Tolls, Exchange Rates, and Borderplex International Bridge Traffic

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June 2009

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International Journal of Transport Economics
Volume 36, 2009, Pages 223-259

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Abstract

Budget constraints are forcing many governments to consider implementing tolls as a means for financing bridge and road expenditures. Newly available time series data make it possible to analyze the impacts of toll variations and international business cycle fluctuations on cross-border bridge traffic between El Paso and Ciudad Juarez. Parameter estimation is carried out using a linear transfer function ARIMA methodology. Price elasticities of demand are similar to those reported for other regional economies, but out-of-sample forecasting results are mixed.

Key Words: Bridge Traffic, Tolls, Applied Econometrics, Mexico Border

JEL Category: R41, Transportation Demand

Acknowledgements

Financial support was provided by National Science Foundation Grant SES 0332001, El Paso Electric Company, El Paso Metropolitan Organization, Hunt Building Corporation, Hunt Communities, Wells Fargo Bank of El Paso, the James Foundation Scholarship Fund, and a UTEP College of Business Administration Faculty Research Grant. Helpful comments and suggestions were provided by Tim Roth, Soheil Nazarian, Martha Patricia Barraza de Anda, and Roberto Tinajero. Econometric research assistance was provided by George Novela and Angel Molina.

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Introduction

During the last 100 years, most highways have been built, owned, and maintained by governments (Geltner and Moavenzadeh, 1987). However, construction costs for new roads, plus maintenance and enhancements to existing road networks, impose substantial public sector budgetary pressures. Those costs can frequently exceed tax revenue capacity. As a result, governments have been forced to look for alternative funding. One mechanism governments have periodically considered as a means for financing the costs of construction and maintenance of new roads is tolls (Matas and Raymond, 2003).

In the United States, tollways have been present almost since the establishment of the nation. The first authorized private toll road in the United States, The Little River Turnpike Company, was created in 1785 by legislation passed by the Virginia General Assembly (Newlon, 1987). Most early toll roads did not prove to be productive investments. In the 1980s, however, tollways began to be viewed more favorably. At that time, grid deficiencies caused the public to realize that funding constraints were affecting road maintenance efforts at all levels of government (Federal Highway Administration, 1999).

Another reason the use of toll roads has become more widespread is that they are now becoming an important tool in controlling traffic (Burris, 2006). Tolls imposed on roads can diminish network congestion by increasing transportation costs and thereby reducing transportation demand (Ferrari, 2002). As congestion subsides, vehicle emission reductions also occur. Furthermore, improved technology now allows electronic toll collection, which eliminates the need for toll booths and also saves substantial amounts of time otherwise spent in queues by motorists, at least for tolled infrastructure within countries (Federal Highway Administration, 1999). Tolls can also be utilized to limit vehicle emissions and improve air quality.

Because the use of tollways is becoming more prevalent, there is an expanding literature on this general topic. Matas and Raymond (2003) state that it is of extreme importance to have accurate knowledge of demand for toll roads for the purposes of traffic forecasting and evaluation. That study also argues that, if the toll road industry is to grow in a cost-effective manner, this literature must be available for government officials and private investors to utilize. To generate accurate traffic and revenue forecasts, and to measure the effect of a toll road on a parallel free road, then the price elasticity of demand must be known. Similar analyses are also required for bridges.

The Borderplex economy encompasses the El Paso, USA and Ciudad Juarez, Mexico metropolitan economies. While closely linked in an economic sense, these markets are separated physically by the Rio Grande River, geopolitically by an international boundary, and monetarily by separate currencies. The purpose of this paper is to examine the impacts of tolls on cross-border regional travel patterns using newly available historical data on the international bridge tolls charged by the City of El Paso. To achieve this, southbound commuter travel by pedestrians, passenger vehicles, and commercial vehicles between El Paso and Ciudad Juarez are studied. To model these traffic categories, autoregressive-moving average (ARIMA) transfer functions are utilized. The transfer functions model international toll bridge demand as a function of toll prices and regional economic variables. For this analysis, monthly data from January 1991 – December 2004 are utilized from three of the international bridges in the area. The data include the tolls charged to pedestrians, passenger vehicles, and commercial vehicles, along with the numbers of pedestrians, passenger vehicles, and commercial vehicles that cross each bridge.

The next section provides an overview of previous research on toll road demand. Data and methodology are described in the following section. Model estimation results are then summarized. Out-of-sample forecast accuracy results are presented next. Policy implications are then discussed. The final section includes the conclusion and suggestions for future research.

Literature Review

Because of budgetary pressures, the number of empirical analyses on tolled transportation infrastructure has grown in recent years. Matas and Raymond (2003) study demand elasticity on toll roads with respect to different variables that influence travel. These explanatory variables include real gross domestic product (GDP), gasoline prices, toll price per kilometer, and a set of dummy variables to represent changes in the road network such as improvements to parallel roads. Parameter estimation is carried out using weighted least squares. Results indicate that toll road usage is positively correlated with GDP and that it is negatively inelastic with respect to gasoline prices. Elasticity with respect to toll prices is found to vary for each tollway depending on the characteristics of the road itself and the alternative roads surrounding it. Not surprisingly, demand for a toll road is more price elastic when there is an alternate free road of better quality.

In an earlier effort, Wuestefeld and Regan (1981) also conclude that each toll road is unique and, therefore, each has a different elasticity. That study focuses on the impact of toll increases on revenue and traffic. Multiple factors are found to affect toll road price sensitivity such as alternate roads, trip length, trip purpose, vehicle mix, and timing of toll increases. If the purpose of a trip is recreational, then an increase in tolls will have a greater impact on traffic than it will have if the toll road is mostly utilized by commuters. Toll sensitivity curves are developed to determine revenue potentials for different price increases based on previous travel patterns.

Hirschman et al. (1995) model the demand for toll bridges and tunnels in New York. Demand is specified as a function of tolls, regional employment, motor vehicle registrations, gas prices, and mass transit fares. Motor vehicle registrations are utilized to represent the size of the market and mass transit fares represent an alternative to paying bridge tolls. A dummy variable for seasonal variation is also included. Similar to other studies, parameter heterogeneity indicates that elasticities must be estimated for each individual toll bridge since they vary even within the same general market area. Although the elasticities vary for each bridge, all are relatively low and the bridges that are most price sensitive are those that are near untolled roads.

Loo (2003) examines toll traffic for six tunnels in Hong Kong. A public transport dominated city, the toll elasticities in Hong Kong are hypothesized to differ substantially from those of more automobile dominant markets. Monthly tunnel toll traffic is modeled as a function of tolls, spatial distribution of the population, real income, gasoline prices, real parking charges, number of private cars registered, seasonal variations, and improvements in mass transit systems. Surprisingly, the results of the analysis indicate that toll price sensitivities in Hong Kong tunnels (-0.103 to -0.291) are more inelastic than those of New York. Similar to empirical evidence reported in other studies (Oum, Waters, and Yong, 1992), the low elasticity estimates indicate that toll increases would be ineffective in reducing traffic volumes, but would raise revenue for construction and maintenance.

Armelius (2005) analyzes congestion tolls with models that include public transport as an alternative to toll roads and different departure times. A toll on a fast mode of transportation (toll road) can lead to congestion on the untolled slow mode (public transportation). To avoid congestion on public transport system, additional measures must be employed. One possibility is to implement an integrated toll and parking policy. Cars entering the central zone during hours when congestion is lowest would be given parking discounts. This would keep some car users from switching to the public transport system and also reduce congestion on toll roads. Even in cases when public transportation congestion results, tolls are still found to improve welfare. That result is in line with earlier analyses where unpriced roads are treated as substitutes for tolled routes (Braid, 1996; Verhoef, Nijkamp, and Rietveld, 1996).

Several studies examine the performance of congestion pricing programs that vary tolls in order to make traffic flows more manageable (Burris, 2006; Muriello and Jiji, 2004; Olszewski and Xie, 2005). Some reductions in traffic volumes are documented in response to time-of-day pricing. Because most road and bridge demand functions are price inelastic, the resulting gains in travel times tend to be relatively small. Not surprisingly, those same characteristics also lead to important revenue enhancements for the public agencies managing the roads and bridges in question. Many of the results documented confirm conclusions pointed to by separate research involving optimal pricing strategies (Miniason, 1979; Yang and Bell, 1996; Yildirim and Hearn; 2002).

Other studies examine factors that influence the political acceptability of toll roads and bridges (Lave, 1994; Brownstone et al., 2003; Raux and Souche, 2004). Among the various items that affect whether residents will support tolls are geographic market size and willingness to charge higher tolls for cargo vehicles. Capacity constraints on existing parallel roads increases the likelihood of toll infrastructure approvals. In many regions, it is ultimately funding constraints that convince stakeholders to turn to tolled facilities as a means for addressing network congestion and bottlenecks (Podgorski and Kockelman, 2006).

There have been several analyses of international bridge traffic in the El Paso and Ciudad Juarez Borderplex regional economy (Villegas et al., 2006). Fullerton (2001) builds a structural econometric model of the Borderplex economy that examines the impacts of population, incomes, and maquiladora manufacturing growth on annual bridge volumes. In turn, those traffic flows affect various categories of retail sales activity on the north side of the river. Fullerton (2004) tabulates the historical accuracies of the various annual frequency bridge traffic category econometric forecasts published every year by the University of Texas at El Paso. Fullerton (2000) models the effects of currency fluctuations on monthly frequency international border crossings. Fullerton and Tinajero (2002) also use monthly frequency data to analyze northbound cargo flows.

None of the studies to date on this topic examine the impact of tolls on cross-border bridge traffic. Toll collections, however, represent an important source of municipal revenue in El Paso (www.ci.el-paso.tx.us, accessed 19 March 2007). This study attempts to partially fill that gap by analyzing southbound traffic volumes across tolled international bridges connecting El Paso, Texas and Ciudad Juarez, Chihuahua. Completion of the analysis is now feasible due to newly available historical time series data regarding southbound bridge flows and the tolls charged to each respective traffic category. In addition to bridge tolls, the analysis also examines the roles played by inflation adjusted (real) exchange rate movements and business cycle fluctuations.

Data and Methodology

In December 2004, more than 19.7 thousand pedestrians, 13.3 thousand cars, and 710 cargo trucks used the tolled international bridges linking El Paso and Ciudad Juarez on a daily basis. During fiscal year 2006, the fees for using that infrastructure generated more than $14.2 million for the El Paso city budget (www.ci.el-paso.tx.us, accessed 19 March 2007). To date, however, an empirical analysis of the various traffic categories that pay those tolls charged on international bridge use in El Paso has not previously been attempted. Time series data for southbound traffic flows and tolls are now available to support such an effort. Historical toll data for the corresponding northbound traffic out of Mexico have not yet been compiled and are, thus, excluded from the analysis.

Different types of users are associated with the various bridges. For example, the Santa Fe Bridge near downtown El Paso is typically used by pedestrian tourists from the United States who want to visit Mexico without driving. The nearby Stanton Bridge is traversed primarily by students, shoppers, and workers who reside in Ciudad Juarez and commute between the two border cities either by car or on foot. The Zaragoza International Bridge mostly carries two types of southbound traffic. One is cargo vehicles headed to maquiladora plants in the eastern quadrants of Ciudad Juarez or farther south in the state capital of Chihuahua City. The second is working professionals who commute to jobs on the opposite side of the border from where they reside.

Data utilized for this analysis are from three of the international bridges in the Borderplex: Santa Fe, Stanton, and Zaragoza. Monthly data gathered from the international bridges include the numbers of pedestrians, passenger vehicles, and commercial vehicles, plus the respective tolls paid by each group. The sample period is January 1991 to December 2004. The information is collected by the City of El Paso Streets Department and reported by the City of El Paso Office of Management and Budget. Those time series, plus others employed in the study, are shown in Appendix Tables A1 and A2 below. As shown in the data tables, the tolls charged for each traffic category generally remain fixed in nominal terms for long periods of time. In real terms, however, the tolls vary on a monthly basis.

Other data utilized include Ciudad Juarez maquiladora employment, Mexico Industrial Production Index, El Paso non-agricultural employment, United States consumer price index (CPI), and a real exchange rate index for the peso. The CPI and El Paso monthly employment data are reported by the United States Bureau of Labor Statistics (www.bls.gov, accessed 19 October 2006). The Mexico industrial production index and Ciudad Juarez in-bond manufacturing employment data series are available from the INEGI national statistics website (www.inegi.gob.mx, accessed 14 November 2006). The inflation adjusted peso index is from the University of Texas at El Paso Border Region Modeling Project (Fullerton and Tinajero, 2002).

The 14-year sample period spans a long enough period to contain expansion, recession, and recovery phases of the national business cycles in both the United States and Mexico. With a total of 168 observations, the sample is sufficiently large to permit time series analysis of the data in question (Wei, 1990). Because El Paso and Ciudad Juarez are both growing fairly rapidly, the data used in this and other studies of cross-border bridge transportation are non-stationary (Fullerton, 2000). Given that, the variables are differenced prior to modeling (Pindyck and Rubinfeld 1998).

Empirical analyses for each series are completed using linear transfer function (LTF) ARIMA procedures. Cross correlation functions are used to identify the potential lag structures for each equation. Once parameter estimation has been completed for a particular lag structure, diagnostic statistics are utilized to examine its performance. Among the latter, an autocorrelation function is estimated using model residuals to specify autoregressive and moving average terms for any systematic movements in the dependent variable that the lags of the explanatory variables fail to capture. An LTF for a dependent variable y with multiple lags of two explanatory variables, x and z, plus autoregressive and moving components, can be expressed as follows:

1. $$y_t = \theta_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j e_{t-j} + \sum_{a=1}^{n} A_a x_{t-a} + \sum_{b=1}^{k} B_b z_{t-b} + e_t \,.$$

LTF procedures frequently perform well when used to analyze model time series data. Because it emphasizes the relationships between the dependent variable of interest and potential explanatory variables, it has been used in numerous econometric settings. Several examples are from regulated markets such as residential natural gas consumption, electricity consumption, and municipal water consumption dynamics. In addition to good in-sample estimation diagnostics, many studies also indicate that LTF models often exhibit reliable out-of-sample simulation properties. In at least one instance, an LTF modeling approach has been utilized to analyze cross-border bridge traffic, albeit without taking into account the effects of toll changes (Fullerton and Tinajero, 2002).

Individual LTF equations are estimated for each bridge and traffic category. The five equations include cars heading south across the Zaragoza Bridge (ZC), cargo trucks using the Zaragoza Bridge (ZT), pedestrians utilizing the Stanton Bridge (STW), cars using the Stanton Bridge (STC), and pedestrians crossing the Santa Fe Bridge (SFW) into Mexico. In the equations, demand for the use of the toll bridges is modeled as a function of lags of the relevant inflation adjusted toll (TOLL), Ciudad Juarez maquiladora employment (CJMQM), industrial production in Mexico (MXIP), the real exchange rate (REX), and El Paso employment (ELPM). Implicit functions for each traffic category can be expressed as follows:

2. $\text{Traffic}_t = f(\text{TOLL}_{t-i}, \text{CJMQM}_{t-j}, \text{MXIP}_{t-k}, \text{REX}_{t-m}, \text{ELPM}_{t-n}, \text{AR}_{t-p}, \text{MA}_{t-q})$.

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The arithmetic signs in the parentheses below Equation 2 represent the overall hypothesized relationship between the left-hand side variable and each independent variable. The deflated toll series obviously serve as real price variables for each respective equation and will tend to reduce bridge usage when they increase (Hirschman et al., 1995). The sign underneath the inflation adjusted peso index is ambiguous. While depreciation of the peso generally leads to reduced numbers of Mexican pedestrians and automobiles, it also generates increased volumes of cross-border cargo traffic and tourists from the United States (Fullerton, 2000).

Monthly income data are not available for either Borderplex city. Given that, alternative business cycle indicators are employed. For El Paso, total non-agricultural employment provides a fairly inclusive measure of economic conditions on the north side of the river. Because no similar broad metric is available for Ciudad Juarez, two variables are utilized. They are in-bond manufacturing payroll employment and the Mexico industrial production index (Fullerton and Tinajero, 2002). Transfer ARIMA models assume unidirectional causality from the explanatory variables to the left-hand side variables (Wei, 1990). None of the independent variables employed below violate this assumption. Empirical estimation results from the various models are discussed in the next section.

Estimation Results

Tables 1 through 5 summarize the estimation results for each of the different bridge traffic categories. Due to trend non-stationarity, all of the series are differenced prior to estimation. Following parameter estimation, the series are brought back to level form and a pseudo R-squared is calculated for each equation. A price elasticity of demand is also calculated for each model.

<INSERT TABLE 1 ABOUT HERE>

Table 1 summarizes the results from the linear transfer function estimated for cargo vehicles utilizing the Zaragoza Bridge. An increase in the toll leads to a decrease in cargo traffic within one month of implementation. Ciudad Juarez maquiladora employment, the Mexico industrial production index, and the real exchange rate are all positively correlated with cargo vehicle traffic on the Zaragoza Bridge. A devaluation of the peso leads to a rapid increase in cargo vehicle traffic. Four of the eight parameters in this equation fail to satisfy the 5-percent significance criterion, but the F-statistic is significant at the 1-percent level. That may reflect the presence of multicollinearity such as what has been noted in other border econometric studies (Fullerton and Tinajero, 2002). With the lone exception of the real exchange rate index, the simple correlation coefficients between the inflation adjusted toll for cargo vehicles with each of the other four explanatory variable range between 0.79 and 0.93. The pseudo coefficient of determination is 0.812. As shown in Table 6, the price elasticity calculated for this model is -0.474 implying that cargo vehicle traffic is not very responsive to changes in the toll. Because there are only two international bridges that carry trucks directly into Ciudad Juarez, the inelasticity with respect to the toll is not surprising (Graham and Glaister, 2004).

The results for Zaragoza Bridge passenger vehicles are given in Table 2. In this equation, Zaragoza Bridge passenger vehicle traffic is positively correlated with El Paso employment, Ciudad Juarez maquiladora employment, and the Mexico industrial production index. The inflation adjusted toll and real exchange rate are negatively correlated with passenger vehicle traffic. That a devaluation of the peso leads to a decrease in passenger vehicle traffic probably reflects the loss of purchasing power experienced by Mexican shoppers who visit large shopping centers such as Cielo Vista Mall and Las Palmas Marketplace in East El Paso. The pseudo R-squared for this equation is also relatively high, 0.813. The price elasticity of demand reported in Table 6 for Zaragoza Bridge passenger vehicles is -0.0035. That indicates that passenger vehicle traffic on this bridge reacts very little to increases in the toll paid by cars. While the failure of the toll coefficient to satisfy the 5-percent significance criterion means that result should potentially be treated with caution, similarly low elasticities have also been documented for other regions (Wuestefeld and Regan, 1981; Hirschman et al., 1995; Loo, 2003). Multicollinearity may also affect these results. With the exception of the real exchange rate index, the simple correlation coefficients between the real toll for cars and the four remaining regressors range between 0.82 and 0.91.

<INSERT TABLE 2 ABOUT HERE>

Stanton Bridge passenger vehicle results are reported in Table 3. In this model, passenger vehicle traffic flows are inversely related to the real toll and exchange rate variables. The sign of the real peso parameter potentially reflects the proximity of this bridge to the downtown retail sector on the north side of the border (Villegas et al., 2006). El Paso employment, Ciudad Juarez in-bond assembly employment, and the Mexico industrial production index are positively correlated with volume of cars that travel across the artery. With a pseudo coefficient of determination of 0.889, the model explains a relatively high percentage of the variation in passenger vehicle traffic on the Stanton Bridge. As with the other traffic categories, the price elasticity of demand of -0.278 indicates that the number of vehicles heading south on this artery is not strongly affected by increases in the toll. It is also similar to what has been documented for other markets (Matas and Raymond, 2003).

<INSERT TABLE 3 ABOUT HERE>

Results for the Stanton Bridge pedestrian equation are summarized in Table 4. Large numbers of shoppers who cross on foot from Mexico return home over this structure. Not surprisingly, southbound pedestrian traffic flows on this bridge are inversely related to changes in the inflation adjusted values of the toll and the exchange rate. El Paso non-agricultural jobs, Ciudad Juarez maquiladora employment, and the Mexico industrial production index are all positively correlated with pedestrian traffic on the Stanton Bridge. The pseudo R-squared for this equation indicates that it successfully accounts for nearly two-thirds of the historical variation in the dependent variable for the sample period in question. Most pedestrian travel studies do not examine the impacts of tolls on this traffic category (Hoogendoorn and Bovy, 2005). While a comparison to other estimates is not, therefore, possible, the -0.482 price elasticity measured for this bridge seems fairly reasonable. As with the truck and automobile equations, multicollinearity may affect the pedestrian modeling results. With the exception of the real exchange rate index, the simple correlation coefficients between the inflation adjusted pedestrian toll and the other independent variables ranges between 0.72 and 0.91.

<INSERT TABLE 4 ABOUT HERE>

The results for Santa Fe Bridge pedestrians are given in Table 5. Pedestrian traffic is inversely related to changes in real toll along this bridge. For all other explanatory variables, the regression coefficients carry positive signs. For the real exchange rate, that means that peso depreciation leads to an increase in foot traffic to the downtown Ciudad Juarez tourist district. This bridge is the one that most visitors from the United States use when they walk across the border. The response is more rapid than what is separately reported for total commuter flows (Fullerton, 2000). A stronger dollar probably attracts tourists who visit entertainment venues, restaurants, and shops, as well as medical tourists who are customers at the many health facilities and pharmacies located in this sector of the city. The pseudo coefficient of determination is 0.73. A price elasticity of -0.483 is estimated for Santa Fe Bridge pedestrians, almost identical to that calculated for pedestrians that utilize the Stanton Bridge, even though the two series respond very differently to real changes in the peso/dollar exchange rate.

<INSERT TABLE 5 ABOUT HERE>

The passenger and cargo vehicle price elasticities shown in Table 6 are similar in magnitude to many of those reported over time in the transport economics literature (Wuestefeld and Regan, 1981; Hirschman et al., 1995; Matas and Raymond, 2003). One area in which some uncertainty remains for Table 6 is that comparative results for pedestrian reactions to changes in tolls have not been documented elsewhere. Another source of uncertainty regarding the information in Tables 1 through 6, and not already discussed above, is the absence of variables that reflect the availability of alternative routes that are not subject to tolls (Braid, 1996). Due to the distances involved, realistic untolled international bridge choices only exist for passenger and cargo vehicles. Experimentation with a combination of traffic volume and population estimates did not yield coefficients in any of the equations that satisfied the 5-percent significance criterion. The various traffic volume measures included totals for all bridges, as well as for the untolled Bridge of the Americas alone.

<INSERT TABLE 6 ABOUT HERE>

Results in Tables 1 through 6 are comparable to those reported elsewhere and seem fairly reasonable from an economic perspective (McCloskey and Ziliak, 1996). However, good in-sample traits do not always guarantee reliable out-of-sample simulation performance (Leamer, 1983). For municipal revenue models, forecast performance is an important question that frequently gets overlooked (Chang, 1979; Forrester, 1991). To date, there is little evidence that such an exercise has ever been completed for bridge tolls collected at international borders. Results of such an effort using the LTF traffic models are discussed below.

Comparative Simulation Results

Following LTF parameter estimation, forecasts are generated in rolling 12-month increments over the period covering January 2001 to December 2004 for each bridge category. Predictive accuracy for these forecasts is assessed relative to random walk benchmarks. The random walk (RW) forecasts are assembled using the last actual sample observations for each traffic category. To evaluate the performances of the two forecast categories, three different metrics are employed: a descriptive U-statistic (Pindyck and Rubinfeld, 1998), a non-parametric t-test (Diebold and Mariano, 1995), and a regression based F-test (Ashley, Granger, Schmalensee, 1980).

Out-of-sample simulations for the linear transfer function and corresponding random walks are generated in the same manner. For the first set of predictions, a historical sample period is defined from January 1990 to December 2000. The first simulation conducted is from January 2001 to December 2002. The historical sample period is then extended by one month to include January 2001 and the new forecast period is February 2001 to January 2003. This rolling forecast procedure is conducted sequentially through December 2004. This yields a total of 48 one-month forecasts, 47 two-month forecasts, 46 three-month forecasts, and so forth.

The first measure utilized to compare the LTF and RW forecasts is the U-statistic or Theil inequality coefficient. A U-statistic scales the root mean square error for a forecast such that it ranges between 0 and 1 (Pindyck and Rubinefeld 1998). The second accuracy measure is based on an error differential regression test (AGS) conducted at different step lengths (Ashley, Granger, and Schmalensee 1980). The third accuracy metric employs a non-parametric t-test (DM) based on the differences between RW and LTF root mean square errors (Diebold and Mariano, 1995).

<INSERT TABLE 7 ABOUT HERE>

Results for the Zaragoza cargo vehicles forecasts are summarized in Table 7. The descriptive U-statistics favor the LTF out-of-sample simulations in 19 of the 24 individual step-lengths for this traffic category. The DM procedure also indicates that the LTF root mean square errors (RMSEs) are significantly lower than the RW RMSEs across all step-lengths. The AGS test outcomes for southbound truck travel on this bridge are much less decisive. Only in the case of the single month-ahead forecasts did the AGS test point to LTF predictive superiority. For all other 23 step-lengths, the AGS results are statistically inconclusive. Accordingly, some caution appears warranted with respect to using the LTF equation in operations planning or revenue forecasting applications for cargo vehicle usage of the Zaragoza Bridge.

Table 8 reports the forecast rankings for Zaragoza Bridge passenger vehicles. Results for the descriptive inequality coefficient point to LTF relative forecast accuracy across all step-lengths. Statistically significant results in favor of the LTF predictions are tallied in 20 of the 24

AGS regression tests. Not surprisingly, the DM t-test also yields evidence that the LTF RMSEs are significantly smaller than those of the RW passenger flow to Mexico forecasts via this bridge. These outcomes offer partial confirmation that the price elasticity reported for this bridge usage category in Table 6, while still relatively low, may be accurate.

<INSERT TABLE 8 ABOUT HERE>

The Stanton Bridge near the downtown region of El Paso also carries passenger vehicle traffic. As shown in Table 9, the out-of-sample simulation results for this variable are very different from those for passenger vehicles in East El Paso. The LTF equation obtains lower U-statistics for the one-month and two-month ahead forecasts. For the AGS error difference regression tests, the evidence against the LTF simulations is also very pronounced. In six cases, the results are inconclusive. For the other 18 step-lengths, significantly better prediction accuracy is recorded for the RW forecasts. The DM t-test also points to lower RMSEs for the RW passenger vehicle benchmarks for this commuter category.

<INSERT TABLE 9 ABOUT HERE>

The Stanton Bridge also provides southbound pedestrians entry into Mexico. Table 10 lists the relative predictive accuracies of the LTF equation and the RW procedure. The inequality coefficients are lower at every step-length for the RW forecasts. For the AGS regressions, 23 of the 24 sets of forecasts point to superior statistical precision for the RW method. Although those results seem one-sided, the error differences may not be as large or clear cut as the AGS column of Table 10 indicates. That is because the DM t-test for RMSE equality across all 24 step-lengths is inconclusive.

<INSERT TABLE 10 ABOUT HERE>

Pedestrians can also cross the Santa Fe Bridge into Mexico. The out-of-sample simulation rankings in Table 11 document the academic equivalent of a forecast shutout on behalf of the RW extrapolations. Both the descriptive U-statistics and the AGS test outcomes indicate relative LTF inaccuracy at all 24 step-lengths. The DM t-test also documents statistically smaller RMSEs across all step-lengths.

<INSERT TABLE 11 ABOUT HERE>

The out-of-sample simulation results imply that the LTF model achieves greater accuracy than the RW benchmarks for both the Zaragoza Bridge cargo vehicle and the Zaragoza Bridge passenger vehicle forecasts. However, the comparative test statistics also indicate that the RW predictions are more accurate than the LTF forecasts for southbound pedestrian traffic flows across the Stanton Bridge and the Santa Fe Bridge. It is somewhat more difficult to interpret the accuracy ranking for the passenger vehicle flows across the Stanton Bridge, but the overall evidence favors the RW benchmark at the expense of the LTF model. These mixed results are similar to those previously reported by Fullerton (2004) using annual frequency data and call for some care to be used with regard to employing the LTF estimates in public administrative exercises.

Policy Implications

Several results from the analysis above can potentially be of use to policy makers. Given that all five categories of bridge traffic are inelastic with respect to the respective tolls charged, rate increases will raise revenues without substantial reductions in volume usage. Although it would be politically, and diplomatically, difficult to use international bridges connecting the United States and Mexico as “cash cows,” the City of El Paso should be capable of covering a substantial portion of current maintenance and future structural enhancement costs with the tolls charged. At one point, there was a 9-year period from November 1994 to December 2003 during which passenger vehicle tolls were left unchanged in nominal terms. There is no need to allow real erosion of the tolls to occur for such a long time. All three user fees can be adjusted more frequently without damaging the respective revenue streams. Given the rapid growth of international commerce in this region, plus the strong rates of population and economic expansion in the Borderplex, raising tolls provides one means for financing the infrastructure expansion and upgrades that will undoubtedly become necessary in future years.

The lag structures in each equation are also of interest from a public administration standpoint. All of the traffic categories respond within 60 days or less to toll rate changes. Cargo traffic across the Zaragoza bridges reacts in less than 30 days to variations in in-bond assembly payrolls and industrial production activity in Mexico. Staffing levels at that bridge will have very little time to be altered as economic fortunes wax and wane south of the border. Similarly rapid responses also occur at all three bridges as consequences of variations in the currency value of the peso and non-agricultural employment in El Paso. Accordingly, flexible staffing schedules will have to be maintained in order to maximize efficiencies and revenues at these international exit points from El Paso. Because the price reactions are inelastic, raising tolls at the bridges would probably not be very effective as a means for reducing vehicle emissions via reduced traffic flows.

Given the mixed outcomes for the comparative out-of-sample simulation results, the LTF models should be used with caution in municipal revenue forecasting endeavors. This is especially true for the two downtown international bridges that charges tolls on southbound traffic to Ciudad Juarez. At a minimum, LTF traffic forecasts should be compared to recent historical observations as a means of providing "sanity checks" for the extrapolation results. During periods in which rate increases are enacted, policy analysts may elect to rely more heavily on the LTF model simulations since those equations provide a quantitatively systematic manner for anticipating potential bridge usage impacts.

To date, the City of El Paso has only used fixed toll schedules. That is probably because nearly all of the congestion that occurs on the international bridges is experienced by northbound traffic heading into El Paso. The latter circumstance is largely due to more time consuming inspection practices historically applied by the United States at its ports of entry. It is possible, however, that Borderplex economic and demographic expansion may also lead to capacity constraints on the southbound lanes of the tolled bridges. Should that eventuality come to pass, variable congestion tolls might offer a viable mechanism for managing the greater traffic flow volumes and raising additional revenues for infrastructure expansion (Burris, 2006). The fixed schedules now in place, however, may be good choices for a regional road network already split in two by an international boundary (Bonsall et al., 2007).

Tolls remain a highly controversial topic in El Paso and other parts of Texas (Podgorski, and Kockelman, 2006; Crowder, 2007). State government funding constraints increase the likelihood that a portion of the road network in El Paso may one day be funded with tolls. Econometric analysis of the long history of charging tolls on three of the international bridges indicates that local traffic behavior patterns are similar to those documented for other regional economies where these user fees are charged. Based on that, it would appear that employing tolls to partially fund the street and highway grid in El Paso should meet with success.

Conclusion

As road construction and maintenance costs continue to increase, governments periodically look to tolls as a means of financing roadway construction and improvements. Although tolls have been charged on three of the international bridges linking El Paso and Ciudad Juarez for many years, empirical assessment of the impacts of those fees on traffic patterns had not previously been completed. This study takes advantage of newly available monthly historical toll data for El Paso to examine this aspect of the Borderplex economy.

A linear transfer function methodology is used to model toll bridge demand as a function of several explanatory variables: Ciudad Juarez maquiladora employment, Mexico industrial production, El Paso employment, inflation adjusted tolls for each traffic category, and the real exchange rate. Individual equations are estimated for each of the five traffic categories that pay the bridge user fees. As with other transfer function studies, multicollinearity appears to be present, but overall in-sample diagnostics are relatively favorable. The price elasticities of demand are similar in magnitude to those calculated for other regional economies. Mixed results, however, are obtained for the out-of-sample model simulation exercises. Given that, caution should be used if the equations are applied in municipal revenue forecasting tasks.

Data constraints currently prevent analyzing the impacts of tolls on northbound international bridge traffic into El Paso, but eventual comparative analyses for the other side of the river would be helpful. It would also be interesting to examine whether the results for southbound traffic out of El Paso into Mexico can be replicated using data for other border metropolitan economies. Potential examples include San Diego – Tijuana, Calexico – Mexicali, Douglas – Agua Prieta, Laredo – Nuevo Laredo, McAllen – Reynosa, and Brownsville – Matamoros. Additional toll bridge research for other regions would also be useful due to the relatively small amount of research currently available for this topic.

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TABLE 1, Zaragoza Bridge Cargo Vehicles, ZT

Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-0.136059	0.222145	-0.612477	0.5412
TOLLT(-1)	-81.30670	586.0849	-0.138729	0.8899
CJMQM	0.000172	6.32E-05	2.714161	0.0075
MXIP	0.201084	0.045524	4.417113	0.0000
MXIP(-5)	0.084077	0.035686	2.355987	0.0198
MXIP(-12)	0.133327	0.041862	3.184887	0.0018
REX	0.018559	0.039964	0.464402	0.6431
AR(2)	0.111979	0.079043	1.416676	0.1587

R-Squared	0.448186	Dependent Variable Mean	0.042170
Pseudo R-Squared	0.812798	Dependent Variable Std. Deviation	3.166322
Std. Err. Regression	2.408182	Akaike Information Criterion	4.646492
Sum Sq. Residuals	840.9041	Schwarz Information Criterion	4.804946
Log-Likelihood	-347.4566	F-Statistic	16.82424
Durbin Watson Stat.	2.747830	F-Statistic Probability	0.000000

Linear Transfer Function Table Notes:
Sample Period, January 1991 – December 2004.
ZT, Zaragoza Bridge monthly cargo truck traffic.
ZC, Zaragoza Bridge monthly passenger car traffic.
STC, Stanton Bridge monthly passenger car traffic.
STW, Stanton Bridge monthly pedestrian traffic.
SFW, Santa Fe Bridge monthly pedestrian traffic.

TOLLT, inflation adjusted cargo truck toll.
TOLLC, inflation adjusted passenger car toll.
TOLLW, inflation adjusted passenger car toll.

ELPM, El Paso monthly non-agricultural employment.
CJMQM, Ciudad Juarez monthly maquiladora employment.
MXIP, monthly industrial production index for Mexico.
REX, monthly peso/dollar real exchange rate index.

Table 2, Zaragoza Bridge Passenger Vehicles, ZC

Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	0.128304	1.779904	0.072085	0.9426
TOLLC	-122.4508	246.3155	-0.497130	0.6199
ELPM	1.300847	0.584379	2.226032	0.0276
ELPM(-8)	1.579734	0.559434	2.823809	0.0054
CJMQM	5.08E-05	0.000198	0.256336	0.7981
MXIP	0.746725	0.255249	2.925480	0.0040
MXIP(-9)	0.815261	0.259795	3.138095	0.0021
REX	-0.429744	0.168805	-2.545801	0.0119
AR(1)	-0.554606	0.083481	-6.643508	0.0000
MA(2)	-0.339905	0.083091	-4.090762	0.0001
MA(3)	-0.247425	0.080211	-3.084672	0.0024
MA(12)	0.253712	0.076180	3.330448	0.0011

R-Squared	0.531949	Dependent Variable Mean	0.709452
Pseudo R-Squared	0.814279	Dependent Variable Std. Deviation	19.40203
Std. Err. Regression	13.76804	Akaike Information Criterion	8.155932
Sum Sq. Residuals	27486.05	Schwarz Information Criterion	8.389530
Log-Likelihood	-628.2406	F-Statistic	14.98138
Durbin Watson Stat.	2.041143	F-Statistic Probability	0.000000

Linear Transfer Function Table Notes:
Sample Period, January 1991 – December 2004.
ZC, Zaragoza Bridge monthly cargo truck traffic.
ZT, Zaragoza Bridge monthly passenger car traffic.
STC, Stanton Bridge monthly passenger car traffic.
STW, Stanton Bridge monthly pedestrian traffic.
SFW, Santa Fe Bridge monthly pedestrian traffic.

TOLLT, inflation adjusted cargo truck toll.
TOLLC, inflation adjusted passenger car toll.
TOLLW, inflation adjusted passenger car toll.

ELPM, El Paso monthly non-agricultural employment.
CJMQM, Ciudad Juarez monthly maquiladora employment.
MXIP, monthly industrial production index for Mexico.
REX, monthly peso/dollar real exchange rate index.

Table 3, Stanton Bridge Passenger Vehicles, STC

Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-1.524972	2.209717	-0.690121	0.4912
TOLLC(-2)	-8096.849	2405.142	-3.366475	0.0010
ELPM	1.249981	0.567939	2.200906	0.0293
CJMQM(-2)	0.000419	0.000321	1.306284	0.1935
MXIP	0.494718	0.254148	1.946572	0.0535
MXIP(-9)	1.009340	0.257273	3.923231	0.0001
MXIP(-10)	1.088690	0.252339	4.314396	0.0000
REX	-0.191207	0.204161	-0.936551	0.3505
AR(12)	0.705886	0.070025	10.08051	0.0000
MA(3)	-0.155615	0.049561	-3.139830	0.0020
MA(5)	0.351985	0.044083	7.984675	0.0000
MA(12)	-0.649743	0.049563	-13.10953	0.0000

R-Squared	0.515444	Dependent Variable Mean	-0.272089
Pseudo R-Squared	0.888619	Dependent Variable Std. Deviation	18.63443
Std. Err. Regression	13.45447	Akaike Information Criterion	8.109854
Sum Sq. Residuals	26248.31	Schwarz Information Criterion	8.343453
Log-Likelihood	-624.6236	F-Statistic	14.02207
Durbin Watson Stat.	1.949316	F-Statistic Probability	0.000000

Linear Transfer Function Table Notes:
Sample Period, January 1991 – December 2004.
ZC, Zaragoza Bridge monthly cargo truck traffic.
ZT, Zaragoza Bridge monthly passenger car traffic.
STC, Stanton Bridge monthly passenger car traffic.
STW, Stanton Bridge monthly pedestrian traffic.
SFW, Santa Fe Bridge monthly pedestrian traffic.

TOLLT, inflation adjusted cargo truck toll.
TOLLC, inflation adjusted passenger car toll.
TOLLW, inflation adjusted passenger car toll.

ELPM, El Paso monthly non-agricultural employment.
CJMQM, Ciudad Juarez monthly maquiladora employment.
MXIP, monthly industrial production index for Mexico.
REX, monthly peso/dollar real exchange rate index.

Table 4, Stanton Bridge Pedestrians, STW

Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-2.213653	0.925308	-2.392341	0.0180
TOLLW(-1)	-38869.99	24449.44	-1.589811	0.1140
ELPM	2.927025	0.720681	4.061471	0.0001
ELPM(-12)	2.245174	0.733973	3.058935	0.0026
CJMQM(-2)	0.000261	0.000320	0.814015	0.4169
MXIP(-9)	1.339868	0.183564	7.299173	0.0000
MXIP(-14)	0.606153	0.191548	3.164490	0.0019
REX(-1)	-0.386083	0.203893	-1.893558	0.0602
AR(5)	-0.141582	0.082408	-1.718054	0.0878

R-Squared	0.597795	Dependent Variable Mean	0.082550
Pseudo R-Squared	0.640829	Dependent Variable Std. Deviation	19.94331
Std. Err. Regression	12.97870	Akaike Information Criterion	8.019102
Sum Sq. Residuals	25435.45	Schwarz Information Criterion	8.192081
Log-Likelihood	-632.5282	F-Statistic	28.05375
Durbin Watson Stat.	2.166103	F-Statistic Probability	0.000000

Linear Transfer Function Table Notes:
Sample Period, January 1991 – December 2004.
ZC, Zaragoza Bridge monthly cargo truck traffic.
ZT, Zaragoza Bridge monthly passenger car traffic.
STC, Stanton Bridge monthly passenger car traffic.
STW, Stanton Bridge monthly pedestrian traffic.
SFW, Santa Fe Bridge monthly pedestrian traffic.

TOLLT, inflation adjusted cargo truck toll.
TOLLC, inflation adjusted passenger car toll.
TOLLW, inflation adjusted passenger car toll.

ELPM, El Paso monthly non-agricultural employment.
CJMQM, Ciudad Juarez monthly maquiladora employment.
MXIP, monthly industrial production index for Mexico.
REX, monthly peso/dollar real exchange rate index.

Table 5, Santa Fe Bridge Pedestrians, SFW

Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-2.004015	2.303618	-0.869942	0.3858
TOLL(-1)	-91012.84	49918.31	-1.823236	0.0704
ELPM	7.320916	1.184945	6.178274	0.0000
CJMQM	0.000134	0.000587	0.227974	0.8200
MXIP(-9)	2.366747	0.498151	4.751067	0.0000
MXIP(-10)	0.901551	0.508109	1.774327	0.0782
MXIP(-14)	2.301122	0.447109	5.146672	0.0000
REX	0.670519	0.424025	1.581318	0.1160
AR(12)	-0.417738	0.093609	-4.462598	0.0000
MA(2)	-0.242022	0.047020	-5.147209	0.0000
MA(12)	0.705258	0.040071	17.60023	0.0000

R-Squared	0.569027	Dependent Variable Mean	0.982320
Pseudo R-Squared	0.732180	Dependent Variable Std. Deviation	39.93342
Std. Err. Regression	27.12307	Akaike Information Criterion	9.507827
Sum Sq. Residuals	104463.9	Schwarz Information Criterion	9.725701
Log-Likelihood	-716.3487	F-Statistic	18.74873
Durbin Watson	2.157281	F-Statistic Probability	0.000000

Linear Transfer Function Table Notes:
Sample Period, January 1991 – December 2004.
ZC, Zaragoza Bridge monthly cargo truck traffic.
ZT, Zaragoza Bridge monthly passenger car traffic.
STC, Stanton Bridge monthly passenger car traffic.
STW, Stanton Bridge monthly pedestrian traffic.
SFW, Santa Fe Bridge monthly pedestrian traffic.

TOLLT, inflation adjusted cargo truck toll.
TOLLC, inflation adjusted passenger car toll.
TOLLW, inflation adjusted passenger car toll.

ELPM, El Paso monthly non-agricultural employment.
CJMQM, Ciudad Juarez monthly maquiladora employment.
MXIP, monthly industrial production index for Mexico.
REX, monthly peso/dollar real exchange rate index.

Table 6
Toll Elasticity Estimates

Bridge	Location	Traffic Category	Elasticity
Zaragoza	East El Paso	Cargo Vehicles	-0.4736
Zaragoza	East El Paso	Passenger Vehicles	-0.0035
Stanton	Downtown El Paso	Passenger Vehicles	-0.2782
Stanton	Downtown El Paso	Pedestrians	-0.4816
Santa Fe	Downtown El Paso	Pedestrians	-0.4829

TABLE 7
Zaragoza Bridge Cargo Vehicle Forecast Accuracy Rankings

Step Length	Number of Observations	U-statistic	AGS Error Differential	DM RMSE Differential
1-Month	48	LTF	LTF	LTF
2-Months	47	LTF	Inconclusive	
3-Months	46	LTF	Inconclusive	
4-Months	45	LTF	Inconclusive	
5-Months	44	RW	Inconclusive	
6-Months	43	LTF	Inconclusive	
7-Months	42	RW	Inconclusive	
8-Months	41	LTF	Inconclusive	
9-Months	40	LTF	Inconclusive	
10-Months	39	LTF	Inconclusive	
11-Months	38	LTF	Inconclusive	
12-Months	37	RW	Inconclusive	
13-Months	36	LTF	Inconclusive	
14-Months	35	LTF	Inconclusive	
15-Months	34	LTF	Inconclusive	
16-Months	33	LTF	Inconclusive	
17-Months	32	RW	Inconclusive	
18-Months	31	LTF	Inconclusive	
19-Months	30	LTF	Inconclusive	
20-Months	29	LTF	Inconclusive	
21-Months	28	LTF	Inconclusive	
22-Months	27	RW	Inconclusive	
23-Months	26	LTF	Inconclusive	
24-Months	25	LTF	Inconclusive	

Sample Period: January 2001 – December 2004
LTF, autoregressive integrated moving average linear transfer function.
RW, random walk.
RMSE, root mean square error.
AGS, error difference regression test.
DM, non-parametric RMSE difference t-test.

TABLE 8
Zaragoza Bridge Passenger Vehicle Forecast Accuracy Rankings

Step Length	Number of Observations	U-statistic	AGS Error Differential	DM RMSE Differential
1-Month	48	LTF	LTF	LTF
2-Months	47	LTF	LTF	
3-Months	46	LTF	LTF	
4-Months	45	LTF	LTF	
5-Months	44	LTF	LTF	
6-Months	43	LTF	LTF	
7-Months	42	LTF	LTF	
8-Months	41	LTF	LTF	
9-Months	40	LTF	LTF	
10-Months	39	LTF	LTF	
11-Months	38	LTF	LTF	
12-Months	37	LTF	Inconclusive	
13-Months	36	LTF	LTF	
14-Months	35	LTF	LTF	
15-Months	34	LTF	LTF	
16-Months	33	LTF	LTF	
17-Months	32	LTF	Inconclusive	
18-Months	31	LTF	LTF	
19-Months	30	LTF	LTF	
20-Months	29	LTF	Inconclusive	
21-Months	28	LTF	LTF	
22-Months	27	LTF	LTF	
23-Months	26	LTF	LTF	
24-Months	25	LTF	Inconclusive	

Sample Period: January 2001 – December 2004
LTF, autoregressive integrated moving average linear transfer function.
RW, random walk.
RMSE, root mean square error.
AGS, error difference regression test.
DM, non-parametric RMSE difference t-test.

TABLE 9
Stanton Bridge Passenger Vehicle Forecast Accuracy Rankings

Step Length	Number of Observations	U-statistic	AGS Error Differential	DM RMSE Differential
1-Month	48	LTF	Inconclusive	Inconclusive
2-Months	47	LTF	Inconclusive	
3-Months	46	RW	RW	
4-Months	45	RW	Inconclusive	
5-Months	44	RW	RW	
6-Months	43	RW	Inconclusive	
7-Months	42	RW	Inconclusive	
8-Months	41	RW	Inconclusive	
9-Months	40	RW	RW	
10-Months	39	RW	RW	
11-Months	38	RW	RW	
12-Months	37	RW	RW	
13-Months	36	RW	RW	
14-Months	35	RW	RW	
15-Months	34	RW	RW	
16-Months	33	RW	RW	
17-Months	32	RW	RW	
18-Months	31	RW	RW	
19-Months	30	RW	RW	
20-Months	29	RW	RW	
21-Months	28	RW	RW	
22-Months	27	RW	RW	
23-Months	26	RW	RW	
24-Months	25	RW	RW	

Sample Period: January 2001 – December 2004
LTF, autoregressive integrated moving average linear transfer function.
RW, random walk.
RMSE, root mean square error.
AGS, error difference regression test.
DM, non-parametric RMSE difference t-test.

TABLE 10
Stanton Bridge Pedestrian Forecast Accuracy Rankings

Step Length	Number of Observations	U-statistic	AGS Error Differential	DM RMSE Differential
1-Month	48	RW	Inconclusive	Inconclusive
2-Months	47	RW	RW	
3-Months	46	RW	RW	
4-Months	45	RW	RW	
5-Months	44	RW	RW	
6-Months	43	RW	RW	
7-Months	42	RW	RW	
8-Months	41	RW	RW	
9-Months	40	RW	RW	
10-Months	39	RW	RW	
11-Months	38	RW	RW	
12-Months	37	RW	RW	
13-Months	36	RW	RW	
14-Months	35	RW	RW	
15-Months	34	RW	RW	
16-Months	33	RW	RW	
17-Months	32	RW	RW	
18-Months	31	RW	RW	
19-Months	30	RW	RW	
20-Months	29	RW	RW	
21-Months	28	RW	RW	
22-Months	27	RW	RW	
23-Months	26	RW	RW	
24-Months	25	RW	RW	

Sample Period: January 2001 – December 2004
LTF, autoregressive integrated moving average linear transfer function.
RW, random walk.
RMSE, root mean square error.
AGS, error difference regression test.
DM, non-parametric RMSE difference t-test.

TABLE 11
Santa Fe Bridge Pedestrian Forecast Accuracy Rankings

Step Length	Number of Observations	U-statistic	AGS Error Differential	DM RMSE Differential
1-Month	48	RW	RW	RW
2-Months	47	RW	RW	
3-Months	46	RW	RW	
4-Months	45	RW	RW	
5-Months	44	RW	RW	
6-Months	43	RW	RW	
7-Months	42	RW	RW	
8-Months	41	RW	RW	
9-Months	40	RW	RW	
10-Months	39	RW	RW	
11-Months	38	RW	RW	
12-Months	37	RW	RW	
13-Months	36	RW	RW	
14-Months	35	RW	RW	
15-Months	34	RW	RW	
16-Months	33	RW	RW	
17-Months	32	RW	RW	
18-Months	31	RW	RW	
19-Months	30	RW	RW	
20-Months	29	RW	RW	
21-Months	28	RW	RW	
22-Months	27	RW	RW	
23-Months	26	RW	RW	
24-Months	25	RW	RW	

Sample Period: January 2001 – December 2004
LTF, autoregressive integrated moving average linear transfer function.
RW, random walk.
RMSE, root mean square error.
AGS, error difference regression test.
DM, non-parametric RMSE difference t-test.

Appendix

Table A1. Southbound Bridge Traffic Historical Data

Month	ZT Zaragoza Trucks	ZC Zaragoza Cars	STC Stanton Cars	STW Stanton Pedestrians	SFW Santa Fe Pedestrians
Jan-91	5.942	124.340	165.370	144.804	268.349
Feb-91	4.862	130.563	165.275	145.494	227.893
Mar-91	4.328	157.145	182.847	169.542	280.588
Apr-91	4.613	155.489	186.109	163.370	263.872
May-91	5.507	170.166	213.364	168.550	282.695
Jun-91	4.129	157.384	183.416	155.025	271.726
Jul-91	3.999	170.430	198.481	166.557	286.200
Aug-91	4.453	169.448	195.863	172.837	294.749
Sep-91	9.200	149.559	172.907	153.301	268.434
Oct-91	12.611	162.347	194.068	156.652	281.934
Nov-91	11.937	157.817	188.405	160.817	290.392
Dec-91	10.946	169.981	222.219	187.550	311.561
Jan-92	29.659	150.459	189.804	127.647	261.666
Feb-92	15.246	160.316	213.199	138.220	276.608
Mar-92	15.829	176.396	206.412	129.561	274.413
Apr-92	11.537	177.633	223.444	144.147	295.647
May-92	11.443	190.039	252.487	146.386	302.776
Jun-92	12.123	177.853	237.316	127.947	276.557
Jul-92	11.937	192.173	244.240	131.872	283.318
Aug-92	12.647	186.611	242.853	136.777	292.657
Sep-92	12.699	177.287	231.007	126.480	277.597
Oct-92	17.229	193.713	230.800	139.670	297.528
Nov-92	16.489	179.132	236.051	126.734	268.811
Dec-92	15.761	197.781	250.255	164.871	315.447
Jan-93	15.400	172.006	202.245	117.752	262.785
Feb-93	17.086	173.102	201.349	114.627	250.904
Mar-93	19.776	196.028	225.714	124.505	279.778
Apr-93	14.762	190.881	221.400	131.678	275.774
May-93	18.188	201.354	221.020	133.367	280.263
Jun-93	17.243	190.397	211.197	120.243	263.950
Jul-93	16.106	199.278	221.454	134.560	289.728
Aug-93	16.930	202.501	221.657	131.959	279.101
Sep-93	16.886	195.423	211.200	118.779	248.859
Oct-93	14.518	196.273	219.791	112.174	211.517
Nov-93	17.443	149.799	214.925	115.603	227.714
Dec-93	16.521	203.700	250.898	162.756	289.933
Jan-94	15.971	192.562	200.330	122.690	238.932
Feb-94	14.125	190.063	202.686	137.215	236.257
Mar-94	19.005	205.686	226.999	157.960	273.481
Apr-94	17.195	201.872	216.771	142.224	254.065
May-94	18.774	205.656	221.350	138.006	258.071
Jun-94	17.256	198.643	207.553	115.424	233.207

Jul-94	16.968	214.983	229.457	126.274	259.291
Aug-94	19.965	215.530	224.407	128.049	256.521
Sep-94	21.211	215.314	213.355	124.505	250.404
Oct-94	22.186	222.829	219.234	128.963	268.094
Nov-94	23.619	205.272	228.039	123.174	249.498
Dec-94	20.519	215.317	231.916	166.673	330.061
Jan-95	21.417	194.545	172.031	103.526	218.286
Feb-95	18.417	179.503	160.398	99.514	214.856
Mar-95	20.642	207.313	185.225	103.679	248.588
Apr-95	18.128	203.008	173.123	91.089	217.866
May-95	19.341	205.888	177.253	108.984	258.163
Jun-95	20.000	206.592	194.949	98.294	247.957
Jul-95	18.443	214.971	198.778	99.041	256.152
Aug-95	21.657	221.614	201.976	97.636	247.453
Sep-95	18.476	205.900	198.626	97.583	242.407
Oct-95	23.577	215.638	196.601	98.115	251.081
Nov-95	23.270	202.853	203.824	98.821	244.848
Dec-95	18.865	219.725	205.441	119.127	292.734
Jan-96	21.193	197.902	178.688	94.655	223.563
Feb-96	20.892	203.831	167.434	101.134	232.535
Mar-96	20.262	217.670	182.977	116.202	271.916
Apr-96	18.544	210.304	177.557	106.444	231.541
May-96	23.267	218.023	182.401	104.614	238.713
Jun-96	22.494	206.453	161.501	102.841	258.768
Jul-96	23.464	205.279	158.509	116.178	283.564
Aug-96	26.644	215.081	172.060	118.122	320.470
Sep-96	24.812	209.510	187.751	110.183	281.137
Oct-96	29.402	226.912	213.128	114.753	278.120
Nov-96	27.337	224.958	224.058	104.412	281.740
Dec-96	25.708	231.457	234.503	125.020	326.033
Jan-97	24.288	208.141	182.838	95.257	237.611
Feb-97	22.504	208.959	183.764	98.914	246.414
Mar-97	19.951	239.664	217.976	113.146	306.724
Apr-97	23.864	224.024	203.391	102.050	259.245
May-97	22.955	238.697	205.950	107.820	303.584
Jun-97	23.435	209.849	189.732	91.648	263.979
Jul-97	23.062	234.228	187.825	99.755	269.662
Aug-97	24.623	223.825	197.072	103.741	294.857
Sep-97	27.902	201.277	179.127	103.400	251.365
Oct-97	31.536	222.572	199.998	107.355	262.816
Nov-97	29.324	213.177	188.785	107.281	273.251
Dec-97	20.000	200.000	210.000	140.000	350.000
Jan-98	30.320	216.720	196.645	110.187	278.779
Feb-98	31.681	205.717	221.599	94.403	244.459
Mar-98	32.972	227.660	248.972	102.914	278.231
Apr-98	30.154	215.397	238.901	108.297	276.448
May-98	29.978	240.145	252.943	116.495	291.874

Jun-98	28.686	217.674	203.331	100.790	269.669
Jul-98	27.476	219.338	187.154	98.858	291.560
Aug-98	31.079	229.200	175.878	100.891	310.498
Sep-98	29.863	182.251	162.018	95.865	278.845
Oct-98	34.730	223.023	171.377	105.798	294.487
Nov-98	32.647	215.017	150.503	129.660	336.705
Dec-98	29.945	226.348	176.032	161.722	412.854
Jan-99	28.770	207.505	168.243	107.647	300.722
Feb-99	25.269	206.015	162.927	106.348	295.590
Mar-99	29.286	255.831	188.358	118.942	330.073
Apr-99	26.716	237.571	176.742	110.351	315.691
May-99	26.730	243.848	183.682	108.911	337.540
Jun-99	27.188	240.064	181.351	101.816	309.240
Jul-99	26.708	243.335	184.085	107.496	341.761
Aug-99	26.724	239.471	183.666	104.001	339.988
Sep-99	26.756	240.513	175.592	100.778	306.290
Oct-99	27.038	237.145	184.866	109.070	330.699
Nov-99	29.645	242.488	179.228	116.751	345.884
Dec-99	27.457	253.949	194.914	140.411	410.707
Jan-00	30.000	263.904	167.982	105.765	304.857
Feb-00	25.269	258.611	169.119	107.358	307.949
Mar-00	32.436	272.227	182.203	116.522	336.900
Apr-00	26.716	237.571	176.742	110.351	315.691
May-00	28.800	275.720	181.308	120.278	323.574
Jun-00	31.521	268.714	179.148	107.261	322.236
Jul-00	26.823	265.814	205.603	104.461	338.790
Aug-00	31.872	270.383	189.095	126.924	329.679
Sep-00	28.485	251.864	177.562	129.239	310.112
Oct-00	31.669	263.711	161.476	133.336	320.133
Nov-00	31.969	264.997	162.989	158.520	345.892
Dec-00	23.112	287.785	195.168	215.902	411.688
Jan-01	29.960	265.766	157.664	115.420	301.802
Feb-01	29.012	254.279	148.032	115.316	303.835
Mar-01	32.796	289.013	166.750	122.155	357.385
Apr-01	29.029	273.071	158.671	116.756	330.585
May-01	30.823	291.594	166.903	121.786	340.470
Jun-01	29.274	283.385	164.031	110.981	330.942
Jul-01	25.910	287.870	161.443	113.030	347.109
Aug-01	29.798	297.894	169.858	120.261	352.710
Sep-01	25.431	222.255	112.522	140.029	361.301
Oct-01	29.815	207.889	95.061	134.623	326.788
Nov-01	28.099	211.608	98.523	115.315	300.822
Dec-01	24.076	236.242	122.351	147.209	378.031
Jan-02	28.100	274.390	178.880	125.200	338.540
Feb-02	24.850	254.100	169.500	134.980	278.230
Mar-02	25.500	270.900	169.900	135.750	326.770
Apr-02	20.020	246.750	160.000	140.740	296.300

May-02	29.600	287.000	164.100	170.450	393.010
Jun-02	22.400	245.020	162.020	128.200	385.950
Jul-02	24.800	265.200	163.140	128.820	408.280
Aug-02	25.080	248.159	120.795	145.285	400.529
Sep-02	23.613	235.334	112.806	134.722	344.087
Oct-02	27.052	216.777	118.977	140.920	347.306
Nov-02	29.500	240.620	139.400	150.000	370.060
Dec-02	20.734	257.912	154.194	150.385	357.908
Jan-03	22.440	232.100	127.126	112.695	312.722
Feb-03	21.399	193.195	106.716	118.295	294.115
Mar-03	23.015	229.882	122.045	123.312	308.449
Apr-03	22.596	228.045	121.521	131.737	326.318
May-03	22.919	263.951	135.214	137.841	344.481
Jun-03	22.524	249.664	129.825	118.479	322.585
Jul-03	22.446	249.842	134.495	123.467	340.352
Aug-03	23.600	267.230	141.069	127.594	350.551
Sep-03	24.977	249.087	126.418	126.060	306.741
Oct-03	27.944	254.266	142.015	118.690	313.290
Nov-03	24.979	247.549	135.193	121.620	327.897
Dec-03	21.661	260.413	149.639	157.261	330.164
Jan-04	23.032	231.412	117.622	129.184	273.185
Feb-04	22.537	228.768	111.983	116.686	227.540
Mar-04	26.214	249.024	125.329	138.987	287.445
Apr-04	24.388	243.029	119.855	141.428	280.148
May-04	23.567	254.342	122.188	135.775	364.122
Jun-04	25.533	243.177	121.866	134.443	416.743
Jul-04	23.018	253.460	128.063	127.588	437.068
Aug-04	25.009	253.888	124.451	132.302	360.060
Sep-04	25.240	239.897	118.060	141.435	398.812
Oct-04	25.537	252.321	123.941	144.537	440.429
Nov-04	25.932	238.848	123.531	143.949	346.898
Dec-04	22.281	269.201	145.687	186.477	424.708

Table A2. Real Exchange Rate, Employment, and Toll Historical Data

Month	REX Peso per Dollar Real Exchange Rate	ELPM El Paso Nonfarm Total Employment	MXIP Mexico Industrial Production Index	CJMQM Ciudad Juarez Maquiladora Employment	TOLLC Dollar Toll Charged to Cars, Nominal	TOLLT Dollar Toll Charged to Trucks, Nominal	TOLLW Dollar Toll Charged to Pedestrians, Nominal
Jan-91	94.711	207.100	94.60	116989	0.50	1.00	0.25
Feb-91	93.700	206.900	92.90	122875	0.50	1.00	0.25
Mar-91	92.778	207.900	91.70	121174	0.50	1.00	0.25
Apr-91	92.444	209.100	98.90	122399	0.50	1.00	0.25
May-91	92.169	210.500	99.10	123545	0.50	1.00	0.25
Jun-91	91.790	210.500	96.10	123032	0.50	1.00	0.25
Jul-91	91.455	210.500	99.40	121873	0.50	1.00	0.25

Aug-91	91.486	212.300	97.70	124530	0.50	1.00	0.25
Sep-91	91.413	214.100	94.00	127963	0.50	1.00	0.25
Oct-91	90.868	213.800	105.00	129474	0.50	1.00	0.25
Nov-91	89.089	213.800	100.10	127809	0.50	1.00	0.25
Dec-91	86.949	215.800	90.60	124994	0.50	1.00	0.25
Jan-92	85.427	211.000	96.40	123817	0.50	2.00	0.25
Feb-92	84.603	212.100	96.20	125232	0.50	2.00	0.25
Mar-92	84.764	214.300	106.70	125512	0.50	2.00	0.25
Apr-92	84.068	215.600	96.30	127094	0.50	2.00	0.25
May-92	84.481	216.600	101.50	128600	0.50	2.00	0.25
Jun-92	84.497	217.500	104.40	130589	0.50	2.00	0.25
Jul-92	83.897	217.700	104.80	130840	0.50	2.00	0.25
Aug-92	82.714	218.100	99.30	131196	0.50	2.00	0.25
Sep-92	83.196	220.000	101.50	132288	0.50	2.00	0.25
Oct-92	83.349	223.800	104.80	132795	0.50	2.00	0.25
Nov-92	82.334	223.200	100.40	132427	0.50	2.00	0.25
Dec-92	81.137	223.600	96.00	129364	0.50	2.00	0.25
Jan-93	79.925	218.700	95.20	131768	0.50	2.00	0.25
Feb-93	79.581	221.400	96.90	134981	0.50	2.00	0.25
Mar-93	79.498	221.000	108.10	136882	0.50	2.00	0.25
Apr-93	79.365	223.500	98.90	136060	0.50	2.00	0.25
May-93	79.567	224.100	101.80	136392	0.50	2.00	0.25
Jun-93	79.191	224.300	101.10	128074	0.50	2.00	0.25
Jul-93	78.726	225.300	97.70	130822	0.50	2.00	0.25
Aug-93	78.426	226.800	98.20	130572	0.50	2.00	0.25
Sep-93	78.124	228.800	98.30	131672	0.50	2.00	0.25
Oct-93	78.103	228.300	101.60	128635	0.50	2.00	0.25
Nov-93	77.702	227.900	101.20	130060	0.50	2.00	0.25
Dec-93	76.957	228.500	101.00	128639	0.50	2.00	0.25
Jan-94	76.554	223.200	97.50	129991	0.50	2.00	0.25
Feb-94	78.940	224.400	96.60	135234	0.50	2.00	0.25
Mar-94	82.576	226.100	106.20	136427	0.50	2.00	0.25
Apr-94	79.982	227.700	106.10	138862	0.50	2.00	0.25
May-94	80.815	228.700	104.60	137426	0.50	2.00	0.25
Jun-94	82.543	229.800	107.30	137842	0.50	2.00	0.25
Jul-94	82.659	230.900	101.80	139735	0.50	2.00	0.25
Aug-94	82.007	233.300	106.70	141343	0.50	2.00	0.25
Sep-94	82.231	234.800	104.00	145617	0.50	2.00	0.25
Oct-94	82.491	236.400	107.10	147322	0.50	2.00	0.25
Nov-94	82.673	237.600	108.00	148070	1.25	2.30	0.25
Dec-94	126.571	237.500	102.80	146990	1.25	2.30	0.25
Jan-95	132.259	231.800	102.20	148475	1.25	2.30	0.25
Feb-95	130.495	233.300	97.70	150355	1.25	2.30	0.25
Mar-95	144.451	234.000	105.50	152129	1.25	2.30	0.25
Apr-95	113.932	233.900	92.80	152937	1.25	2.30	0.25
May-95	116.976	235.100	98.60	155135	1.25	2.30	0.25
Jun-95	114.853	235.100	96.70	154422	1.25	2.30	0.25

Jul-95	108.641	234.100	93.50	152842	1.25	2.30	0.25
Aug-95	111.053	236.800	99.10	153971	1.25	2.30	0.25
Sep-95	110.949	237.900	96.00	151260	1.25	2.30	0.25
Oct-95	121.748	235.100	101.80	153486	1.25	2.30	0.25
Nov-95	126.762	234.900	102.40	154153	1.25	2.30	0.25
Dec-95	122.945	237.500	100.80	160702	1.25	2.30	0.25
Jan-96	115.055	231.400	105.20	161170	1.25	2.30	0.25
Feb-96	115.078	232.500	105.30	161472	1.25	2.30	0.25
Mar-96	113.299	233.700	110.00	161415	1.25	2.30	0.25
Apr-96	108.447	234.600	105.30	161127	1.25	2.30	0.25
May-96	106.849	236.200	111.40	164287	1.25	2.30	0.25
Jun-96	108.001	235.300	108.10	165745	1.25	2.30	0.25
Jul-96	106.445	235.300	108.70	167246	1.25	2.30	0.25
Aug-96	105.807	238.100	111.90	171110	1.25	2.30	0.25
Sep-96	103.400	238.500	106.80	177328	1.25	2.30	0.25
Oct-96	109.199	240.700	116.80	180421	1.25	2.30	0.25
Nov-96	105.615	241.100	114.10	180290	1.25	2.30	0.25
Dec-96	102.088	242.400	112.00	177981	1.25	2.30	0.25
Jan-97	107.740	236.200	113.10	184815	1.25	2.30	0.25
Feb-97	99.832	237.800	112.00	183750	1.25	2.30	0.25
Mar-97	98.297	239.400	113.70	185650	1.25	2.30	0.25
Apr-97	98.259	240.800	123.50	188345	1.25	2.30	0.25
May-97	97.567	242.900	121.40	189673	1.25	2.30	0.25
Jun-97	100.070	243.300	121.30	187784	1.25	2.30	0.25
Jul-97	98.364	243.000	121.80	190606	1.25	2.30	0.25
Aug-97	98.135	244.700	120.40	190723	1.25	2.30	0.25
Sep-97	96.730	247.100	121.40	195114	1.25	2.30	0.25
Oct-97	97.217	246.300	130.60	197509	1.25	2.30	0.25
Nov-97	102.007	247.200	123.90	198059	1.25	2.30	0.25
Dec-97	99.358	248.900	123.30	196056	1.25	2.30	0.25
Jan-98	98.431	243.300	122.20	197604	1.25	2.30	0.25
Feb-98	99.838	243.900	121.30	201909	1.25	2.30	0.25
Mar-98	100.167	245.900	135.00	205195	1.25	2.30	0.25
Apr-98	98.245	247.000	126.80	203659	1.25	2.30	0.25
May-98	99.023	249.000	130.50	202097	1.25	2.30	0.25
Jun-98	97.443	248.400	132.20	203216	1.25	2.30	0.25
Jul-98	96.601	246.300	130.40	209872	1.25	2.30	0.25
Aug-98	108.111	248.600	130.50	208124	1.25	2.30	0.25
Sep-98	114.868	249.600	130.60	210629	1.25	2.30	0.25
Oct-98	112.072	250.600	135.30	213675	1.25	2.30	0.25
Nov-98	107.612	251.000	129.90	215429	1.25	2.30	0.25
Dec-98	104.879	251.700	128.40	211356	1.25	2.30	0.25
Jan-99	105.834	246.300	123.50	217014	1.25	2.30	0.25
Feb-99	102.983	248.200	124.00	218215	1.25	2.30	0.25
Mar-99	99.607	248.700	137.50	217345	1.25	2.30	0.25
Apr-99	96.143	250.000	132.90	216087	1.25	2.30	0.25
May-99	95.773	250.900	135.40	211662	1.25	2.30	0.25

Jun-99	96.033	250.500	140.50	214369	1.25	2.30	0.25
Jul-99	94.275	249.900	137.60	214987	1.25	2.30	0.25
Aug-99	94.267	251.400	137.90	218356	1.25	2.30	0.25
Sep-99	93.168	253.600	136.90	220793	1.25	2.30	0.25
Oct-99	95.246	251.000	138.30	222507	1.25	2.30	0.25
Nov-99	92.424	251.900	138.20	226816	1.25	2.30	0.25
Dec-99	92.276	256.900	135.80	222808	1.25	2.30	0.25
Jan-00	92.049	252.000	134.20	229478	1.25	2.30	0.25
Feb-00	90.906	253.600	137.50	232541	1.25	2.30	0.25
Mar-00	89.822	255.100	150.30	238593	1.25	2.30	0.25
Apr-00	90.377	255.000	137.60	235280	1.25	2.30	0.25
May-00	91.328	256.300	149.10	251492	1.25	2.30	0.25
Jun-00	94.359	255.900	151.20	252234	1.25	2.30	0.25
Jul-00	90.486	254.300	146.20	253315	1.25	2.30	0.25
Aug-00	88.614	256.700	150.20	258619	1.25	2.30	0.25
Sep-00	89.197	259.100	145.00	262653	1.25	2.30	0.25
Oct-00	90.431	257.900	150.10	264241	1.25	2.30	0.25
Nov-00	91.241	259.500	145.20	258583	1.25	2.30	0.25
Dec-00	89.958	260.700	133.60	255531	1.25	2.30	0.25
Jan-01	92.810	254.900	137.30	257069	1.25	2.30	0.25
Feb-01	92.603	255.600	132.10	249511	1.25	2.30	0.25
Mar-01	91.141	257.600	146.50	245378	1.25	2.30	0.25
Apr-01	88.493	255.100	133.70	241288	1.25	2.30	0.25
May-01	86.792	256.300	145.10	236152	1.25	2.30	0.25
Jun-01	86.162	255.500	143.90	227550	1.25	2.30	0.25
Jul-01	86.961	251.400	138.50	223678	1.25	2.30	0.25
Aug-01	86.109	254.700	142.50	218362	1.25	2.30	0.25
Sep-01	88.435	257.000	135.80	215964	1.25	2.30	0.25
Oct-01	86.943	253.900	142.50	211783	1.25	2.30	0.25
Nov-01	85.390	254.800	138.70	208636	1.25	2.30	0.25
Dec-01	84.361	254.700	127.50	205963	1.25	2.30	0.25
Jan-02	83.818	251.600	131.50	209649	1.25	2.30	0.25
Feb-02	83.591	251.900	128.20	208192	1.25	2.30	0.25
Mar-02	83.358	254.700	134.00	205950	1.25	2.30	0.25
Apr-02	84.275	255.300	146.10	203194	1.25	2.30	0.25
May-02	87.423	255.700	144.70	205150	1.25	2.30	0.25
Jun-02	88.333	254.700	140.80	202717	1.25	2.30	0.25
Jul-02	88.347	251.700	141.00	198722	1.25	2.30	0.25
Aug-02	88.769	256.100	141.50	196759	1.25	2.30	0.25
Sep-02	90.274	261.000	135.00	197162	1.25	2.30	0.25
Oct-02	90.569	258.600	144.60	197048	1.25	2.30	0.25
Nov-02	90.794	260.200	136.60	195277	1.25	2.30	0.25
Dec-02	90.153	261.100	129.30	190871	1.25	2.30	0.25
Jan-03	93.497	254.300	132.30	192712	1.25	2.30	0.25
Feb-03	97.022	255.100	129.60	193449	1.25	2.30	0.25
Mar-03	96.773	255.400	139.00	193893	1.25	2.30	0.25
Apr-03	93.563	255.700	136.50	194110	1.25	2.30	0.25

May-03	90.698	254.800	140.30	193928	1.25	2.30	0.25
Jun-03	92.962	251.200	138.40	189976	1.25	2.30	0.25
Jul-03	92.451	249.900	137.00	189680	1.25	2.30	0.25
Aug-03	95.454	253.400	134.90	192913	1.25	2.30	0.25
Sep-03	96.485	257.400	134.40	197809	1.25	2.30	0.25
Oct-03	98.202	257.000	143.10	200247	1.25	2.30	0.25
Nov-03	96.872	258.000	133.10	200057	1.25	2.30	0.25
Dec-03	97.247	258.300	133.40	196933	1.25	2.30	0.25
Jan-04	94.527	254.300	131.60	196500	1.65	3.00	0.35
Feb-04	95.111	255.800	131.60	196578	1.65	3.00	0.35
Mar-04	95.358	256.000	148.10	201767	1.65	3.00	0.35
Apr-04	97.825	257.100	140.80	204922	1.65	3.00	0.35
May-04	100.721	258.100	143.40	205456	1.65	3.00	0.35
Jun-04	99.801	255.400	146.70	207801	1.65	3.00	0.35
Jul-04	100.551	254.700	142.60	207222	1.65	3.00	0.35
Aug-04	99.377	255.200	142.20	205815	1.65	3.00	0.35
Sep-04	99.565	258.900	141.60	206741	1.65	3.00	0.35
Oct-04	98.566	258.900	144.60	207413	1.65	3.00	0.35
Nov-04	97.525	258.600	141.00	211020	1.65	3.00	0.35
Dec-04	95.543	258.600	139.10	206327	1.65	3.00	0.35