Bridge and Tunnel Toll Elasticities in New York: Some Recent Evidence

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Economists have long advocated comprehensive roadway pricing in the form of user charges as the most efficient way to allocate scarce roadway capacity among competing travel demands.[1] Actual transport policy, however, lags far behind theories of optimal pricing. In the U.S., the only form of roadway pricing that currently exists is the tolling of a small fraction of the nation's bridges, tunnels, and limited access highways. Most tolled

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[1] For an early and consistent expression of this principle, one can refer to the writings of economist William Vickrey. See for example, Vickrey's 1963 article, "Pricing in Urban and Suburban Transport", reprinted in Ronald Grieson, ed., Urban Economics: Readings and Analysis (Boston: Little Brown, 1973, pp. 106-118. Also, A.A. Walters, The Economics of Road User Charges (Baltimore: Johns Hopkins University Press, 1968), chs. 2 and 3; more recently, for example, Kenneth Small, et. al., Road Work: A New Highway Pricing & Investment Policy (Washington, D.C., The Brookings Institution, 1989)

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roadways are in the Northeast, and by far the highest concentration is in the New York City region.

As a practical matter, the use of tolls has been almost exclusively for raising revenues to finance roadway construction and maintenance. Economists and transportation planners, by comparison, increasingly view roadway pricing as the best means to limit travel demand, or at least to reallocate it, in order to mitigate the growing problem of roadway congestion.

Whether the purpose is to raise revenues or to reallocate traffic volume, price elasticities of travel demand can provide useful indicators of the responsiveness of travel behavior to changes in public policies that affect travel costs. The more elastic is travel demand, the greater the reduction in travel volume resulting from an increase in price, and the less the gain in toll revenue. Conversely, the less elastic is travel demand, the less the reduction in travel volume resulting from price increases, and the greater the gain in toll revenue.

There have been many empirical studies of price elasticities for various transportation modes. Comprehensive surveys of such studies have been undertaken by Oum et al. (1992), Goodwin (1992), and Cervero (1990).[2] Almost all of these studies found that travel

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[2] T.H. Oum, W.G. Waters II, J.-S. Yong, "Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates," Journal of Transport Economics and Policy, Vol. XXVI No. 2, May 1992, pp. 139-154; P.B. Goodwin, "A Review of New Demand Elasticities with Special References to Short and Long Run Effects of Price Changes," Journal of Transport Economics and Policy, Vol. XXVI No. 2, May 1992, pp. 155-170; and R. Cervero, "Transit Pricing Research: A Review and Synthesis," Transportation, Vol. 17 No. 2,

demand is inelastic with respect to money price. However, elasticities can vary dramatically according to mode, time of day, travel purpose, household income, and by the amount and direction of the price change. Moreover, elasticities can change from one year to another, and their values can vary greatly from one city to another, and even from one specific site to another within the same city. For the purpose of predicting the traffic and revenue impacts of toll increases on specific bridges and tunnels in any city, one must estimate elasticities for the individual facilities in that city.

In 1992 the University Transportation Research Center carried out an econometric analysis for the Triborough Bridge and Tunnel Authority (TBTA) of New York City. The TBTA's objective was to determine the impact of toll increases on revenues, since revenue growth was virtually the only reason the TBTA wanted to raise tolls. From a transportation planner's perspective, however, the impact of toll increases on traffic volumes is more interesting and will be our focus here.

Using twelve years of time-series monthly data, we developed a series of multiple regression models that estimated traffic volumes on each TBTA bridge and tunnel as a function of the toll level and various other explanatory variables. For the purposes of policy analysis, we would ideally have included traffic volumes on all regional bridges and tunnels; however, given our specific

1990, pp. 117-140.

assignment and data limitations, our analysis was restricted to the TBTA facilities. The purpose of this paper is to make our regression results and elasticity estimates available for consideration and possible use by other analysts and policy makers.

In the following section, we describe the overall bridge and tunnel network in New York City and the current TBTA toll structure. Next, we examine the available data and the alternative methods for calculating elasticities. Finally, we report the actual elasticity estimates and discuss their policy implications.

BACKGROUND

The six TBTA bridges and two TBTA tunnels examined in this article connect the five boroughs and, for some boroughs, provide the main roadway link to the rest of the country.[3] (See Table I and Figure 1.)

Four of the TBTA facilities (Brooklyn Battery Tunnel, Queens Midtown Tunnel, Triborough Manhattan Plaza, and Henry Hudson Bridge) connect Manhattan to other boroughs. In 1988, these four facilities, out of a total of 20 links to Manhattan, carried about 17 percent of the daily traffic into and out of Manhattan[4]. (See Figure 2.) They are in competition with 13 free bridges that connect Manhattan to other NYC boroughs; the free bridges carried

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[3] The Triborough Bridge actually has two connections: from Queens to Manhattan and from Queens to the Bronx. For the purposes of this article, these were counted as two bridges.

[4] Manhattan River Crossings, 1988, New York City Department of Transportation, Bureau of Planning, February 1990.

about 56 percent of total daily traffic. Two tunnels and one bridge, operated by the Port Authority of New York and New Jersey, connect Manhattan to New Jersey; all three are tolled and carry 28 percent of the daily traffic.

Three TBTA bridges (Triborough Bronx Plaza, Whitestone Bridge, and Throg’s Neck Bridge) connect Queens and Long Island to the Bronx (and the rest of the country). There are no free crossings in competition with these three bridges. The Verrazano Narrows Bridge links Staten Island with Brooklyn, a crucial segment in the most direct route from New Jersey to Long Island. The Verrazano Narrows Bridge competes with the tolled tunnels and bridge from New Jersey to Manhattan operated by the Port Authority.

The TBTA has nine toll classes. At the time of the study in 1992, they varied from $1 for motorcycles to $13 for five axle trucks, with surcharges of $0.25 for extra axles. Automobiles, which account for the vast majority of vehicles, paid $2.50. There are two exceptions. On the Henry Hudson Bridge cars and motorcycles, the only vehicles allowed, pay half these rates. And because the Verrazano-Narrows Bridge has one-way tolls, they are twice the rate of the other bridges.

During the 12 years of the study, automobile tolls have increased from $0.75 to $2.50 in six jumps, roughly tripling in nominal terms or increasing 65 percent in real terms. (See Table II.) The tolls for other classes of vehicles increased by the same percent.

While tolls increased over the 12 year period, combined traffic on the eight TBTA bridges and tunnels grew 20 percent over the period of our study from 1979 to 1991. Traffic into Manhattan on all bridges and tunnels has also grown about 20 percent. However,. traffic on the TBTA facilities that connect Manhattan to other boroughs grew only 15 percent in the twelve year period, while traffic on the free East River and Harlem River bridges to Manhattan has grown 17 and 26 percent respectively. Traffic from New Jersey to Manhattan on the tolled Port Authority Bridges, which have no free substitutes, increased by 22 percent (see Figure 2[5]) .

DATA AND METHODS

We based our analysis on monthly vehicle crossings data between 1979 and 1990, disaggregated by TBTA facility and vehicle class. Prior to 1979, these data were not available.

There are several approaches to estimating elasticities from historical data. The simplest method is to compute the "shrinkage" ratio, which compares the traffic on the facility before and after a toll change. In this technique, the toll elasticity is estimated by computing the ratio of the percentage change in traffic to the percentage change in the toll, using the initial traffic and toll levels as the bases of the calculations.

Although this method has the advantage of being simple, it is apt to yield distorted results because it does not control for changes in other important variables that could effect bridge and

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5 New York City Department of Transportation, 1993, New York City Bridge Traffic Volumes 1992.

tunnel traffic such as employment and fuel prices. Because of this shortcoming, we did not use this method to predict the impacts of future toll increases. However, we computed these ratios as a validity check of our chosen methodology.

A look at the six-month shrinkage ratios in Table III suggests that toll increases in New York City can sometimes have surprising consequences. For example, when the TBTA raised the toll in 1980, traffic increased in the subsequent six months on all but one facility. Traffic growth also occurred in the six-month periods following the toll increases in 1982 and 1987.

As noted, we chose not to use the simple shrinkage ratios to make predictions. Instead, we used multiple regression analysis, which allows the analyst to incorporate factors besides the toll into the model, thus isolating the effects of toll changes by statistically holding constant the other impacts on travel volume.

The Dependent Variable

For the dependent variable, total monthly traffic volumes on each of the TBTA's crossings, by vehicle class, were available from the TBTA starting in 1979 and extending through 1990. This data set established the regression framework as a monthly time series analysis with 144 observations for each facility. Although the TBTA has nine toll classes, regression models were calibrated for only three groups of vehicles: passenger cars; light trucks; and heavy trucks. Together, these three groups comprise 99.2% of all the TBTA's crossings.

Independent Variables

The set of independent variables to explain monthly variations in the number of vehicle crossings included, for passenger cars, the following variables:

Bridge and Tunnel Tolls: This, of course, is the variable that we were most interested in. For each facility, the real one-way toll for Class 1 vehicles was calculated using the Consumer Price Index for the New York metropolitan area.[6]

Employment: Employment is a primary determinant of the overall amount of travel.[7] While the relationship between employment and work trips is obvious, employment levels may also influence non-work trips since higher employment and income are likely to mean more travel for shopping and cultural events.

For this analysis, the employment variable was measured differently for each facility. Specifically, a "market area" was estimated for each TBTA crossing by computing a weighted average employment for each facility, where the weights were the share of destinations to each county in the region for automobile trips utilizing each particular crossing. These weights were derived from a travel survey conducted by the TBTA in 1989.

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[6] In the case of the Verrazano Narrows Bridge, an additional adjustment had to be made for the change from two-way to one-way toll collection in March 1986. To control for that discontinuity, a dummy variable was used in the Verrazano Narrows Bridge model to distinguish the months after the change from those before.

[7] Michael Meyer and Eric Miller, Urban Transportation Planning, New York: McGraw Hill, 1984, pp. 232-283; Thomas Domencich and Daniel McFadden, Urban Travel Demand, Amsterdam: North Holland Publishing, 1975.

Motor Vehicle Registrations: In addition to the size of the "market" for trip attractions, the analysis also considered the size of the market at the origin. Here, the market was computed as the weighted average of motor vehicle registrations, where the weights are the share of origins from each county. Again, for each facility, origin weights were determined from the TBTA travel survey.

Gasoline Prices: The average retail gasoline price was adjusted for inflation using the New York regional Consumer Price Index.

Mass Transit Fares: Since many commuters, especially those traveling into Manhattan, have the option of driving or using mass transit, the price of transit was also considered for inclusion in our model.

The 1980 Transit Strike: A strike by New York City Transit Authority bus and subway workers occurred from April 1 to April 11, 1980. To control for the potential increase in bridge travel during the strike, a 0-1 dummy variable was entered into the model.

Seasonal Variation: Since the model attempted to explain month-to-month variations in automobile crossings, it was necessary to control for the regular peaks and valleys which occur strictly as a result of the month and season. A number of possible statistical techniques to control for seasonality were considered. Ultimately, our choice was to use 0-1 dummy variables for the months.

A number of other factors that may also influence auto crossings could not be included in the analysis because the data were not available on a monthly basis over the twelve years. For example, parking costs were not included because a summary measure of these prices was not available from existing information sources. Moreover, the complexity and diversity of parking rates, especially among private parking lots and garages in New York City, made it impractical to try to estimate this on our own.

Excluding some variables such as parking prices may have introduced specification error bias. In order for this to occur, there must be some degree of correlation between the excluded variable and the toll variable.[8] In that case, the toll variable could incorrectly pick-up some of the independent effects of the excluded variable. If anything, specification error bias in our sample might have led to a small overestimate of the toll elasticity.

A few other variables that were originally included in our specifications during the early model development phases were ultimately dropped from the models. These included monthly takeoffs and landings at regional airports, regional retail sales, and dummy variables for months in which heavy snowstorms occurred. In most cases, these variables were discarded because their contribution to the R^2 value was small, their coefficients were consistently insignificant or had the wrong sign, or because they

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[8] For a good explanation of specification-error bias, see Damodar Gujarati, *Basic Econometrics,* 2nd edition, New York: McGraw Hill, 1988, pp. 178-182.

were strongly correlated with other variables already in the model.

For both the light and heavy truck models, there were fewer independent variables. In addition to the inflation-adjusted toll for that class of vehicles, the model included regional employment and the real price of diesel fuel. In this case, the relationship between employment and truck travel was thought to be less specific and direct than in the case of auto travel: total regional employment was essentially used as a proxy for the general level of economic activity in the region, which in turn was viewed as the best overall determinant of the demand for goods movement. The monthly dummy variables were also entered into the truck models.

Functional Form of the Model

We experimented with a number of alternative forms including a simple linear model using the raw data for each month; a log transformation of the simple model using the natural logs of the variables; and several variations of a year-to-year change model.

After calibrating models using all the functional forms mentioned above, it was determined that the second option -- the simple log transformation model - yielded the best results in terms of interpretability and statistical validity. This model form is presented below:

$$\ln \text{Crossings}_t = f(\ln \text{Toll}_t + \ln \text{Employment}_t + \ln \text{MVR}_t + \ln \text{Fare}_t + \ln \text{Gas}_t + \text{Strike}_t + \ldots \text{ monthly dummy variables for January through November})$$

where:

$\ln \text{Crossings}_t$ = natural log of monthly automobile crossings

$\ln \text{Toll}_t$ = natural log of the real auto toll, that month

$\ln \text{Employment}_t$ = natural log of employment weighted by trip destinations, that month

$\ln \text{MVR}_t$ = natural log of motor vehicle registrations weighted by trip origins, that month

$\ln \text{Fare}_t$ = natural log of the real subway fare, that month

$\ln \text{Gas}_t$ = natural log of real retail gasoline price, that month

Strike_t = 0/1 dummy variable for TA strike months

Monthly variables= a series of eleven 0/1 dummy variables for January through November

This form is commonly used in economics to specify a demand function. One of the principal advantages of the log form over a standard linear model using raw data is that for an unbiased estimate, the regression coefficient for the price or toll variable can be directly interpreted as the price or toll elasticity. Mathematically, the coefficient on the toll variable indicates the percentage change in crossings resulting from a one percent change in the toll, independent of the initial level of tolls. The elasticity value is most valid for small changes in the toll. Because the model is stochastic, the true elasticity value will lie somewhere within the range of the confidence limits of the coefficient at a specific probability.

RESULTS

The results of the estimation are summarized in Tables IV through VI, which correspond to the three vehicle types. Estimated coefficients are shown in the tables for each of the explanatory variables. Each column represents the equation for a specific TBTA bridge or tunnel. In almost all cases, the toll elasticity is very low, consistent with the findings of most other studies. As shown by the F-statistics, most of the models are significant at the 0.01 level. Moreover, the R-square values indicate that in most cases, most of the variation in traffic volumes is explained by the model.

Of greater importance are the results for the individual coefficients, particularly the coefficients for the toll variable. In almost every case, the toll coefficients, which can be interpreted directly as elasticities, are negative and much less than 1.0 in absolute value. This is consistent with virtually all previous transportation demand studies.[9] In most cases, these coefficients are statistically significant at the 0.05 level, as measured by the t-statistic. In a few instances, the toll coefficients are negative but not significant. In those cases, it can be assumed that traffic is insensitive to changes in the toll. For example, the toll coefficient for passenger cars on the Triborough Bridge Bronx Plaza was estimated at -0.03, but the

[9] See, for example, Oum et al., "Concepts of Price Elasticities ...”, pp. 139-154.

result was not statistically significant.

The least inelastic demand was found on those facilities which have "free" substitutes. These include the Brooklyn Battery Tunnel and the Henry Hudson Bridge, both of which can be circumvented without major rerouting by utilizing "free" river crossings owned by the City. In the case of the Brooklyn Battery Tunnel, both the Brooklyn and Manhattan bridges are nearby free substitutes, as all three serve lower Manhattan. The tolls on the Henry Hudson Bridge can likewise be avoided by using the alternative free crossings of the Harlem River. In the absence of these free substitutes, the toll elasticities on these crossings would probably have been lower. In addition, Manhattan-bound Brooklyn and Bronx residents are well served by mass transit, a factor which may also help explain the somewhat higher elasticities on the Brooklyn Battery Tunnel and the Henry Hudson Bridge.[10]

Overall, automobile elasticities were found to be at maximum -0.50, with a median value of -0.10, indicating considerable inelasticity. Toll elasticities for trucks, although somewhat higher, were also inelastic on average.

The coefficients for employment and motor vehicle

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[10] Surprisingly, there were two cases where the toll variable was estimated to be positive: for passenger cars on the Throgs Neck Bridge and for heavy trucks on the Verrazano Narrows Bridge. These results are so counter-intuitive that alternative explanations are required, such as the omission of a significant explanatory factor not available in the data set. In these instances, the prudent assumption is that the true toll elasticity is zero. It is obviously impossible that higher tolls in themselves actually encourage more traffic.

registrations appear reasonable; in most equations, they are positive and large. For instance, the employment coefficient was found to be positive and significant in six out of eight cases. Employment coefficients obtained from the truck models conformed with expectations even more frequently. Although there was considerable variability in the size of the employment coefficients, the impact of employment on travel was generally substantial, ranging in the case of passenger cars from 0.55 on the Triborough Bridge Manhattan Plaza to 1.61 for the Queens Midtown Tunnel. Similarly, motor vehicle registrations were found to have a major impact, with significant positive coefficients ranging between 0.47 in the case of the Queens Midtown Tunnel and 1.89 on the Henry Hudson Bridge.

The results for the transit fare, gasoline price, and strike variables are less credible, as they are often either statistically insignificant or counterintuitive. For example, the transit fare variable was negative in several instances, while the coefficient for gasoline prices was sometimes positive. Our best explanation for these results is the intercorrelation among several of the independent variables. For example, the employment variable is correlated with motor vehicle registrations, the transit fare, and gasoline prices.

POLICY CONSIDERATIONS

The key question facing local transportation policy makers is whether raising bridge and tunnel tolls can help to mitigate the severe congestion problems in Manhattan's CBD. Our regression results suggest that traffic volumes into and out of Manhattan are not very sensitive to gradual toll increases. It is important to keep in mind, however, that our elasticity findings were based on small percentage changes in TBTA tolls, amounting on average to about four percent per year after inflation.

In contrast, a steep and sudden increase in tolls -- say, an immediate doubling or tripling - would almost certainly have a much larger effect on traffic. At higher toll levels, drivers may be much more sensitive to increases.[11] However, large increases of this magnitude would be extremely difficult to implement in New York City. As documented by Zupan, there are formidable political obstacles to major toll increases of any kind on the bridges and tunnels leading into Manhattan.[12] Congestion tolls would require completely new charges on currently free facilities, as well as much higher rates on currently tolled crossings. In both cases, large increases and new tolls would run up against powerful resistance from organized political constituencies in the outlying boroughs and New Jersey.

[11] From a theoretical standpoint alone, toll elasticities may be expected to rise at increasingly higher toll levels. Although the exponential form of our regression model assumes a constant elasticity, that assumption applies only within the range of toll increases actually observed. At much higher toll levels, the demand function could be less curved, resulting in higher elasticities. For a linear demand curve, the elasticity exceeds -1.0 when the ratio of P/Q exceeds the inverse of the slope of the demand curve.

[12] Jeffrey M. Zupan, "The New York Region: First in Tolls, Last in Road Pricing?" presented to the Transportation Research Board Congestion Pricing Symposium, June, 1993.

Although it would be unrealistic for local transportation officials to rely exclusively on tolls for congestion management, a carefully coordinated set of market-based strategies, including higher tolls as an essential component, could be effective and acceptable. Congestion tolls would have to be complemented by higher parking taxes, increased metered rates for on-street parking, strict limits on the supply of CBD parking, incentives to eliminate employer-subsidized parking, and higher gasoline taxes.

Our regression results highlight the need to implement a coordinated transportation management strategy. Our analysis focused on toll elasticities. In fact, bridge and tunnel tolls comprise only a small proportion -- about one-quarter -- of the total variable cost of a trip into and out of Manhattan. Because of this, the total price elasticity of automobile travel into the CBD is higher than the partial elasticity with respect to tolls alone. Assuming, for example, that the average driver into Manhattan pays $6.00 per day for tolls (the current base TBTA toll), $10 for parking and $9.00 for other costs such as gas, oil, and vehicle depreciation, our average auto toll elasticity of -0.10 could imply an overall price elasticity of approximately –0.40. Although that is still inelastic, it suggests that a multi-faceted price strategy could substantially shift travel behavior.

There would be few physical or administrative problems in raising parking fees, tolls, and gasoline taxes immediately. Likewise, the technical problem of instituting tolls on the currently free East River and Harlem River Bridges is soluble, given the recent innovations in toll collection technology. Overcoming political opposition would require an intensive public education campaign, creation of the necessary political alliances, and somehow convincing even those who would pay the higher costs of auto use that they too would ultimately benefit.

One important key to implementation would be a gradual, predictable phase-in over time. That would facilitate planning for future location decisions of both firms and households. It would also give travelers time to adjust their travel behavior accordingly and would avoid the sudden shock of precipitous price increases in the form of higher tolls, parking charges, and gasoline taxes. Such a gradual phase-in would lessen the impression of punitive price increases.

The assortment of auto user charges and taxes proposed here would produce a greatly expanded stream of revenues for the local public sector, which desperately needs additional funds, especially for investment in transportation infrastructure projects. The revenues from increased auto and truck user charges could be used to rehabilitate and then properly maintain the seriously deteriorated infrastructure of the New York City region. Moreover, there are a number of expensive transit and roadway construction projects that are crucial to the more efficient functioning of the overall regional transportation system but which have been delayed for decades due to inadequate funding. These also could be funded through the proceeds of increased charges for auto and truck use. Whether they are used for rehabilitation and maintenance or for upgrading and new construction, the earmarking of increased taxes and user charges for transportation projects is certain to enhance the political acceptability of any pricing strategy. It would give those who make the payments the impression that they are getting something in return, and that they are at least indirectly benefiting from the pricing program. Even those who continue to use the automobile after the higher charges might support the use of the proceeds for public transit on the assumption that they will help keep other travelers off the roadways and thus reduce congestion.

Wider applicability of study findings

The low toll elasticity values we estimated for the TBTA bridges and tunnels in New York fall within the same range as money price elasticities estimated in other studies. One might expect that the unique circumstances in New York would lead to very different results than those found elsewhere in the United States. Instead, the results are similar to those that have been estimated for other parts of the country. Our elasticity estimates provide strong additional evidence that auto travel is inelastic with respect to tolls across a wide variety of settings, at least for moderate increases.

Nevertheless, findings such as ours must be used with caution when extrapolating to specific toll facilities elsewhere. As noted earlier, drivers' responses to tolls can vary depending on many circumstances, including the availability of highway and transit substitutes, driver expectations, congestion levels, the level of the toll, income and land use patterns in an area, and time-of-day and direction of travel. Indeed, our own results demonstrate that toll elasticities can vary substantially among toll facilities even *within* the same urban area. Outside the New York area, even greater underlying differences are likely to be found. One would anticipate, for instance, a higher elasticity on a suburban toll bridge located a few miles downstream of a free river crossing. The alternative free crossings in New York City, in contrast, are highly congested, especially during peak hours and in the peak direction, thus limiting their use as substitutes for the free bridges and tunnels. Moreover, tolls are so familiar to New York area drivers that they are an expected part of life. In contrast, introducing tolls in locales where they have not previously existed could elicit a much sharper response, particularly in the short run.

In light of such wide variability in background conditions, it is our view that a site specific analysis is almost always required in order to derive reliable forecasts of the impact of new or higher tolls on a particular facility.

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