New Jersey Public Transportation Ridership: The Effect of Fuel Prices, Infrastructure and Socioeconomic Factors

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Abstract: Fuel prices and public transportation use have been increasing over the last few decades. Previous studies have found varied cross elasticities between the two revealing both significant and insignificant correlations. Despite the increase in ridership, funding for public transportation has fallen and fares are increasing. The purpose of this study is to explain the determinants of public transportation ridership growth, and to examine the relative importance of socioeconomic factors in addition to fuel prices and fares. Thus, the paper will analyze the effect of fuel prices, structural, and socioeconomic factors on New Jersey Transit's light rail, heavy rail, and bus ridership levels. This study suggests that fares and fuel prices are the most important factors in determining ridership levels. Only bus ridership responds to investments in infrastructure and only bus ridership is sensitive to GDP and unemployment.

1. Introduction

While fossil fuels allow for cost effective transportation, they cause a series of environmental problems. For instance, extracting oil and natural gas causes groundwater contamination and threatens marine life. Refining and burning fossil fuels cause carbon emissions, ambient air quality reductions, and an extended list of environmental concerns. While clean energy sources are clearly part of the solution, the consensus among energy analysts is that clean energy sources like wind and solar can only meet a portion of our energy needs. Consequently, fossil fuels will be with us for the foreseeable future.

As such, we may reduce the harmful effects of fossil fuel use through a program of energy conservation. One key source of energy conservation is public transportation. Public transit conserves energy not only because public transit uses less energy per rider than automobiles but also because it increases residential densities. Thus, a healthy public transportation system is source of energy saving and a clear route to a cleaner environment. In New Jersey, there has been steady growth in the levels of public transportation ridership over the last decade. Between 1999 and 2006 light rail ridership grew at 4.8% per year, commuter rail at 1.5%, and bus ridership at 0.9% annually.

This increase in ridership has likely been aided by rising gas prices. Nationally, gasoline prices have also increased steadily over the last decade, nearly tripling in price. In the State of New Jersey gas prices have increased from $2.10 in 2000 to $3.36 in 2009 (Energy Information Administration, 2011). While higher gas prices may cause public transportation agencies increase their fares to compensate for the additional costs, the larger effect of higher gas prices on ridership occurs as commuters abandon their cars in favor of public transit. Empirical studies support this claim. Maley and Weinberger (2009) find that the cross price elasticity of gasoline prices and public transit ridership varies 0.10 to 0.40. Determining the magnitude of the effect is important if we wish to finance the public transit system with a gas tax. This is especially true if the transit system is subject to the tax. If ridership is relatively sensitive to increases in the price of gas, the revenue increases from greater ridership will more than offset the effect of higher gas prices on the cost of running the system.

With the State of New Jersey experiencing serious budget deficits, fare hikes and reductions in funding continue to plague the public transportation agencies of New Jersey. According to the American Public Transportation Association (2008), local and state financial aid has decreased or remained stagnant for 58% of the agencies. Additionally, 35% of the agencies are combating rising gas prices and decreases in financial assistance through service cuts, while 61% use fare increases and fuel surcharges to combat additional costs. According to NJ Transit statistics, their overall ridership levels fell in 2009 after years of growth, suggesting that funding could play a part in ridership levels.

Consequently, this study will investigate the impact of gas prices and infrastructure investments of public transit ridership rates in the State of New Jersey. It will also investigate other factors including income and employment that may affect the public transportation sector and test for differences in the impact of rising fuel prices among the different modes of public transit (i.e., bus, heavy, and light rail). Lastly it will investigate structural factors, such as rail and hub construction, and vehicle investment.

We find that fuel prices have a statistically significant effect on transit ridership. Socioeconomic factors, such as GDP growth and unemployment have minimal and sometimes insignificant effects on ridership. Of the variables included, fares were a largest influence on the variation in ridership levels. If we disaggregate ridership by transit mode, we find that light rail and heavy rail ridership had only two significant variables: fuel and fares. Only bus ridership responds to investments in infrastructure and only bus ridership is sensitive to GDP and unemployment.

2. Literature Review

Newspaper columnists often speculate that rising fuel prices lead to rising public transportation ridership. However, the empirical evidence on this link is mixed (Maley and Weinberger 2009, Blanchard 2009, Mattson 2008, Taylor and Miller 2004, Taylor and Fink 2002, Taylor, Haas, and Boyd 2002). Some studies find a strong correlation (Maley and Weinberger 2009, Blanchard, 2009) while others have less confidence in the correlation (Mattson 2008). Several studies find a correlation between fuel prices and certain modes of public transit (i.e., buses) while no link is detected for other modes. Moreover, each study established different factors as the central causes of ridership growth. These factors included both internal and external elements. Unemployment, GDP, fares, wages, fuel prices, and service mileage, among others, all surfaced as relevant factors.

The Effect of Fuel Prices on Ridership Levels

Maley and Weinberger (2009) found that the ridership from 2001-2008 in the City of Philadelphia was significantly affected by the price of gasoline. They ran regressions that controlled for the seasonal effects on ridership. The study found that each dollar increase in fuel costs contributed to an additional 178,117 riders/week. Regional rail ridership was fairly static at fares between $1 and $2 and the same for fares of $3.20 and greater. From $2.20 to $3.20, ridership varied dramatically. While this is an interesting result, their model failed to adjust gas prices for inflation and included only two fare increases over the evaluated time period.

The effect of fuel prices on ridership may not have immediate significance. It may take months for commuters to relocate and rearrange their schedules to facilitate a switch to public transit. Consequently, Mattson (2008) estimates a lagged model to capture the response of ridership to higher fuel prices. Areas with low population densities are less inclined to use public transportation and therefore had lower elasticities. For smaller cities, unemployment, service miles, and fares were important factors in the ridership. He finds that for large and medium cities in the short run, the effects surfaced within the month or one month after the price change. Mattson finds that the effects of fuel prices on bus ridership are concluded after three months, with significance in both one and two month lags. He finds gas price elasticities of .113 for the one month lag and .107 in the second month lag.

However, it may be a mistake to estimate the effect of higher gas prices on ridership across all transport modes. Blanchard (2009) discovered that gas prices did not have a significant influence on the ridership when the modes were observed as a whole. However, the effect of higher fuel prices on ridership was discernable when public transport ridership was disaggregated into bus, light, and heavy rail, largely due to the relatively more significant effect on buses. Blanchard also found that a given change in gas prices had a larger effect on ridership when gas prices were already high. He attributed this to a reduction in private vehicle use from higher taxes, congestion tolls, and the increasing burden of private travel at higher fuel prices.

Other Determinants of Public Transportation Ridership

Taylor and Miller (2004) argue that earlier studies of public transit ridership fail to consider a series of important factors. Therefore they construct a per capita ridership model that includes external factors such as vehicle service hours, land area, and housing costs, along with two internal factors, service supply and fare levels. They perform a cross-sectional analysis on 265 urbanized areas. The external factors (vehicle service hours, land area, and housing costs) and the internal factors (service supply and fare levels) all showed significant effects on ridership. Their original model revealed population to have a significant effect on ridership levels. However, population was strongly correlations to the other independent variables.

Like Maley and Weinberger, Taylor and Fink (2002) examine fuel prices and ridership. However, they integrate more internal and external variables than Maley and Weinberger. Taylor and Fink contend that external factors have more influence than internal factors on the level of ridership. They classify factors in which management has some control over, such as fares and service levels, as internal factors, and factors that are exogenous to the system, such as service area population and employment as external factors. Consistent with this claim, they find that employment is a major factor in determining ridership levels. In addition, auto ownership and parking statistics had the greatest effect on ridership, and other external effects such as population and employment also had significant effects. However there was strong co linearity between many of the independent variables. Regarding internal factors, they found service factors to be more significant than fare variations.

Taylor et al. (2002) adopts a broader focus and examines the factors that influenced ridership in successful transit systems during the 1990s. Their study concluded that external factors once again dominated in creating ridership variability, specifically the unemployment rate, the real hourly wage, and the real GDP. Population growth contributed to an increased demand. Fare programs targeted towards different age groups and pricing schemes were also effective in changing ridership levels. They concluded that ridership is mostly a function of the external factors; however it is influenced by internal control

3. Data and Methods

To analyze the determinants of ridership levels, this study will examine both external and internal factors. Because we wish to analyze the effect of investment decisions for New Jersey Transit, all of the data was isolated to the State of New Jersey. The dependent variable of this study measures the ridership levels among NJ Transit's vehicles at monthly intervals. NJ Transit provided data for bus, light rail, and heavy rail ridership levels, along with the total ridership levels over all types of transportation. They span over the region of quarter three 1990 (July 1990) through quarter two 2010 (Jun 2010). Accordingly, we estimate the following model:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5$$

Y = Per Capita Transit Ridership
X1 = real fuel prices
X2 = real fare
X3 = real GDP growth rates
X4 = unemployment rates
X5 = real investment

Because the effect of the some variables on ridership may take some time to emerge, we employ a series of lags. Fuel prices and investment are lagged by one month, while GDP growth rates are lagged one quarter, and fares are lagged six months. In addition to estimating the impact of the internal and external factors on overall public transit ridership, we also estimate separate models for each public transit mode. Finally, we run separate regressions to discern the effects of investment and fares on ridership because of high correlation between fares and investment. Data for the independent variables were gathered from a series of sources.

New Jersey civilian non-institutional population figures were gathered from The New Jersey Department of Labor and Workforce Development (NJDLWD). Because population is highly correlated with several of our key independent variables, we incorporate population levels into our analysis by examining all ridership on a per capita basis.

The U.S. Energy Information Administration (EIA) provided a data set of monthly New Jersey gasoline prices measured in cents excluding taxes. They also provided an additional set of fuel tax rates for New Jersey that was combined to create the total average retail fuel prices in monthly intervals. In order to establish consistency, fuel prices were deflated to 1979 prices as the fare prices used a 1979 base year for their deflated values.

To capture internal factors, we incorporate the average real fare into the analysis. NJ Transit provided average real fares (in 1979 dollars). Because better economic conditions generally imply more commuters and more public transit riders, we include both the unemployment rate and the growth in real GDP. The unemployment rates in New Jersey came from The New Jersey Department of Labor and Workforce Development (NJDLWD). The unemployment rates are seasonally adjusted and recorded in a monthly interval.

The Bureau of Economic Analysis (BEA) provided the real GDP data. The growth rates were seasonally adjusted and recorded in quarterly intervals. Growth rates applied specifically to the state of New Jersey. The last explanatory variable included in the analysis was investment in new plant and equipment. Because NJ Transit reports investment only on an annual basis, we divided the annual figures by twelve to find the monthly rate. These figures were then deflated to 1979 prices to remove the effect of inflation. Investment was included to cover the effects of public funding and investment in infrastructure on the levels of ridership.

4. Results and Analysis

The means and standard deviations for both the dependent and independent variables are reported in Table 1. The means for total, bus, light rail, and heavy rail ridership were (17,700,000), (12,100,000), (4,829,168), and (771,770.8) respectively. In per-capita terms, the means were 2.741, 1.877, .117, and .747 rides per month. Bus ridership accounted for over two thirds of the total ridership on average each month with heavy rail ridership accounting for a majority of the other third proportion of total ridership. Light rail accounts for a relatively small fraction of the total ridership levels. Real fuel prices adjusted to 1979 prices averaged out at 53.06 cents over the span of 1990-2010.

The per-capita model transformed the dependent variable to the number of riders per month divided by the civilian non institutional NJ population each month. This model utilized the same explanatory variables less the NJ population. This model returned a similarly high R^2 at 0.8512, with all of the variables being significant at the .01 level less unemployment which was insignificant. However, the model still suffered from correlation issues, particularly the conflict between investment and fares. This suggests that investment could be represented in the fares. The final models for total ridership were developed to eliminate this issue.

Total Ridership Levels

The final models for total per capita ridership utilized all of the variables from the original estimated model, while separating fare prices from gains in capital assets. Creating two models eliminated most of the significant correlation between the independent variables, also correcting for the unexpected negative coefficient for the gains in capital assets.

The results of both models for total per capita ridership levels are shown in Table 2. To correct for any heteroskedasticity, we report robust standard errors. Durbin-Watson statistics for the total per-capita ridership fare and capital investment models were 1.418201 and 0.802533 respectively, revealing signs of autocorrelation. To correct for any autocorrelation within the time series regressions, we estimate Prais-Winsten regressions for both specifications.

From Table 2 we can see that, when fares were included in the model, excluding the presence of investment from the gains in capital assets, the R^2 value was .7244, still relatively close to the original model. Fuel prices, fares, GDP growth rates, and the intercept were all significant at the .01 level. However unemployment rates were insignificant in this model. Fuel prices were found to be the most significant when lagged by a month, suggesting that overall ridership responds to changes in fuel prices a month after they occur. The regression shows a .0088 increase in per capita ridership for each one cent increase in average retail fuel prices deflated to 1979 prices. Thus, a one-dollar increase in fuel prices (1979 dollars) would increase per-capita ridership 0.88 or about 32%. A one-dollar increase in the nominal 2010 fuel prices is estimated to produce a .27 gain in total per-capita ridership per month. Although not a substantial proportion of the total ridership, large shifts in fuel prices, which are relevant in recent times, will have a noticeable effect.

Transit fares however have a far more substantial effect on the total per capita ridership. Fares were found to be the most significant when lagged by six months. The regression shows a 2.23 decrease in per capita ridership for each one dollar increase in the average fare (1979 dollars). Thus, a one-dollar increase in fares (1979 dollars) would decrease per-capita ridership about 81%. This translates to a $1.00 nominal increase in 2010 fares creating a .15 decrease in per-capita ridership, a fairly significant impact. The GDP growth rates, although significant at the .01 level, had little influence on per capita ridership with unemployment having almost no effect while being insignificant at the 0.1 level.

When gains in capital assets were present in the model, excluding fare prices, the R^2 was 0.2674, significantly lower than the original model. All the variables were significant at least at the 0.05 level aside from capital investment, yet GDP was negatively correlated with total per-capita ridership but the impact was small. Each one percentage point increase in unemployment had a -.049 impact on per-capita ridership, largely significant in relation to unemployment's effect in the fare model. Changes in the net capital assets had almost no effect on the per capita ridership, raising into question the impact of investment on transit ridership.

Ridership among Individual Modes of Transportation

The per capita ridership models were also applied to the individual modes of transportation to further investigate the effects of fuel prices and other factors on NJ Transit ridership. The regressions were recorded in Table 3. Looking across the regressions, only bus ridership responds to investments in infrastructure and only bus ridership is sensitive to GDP and unemployment.

Bus Ridership

Bus ridership estimates were generally consistent with the total per-capita ridership models, which should not be surprising as 2/3 of the total ridership is represented by bus ridership. The regression including gains in capital assets utilized the same lag periods, however in the fare regression, the changes in fares became more significant at a two month lag rather than at a six month lag like the total per capita ridership regression. When fares were included in the regression, the R^2 was 0.4521. Higher fares once again significantly decreased ridership levels with a 0.86 decrease in per capita bus ridership for each dollar increase in the deflated fare value. This represents about a 46% decrease in per-capita ridership from a one-dollar increase in fares. Although significant at the .01 level, fuel price changes now only responded with a .0025 increase in per capita bus ridership for each one cent increase in the price of gas deflated to 1979 prices. Thus, a one dollar increase in the fuel price (1979 dollars) would cause a 13% increase in ridership. Mattson's (2004) claim that fuel prices were significant at both the one and two month lags was confirmed when both variables were included in the regression, although due to high correlation between the two, the sign was unexpectedly negative in the two month lag.

Bus ridership responds to investments in infrastructure and bus ridership is sensitive to GDP and unemployment. However, the effects of each of these variables on per-capita bus ridership are small. A one million dollar net investment raises per-capita bus ridership 0.0025. A one percentage point increase in real GDP growth decreases per-capita ridership by only 0.0088 and a one percentage point increase in unemployment decreases per-capita ridership by only 0.032.

Light Rail Ridership

In both the capital and fare price regressions, GDP rates, unemployment rates, and gains in capital assets were insignificant and therefore irrelevant in determining the per capita light rail ridership rates. The fuel price and fare coefficients were 0.0004 and -0.069 respectively in the regression including fares. With a mean per capita light rail ridership of .117, fares have a substantial negative influence for light rail per capita ridership. Thus, a one-dollar increase in fares is associated with a 59% decrease in per-capita rail ridership. In contrast, the impact of fuel prices on per- capita ridership is smaller. A one-dollar increase in fuel price is associated with a 34% increase in per-capita rail ridership. The fares responded quicker in light rail ridership than bus ridership, with the fares prices having a significant effect during the month that they occur as opposed to a two month lag. The R^2 value for the fare regression was 0.0717 however, suggesting that the model inadequately explains the per-capita ridership for the light rail mode of transport.

Heavy Rail Ridership

Heavy Rail per capita ridership represented over one fourth of the total per-capita ridership levels on average per month, therefore it has relevance in determining the total ridership for NJ Transit. In both the fare and capital based regressions, unemployment and GDP rates were insignificant, revealing no influence from income and employment on per capita heavy rail ridership. In the capital model, gains in capital investment were not significant at the 0.1 level, and the coefficient revealed a miniscule impact on the ridership levels for heavy rail. Fuel prices and fares once again were both significant at the .01 and .05 levels respectively. However, fuel prices had a small effect on the variation of per capita heavy ridership with a coefficient of 0.000925. A one-dollar increase in fuel prices will raise ridership levels by about 12%. On the other hand, a one-dollar increase in fares would decrease heavy rail ridership levels by 0.38 or about 50%.

Conclusion

While it is logical to view certain factors, such as fuel prices, as obvious determinants of public transit ridership, the existing literature on this relation is unconvincing. The literature shows wide variation in the estimated effect of key factors on public transit ridership. This study finds that exogenous factors, such as GDP and unemployment rates, measures of economic growth, have little effect on the outcome of public transit ridership. It also shows that fuel prices have a substantial effect on all modes of public transit. There was evidence that bus ridership was more sensitive to fares, fuel prices, and capital investments than both light and heavy rail ridership. Light rail ridership was the least sensitive to both fares and fuel prices.

Fares assumed a larger role in developing the per capita ridership levels. High fares are estimated to have enormous consequences on the levels of ridership, a relevant issue among the recent public transit fare increases in New Jersey Governor Chris Christie's budget. Although fares are likely determined by many factors, high fares can strangle public transit systems.

The models developed for this study do reveal some insight into NJ Transit's ridership determinants. Subsequent research should concentrate on adding more external factors to the model to further investigate the impact of the broader economy on ridership. Since fares had such a substantial influence, other internally controlled factors would be investigated to establish the weight of internal influence over external factors. Further investigation into the gains in capital assets would also be pursued, deriving direct statistics for public budgets and specific investment in infrastructure. These could provide further support for the conclusions of this study. In regards to individual modes of transportation, the internal variables should have been specific to the mode of transportation rather than overall averages.

Table 1. Means and Standard Deviations

Variable	obs	Mean	Std. Dev.	Min	Max
Ridership Totals	240	17700000	2678323	12700000	23900000
Bus Ridership	240	12100000	1255442	9194900	15200000
Light Rail Ridership	240	771770.8	557539.4	196800	2060100
Heavy Rail Ridership	240	4829168	1000908	3218300	6846600
Percapridership	240	2.740733	0.3247462	2.078914	3.5456
Percapbusridership	240	1.876518	0.1450046	1.504234	2.25338
Percaplightridership	240	0.1174043	0.0812883	0.0321395	0.3053991
Percapheavyridership	240	0.74681	0.1295974	0.5286648	1.017325
Fuelprices	240	53.05637	17.02018	3.487106	116.0409
Fares	240	1.163586	0.09439	1.029559	1.417708
NJPopulation	240	6427642	235536.9	6057200	6828400
Unemp_rate	240	5.842917	1.607394	3.6	10
Gdprate	240	2.52875	2.644463	-6.8	8
Gainsincapitalassets	240	9.745757	7.865946	-3.111815	27.86287

Ridership Totals, Bus Ridership, Light Rail Ridership, and Heavy Rail Ridership – Riders per month measured over 1990-2010
Percapridership, Percapbusridership, Percaplightridership, and Percapheavyridership - Monthly ridership divided by monthly civilian non-institutional population over 1990-2010
Fuelprices – Monthly real average retail fuel prices in the state of New Jersey measured in cents deflated to (1979 dollars)
Fares – Monthly average real fare values deflated to (1979 dollars)
NJPopulation - Monthly New Jersey civilian non institutional population statistics
Unemp_rate - Monthly New Jersey unemployment rates
Gdprate - Quarterly New Jersey real GDP growth rates seasonally adjusted applied to monthly intervals in (2000 dollars)
Gainsincapitalassets – Annual NJ Transit's real gains in capital assets divided into monthly intervals in (1979 dollars) Is this thousands of dollars

Table 2. Total Ridership Regression Results – Coefficients and Standard Errors

	Prais Regression	Prais Regression
FUEL_LAG	.008832*** (.0008038)	.0084697*** (.0016027)
FARE_LAG6	-2.229873*** (.1515007)	
CAP_LAG		.0041642 (.0037752)
GDP_LAG	-.0128747*** (.0046111)	-.0152622** (.0072572)
UNEMP	.0060046 (.0107349)	-.0492391** (.023371)
cons	4.876985*** (.1632853)	2.606776*** (.2009334)
R^2	0.7244	0.2674
d stat - original	1.418201	0.802533
transformed	2.107201	2.468182

* Significant at the .1 level
** Significant at the .05 level
*** Significant at the .01 level

Table 3. Individual Modes of Transportation Regression Results

	PERCAPBUSRIDER		PERCAPLIGHTRIDER		PERCAPHEAVYRIDER	
	R1	R2	R1	R2	R1	R2
FUEL_LAG	.002496***	.0037666***	.0004203***	.0004332***	.000925***	.000941***
	(.0004428)	(.0004946)	(.0001479)	(.0001513)	(.0002775)	(.0002806)
FARES			-.0693002***			
			(.0187933)			
FARE_LAG2	-.8627558***				-.3882215**	
	(.1001241)				(.1699738)	
CAP_LAG		.0025596*		.0007003		
		(.0013386)		(.000562)		
CAP_LAG24						.0015165
						(.0009781)
GDP_LAG	-.0028248	-.0088944**	-.0005617	-.0007132	-.0009039	-.0013248
	(.003232)	(.0038661)	(.0004688)	(.0005107)	(.0013195)	(.0014982)
UNEMP	-.011184*	-.0318363***	-.0036131	-.0030083	-.0088139	-.0155648
	(.0066425)	(.0072425)	(.0089652)	(.0093482)	(.0135777)	(.0165454)
cons	2.821473***	1.875113***	.2313267***	.1309164	1.208682***	.798677***
	(.1083269)	(.0656683)	(.0889553)	(.0823809)	(.214455)	(.1091583)
R^2	0.4521	0.2975	0.0717	0.0623	0.1528	0.1114
d stat - original	1.570085	1.370163	0.503135	0.405454	0.702167	0.426217
transformed	2.047552	2.100319	2.813362	2.820006	2.521587	2.527289

* Significant at the .1 level
** Significant at the .05 level
*** Significant at the .01 level

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