%	7%	20%	20%
Sam South	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	18%	20%	25%	28%
Mainline - EZ Tag	25%	18%	20%	25%	28%
Sam Central	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	18%	20%	25%	28%
Mainline - EZ Tag	25%	18%	20%	25%	28%
Sam North	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	18%	20%	25%	28%
Mainline - EZ Tag	25%	18%	20%	25%	28%
Bridge	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	8%	22%	25%	27%
Mainline - EZ Tag	0%	8%	22%	25%	27%
Sam East	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	9%	7%	20%	20%
Mainline - EZ Tag	25%	9%	7%	20%	20%
Sam Southeast	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	18%	20%	25%	28%
Mainline - EZ Tag	25%	18%	20%	25%	28%
Sam Southwest	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	20%	18%	20%	25%	28%
Mainline - EZ Tag	25%	18%	20%	25%	28%

Proportional Changes in Toll Adjustment (September 2009)

Hardy North	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Hardy South	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Sam South	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Sam Central	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Sam North	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Bridge	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	0%	0%	0%
Mainline - EZ Tag	0%	0%	0%	0%	0%
Sam East	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Sam Southeast	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%
Sam Southwest	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Mainline - Cash	0%	0%	13%	0%	0%
Mainline - EZ Tag	4%	0%	13%	0%	0%

5.13.2 Time Series Analyses on Tolled Traffic

Table 5-13 shows time series analysis results. Some data are excluded from the regression equations due to Hurricane Ike and other unknown reasons. Statistically significant elasticity estimates with respect to gas price ranged from −0.06 to −0.02—all were negative. This implies that the use of toll roads decreased as gas prices increased. Statistically significant elasticity estimates with respect to toll rate ranged from −0.31 to −0.05. Five elasticity estimates with respect to unemployment rates were statistically significant.

Table 5-13: Summarized Regression Results for Individual Toll Plaza (HCTRA System)

Toll Plaza	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Hardy North	0.96*** (0.02)	-0.01 (0.01)	0.02 (0.04)	-0.01*** (0.002)	0.09 (0.08)	0.83	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
Hardy South	-0.07 (0.19)	-0.06*** (0.03)	-0.31*** (0.11)	-0.01 (0.01)	1.64*** (0.40)	0.71	**Sample Period**: 2001:04-2008:08, 2008:10-2009:12 **Sample Size**: 105
Sam Houston South	0.32*** (0.08)	-0.05*** (0.02)	-0.25*** (0.05)	-0.01*** (0.003)	1.11*** (0.17)	0.77	**Sample Period**: 2000:03-2008:08, 2008:10-2009:12 **Sample Size**: 117
Sam Houston Central	0.20** (0.09)	-0.02 (0.02)	-0.13** (0.06)	-0.01*** (0.004)	1.10*** (0.18)	0.84	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
Sam Houston North	0.39*** (0.09)	-0.00 (0.02)	-0.05 (0.05)	-0.01** (0.003)	1.15*** (0.20)	0.93	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
SHSC Bridge	0.56*** (0.08)	-0.02 (0.02)	-0.17*** (0.06)	-0.01 (0.004)	0.95*** (0.16)	0.92	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
Sam Houston East	0.74*** (0.06)	-0.02** (0.01)	-0.17*** (0.04)	-0.01*** (0.002)	0.77*** (0.18)	0.95	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
Sam Houston SouthEast	0.79*** (0.05)	-0.02* (0.01)	-0.05** (0.03)	-0.003 (0.002)	0.42*** (0.12)	0.94	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
Sam Houston SouthWest	0.89*** (0.04)	-0.01 (0.01)	-0.05* (0.03)	-0.001 (0.002)	0.12 (0.08)	0.92	**Sample Period**: 2000:01-2008:08, 2008:10-2009:12 **Sample Size**: 119
Notes:	• *=10% significance level, **=5% significance level, ***=1% significance level. • Standard errors in brackets ().						

5.14 Summary of Results

Traffic consisted primarily of 2- and 5-axle vehicles for the nineteen toll roads/bridges operated by six agencies.[35] Demand elasticities of toll traffic volume (for 2- and 5-axle vehicles for the entire sample period) with respect to gas price, toll rate, unemployment rate and population are discussed below and shown in Table 5-14 and Table 5-16, respectively. To achieve our research objective, estimate the impact of rising gas prices, in particular for the two-year period from 2006 to 2008 when the price of gas more than doubled, the time series regression were run on a

[35] We obtained traffic volume data by vehicle classification from six operating agencies. Data from other agencies were combined traffic volume for all vehicle classes.

subset of the data (October 2006 to July 2008) for 2-, 5-axle vehicles, and the other six agencies where volumes were not disaggregated by vehicle class. By comparing elasticity estimates for the entire 10-year period versus this 2-year period, it was possible to check if toll road users' behavior changed during the period when gas prices increased. The results for the 2-year period subsample are shown in Table 5-15 and Table 5-17 and discussed in this section. Results for the other six agencies are summarized in Table 5-18.

5.14.1 Results for 2-Axle Vehicles (Entire Sample Period, 2000 to 2010)

For 2-axle vehicles, statistically significant elasticity estimates with respect to gas price ranged from −0.11 to −0.002 (with a mean of −0.06). This implies that the use of the toll facility by 2-axle vehicles would decrease as gas price increases. It is interesting to note that for toll roads in the Miami-Dade (Florida) area statistically significant elasticity estimates with respect to gas price are only for cash-paying vehicles. No statistically significant elasticities were observed for ETC customers. This may imply that the cash-paying 2-axle customers in the Miami-Dade area were more sensitive to a gas price change than were the 2-axle ETC customers. The fact that cash-paying customers could not receive a toll discount as ETC customers did may be one factor that may help explain this phenomenon.

Statistically significant elasticity estimates with respect to toll rate ranged from −0.79 to −0.02 (with a mean of −0.30). The magnitudes of demand elasticity estimates with respect to toll rate were generally larger than that for the price of gas. It is again interesting that for toll roads in the Miami-Dade area the statistically significant estimates of elasticity of demand with respect to the toll rate were all for cash-paying vehicles, while none were statistically significant for ETC customers. This may imply that the cash-paying 2-axle vehicle customers in the Miami-Dade area were more sensitive to a change in the rate of the toll than were the 2-axle ETC vehicle customers. 2-axle toll road/bridge users in San Francisco (California), Orange County (California), and Baltimore (Maryland) were not sensitive to changes in the rate of the toll (Table 5-14). This was expected since the toll facility travelers in San Francisco and Baltimore have limited alternatives. The statistically significant elasticity estimates of toll road use with respect to unemployment rate were relatively small: −0.01 to +0.03 (with a mean of 0.00). Statistically significant elasticity estimates with respect to population ranged from +0.30 to +2.94 (with a mean of +1.31). This implies that the use of the toll facility by 2-axle vehicles increased as population increased.

5.14.2 Results for 2-Axle Vehicles (Two-Year Subsample Period, 2006 to 2008)

Due to the high correlation between gas price, toll rate, unemployment rate, and population during the two-year period, the explanatory variables 'toll rate,' 'unemployment rate,' and 'population' were excluded from most regression equations (see Table 5-15).

Results indicate that during the two-year period the elasticity estimates with respect to gas price of about half the toll facilities either switch from insignificant to statistically significant or their magnitude increased (ranged from −0.24 to +0.19 with a mean of −0.05). The switch from insignificant to significant or increased magnitudes of elasticity estimates indicate that the 2-axle vehicle customers on such toll facilities were more sensitive to the change in gas price in the two-year period than to the "average" level in the entire sample period.

Table 5-14: Summarized Regression Results (2-Axle Vehicles, 2000 to 2010)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Toll bridges in the San Francisco Bay Area	San Francisco, California	0.91*** (0.03)	-0.002*** (0.01)	-0.01 (0.01)	0.00 (0.00)	×	0.96	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
SR73 (San Joaquin)	Orange County, California	0.96*** (0.04)	-0.02*** (0.02)	-	-0.005** (0.002)	0.51** (0.21)	0.92	**Sample Period**: 2000:01-2009:12 **Sample Size**: 120
SR241 + SR261 (Foothill + Eastern)		0.93*** (0.04)	-0.01 (0.005)	-0.01 (0.04)	-0.005** (0.002)	0.41 (0.28)	0.94	**Sample Period**: 2000:01-2009:12 **Sample Size**: 120
SR112 (Cash)	Miami-Dade, Florida	0.57*** (0.10)	-0.11** (0.05)	-0.28*** (0.07)	-0.01** (0.00)	×	0.92	**Sample Period[a]**: 2004:01-2004:07, 2004:10-2005:07, 2005:11 -2010:04 **Sample Size**: 71
SR112 (ETC)		0.70*** (0.07)	0.003 (0.03)	0.01 (0.04)	-0.001 (0.001)	2.94** (1.20)	0.96	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
SR836 (Cash)		0.77*** (0.07)	-0.11** (0.04)	-0.24** (0.12)	-0.01** (0.00)	×	0.89	**Sample Period**: 2004:01-2010:04 **Sample Size**: 76
SR836 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
SR874 North (Cash)		0.88*** (0.08)	-0.03* (0.02)	-	-0.004* (0.002)	-	0.87	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
SR874 North (ETC)		0.96*** (0.05)	-0.01 (0.02)	-	-0.002** (0.001)	-	0.80	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
SR874 South (Cash)		0.81*** (0.10)	-0.02 (0.02)	-	-0.01** (0.00)	-	0.88	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
SR874 South (ETC)		0.96*** (0.04)	-0.01 (0.01)	-	-0.002*** (0.001)	-	0.84	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
SR924 (Cash)		0.84*** (0.07)	-0.10* (0.05)	-0.20 (0.14)	-0.01** (0.004)	-	0.94	**Sample Period[a]**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
SR924 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Kansas Turnpike	Cities in Kansas	0.91*** (0.05)	-0.01 (0.01)	-0.08* (0.05)	0.001 (0.002)	0.30* (0.17)	0.79	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
Harbor Tunnel Thruway	Baltimore, Maryland	0.02 (0.27)	-0.03 (0.02)	-0.02** (0.01)	-0.01* (0.004)	0.69 (0.48)	0.06	**Sample Period[b]**: 2003:03-2010:01 **Sample Size**: 92

Table 5-14: Summarized Regression Results (2-Axle Vehicles, 2000 to 2010) (continued)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
		-0.14 (0.52)	-0.02 (0.03)	-0.03 (0.03)	-0.01 (0.005)	0.57 (0.67)	0.85	**Sample Period**[a]: 2003:03-2010:01 **Sample Size**: 92
Cherokee	Oklahoma	-0.09 (0.07)	-0.07* (0.04)	-0.79*** (0.06)	0.02* (0.01)	-0.10 (0.61)	0.72	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Chickasaw	Oklahoma	-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Cimarron	Oklahoma	0.28*** (0.09)	-0.02 (0.03)	-0.27*** (0.07)	0.01*** (0.005)	0.67* (0.35)	0.89	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Creek	Oklahoma	0.39*** (0.09)	0.001 (0.03)	-0.36*** (0.08)	0.0001 (0.007)	2.87*** (0.61)	0.94	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91
H.E. Bailey	Oklahoma	0.74*** (0.07)	0.02 (0.02)	-0.11* (0.06)	0.01** (0.01)	0.21 (0.25)	0.91	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Indian Nation	Oklahoma	-0.31*** (0.08)	-0.05** (0.06)	-0.64*** (0.18)	0.02 (0.01)	0.07 (0.91)	0.62	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Kilpatrick	Oklahoma	0.80*** (0.07)	-0.003 (0.02)	-0.14** (0.06)	-0.001 (0.003)	0.85** (0.35)	0.94	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
Muskogee	Oklahoma	0.48*** (0.06)	0.02 (0.02)	-0.33*** (0.07)	0.02*** (0.004)	0.10 (0.28)	0.89	**Sample Period**[c]: 2000:01-2010:09 **Sample Size**: 129
Turner	Oklahoma	0.29*** (0.08)	-0.01 (0.02)	-0.41*** (0.06)	0.02*** (0.004)	1.02** (0.42)	0.91	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Will Rogers	Oklahoma	0.46*** (0.07)	0.02 (0.03)	-0.38*** (0.07)	0.03*** (0.01)	-0.42 (0.37)	0.87	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Standard errors in brackets ().
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a cross) were subject to "spurious regression" problem associated with inclusion of the "population" as a variable in the regression equations.
- a: due to serial correlation in the residuals from the regression on seasonally adjusted data, this regression is on the actual traffic volume. Eleven monthly dummy variables were included.
- b: this regression is on the seasonally adjusted traffic volume.
- c: Traffic on Kilpatrick was significantly interrupted for unknown reasons, though with a complete dataset for the sample period, so results may not be accurate.

Table 5-15: Summarized Regression Results (2-Axle Vehicles, 2006 to 2008)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Note
Toll bridges in the San Francisco Bay Area	San Francisco, California	0.35* (0.19)	-0.12*** (0.04)	-0.02 (0.04)	-	-	0.78	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR73 (San Joaquin)	Orange County, California	0.18 (0.23)	-0.15*** (0.05)	-	-	-	0.62	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR241 + SR261 (Foothill + Eastern)		0.34*** (0.22)	-0.12 (0.04)	-	-	-	0.61	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR112 (Cash)	Miami-Dade, Florida	-0.60* (0.29)	-0.22*** (0.06)	-	-	-	0.78	**Sample Period**[a]: 2006:10-2008:07 **Sample Size**: 22
SR112 (ETC)		0.24 (0.20)	0.13** (0.05)	-	-	-	0.56	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR836 (Cash)		0.32 (0.23)	-0.18*** (0.07)	-	-	-	0.69	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR836 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
SR874 North (Cash)		0.31 (0.24)	-0.12** (0.06)	-	-	-	0.55	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR874 North (ETC)		0.65*** (0.18)	0.04 (0.04)	-	-	-	0.66	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR874 South (Cash)		0.33 (0.23)	-0.09* (0.02)	-	-	-	0.39	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR874 South (ETC)		0.38* (0.22)	0.10* (0.05)	-	-	-	0.57	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR924 (Cash)		0.41* (0.21)	-0.24** (0.10)	-	-	-	0.83	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR924 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Kansas Turnpike	Cities in Kansas	0.03 (0.24)	-0.02 (0.03)	-	-	-	-0.08	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Harbor Tunnel Thruway	Baltimore, Maryland	-0.04 (0.23)	-0.03 (0.02)	-	-	-	-0.08	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Cherokee	Oklahoma	0.13 (0.24)	0.02 (0.05)	-	-0.01 (0.02)	-	-0.10	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Chickasaw		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Cimarron		0.01 (0.25)	0.04 (0.05)	-	-0.02 (0.02)	-	-0.06	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Table 5-15: Summarized Regression Results (2-Axle Vehicles, 2006 to 2008) (continued)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Note
Creek		0.23 (0.21)	0.19** (0.08)	-	-0.03 (0.03)	-	0.43	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
H.E. Bailey		-0.07** (0.24)	0.03 (0.06)	-	-0.01 (0.02)	-	-0.09	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Indian Nation		-0.01 (0.24)	0.05 (0.05)	-	-0.01 (0.02)	-	-0.06	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Kilpatrick		0.18 (0.21)	0.19** (0.08)	-	-0.03 (0.02)	-	0.45	**Sample Period**[b]: 2006:10-2008:07 **Sample Size**: 22
Muskogee		0.22 (0.23)	0.04 (0.04)	-	-0.00 (0.02)	-	0.05	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Turner		0.05 (0.25)	0.03 (0.05)	-	-0.02 (0.02)	-	-0.05	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Will Rogers		-0.39 (0.27)	0.07 (0.04)	-	-0.04** (0.02)	-	0.16	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Standard errors in brackets ().
- Missing estimates, unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification.
- a: due to serial correlation in the residuals from the regression on seasonally adjusted data, this regression is on the actual traffic volume. Eleven monthly dummy variables were included.
- b: Traffic significantly interrupted for unknown reasons − results may not be accurate.
- The time series regression program reports a negative R^2 for a model that fits worse than a model consisting only of the sample mean.

5.14.3 Results for 5-Axle Vehicles (Entire Sample Period, 2000 to 2010)

Results for 5-axle vehicles (see Table 5-16) showed more fluctuation and variation than for 2-axle vehicles. The statistically significant gas price elasticity of demand estimates ranged from −0.22 to +0.14 (with a mean of −0.03). Statistically significant elasticity of demand estimates with respect to toll rates ranged from −0.85 to −0.09 (with a mean of −0.35). The magnitude of the elasticity of demand estimates with respect to toll rates for 5-axle vehicles was generally larger than that of elasticity of demand estimates with respect to the price of gas. It is interesting that for the Turner Turnpike in Oklahoma the toll rate elasticity of demand estimate is −0.85 at a 1 percent significance level. The relatively high elasticity may be because the Turner Turnpike parallels historic U.S. Route 66, which is a toll-free alternative for these vehicles. Odeck and Brathen [7] indicated that if suitable alternatives exist, elasticities tend to be higher. This is intuitive and also consistent with an observation of Hirschman et al. [23] that demand is more sensitive on those roads with good toll-free alternatives.

The statistically significant elasticity estimates with respect to unemployment rate ranged from −0.08 to +0.02 (with a mean of −0.03). In comparison, the elasticity estimates with respect to unemployment rate for 2-axle vehicles were closer to zero. These results are consistent with the authors' expectation that an economic downturn may be more evident on business activities (symbolized by 5-axle vehicle trips) than on personal trips (as represented by 2-axle vehicle trips).

5.14.4 Results for 5-Axle Vehicles (Two-Year Subsample Period, 2006 to 2008)

Similar to the previous analysis for 2-axle vehicles, due to the high correlation between gas price, toll rate ,unemployment rate, and population during the two-year period, the explanatory variables 'toll rate,' 'unemployment rate,' and 'population' were excluded from most of the regression equations (see Table 5-17).

Some elasticity estimates with respect to the price of gas switched from insignificant to statistically significant (negative). The magnitude of some elasticity estimates with respect to gas price also increased (mean of −0.23). The switch from insignificant to statistically significant and/or the enlarged magnitude of elasticity estimates may suggest that during the two-year period travelers of 5-axle vehicles were more responsive to increases in gas prices than the "average" in the entire sample period.

Table 5-16: Summarized Regression Results (5-Axle Vehicles, 2000 to 2010)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Toll bridges in the San Francisco Bay Area	San Francisco	0.75*** (0.07)	-0.05** (0.02)	-0.21** (0.09)	-0.01** (0.00)	×	0.88	**Sample Period**: 2000:07-2009:12 **Sample Size**: 114
SR73 (San Joaquin)	Orange County, California	0.49*** (0.13)	0.06 (0.15)	-	-0.08*** (0.02)	-	0.78	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
SR241 + SR261 (Foothill + Eastern)		0.71*** (0.13)	-0.03 (0.06)	0.52 (0.32)	-0.04** (0.02)	-	0.93	**Sample Period**: 2005:06-2009:12 **Sample Size**: 55
SR112 (Cash)	Miami-Dade, Florida	0.47*** (0.07)	-0.06 (0.07)	-0.46*** (0.09)	-0.03*** (0.01)	5.67*** (1.67)	0.79	**Sample Period**: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 71
SR112 (ETC)		-0.10 (0.11)	0.14*** (0.05)	0.12 (0.05)	-0.02*** (0.01)	4.05*** (1.26)	0.77	**Sample Period**[a]: 2004:01-2004:07, 2004:10-2005:07, 2005:11-2006:05, 2007:09-2010:04 **Sample Size**: 56 Traffic severely impacted by unknown factors.
SR836 (Cash)		0.42*** (0.06)	0.01 (0.05)	-0.31** (0.16)	-0.04*** (0.01)	-1.13 (0.97)	0.93	**Sample Period**: 2004:03-2005:09, 2006:01-2010:04 **Sample Size**: 71
SR836 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
SR874 North (Cash)		0.82*** (0.08)	-0.01 (0.04)	-	-0.01 (0.004)	-	0.90	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
SR874 North (ETC)		0.36* (0.18)	-0.22* (0.12)	-	-0.02** (0.01)	-	0.37	**Sample Period**: 2007:09-2010:04 **Sample Size**: 32
SR874 South (Cash)		0.82*** (0.08)	-0.01 (0.04)	-	-0.01 (0.004)	-	0.80	**Sample Period**: 2006:01-2010:04 **Sample Size**: 52
SR874 South (ETC)		0.85*** (0.14)	-0.04 (0.06)	-	-0.01 (0.01)	-	0.66	**Sample Period**: 2007:11-2010:04 **Sample Size**: 30
SR924 (Cash)		0.64*** (0.09)	-0.17** (0.06)	-0.31 (0.22)	-0.02*** (0.01)	-	0.84	**Sample Period**: 2004:04-2004:07, 2004:10-2005:07, 2005:11-2010:04 **Sample Size**: 68
SR924 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.

Table 5-16: Summarized Regression Results (5-Axle Vehicles, 2000 to 2010) (continued)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Kansas Turnpike	Cities in Kansas	0.31** (0.12)	0.03 (0.03)	-0.01 (0.11)	-0.01 (0.003)	×	0.87	**Sample Period**: 2000:01-2010:07 **Sample Size**: 127
Harbor Tunnel Thruway	Baltimore, Maryland	0.73*** (0.05)	-0.07*** (0.02)	-0.01 (0.01)	-0.02*** (0.00)	×	0.94	**Sample Period**: 2003:01-2010:08 **Sample Size**: 92
Cherokee		0.67*** (0.07)	0.06* (0.03)	-0.22*** (0.07)	0.02** (0.01)	-1.82 (0.50)	0.73	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129 Pop-Gas correlation 0.74
Chickasaw		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Cimarron		0.33*** (0.09)	-0.05* (0.03)	-0.21*** (0.07)	-0.01 (0.01)	0.18 (0.50)	0.82	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Creek		0.27** (0.13)	-0.07 (0.05)	-0.11 (0.13)	-0.03*** (0.01)	2.11*** (0.78)	0.48	**Sample Period**: 2003:03-2010:09 **Sample Size**: 91 ARCH Model
H.E. Bailey		0.25*** (0.09)	0.10*** (0.03)	-0.12 (0.10)	-0.02*** (0.01)	0.15 (0.44)	0.64	**Sample Period**[b]: 2000:01-2010:09 **Sample Size**: 129
Indian Nation		0.39*** (0.08)	0.08*** (0.02)	-0.02 (0.06)	-0.01 (0.01)	-0.02 (0.39)	0.55	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Kilpatrick	Oklahoma	0.70*** (0.09)	0.05 (0.05)	-0.08 (0.13)	-0.02 (0.01)	0.56 (0.61)	0.87	**Sample Period**: 2003:04-2010:09 **Sample Size**: 90
Muskogee		0.31*** (0.08)	0.03 (0.02)	0.02 (0.06)	-0.02*** (0.01)	-0.05 (0.34)	0.49	**Sample Period**: 2000:01-2010:09 **Sample Size**: 129
Turner		-0.10*** (0.03)	-0.02** (0.04)	-0.85*** (0.05)	-0.01 (0.01)	-0.27 (0.80)	0.76	**Sample Period**: 2000:01-2002:02, 2002:04-2010:09 **Sample Size**: 128
Will Rogers		0.88*** (0.07)	0.03* (0.02)	-0.09** (0.06)	-0.001 (0.005)	-0.28 (0.21)	0.85	**Sample Period**: 2003:07-2010:09 **Sample Size**: 87

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Standard errors in brackets ().
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification. Missing estimates (if symbolized with a ×) were subject to “spurious regression” problem associated with inclusion of the “population” as a variable in the regression equations.
- a: traffic significantly interrupted for unknown reason − results may not be accurate.
- b: this regression is on the actual traffic volume with seasonal dummy variables.
- 1: due to high correlation (-0.81) between the Gas Price and Toll Rate, the Toll Rate was excluded in the specification.

Table 5-17: Summarized Regression Results (5-Axle Vehicles, 2006 to 2008)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Toll bridges in the San Francisco Bay Area	San Francisco	-0.09 (0.23)	-0.11 (0.06)	0.12 (0.27)	-	-	0.10	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR73 (San Joaquin)	Orange County, California	0.44** (0.18)	-0.69** (0.28)	-	-	-	0.53	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR241 + SR261 (Foothill + Eastern)		0.39* (0.19)	-0.40** (0.15)	-	-	-	0.72	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR112 (Cash)	Miami-Dade, Florida	-0.21* (0.33)	-0.14 (0.09)	-	-	-	0.54	**Sample Period**[a]: 2006:10-2008:07 **Sample Size**: 22
SR112 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
SR836 (Cash)		-0.06 (0.23)	-0.22*** (0.07)	-	-	-	0.39	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR836 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
SR874 North (Cash)		0.14 (0.21)	-0.30** (0.11)	-	-	-	0.30	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR874 South (Cash)		-0.17 (0.19)	-0.35*** (0.08)	-	-	-	0.54	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR874 North (ETC)		0.73* (0.17)	-0.48** (0.19)	-	-	-	0.75	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR874 South (ETC)		0.72*** (0.13)	-0.18* (0.10)	-	-	-	0.70	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR924 (Cash)		0.02 (0.21)	-0.42*** (0.11)	-	-	-	0.55	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
SR924 (ETC)		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Kansas Turnpike	Kansas	-0.37* (0.21)	0.01 (0.02)	-	-	-	0.05	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Harbor Tunnel Thruway	Baltimore, Maryland	0.28 (0.19)	-0.17*** (0.05)	-	-	-	0.60	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Cherokee	Oklahoma	-0.12 (0.23)	-0.16** (0.06)	-	0.01 (0.02)	-	0.25	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Table 5-17: Summarized Regression Results (5-Axle Vehicles, 2006 to 2008) (continued)

Toll Facilities	Location of the Toll Facilities	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Chickasaw		-	-	-	-	-	-	Traffic severely impacted by unknown factors.
Cimarron		0.59*** (0.08)	0.07*** (0.02)	-	-0.00 (0.00)	-	0.68	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Creek		-0.01 (0.24)	0.03 (0.08)	-	-0.05 (0.03)	-	-0.01	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
H.E. Bailey		-0.43*** (0.22)	0.11** (0.05)	-	0.00 (0.02)	-	0.16	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Indian Nation		-0.20 (0.24)	0.03 (0.04)	-	-0.01 (0.02)	-	-0.09	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Kilpatrick		0.38* (0.22)	0.09 (0.10)	-	0.00 (0.04)	-	0.15	**Sample Period**[b]: 2006:10-2008:07 **Sample Size**: 22
Muskogee		-0.28 (0.25)	0.11** (0.04)	-	-0.02 (0.02)	-	0.21	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Turner		-0.07*** (0.23)	0.05 (0.04)	-	0.01 (0.01)	-	-0.07	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Will Rogers		-0.06 (0.23)	0.01 (0.03)	-	0.01 (0.01)	-	-0.14	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Standard errors in brackets ().
- a: Monthly Dummy Model
- b: Traffic significantly interrupted for unknown reason -->results may not be accurate
- Missing estimates (if symbolized with an hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables, the associated variables were then excluded in the specification.
- The time series regression program reports a negative R^2 for a model which fits worse than a model consisting only of the sample mean.

5.14.5 Results from the Six Agencies where Volumes Were not Disaggregated by Vehicle Class

Results from the other six agencies (where volumes were not disaggregated by vehicle class) are very similar to the results for the six agencies discussed previously—all were inelastic except for "Population" (see Table 5-18). Statistically significant elasticity of demand estimates with respect to gas price, for the entire sample period, ranged from −0.36 to −0.02 (with a mean of −0.10). Statistically significant elasticity of demand estimates with respect to toll rate, for the entire sample period, ranged from −0.31 to +0.02 (with a mean of −0.18). Statistically significant elasticity of demand estimates with respect to unemployment, for the entire sample period, ranged from −0.09 to +0.02 (with a mean of −0.02). Statistically significant elasticity of demand estimates with respect to population, for the entire sample period, ranged from +0.42 to +3.93 (with a mean of +1.47).

For the 2-year period, results for the six agencies show that statistically significant elasticity of demand estimates with respect to gas price, ranged from −0.36 to +0.17 (with a mean of −0.04). For Georgia SR400, toll roads in the OOCEA Expressway System, New York State Thruway and five of nine toll plazas in the HCTRA system, the elasticity estimates with respect to unemployment rate either switched from insignificant to statistically significant or the magnitude of estimates increased. This may indicate that the unemployment rate exerted stronger influence on the use of toll roads in those regions during the 2-year period.

5.14.6 Comparison of Gas Price Elasticity Estimates of Toll Road Use versus Non-Toll Roads

The literature suggests that the short-run elasticity of travel demand on *non*-toll roads with respect to the price of gas averages approximately −0.25. Elasticities found in this research for the impact of gas price on toll facilities ranged from −0.69 to +0.19, similar to the range found in the literature for non-toll facilities. However, the average value of the elasticities found in our research were much smaller (−0.09) than those found for non-toll facilities. The average elasticity (as shown in Table 5-14, Table 5-16, and Table 5-18) for the 10-year period was −0.06 (for 27 statistically significant observations) and for the 2-year period was −0.12 (for 34 statistically significant observations). This would indicate that either (a) toll facility users are less impacted by changes in gas price, or more likely, (b) some travelers are switching to toll facilities as gas prices rise. Thus, there was some evidence that toll facilities were more insulated from downturns in traffic volumes resulting from rises in gas prices than were toll-free facilities.

Table 5-18: Summarized Regression Results for the Other Six Agencies (the Entire Sample & 2-Year Subsample)

Operating Agency	Category	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
Florida Turnpike	Cash	0.85*** (0.04)	-0.08*** (0.03)	0.02* (0.01)	-0.01** (0.00)	-	0.96	**Sample Period**: 2000:07-2004:08, 2004:10-2005:09, 2005:11-2009:06 **Sample Size**: 106
		0.45*** (0.20)	-0.14* (0.08)	-	-0.02 (0.02)	-	0.90	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	ETC	0.98*** (0.01)	0.01 (0.02)	-	-0.002 (0.003)	-	0.99	**Sample Period**: 2000:07-2004:08, 2004:10-2005:09, 2005:11-2009:06 **Sample Size**: 106
		0.07 (0.23)	0.08 (0.05)	-	-0.02 (0.01)	-	0.07	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
OOCEA[e]	Hiawassee	0.31*** (0.09)	-0.02 (0.05)	-0.18*** (0.05)	-0.004 (0.003)	1.06*** (0.28)	0.82	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.70*** (0.18)	0.02 (0.06)	-	-	-	0.53	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Pine Hills	0.08 (0.25)	-0.02 (0.05)	-0.20*** (0.08)	-0.01*** (0.004)	0.53* (0.28)	0.82	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.55 (0.20)	0.04 (0.05)	-	-	-	0.31	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Conway	-0.04 (0.41)	-0.08* (0.04)	0.02 (0.04)	-0.02** (0.01)	0.89** (0.20)	0.80	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.16 (0.23)	-0.10* (0.05)	-	-	-	0.31	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Dean	-0.03 (0.40)	-0.09* (0.04)	0.004 (0.03)	-0.02*** (0.01)	1.74** (0.69)	0.90	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.30 (0.23)	-0.10* (0.05)	-	-	-	0.45	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Table 5-18: Summarized Regression Results for the other Six Agencies (the Entire Sample & 2-Year Subsample) (continued)

Operating Agency	Category	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	John Young	0.21 (0.09)	-0.09 (0.08)	-0.28** (0.11)	-0.02*** (0.003)	2.34*** (0.54)	0.91	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.72*** (0.18)	0.02 (0.05)	-	-	-	0.57	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Boggy Creek	0.25** (0.11)	-0.01 (0.06)	-0.17* (0.09)	-0.02*** (0.003)	2.71*** (0.49)	0.95	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.66*** (0.19)	0.03 (0.06)	-	-	-	0.52	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Curry Ford	0.02 (0.36)	-0.04 (0.05)	-0.02 (0.06)	-0.03*** (0.01)	3.14** (1.25)	0.95	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.34 (0.23)	-0.05 (0.05)	-	-	-	0.11	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	University	-0.02 (0.53)	-0.03 (0.05)	-0.01 (0.05)	-0.03** (0.01)	1.59* (0.88)	0.92	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.26 (0.23)	-0.11* (0.05)	-	-	-	0.32	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Forest Lake	0.11* (0.15)	0.02 (0.04)	0.10 (0.05)	-0.03*** (0.01)	3.93*** (0.74)	0.98	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.64*** (0.19)	-0.04 (0.04)	-	-	-	0.35	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Beachline Airport	-0.04 (0.60)	0.07 (0.05)	0.06 (0.06)	-0.02* (0.01)	2.02 (1.28)	0.93	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.20 (0.24)	0.004 (0.05)	-	-	-	-0.06	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Table 5-18: Summarized Regression Results for the other Six Agencies (the Entire Sample & 2-Year Subsample) (continued)

Operating Agency	Category	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	Beachline Main	-0.07 (0.24)	-0.06 (0.05)	-	-0.02*** (0.004)	1.28*** (0.35)	0.76	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
		0.66 (0.20)	-0.07 (0.06)	-	-	-	0.50	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Georgia SR400		0.31*** (0.09)	-0.0002 (0.09)	-	-0.002* (0.001)	-	0.68	**Sample Period**[e]: 2000:0-2010:08 **Sample Size**: 128
		-0.08 (0.30)	-0.07** (0.03)	-	-0.03** (0.01)	-	0.43	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
Indiana Toll Road	Barrier System[a]	-	-0.36* (0.17)	-0.18 (0.22)	-0.09*** (0.01)	-	0.78	**Sample Period**: 2006:Q3-2009:Q4 **Sample Size**: 14
	Ticket System[b]	-	-0.02 (0.12)	-0.03 (0.15)	-0.01 (0.01)	-	-0.14	**Sample Period**: 2006:Q3-2009:Q4 **Sample Size**: 14
New York State Thruway	Passenger Vehicle[c]	0.94*** (0.03)	-0.01 (0.01)	-0.02 (0.02)	0.0004 (0.001)	0.30 (0.31)	0.97	**Sample Period**: 2000:01-2010:08 **Sample Size**: 128
		0.21 (0.21)	-0.02 (0.03)	-	0.02* (0.01)	-	0.38	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Commercial Vehicle[d]	0.82*** (0.05)	0.02 (0.02)	-0.14*** (0.04)	0.001 (0.003)	-1.32 (0.88)	0.96	**Sample Period**: 2000:01-2010:08 **Sample Size**: 128
		0.34*** (0.12)	-0.000 (0.03)	-0.16* (0.09)	-0.02*** (0.01)	-	0.77	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
HCTRA	Hardy North	0.96*** (0.02)	-0.01 (0.01)	0.02 (0.04)	-0.01*** (0.002)	0.09 (0.08)	0.83	**Sample Period**[f]: 2000:01-2009:12 **Sample Size**: 120
		0.61*** (0.18)	0.11* (0.06)	-	-0.001 (0.02)	-	0.75	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Hardy South	-0.07 (0.19)	-0.06*** (0.03)	-0.31*** (0.11)	-0.01 (0.01)	1.64*** (0.40)	0.71	**Sample Period**[e]: 2001:04-2008:08, 2008:10-2009:12 **Sample Size**: 104
		-0.41 (0.25)	0.17*** (0.05)	-	-0.19*** (0.04)	-	0.88	**Sample Period**[e]: 2006:10-2008:07 **Sample Size**: 22
	Sam Houston South	0.32*** (0.08)	-0.05*** (0.02)	-0.25*** (0.05)	-0.01*** (0.003)	1.11*** (0.17)	0.77	**Sample Period**[e]: 2000:03-2008:08, 2008:10-2009:12 **Sample Size**: 117
		0.01 (0.39)	-0.08 (0.06)	-	-0.14* (0.07)	-	0.61	**Sample Period**[e]: 2006:10-2008:07 **Sample Size**: 22

Table 5-18: Summarized Regression Results for the other Six Agencies (the Entire Sample & 2-Year Subsample) (continued)

Operating Agency	Category	$LogTollVol_{t-1}$	$LogGas_t$	$LogTollRate_t$	$UEMP_t$	$LogPop_t$	Adjusted R^2	Notes
	Sam Houston Central	0.20** (0.09)	-0.02 (0.02)	-0.13** (0.06)	-0.01*** (0.004)	1.10*** (0.18)	0.84	**Sample Period**[e]: 2000:01-2009:12 **Sample Size**: 120
		-0.04 (0.41)	-0.06 (0.06)	-	0.01 (0.06)	-	0.32	**Sample Period**[e]: 2006:10-2008:07 **Sample Size**: 22
	Sam Houston North	0.39*** (0.09)	-0.00 (0.02)	-0.05 (0.05)	-0.01** (0.003)	1.15*** (0.20)	0.93	**Sample Period**[e]: 2000:01-2009:12 **Sample Size**: 120
		-0.35 (0.42)	0.05 (0.03)	-	0.01 (0.03)	-	0.71	**Sample Period**[e]: 2006:10-2008:07 **Sample Size**: 22
	SHSC Bridge	0.56*** (0.08)	-0.02 (0.02)	-0.17*** (0.06)	-0.01 (0.004)	0.95*** (0.16)	0.92	**Sample Period**[e]: 2000:01-2009:12 **Sample Size**: 120
		-0.43 (0.35)	0.16** (0.05)	-	-0.03 (0.03)	-	0.78	**Sample Period**[e]: 2006:10-2008:07 **Sample Size**: 22
	Sam Houston East	0.74*** (0.06)	-0.02** (0.01)	-0.17*** (0.04)	-0.01*** (0.002)	0.77*** (0.18)	0.95	**Sample Period**[e]: 2000:01-2009:12 **Sample Size**: 120
		-0.46 (0.25)	0.07** (0.02)	-	-0.10*** (0.03)	-	0.88	**Sample Period**[e]: 2006:10-2008:07 **Sample Size**: 22
	Sam Houston SouthEast	0.79*** (0.05)	-0.02* (0.01)	-0.05** (0.03)	-0.003 (0.002)	0.42*** (0.12)	0.94	**Sample Period**: 2000:01-2009:12 **Sample Size**: 120
		0.02 (0.22)	0.09 (0.05)	-	-0.05* (0.03)	-	0.10	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22
	Sam Houston SouthWest	0.89*** (0.04)	-0.01 (0.01)	-0.05* (0.03)	-0.001 (0.002)	0.12 (0.08)	0.92	**Sample Period**: 2000:01-2009:12 **Sample Size**: 120
		0.28 (0.21)	0.01 (0.05)	-	-0.06* (0.03)	-	0.13	**Sample Period**: 2006:10-2008:07 **Sample Size**: 22

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Due to high correlation (absolute > 0.80) between the Gas Price and Toll Rate, the Toll Rate was excluded in the specification. Other missing estimates were due to the data type (not monthly) used in the ADL model.
- a: The barrier system is reported in terms of total transactions.
- b: The ticket system is reported in terms of full-length equivalent trips.
- c: The New York State Thruway Authority defines passenger vehicles as 2-axle passenger vehicles or 2-axle passenger vehicles towing a 1-3 axle trailer.
- d: Commercial vehicles are defined as 2-7 axle trucks that are greater than 7’6” high.
- e: for the 10-year period, models used the unadjusted data with seasonal dummy variables; for the 2-year period, models used seasonally adjusted data.
- Standard errors in brackets ().
- A negative R^2 suggests that the model fits worse than a model consisting only of the sample mean.

CHAPTER 6. IMPACT OF GAS PRICE AND TOLL RATE ON TOLL VIOLATIONS

6.1 Introduction

As part of the data collection process, this study obtained the monthly number of toll violations from June 2003 to December 2009 for the 11 toll plazas[36] of the OOCEA toll roads (see Figure 5-15 for a location map). Toll violation rate (obtained by dividing the number of toll violations by the total toll traffic volume) is very important to toll facility operation and may prove valuable to analyze. For example, as gas price increases, it might be possible that drivers would be more inclined to try to evade the toll.

Several studies have investigated the relationship between gas price and travel demand on toll/non-toll roads (such as this study and many others introduced in Chapter 2), drunk-driving crashes [42] and traffic safety [43]. However, there was no prior attempt found in the literature review to determine the impact of gas price and toll rate on the toll violation rate. Therefore, using similar time series analysis techniques introduced in Chapter 4, this study examined the toll violation rate with respect to gas price and toll rate to see if there was a connection among the three.

6.2 Properties of the Time Series Data and Methodology

During the period 2003 to 2009, a clear upward trend was present in the toll violation rate for the 11 toll plazas (see Figure 6-1). The plots of gas price and toll violation rate indicated a potential relationship between the two (Figure 6-1). The autocorrelation plots of toll violation rate, gas price, toll rate, unemployment rate, and population suggest the presence of a unit root in each series, and the Elliot-Rothenberg-Stock unit root tests also failed to reject a unit root each series. Given these characteristics, the ADL model can be viewed as a cointegrating regression model. Stock [44] proves that provided the regression residuals are stationary, the parameters are super-consistent, converging at a speed of T, rather than root-T.

[36] See Section 5.6 for the 11 toll plazas. Monthly toll violation data were available from July 2000 to June 2010 for the Forest Lake Plaza.

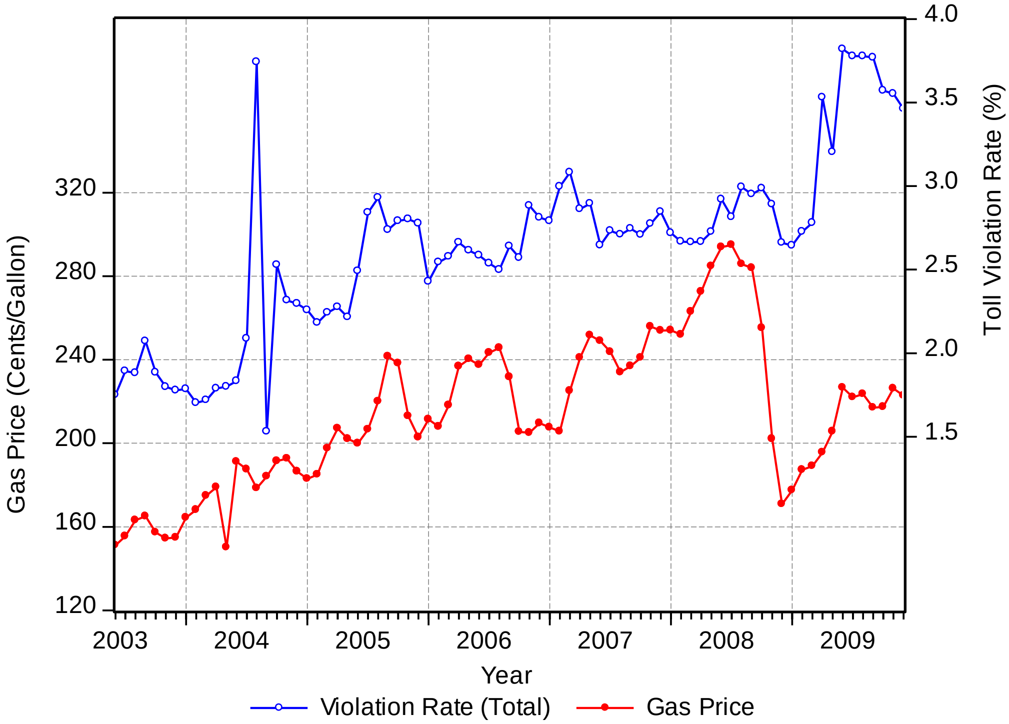

Figure 6-1: Toll Violation Rate (11 OOCEA Plazas) and Gas Price in Florida

In addition to investigating the impact of the change in gas prices on the toll violation rate, other factors that may have influenced the toll violation rate included the toll rates, unemployment rate and population. This led to the model shown in Equation 6-1:

$$TollVioRate_t = c + \beta_1 Log(Gas_t) + \beta_2 Log(TollRate_t) + \beta_3 UEMP_t + \beta_4 Log(Pop) + u_t \quad \text{Equation 6-1}$$

Where:

- $TollVioRate_t$ denotes the toll violation rate (percent) in month *t* for OOCEA toll plaza;
- $Log(Gas_t)$ denotes the logarithm of CPI-adjusted retail price of gasoline in month *t* for Florida;
- $Log(TollRate_t)$ denotes the logarithm of the CPI-adjusted toll rate in month *t* for 1-2 axle vehicles in OOCEA toll plaza;
- $UEMP_t$ denotes the unemployment rate (percent) in month *t* for the Orlando-Kissimmee-Sanford (OKS), Florida Metropolitan Statistical Area;
- $Log(Pop_t)$ denotes the logarithm of the population of the Orange County, Florida, in period *t*; and
- u_t denotes an error term with a mean of zero.

6.3 Time Series Analysis Results

Since influential hurricanes and inclement weather occurred in 2004, 2005, and 2008, data for months that may have been significantly impacted by hurricanes were then removed prior to further regression analyses. Similar to the methods discussed in Chapter 4, serial correlation in the regression residuals were treated by introducing autoregressive process of order p error in the regression. Table 6-1 presents time series analysis results for the 11 toll plazas. The elasticity estimates with respect to gas price, toll rate, and population deserve some notice since scales of the estimates are significantly larger than that of the unemployment rate. This was due to the use of the logarithm of gas price, toll cost, and population in Equation 6-1, while toll violation rate and unemployment rate were not scaled. For example, see Equation 6-2 shown below:

$$y = \beta_0 + \beta_1 \log(x) \quad \text{Equation 6-2}$$

Where $x > 0$. If we take the change in y, we get $\Delta y = \beta_1 \Delta \log(x)$, which can be rewritten as $\Delta y = (\beta_1/100)[100 \times \Delta \log(x)]$. Thus, based on the fact that the difference in logs can be used to approximate proportionate changes, we have Equation 6-3:

$$\Delta y \approx (\beta_1/100)(\%\Delta x) \quad \text{Equation 6-3}$$

In other words, $\beta_1/100$ is the unit change in y when x increases by 1 percent.

Results indicate that the toll violation rate increased as the gas price and toll rate increased during the sample period. Most elasticity estimates of toll violation rate with respect to gas price were statistically significant with a range from +0.009 to +0.025 (with a mean of +0.013). An elasticity estimate of +0.013 would suggest that a 1 percent increase in gas price gave rise to about 0.013 percent increase in the toll violation rate. Statistically significant elasticity estimates of toll violation with respect to toll rate ranged from +0.016 to +0.028 (with a mean of +0.022). Statistically significant elasticity estimates of toll violation with respect to unemployment rate ranged from −0.10 to +0.15 (with a mean of −0.03). Statistically significant elasticity estimates of toll violation with respect to population ranged from +0.088 to +0.25 (with a mean of +0.15). It is surprising to observe that the magnitude and mean of the elasticity estimates with respect to population were significantly larger than that of the gas price and toll rate. A Johansen Cointegration test indicated that there was a cointegrating relationship between the toll violation rate and population, implying a long-run causal relationship between the two (the latter causing the former). Excluding the population in the regression equation (Equation 6-1) changed the results very little from the equations with population included (see Table 6-1).

6.4 Summary of Results

The elasticity estimates of toll violation rate with respect to gas price and toll rate indicated that the toll violation rate increased about 0.01 percent and 0.02 percent with a 1 percent increase in gas price and toll rate, respectively. This is in line with the hypothesis that as the cost of driving increased (due to an increase in gas price or/and toll rate) drivers were more inclined to try to evade the toll—but the increase is very small.

Table 6-1: Summarized Regression Results for Individual OOCEA Toll Plazas

Toll Plaza	**$LogGas_t$**	**$LogTollRate_t$**	**$UEMP_t$**	**$Log(Pop)_t$**	**Adjusted R^2**	**Notes**
Hiawassee	1.21** (0.57)	1.62** (0.61)	-0.07 (0.05)	15.13*** (4.77)	0.87	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	1.69*** (0.57)	1.46** (0.68)	0.02 (0.07)	N/A	0.85	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Pine Hills	0.80 (0.89)	2.27* (1.33)	-0.15 (0.11)	24.77** (9.87)	0.84	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	0.85 (0.89)	2.33* (1.35)	-0.02 (0.12)	N/A	0.83	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Conway	1.34*** (0.40)	2.26*** (0.57)	0.15*** (0.03)	10.71*** (2.30)	0.96	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	1.34*** (0.41)	2.31*** (0.63)	0.19*** (0.05)	N/A	0.95	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Dean	0.87* (0.51)	1.90*** (0.59)	-0.02 (0.05)	12.91*** (4.09)	0.88	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	0.98* (0.50)	1.81*** (0.60)	0.06 (0.06)	N/A	0.88	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
John Young	0.46 (0.48)	2.32*** (0.77)	-0.08** (0.03)	15.04*** (2.20)	0.84	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	0.53 (0.53)	2.47** (0.94)	-0.02 (0.07)	N/A	0.79	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Boggy Creek	1.19** (0.48)	2.83*** (0.83)	-0.10*** (0.03)	14.23*** (2.09)	0.85	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	1.42** (0.54)	3.20*** (0.95)	-0.00 (0.06)	N/A	0.80	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73

Table 6-1: Summarized Regression Results for Individual OOCEA Toll Plazas (continued)

Toll Plaza	**$LogGas_t$**	**$LogTollRate_t$**	**$UEMP_t$**	**$Log(Pop)_t$**	**Adjusted R^2**	**Notes**
Curry Ford	0.32 (0.85)	1.06 (1.22)	-0.02 (0.06)	5.19 (4.29)	0.36	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	0.69 (0.77)	0.87 (1.24)	-0.02 (0.06)	N/A	0.36	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
University	0.72 (0.53)	2.30*** (0.76)	-0.02 (0.04)	1.88 (2.77)	0.52	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	0.91** (0.45)	2.27*** (0.76)	-0.01 (0.03)	N/A	0.52	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Forest Lake	1.21*** (0.32)	1.98*** (0.54)	-0.05* (0.03)	-0.80 (2.08)	0.77	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	1.25*** (0.30)	1.95*** (0.53)	-0.04* (0.02)	N/A	0.78	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Beachline Airport	0.70 (0.48)	0.87 (0.66)	-0.08** (0.03)	8.83*** (2.23)	0.68	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	1.66*** (0.50)	1.16 (0.79)	-0.03 (0.04)	N/A	0.63	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
Beachline Main	2.48*** (0.81)	2.69 (1.64)	0.12 (0.08)	-4.39 (7.26)	0.76	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73
	2.29*** (0.79)	2.77* (1.63)	0.09 (0.06)	N/A	0.77	**Sample Period**: 2003:06-2004:07, 2004:10-2005:07, 2005:11-2008:07, 2008:09-2009:12 **Sample Size**: 73

Notes:

- *=10% significance level, **=5% significance level, ***=1% significance level.
- Missing estimates (if symbolized with a hyphen), unless otherwise specified, were due to high correlation (absolute value > 0.8) between the independent variables; the associated variables were then excluded in the specification.
- All regressions were modeled on unadjusted data with seasonal dummy variables.
- Standard errors in brackets ().

CHAPTER 7. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

7.1 Concluding Remarks

Travelers' response to changes in the cost of travel provides key data to help predict future travel behavior. This study estimated the short-run elasticity of demand for toll facility use with respect to gas price using monthly/quarterly toll traffic data and gas price data for the period 2000 to 2010 from toll facilities operated by 12 agencies around the United States. To try to isolate the impact of the change in gas price on the use of toll facilities, this study considered other factors that may have significantly influenced the use of the toll facilities. These data included the toll rate, unemployment rate and population in the metropolitan area where the toll facility was located. Results from the time series ADL models were examined, with the following findings:

- For the 10-year period, the gas price elasticity of demand for the 12 agencies[37] examined in this study ranged from −0.36 to +0.14 with a mean of −0.06 for 27 statistically significant estimates. Therefore, traffic on some toll facilities was impacted by a change in the price of gas just as were non-toll facilities. However, on average, the toll-facilities were impacted less by rising gas prices than were non-toll facilities. Some facilities even had positive elasticities—indicating more travelers were using the facility as the price of gas rose. This makes sense if the facility offers a shorter, less congested travel route that reduces the travelers' fuel consumption.

- In the 10-year period, for 2-axle vehicles, statistically significant gas price elasticity of demand estimates ranged from −0.11 to −0.002 with a mean of −0.06 for 8 statistically significant estimates (see Table 5-14). Statistically significant gas price elasticity of demand estimates for 5-axle vehicles ranged from −0.22 to +0.14 with a mean of −0.03 for 12 statistically significant estimates (see Table 5-16). This may indicate that 5-axle vehicles on the toll facilities were less sensitive to changes in gas price. However, both average elasticity estimates were highly inelastic.

- The literature suggests that the short-run elasticity of travel demand on *non*-toll roads with respect to the price of gas averages approximately −0.25. Elasticities found in this research for the impact of gas price on toll facilities ranged from −0.69 to +0.19 (see Table 5-14 through Table 5-18), similar to the range found in the literature for non-toll facilities. However, the average value of the elasticities found in this research was much smaller than those found for non-toll facilities. The average elasticity (as shown in Table 5-14, Table 5-16 and Table 5-18) for the 10-year period was −0.06 (for 27 statistically significant observations) and for the 2-year period was −0.12 (for 34 statistically significant observations). This would indicate that either (a) toll facility users are less impacted by changes in gas price, or more likely, (b) some travelers are switching to toll facilities as gas prices rise. This might be the evidence that toll facilities are more

[37] The elasticity estimates of travel demand with respect to gas price discussed here included 2- and 5-axle vehicles from six agencies, as listed in Table 5-14 and Table 5-16 plus the other six agencies, as listed in Table 5-18.

insulated from downturns in traffic volumes resulting from rises in gas prices than are toll-free facilities.

- Many elasticity estimates with respect to gas price switched from insignificant during the entire sample period (mostly a 10-year period) to statistically significant during the 2-year subsample period. This suggests more travelers' behavior changes only in a circumstance of rapidly fluctuating gas prices.

- In the 10-year period, the *toll* rate elasticity of demand for 2-axle vehicles ranged from −0.79 to −0.02 with a mean of −0.30 for 14 statistically significant estimates. The *toll* rate elasticity of demand for 5-axle vehicles ranged from −0.85 to −0.09 with a mean of −0.35 for 8 statistically significant estimates. For results from the six agencies where volumes were not disaggregated by vehicle class, the toll-rate elasticity of demand ranged from −0.31 to −0.05 with a mean of −0.18 for 12 statistically significant estimates. The magnitude of the elasticity estimates with respect to toll rate was generally larger than that for gas price elasticity estimates. This makes sense as increases in the toll price can only be avoided by no longer taking the toll route. However, increases in the price of fuel may be mitigated by driving more fuel efficient vehicles or by switching routes—possibly to the toll route.

- The statistically significant elasticity estimates with respect to unemployment rate were both negative and positive but were small: −0.18 to +0.03 with a mean of −0.01 for 45 statistically significant estimates.

- Elasticity estimates of toll violation rate with respect to gas price and toll rate indicated that the toll violation rate increased about 0.01 percent and 0.02 percent with a 1 percent increase in gas price and toll rate, respectively. This indicated that as the cost of driving increased (due to an increase in gas price or/and toll rate) drivers were more inclined to try to evade the toll, but to a very small degree.

7.2 Limitations and Recommendations

As Oum et al. [13] pointed out, aggregation may average out some of the underlying variabilities of price sensitivity in different toll road user groups [13]. This results in the need for an appropriate degree of aggregation if elasticity estimates are to be of practical use to decision makers. As some of the analyzed data are aggregated traffic volume for all vehicle classes, this may also undermine the accuracy of the elasticity estimates: as toll road users in different vehicle classes may behave differently to a change of situation—in this study the focus was the change in gas price. Analyzing combined traffic volume data using our model may not be able to obtain an accurate estimate of the underlying variabilities of price sensitivity.

This study is subject to lack of control samples: data from adjacent roads can be used to control for whether the observed changes in traffic volume in toll roads were due to the general trend in the area or due to compounded effect of changes in our selected explanatory variables. As we do not have the travel time savings for each user of the toll roads, this may pose a difficulty for interpreting our study results. Our future research work may explore more data incorporating the travel time savings of the toll road users that might produce a better elasticity estimate.

Our study results indicate that elasticity estimates may be markedly different for different cities or countries, and this may be due to different degrees of competition between modes in different cities/countries [13]. To verify conclusions with regard to toll violation, toll violation data from other toll facilities are needed.

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Appendix A. Autoregressive Distributed Lag (ADL) Model[38]

1. A simple model:

   The ADL(*1*,*1*) model:

$$y_t = m + \alpha_1 y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + u_t,$$

   where y_t and x_t are stationary variables, and u_t is a white noise.

2. Estimation:

   If the values of x_t are treated as given, then it can be considered as being uncorrelated with u_t. Ordinary least squares (OLS) would be consistent. However, if x_t is simultaneously determined with y_t and $E(x_t u_t) = 0$, OLS would be inconsistent. As long as it can be assumed that the error term u_t is a white noise process, or more generally-is stationary and independent of $x_t, x_{t-1}, \ldots\ldots$ and $y_t, y_{t-1}, \ldots\ldots$ the ADL models can be estimated consistently by OLS.

3. Interpretation of the dynamic effect:

   We can invert the model as the lag polynomial in y as

$$y = (1 + \alpha_1 + \alpha_1^2 + \ldots)m + (1 + \alpha_1 L + \alpha_1^2 L^2 \ldots)(\beta_0 x_t + \beta_1 x_{t-1} + u_t)$$

   The current value of y depends on the current and all previous values of x and u.

$$\frac{\partial y_t}{\partial x_t} = \beta_0$$

   This is referred as the impact multiplier.

   The effect after one period

$$\frac{\partial y_{t+1}}{\partial x_t} = \beta_1 + \alpha_1 \beta_0$$

   The effect after two periods

$$\frac{\partial y_{t+2}}{\partial x_t} = \alpha_1 \beta_1 + \alpha_1^2 \beta_0$$

   The long-run multiplier (long-run effect) is $\frac{\beta_0 + \beta_1}{1 - \alpha_1}$ if $|\alpha_1| < 1$.

4. Interpretation of the dynamic effect:

   Substitute y_t and x_t with $y_{t-1} + \Delta y_t$ and $x_{t-1} + \Delta x_t$,

[38] This appendix is borrowed from Yiyi Chen at *mail.tku.edu.tw/chenyiyi/**ADL**.pdf*

$$\Delta y_t = m + \beta_0 \Delta x_t - (1-\alpha_1) y_{t-1} + (\beta_0 + \beta_1) x_{t-1} + u_t$$

$$\Delta y_t = \beta_0 \Delta x_t - (1-\alpha_1) \left[y_{t-1} - \frac{m}{1-\alpha_1} - \frac{\beta_0 + \beta_1}{1-\alpha_1} x_{t-1} \right] + u_t$$

This is called the error correction model (ECM). The current change in y is the sum of two components. The first is proportional to the current change in x. The second is a partial correction for the extent to which y_{t-1} deviated from the equilibrium value corresponding to x_{t-1} (the equilibrium error).

5. Generalizations:

The ADL(p, q) model:

$$A(L) y_t = m + B(L) x_t + u_t$$

with

$$A(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p$$
$$B(L) = \beta_0 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_p L^p$$

The general ADL(p, q_1, q_2, ... , q_k) model:

$$A(L) y_t = m + B_1(L) x_{1t} + B_2(L) x_{2t} + \ldots + B_k(L) x_{kt} + u_t$$

If $A(L) = 1$, the model does not contain any lags of y_t. It is called the distributed lag model.

Appendix B. Results of Trials Using Genetic Programming (GPTIPS)

This appendix presents estimated solutions for 100 trials using GP for the fitted model using the San Francisco data. Numbers in each column correspond to the coefficient estimates as shown in the equation below.

$$\text{Log}(\text{TollVol}_t) = \text{Intercept} + c_1\text{Log}(\text{TollVol}_{t-1}) + c_2\text{Log}(\text{Gas}_t) + c_3\text{Log}(\text{TollRate}_t) + c_4\text{UEMP}_t + u_t$$

Where:

- $Log(TollVol_t)$ denotes the logarithm of seasonally adjusted toll traffic volume in month *t* for the 7 toll bridges the San Francisco Bay Area;
- $Log(TollVol_{t-1})$ denotes the 1^{st} lag of $Log(TollVol_t)$;
- $Log(Gas_t)$ denotes the logarithm of retail price of gas in month *t* for the San Francisco-Oakland-San Jose Metropolitan Area;
- $Log(TollRate_t)$ denotes the logarithm of the CPI-adjusted toll rate in month *t* for the toll facilities;
- $UEMP_t$ denotes the unemployment rate in month *t* for the San Francisco-Oakland-San Jose Metropolitan Area; and
- u_t denotes an error term with a mean of zero.

We stopped at the 100 trials since the variation of each estimate is very small (see the standard deviations at the bottom of this table), and we then see further trials would be redundant. As already discussed in Chapter 4, it is the variation of the GOF and estimates for each GP results makes it arbitrary, even the GP could generate a linear model comparable to the one estimated by the ADL model. For those two reasons with the additional advantage of being much easier to interpret the results, and for easier comparison to previous research, this study chose to use the conventional time series analyses.

No. of Trials	intercept	C_1	C_2	C_3	C_4	R^2	Adjusted R^2
1	3.278910	0.810774	-0.090205	-0.100615	-0.003615	0.958196	0.955807
2	3.277450	0.810774	-0.090205	-0.100615	-0.003615	0.958196	0.955807
3	3.277450	0.810774	-0.090205	-0.100615	-0.006155	0.958196	0.955807
4	3.272210	0.810776	-0.090204	-0.100505	-0.005050	0.958196	0.955807
5	3.277030	0.810774	-0.090204	-0.100515	-0.005150	0.958196	0.955807
6	3.277450	0.810774	-0.090205	-0.100615	-0.006155	0.958592	0.956226
7	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
8	3.273520	0.810774	-0.090205	-0.100505	-0.005058	0.958600	0.956234
9	3.277450	0.810774	-0.090205	-0.100615	-0.006155	0.958592	0.956226
10	3.272690	0.810769	-0.090204	-0.100409	-0.004090	0.958602	0.956237
11	3.279090	0.810774	-0.090205	-0.100616	-0.006160	0.958591	0.956225
12	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
13	3.276170	0.810775	-0.090204	-0.100527	-0.005272	0.958597	0.956231
14	3.270400	0.810777	-0.090204	-0.100511	-0.005114	0.958597	0.956231
15	3.279380	0.810774	-0.090205	-0.100616	-0.006162	0.958595	0.956229
16	3.270400	0.810777	-0.090204	-0.100511	-0.005114	0.958599	0.956233
17	3.279070	0.810774	-0.090205	-0.100616	-0.006160	0.958592	0.956226
18	3.270400	0.810777	-0.090204	-0.100511	-0.005114	0.958599	0.956233

No. of Trials	intercept	C_1	C_2	C_3	C_4	R^2	Adjusted R^2
19	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
20	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958593	0.956227
21	3.279100	0.810774	-0.090205	-0.100615	-0.006159	0.958593	0.956227
22	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958593	0.956227
23	3.279090	0.810774	-0.090205	-0.100616	-0.006160	0.958593	0.956227
24	3.270400	0.810777	-0.090204	-0.100511	-0.005114	0.958597	0.956231
25	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
26	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
27	3.270380	0.810777	-0.090204	-0.100511	-0.005114	0.958599	0.956233
28	3.270400	0.810777	-0.090204	-0.100511	-0.005114	0.958596	0.956230
29	3.270390	0.810777	-0.090204	-0.100511	-0.005114	0.958598	0.956233
30	3.270870	0.810775	-0.090205	-0.100616	-0.006164	0.958592	0.956226
31	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
32	3.270400	0.810777	-0.090204	-0.100511	-0.005114	0.958599	0.956233
33	3.270860	0.810775	-0.090205	-0.100616	-0.006164	0.958591	0.956225
34	3.279090	0.810774	-0.090205	-0.100616	-0.006160	0.958593	0.956227
35	3.279370	0.810774	-0.090205	-0.100616	-0.006160	0.958592	0.956226
36	3.274460	0.810774	-0.090204	-0.100477	-0.004775	0.958601	0.956235
37	3.762160	0.810772	-0.090204	-0.100568	-0.005689	0.958596	0.956230
38	3.279100	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
39	3.270860	0.810775	-0.090205	-0.100616	-0.006164	0.958591	0.956225
40	3.277895	0.810770	-0.090205	-0.100497	-0.004975	0.958596	0.956230
41	3.275910	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
42	3.275910	0.810774	-0.090205	-0.100616	-0.006160	0.958594	0.956228
43	3.275937	0.810774	-0.090205	-0.100616	-0.006160	0.958592	0.956226
44	3.275910	0.810774	-0.090205	-0.100616	-0.006160	0.958593	0.956227
45	3.275894	0.810774	-0.090205	-0.100615	-0.003159	0.958592	0.956226
46	3.277590	0.810771	-0.090205	-0.100512	-0.003128	0.958597	0.956231
47	3.275909	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227
48	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958597	0.956231
49	3.275909	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
50	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958599	0.956233
51	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958597	0.956231
52	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
53	3.275890	0.810774	-0.090205	-0.100615	-0.003159	0.958593	0.956227
54	3.275909	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227
55	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
56	3.278284	0.810775	-0.090204	-0.100489	-0.003897	0.958599	0.956233
57	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
58	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
59	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958599	0.956233
60	3.275938	0.810774	-0.090205	-0.100616	-0.003600	0.958592	0.956226
61	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
62	3.275913	0.810774	-0.090205	-0.100616	-0.003160	0.958595	0.956229
63	3.277586	0.810771	-0.090205	-0.100512	-0.003270	0.958596	0.956230
64	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227

No. of Trials	intercept	C_1	C_2	C_3	C_4	R^2	Adjusted R^2
65	3.275745	0.810774	-0.090205	-0.100615	-0.003155	0.958592	0.956226
66	3.279152	0.810767	-0.090204	-0.100409	-0.003095	0.958604	0.956238
67	3.275940	0.810774	-0.090205	-0.100616	-0.003060	0.958595	0.956229
68	3.276786	0.810778	-0.090205	-0.100596	-0.003682	0.952081	0.949343
69	3.275910	0.810774	-0.090205	-0.100616	-0.003060	0.958594	0.956228
70	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
71	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
72	3.275909	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227
73	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
74	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958599	0.956233
75	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
76	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958597	0.956231
77	3.276483	0.810779	-0.090205	-0.100615	-0.003153	0.958593	0.956227
78	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
79	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
80	3.277588	0.810771	-0.090205	-0.100512	-0.003127	0.958596	0.956230
81	3.275800	0.810774	-0.090205	-0.100615	-0.003158	0.958593	0.956227
82	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227
83	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
84	3.275956	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
85	3.275910	0.810774	-0.090205	-0.100615	-0.003159	0.958593	0.956227
86	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
87	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958592	0.956226
88	3.275914	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227
89	3.275909	0.810774	-0.090205	-0.100616	-0.003160	0.958593	0.956227
90	3.276465	0.810779	-0.090205	-0.100615	-0.003153	0.958595	0.956229
91	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958594	0.956228
92	3.275910	0.810774	-0.090205	-0.100616	-0.003160	0.958591	0.956225
93	3.278040	0.810777	-0.090204	-0.100511	-0.003114	0.958599	0.956233
94	3.276688	0.810775	-0.090205	-0.100593	-0.003331	0.958595	0.956229
95	3.279269	0.810775	-0.090205	-0.100487	-0.003372	0.958602	0.956236
96	3.275909	0.810774	-0.090205	-0.100616	-0.003360	0.958593	0.956227
97	3.278040	0.810777	-0.090204	-0.100511	-0.003314	0.958597	0.956231
98	3.275909	0.810774	-0.090205	-0.100616	-0.003360	0.958593	0.956227
99	3.278274	0.810776	-0.090204	-0.100504	-0.003345	0.958591	0.956233
100	3.275741	0.810774	-0.092052	-0.100615	-0.003355	0.958593	0.956224
Mean	2.766022	0.810774	-0.092055	-0.100615	-0.003314	0.958510	0.956139
S.D.	0.101847	0.012916	0.001781	0.023249	0.005807	0.025532	0.026251

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