DOES THE INCOME LEVEL OF A NEIGHBORHOOD AFFECT THE PRICE ELASTICITY OF DEMAND FOR TRANSIT?

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Abstract

Changes in ridership at individual stations on Chicago's mass-transit rail system following fare increases in 2004, 2006 and 2009 are analyzed to determine whether the price elasticity of demand varies with the per capita income in the neighborhood surrounding each station. For two of the three fare changes, the fare elasticity becomes more inelastic for weekday trips as the neighborhood income per capita increases. However, a contradictory result is found for one of the fare increases. The relationship is even less clear for weekend trips. These mixed finding are in line with the prior literature which also found an inconsistent relationship.

Keywords

Transit – price elasticity – income – Chicago

Research Highlights

- Investigates relationship between neighborhood income and price elasticity
- Data from three fare increases on mass-transit rail in Chicago
- In general, price is more inelastic on weekdays in higher-income areas
- However, a contrary result was found for one price increase
- Less clear relationships are found on the weekends

[1] This work was conducted while a student at Northwestern University

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"The effect of income on fare elasticities is not well researched." (Transportation Research Board, 2004)

1. Introduction

When a transit agency raises its fares, does demand for transit change by a similar proportion in all areas of the city, or does it vary with the income or other characteristics of individual neighborhoods within the city? Three recent fare increases by the Chicago Transit Authority for travel on its rail lines offer an opportunity to answer this question. Changes in the number of riders boarding at individual stations are analyzed with respect to the income characteristics of the neighborhoods surrounding each station.

We should emphasize at this point that this paper does not concern the income elasticity of demand, which is to say whether people in higher-income neighborhoods ride public transportation more or less frequently than those in lower-income neighborhoods, but rather whether there are systematic variations in how residents in neighborhoods of differing income characteristics react to fare changes.

The relationship between neighborhood income and price elasticity requires an empirical investigation as it is unclear theoretical whether riders in higher-income neighborhoods are more or less sensitive to a fare change. This is because there are two conflicting effects. Riders in higher-income neighborhoods are more likely to have access to a car, meaning that they are able to switch modes in response to a fare increase. They would therefore be more price elastic than riders in lower-income neighborhoods with more limited car access. However, the higher-income riders are better able to tolerate the effects of a fare increase as it represents a smaller proportion of their daily budget. This would imply that they would be more price inelastic than lower-income riders.

2. Literature Review

There is a large literature on the price elasticity of demand for public transportation. Meta-studies (Wardman, 2014) and practical handbooks have summarized the extensive literature. However, as the quotation at the start of this paper indicates, the nature of how the price elasticity of demand may vary between riders due to differences in their incomes has received little attention. The limited prior literature is summarized in the British (Balcombe et al., 2004, at page 61) and United States (Transportation Research Board, 2004, at pages 12-36 to 12-38) practical handbooks. Some of the prior literature has, like this paper, compared the travel responses of groups of riders that vary in their income following a fare change, whereas others have employed disaggregate methods with data on the income and travel choices of individual travelers.

The earliest paper appears to be Lassow's (1968) analysis of a fare increase in New York City in 1966. He found that ridership declined by 8.6% at 10 stations in "depressed areas of the city," and by only 2.7% at stations near commuter railroad and bus terminals that experience a high volume of commuters of "presumably higher economic status." However, ten years later, Obabini (1977) found a contrary result after the 1975 fare increase in New York City. While in general he found "ridership reductions in roughly equal proportions from all major socioeconomic and demographic groups," there were suggestions that groups with annual household incomes of greater than $15,000 ($68,000 in 2014 dollars) were slightly more likely to change mode as a result of the fare increase. Moreover, the lowest rate of work-trip mode changes occurred among "household heads with lower incomes, having no more than a high school education, under 34 years of age, and nonwhite."

Experiments with free off-peak transit in the United States in the 1970s allowed observation of whether certain income groups were overrepresented among the generated ridership. Swan and Knight (1979) found that higher-income riders (from households with income more than $20,000, the equivalent of $72,600 in 2014 dollars) were more responsive to the fare reduction than were lower-income riders. However, further analysis of the Denver experiment by Mayworm, Lago, and McEnroe (1980) found little variation in price elasticity among income groups. But the latter authors did find some evidence that middle and higher-income riders (those with annual household incomes of $10,000 or more which equates to $36,300 or more in 2014 dollars) were more responsive than lower-income riders during a similar off-peak free fare experiment in Trenton, New Jersey.

Cummings et al (1989) used both stated and revealed preference data to examine the effects of three Chicago Transit Authority fare increases in the early 1980s. For journeys to work, the authors found that lower-income riders (from household with incomes of less than $30,000, the equivalent of $60,500 in 2014 dollars) had slightly more elastic fare sensitivity than higher-income riders. However, there was no difference in fare sensitivity for non-work journeys.

Mackett (1990) used a micro-analytical simulation model to estimate the fare elasticities for bus service in Leeds, United Kingdom. He found a limited variation between the socio-economic groups, and estimated a fare elasticity of -0.67 for unskilled manual workers, -0.69 for skilled manual workers and -0.62 for non-manual workers.

Halcrow Fox and Associates (1993) found in Britain that "the greater a traveller's income, the more elastic the response to a fare increase." For mass-transit rail they concluded that for work trips the fare elasticity was -0.2 for low-income riders, -0.3 for medium-income riders and -0.5 for high-income riders. For non-work trips the fare elasticities were -0.6, -0.65 and -0.75 respectively.

Molnar and Nesheim (2011) used the 2008 National Travel Survey in Great Britain to estimated price elasticities for local bus service in areas outside of London. They found that the travelers drawn from the middle three quintiles of annual household incomes (from £12,500 to £50,000, which is approximately $21,000 to $84,000 in 2014 dollars) had broadly the same price elasticity of -0.36. Travelers in the lowest quintile of household income had a slightly more elastic demand of -0.39 and those in the highest quintile of household incomes were slight more inelastic at -0.32.

The United States practical handbook (Transportation Research Board, 2004 at page 12-7) concludes that "[t]he effect of income . . . is less clear, but it appears that most fare changes have affected ridership of lower income groups . . . less than other groups." A journal article summary (Pauley et al., 2006) of the British handbook makes a stronger statement that "[t]ravellers with high incomes tend to have higher elasticity values because their higher car ownership levels mean that they have an alternative when fares increase." This statement would certainly be consistent with the findings of Halcrow Fox and Associates (1993) for rail service. However, the results in Mackett (1990) and Molnar and Nesheim (2011) for bus services in Britain suggest that there is not a strong relationship, and that higher-income riders might actually be more price inelastic.

3. Data

3.1. Transit in Chicago

The Chicago Transit Authority (CTA) provides bus and heavy rail elevated and subway train service in the City of Chicago and inner suburbs with a fleet of 1,700 buses, and 1,000 railcars operating on eight rail routes. It services a population of 3.4 million. The analysis concerns ridership at rail stations. This study does not examine changes in bus ridership, since CTA bus routes usually span a large geographic area with a wide variance in income and other demographics, and CTA bus ridership is available at the route level only and not for individual stops.

3.2. Transit Fares in Chicago

The CTA pricing structure is a flat fare irrespective of distance traveled or time of day. Since 2000, the CTA has increased its fares three times. The basic cash fare increased from $1.50 to $1.75 on January 1, 2004. It increased to $2.00 on January 1, 2006 and to $2.25 on January 1, 2009. The price of monthly passes also rose by similar percentages.

3.3 Transit Ridership

Data on ridership by station were obtained from the Regional Transportation Authority's[2] "Regional Transportation Asset Management System" (RTAMS) data warehouse at http://www.rtams.org. The origin of the data is a CTA publication "Monthly Ridership Report." The ridership measure is a count of passengers entering stations. Data is reported on the average boardings for weekdays, Saturdays, and Sundays / holidays for each month. The CTA publication also includes a count of the number of weekdays, Saturdays and Sundays / holidays in that particular month.

The analysis concerns changes in ridership for the 12 months before and after the fare increases on January 1, 2004 and 2006. Ridership in calendar year 2004 is compared with ridership in calendar year 2003; and ridership in calendar year 2006 is compared with that in 2005. However, there is a complication in analyzing the January 1, 2009 fare increase because from March 17, 2008 the State of Illinois mandated that senior citizens could ride for free. Consequently in analyzing the 2009 fare increase, ridership in April to December of 2009 is compared with the same months in 2008..

During the period analyzed the CTA had 142 rail stations. However, stations in the downtown area were excluded because boardings at these stations represent people from all parts of the city who are making trips back to their homes. Consequently the income of downtown residents would not be an accurate representation of the income of the riders. Twenty-eight stations in the downtown area bounded by Division Street to north, Halsted Street to the west, Roosevelt Road to the south and Lake Michigan to the east, including stations on the boundary, are excluded. Also excluded are the two airport stations (O'Hare Airport on the Blue Line and Midway Airport on the Orange Line), and two stations near O'Hare (Cumberland and Rosemont) which are park and ride locations that have few residents living nearby and draw from a large catchment area. This leaves 110 stations.[3]

Certain stations also had to be excluded for one or more of the fare increases because reconstruction and engineering work had led to a partial closure for some months. In particular stations along the Douglas Park branch of the Blue Line (renamed the Pink Line in 2006) were excluded in 2003-04 and in 2005-06 because of major reconstruction and subsequent service enhancements. Ashland/Lake Station on the Green Line was also excluded in 2005-06 as the newly-renamed and expanded Pink Line service was rerouted to serve this station from June 2006.

The Brown Line branch from Southport to Kimball was also excluded in 2005-06 and 2008-09 because individual stations were closed for extended periods for reconstruction, and passengers were advised to use neighboring stations. Consequently boardings at stations along this branch fluctuated greatly from year to year. In 2008-09 stations on the southern part of the Brown Line at Diversey and Wellington were excluded due to reconstruction, as were the

[2] The Regional Transportation Authority is the planning and financial oversight agency for public transportation in the Chicago metropolitan area, and has taxing powers to provide subsidies.
[3] One station (Dempster on the Yellow Line) did not receive weekend service until April 2008, but analysis of weekend service at this station in 2008-09 is also excluded as ridership was in its infancy.

neighboring stations at Fullerton and Belmont that were jointly served by the Brown and Red Lines.

Finally an influx of capital funds in 2008-09 led to weekend reroutings and bus substitutions as engineering works dealt with a backlog of track maintenance. Consequently stations from Chicago/Milwaukee to Harlem along the O'Hare branch of the Blue Line, plus North/Clybourn (Red Line) and Sedgwick (Brown Line) were excluded on weekends (but not weekdays) in 2008-09.

3.4 Calculation of Fare Elasticity

A standard calculation is made of the fare elasticity. The percentage change in the average daily ridership is divided by the percentage change in the cash fare. Descriptive statistics and scatterplots of the data are presented later in the paper.

3.5 Neighborhood Characteristics

Information on income and demographics was obtained at the census tract level from the U.S. Census Bureau's 2009 American Community Survey Five Year Estimates in Cook County, Illinois. In addition the Census Bureau provides geographic data on the location and area of the census tracts (the census tracts used in the 2009 American Community Survey are those defined for the 2000 Census). Consequently, while we have three different observations of the price elasticity from the fare increases of 2004, 2006 and 2009, we only have one point observation of the neighborhood characteristics, which is for 2009.

Guerra, Cervero, and Tischler (2012) assert that a half-mile radius circle is the accepted measure in the United States to evaluate a transit station's catchment area. To create "neighborhoods" surrounding each station, an ArcGIS map of Chicago was overlaid with the location of stations and the boundaries of census tracts. A half-mile radius circle was drawn around each station. In some cases stations were close enough together that these circles intersected. In these cases a "watershed" line was drawn equidistant between each station, and the neighborhood for a given station was only that part of the circle that lay on its side of the watershed.

With these boundaries in place, the census tracts that fell either in whole or in part within each station neighborhood were identified. However, a census tract was not included if only a very small part of it fell within the neighborhood boundary. Because the station catchment area boundaries are generally circular in shape, and census tracts are generally rectangular, many of the census tracts associated with a specific station contain households that live more than 0.5 miles from the station. Therefore, the descriptive statistics of a station's neighborhood are generally based on geographic area that is wider than just the half-mile radius circle.

For each station a series of demographic variables were defined based on a weighted average of all of the census tracts that intersect the stations catchment area. The first variable is the density of population. This is calculated as the total population in the relevant census tracts divided by the combined area measured in square miles. The purpose of this variable is to capture the effect of neighborhoods where high population density makes travelers more dependent on transit, and automobile usage less desirable due to congestion and parking difficulties. In Chicago both high and low income groups choose to live in high-density neighborhoods, and therefore the correlation between density and income is just 0.16.

The primary income variable is the weighted (by population) per capita income in the census tracts. Some of the previous literature used household income rather than per capita income as the main explanatory variable. The correlation between the two measures for the 110 stations in the dataset was 0.94. We felt that per capita income was more appropriate in this analysis because the average household size varied significantly between the various station neighborhoods.[4] Alternative measures of income such as the proportion of the population that fell below the official poverty line, or the proportion of the working population who were unemployed were tried but were found to be both less successful as explanatory variables and highly correlated with per capita income.

The next set of variable measured the proportion of the population that were males, were aged 65 years or older, and were children (defined as aged 14 or younger). We wanted to investigated whether there were any gender differences in the price elasticity, and whether the elderly (who in 2008-09 were able to ride for free), or children (many of whom were riding on weekdays to and from school) had a different fare elasticity. There are not strong correlations between per capita income and either gender mix or the proportion of elderly. However, not surprisingly, increasing the proportion of children does have a negative 0.63 correlation with per capita income.

The final variable measured the distance of the station from the center of Chicago. As a flat fare system is used, there may be more diversion from transit for shorter trips as a result of the fare increase. Rather surprisingly distance from the center of town is uncorrelated with either population density (a correlation of -0.08) or per capita income (a correlation of 0.02). The distance was calculated as the great circle distance between the latitude and longitude of a station and the intersection of East Lake Street and North Michigan Avenue. The latter is equidistant from the north, west and south boundaries of the area that was used to exclude the downtown area stations (the eastern boundary is Lake Michigan).

Table 1 shows the descriptive statistics for the explanatory variables used in this analysis. Overall one is struck by the considerable diversity among the station neighborhoods. The per capita income varies from $10,000 a year to $75,000 a year. Population density varies from 3,000 to 78,500 per square mile. The proportion of males in the neighborhood varies from 37% to 79% around a mean of 50%. The proportion of elderly varied from 3% to 29% around a mean of 10%, and the proportion of children varied from 6% to 41% around a mean of 22%.

[4] Average household size varies from 1.5 persons per household up to 4.2 persons per household, around a mean of 2.6 persons.

Table 1: Descriptive Statistics of Explanatory Variables (110 observations)

Variable	Mean	Standard Deviation	Minimum	Maximum
Annual per capita income (2009 dollars)	$29,904	$17,474	$9,719	$74,980
Population density per square mile	18,009	12,525	2,915	78,561
Distance from downtown (miles)	6.3	2.7	1.7	13.4
Proportion of males	0.50	0.05	0.37	0.79
Proportion of elderly (aged 65+)	0.10	0.05	0.03	0.29
Proportion of children (aged 0-14)	0.22	0.08	0.06	0.41

4. Theoretical Considerations

A theoretical model of the ridership (*Q*) for station *j* in time period *t* can be defined as:

$$Q_{jt} = q\left(P_t, M_{jt}, I_{jt}, X_{jt}\right) \tag{1}$$

where *P* is the fare (which is the same for all stations), *M* is the frequency of trains serving the station, *I* is the income of the neighborhood surrounding the station, and *X* is a vector of other exogenous variables describing the neighborhood. The CTA faces a total cost (*TC*) for rail service in period *t* given by a function of the train frequencies provided to all 142 stations in the system, and a vector of exogenous factor prices (*F*):

$$TC_t = c(M_{1t}, \ldots, M_{142t}, F_t) \tag{2}$$

Assuming an exogenous subsidy (*B*) that the public authorities permit to be used for the provision of rail transit service, the CTA faces a budget constraint at time *t* given by:

$$P_t\left[\sum_j q\left(P_t, M_{jt}, I_{jt}, X_{jt}\right)\right] + B_t = c(M_{1t}, \ldots, M_{142t}, F_t) \tag{3}$$

There is an extensive literature since Nash (1978) discussing how the transit authority may select the endogenous variables, fare and service frequency, to satisfy some objective function. Savage (2004) discusses some of the objectives that the CTA has pursued at various times over its existence.

The price elasticity of demand (η) for any station is given by:

$$\eta_{jt} = \frac{\partial q\left(P_t, M_{jt}, I_{jt}, X_{jt}\right)}{\partial P_t} \frac{P_t}{q\left(P_t, M_{jt}, I_{jt}, X_{jt}\right)} \tag{4}$$

The calculations in this paper explain how the dependent variable in equation 4 is determined by the various exogenous variables, including income, on the right-hand side of equation 4. We did not include service frequency on the right-hand side of our estimations because services frequencies did not change in general, and where there were major changes for reconstruction of the Pink and Brown Lines, these observations had already been dropped from the estimation.

Often calculations of demand relationships are complicated by simultaneity between demand and supply. Elementary economics models would have an increase in consumers' incomes shifting the demand curve to the right, and as a result the price of the good would also increase as the new equilibrium would be consistent with an upward sloping supply curve. This is not the case here. The CTA has a flat fare system so the same fare is charged at all stations. If a neighborhood gentrifies then the supply curve (between price and ridership) at the local station is perfectly elastic because fares are set at a system level and not tailored to the market at each station.

5. Descriptive Statistics and a Graphical Analysis

Descriptive statistics of the calculated station price elasticities for each of the three fare increases are shown in Table 2. The table differentiates between elasticities for trips on weekdays, Saturdays and Sundays / holidays. Certain unusual features are immediately apparent. The first is that with the exception of Sundays in 2005-06, weekend ridership at the average station increased rather than decreased after each fare change. Albeit that the fare increase most likely restrained the amount of growth in weekend ridership. The second is that in 2005-06 even weekday ridership increased following the fare change. This was period of economic expansion in the Chicago area with considerable property redevelopment in previously decaying neighborhoods.

Table 2: Descriptive Statistics of Price Elasticities

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
2003-04 Weekdays	99	-0.15	0.22	-0.97	0.42
2003-04 Saturdays	98	0.02	0.30	-0.76	0.70
2003-04 Sundays/holidays	98	0.39	0.33	-0.55	1.11
2005-06 Weekdays	87	0.32	0.33	-0.42	1.36
2005-06 Saturdays	86	0.42	0.37	-0.74	1.30
2005-06 Sundays/holidays	86	-0.05	0.32	-1.31	0.70
2008-09 Weekdays	95	-0.26	0.35	-1.07	0.66
2008-09 Saturdays	80	0.05	0.54	-1.36	1.31
2008-09 Sundays/holidays	80	0.34	0.46	-0.83	1.34

The explanation for the rather counterintuitive increases in ridership following fare rises is that we are not just observing a movement along the demand curve due to the transit fare rise, but also a concurrent outward shift in the demand curve due to changing macroeconomic conditions, the price of gasoline, and changes in land use. Consequently we will be more concerned with the relative magnitude of the price elasticity at different neighborhood income levels, rather that the absolute magnitude. Insights into the relative magnitudes can be obtained from figures 1, 2 and 3 that show scatterplots between per capita income and elasticity on weekdays for the three fare increases. To conserve space the plots for weekends are not shown. For all three fare increases the elasticities at individual stations on Saturdays and Sundays/holidays are correlated with the weekday elasticities at that station with correlation coefficients in the range of 0.7 to 0.8.

Figure 1: Weekday Price Elasticity versus Neighborhood Income per Capita - 2004 Fare Increase

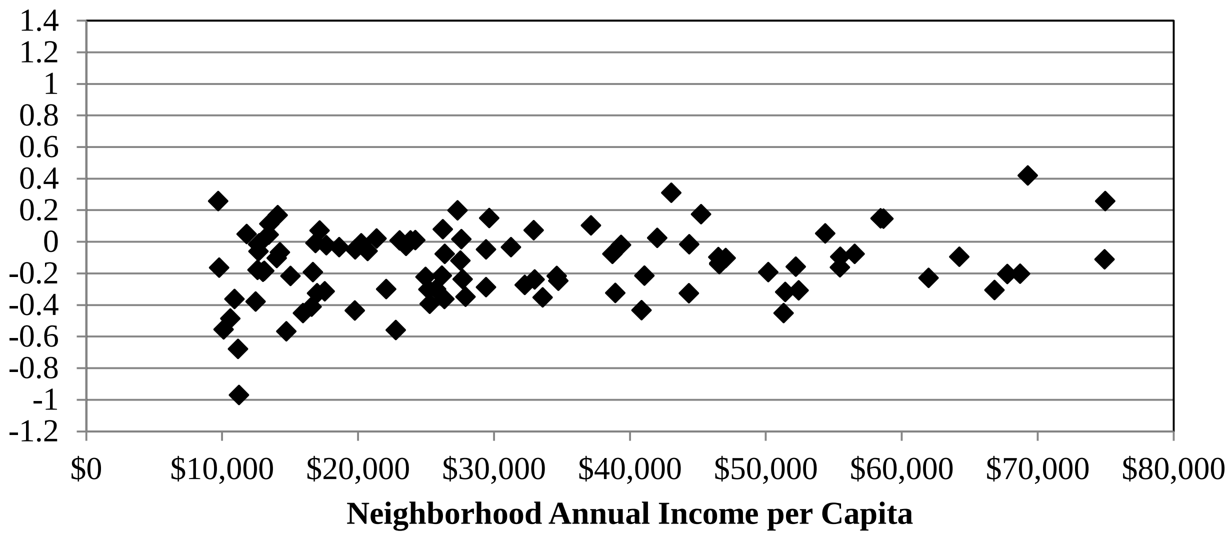
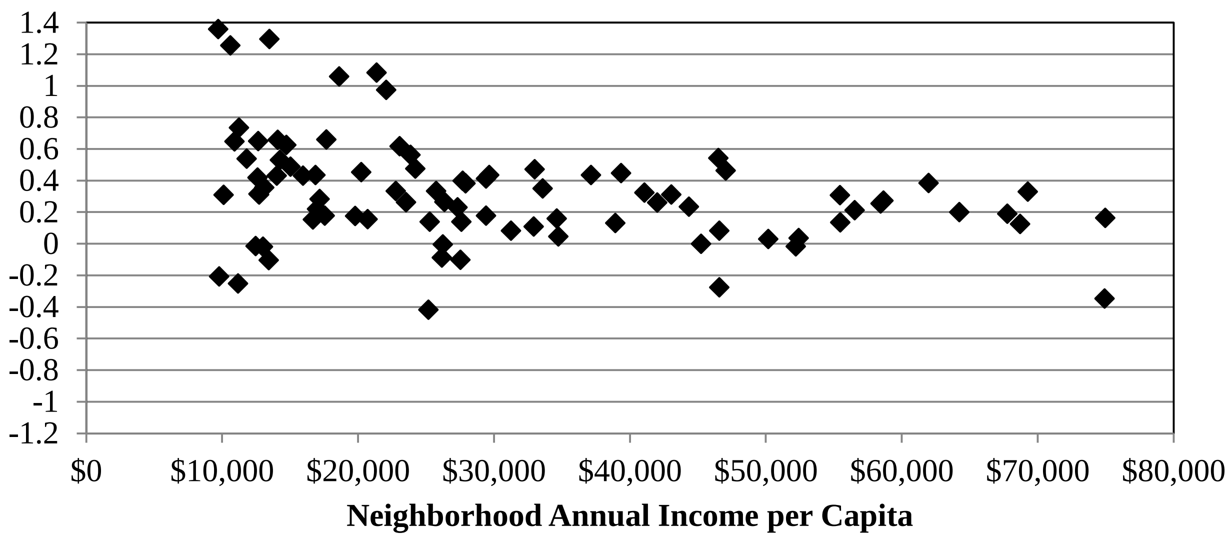
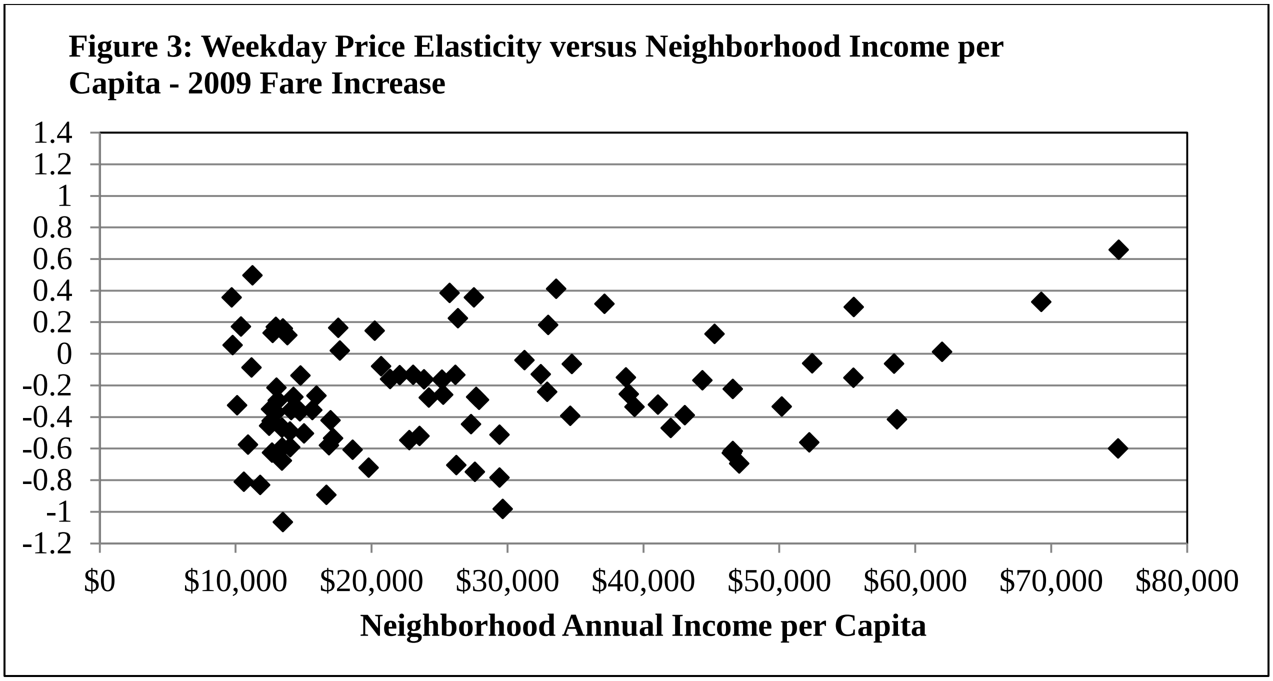


Figure 2: Weekday Price Elasticity versus Neighborhood Income per Capita - 2006 Fare Increase





An initial observation is that one might conclude that these graphs support a proposition that price elasticity does not vary significantly with neighborhood income. In 2004 there is a positive correlation of +0.22 implying that stations in higher-income neighborhoods are more price inelastic. In 2006 the relationship is in the opposite direction with a correlation coefficient of -0.35. In 2009 the variables were essentially unrelated with a correlation coefficient of +0.06.

6. Regression Results

The nine regressions (weekdays, Saturdays, Sundays / holidays for each of the three fare increases) are shown in table 3, with t-statistics in parentheses under each estimated coefficient. The initial observation is that there is a considerable amount of "noise" in the data. The adjusted R^2 of the regressions are generally in the rage of 0.10 to 0.25, with a particularly poor R^2 of just 0.05 for Sundays and holidays in 2009. There are many factors that could explain random fluctuations in boardings at particular stations such as neighborhood gentrification and decline, special events (festivals, concerts, a good year for a sports team), and street reconstruction.

6.1 Neighborhood Characteristics other than Income

Population demographics of a neighborhood seem to have a limited effect on price elasticity. (The reader is reminded that this is an aggregate demand analysis at the neighborhood level and not a disaggregate model, so we are not directly analyzing the choices of people of different genders and ages.) There is some indication that at the 10% significance level stations in neighborhoods with more males are more price inelastic for weekend travel in 2009, but this finding is not repeated for weekdays or for the 2004 and 2006 fare increases. Also, with a couple of exceptions (Saturdays in 2009 for elderly, and Sundays and holidays in 2004 for children both at the 10% significance level only), the proportion of the population that is 14 and younger or 65 and older does not seem to affect the price elasticity.

Table 3: Regression Results on Price Elasticity (t statistics in parentheses)

	2004 Increase			2006 Increase			2009 Increase		
	Weekday	Saturday	Sunday / Holiday	Weekday	Saturday	Sunday / Holiday	Weekday	Saturday	Sunday / Holiday
Constant	-0.719 (1.89)	-0.547 (1.12)	-0.134 (0.25)	0.192 (1.72)	0.802 (1.33)	-0.089 (0.16)	-0.807 (1.63)	-1.611 (2.10)	-1.278 (1.84)
Annual income per capita	4.30×10^{-6} (2.39)	4.77×10^{-6} (2.05)	7.23×10^{-6} (2.87)	-6.23×10^{-6} (2.44)	-8.61×10^{-6} (2.96)	-4.30×10^{-6} (1.63)	5.63×10^{-6} (1.95)	2.26×10^{-6} (0.40)	5.78×10^{-6} (1.13)
Population Density	-2.17×10^{-6} (0.99)	-1.43×10^{-6} (0.50)	-2.88×10^{-6} (0.94)	-1.16×10^{-6} (0.38)	1.54 x 10-6 (0.44)	0.864×10^{-6} (0.27)	10.3 x 10-6 (3.04)	16.9×10^{-6} (3.17)	11.7×10^{-6} (2.43)
Distance from downtown	-0.017 (1.93)	-0.041 (3.48)	-0.044 (3.43)	-0.044 (3.55)	-0.041 (2.83)	-0.031 (2.34)	-0.028 (2.00)	-0.037 (1.47)	-0.013 (0.58)
Proportion of males	.873 (1.60)	1.139 (1.62)	0.599 (0.78)	-0.135 (0.18)	0.431 (0.50)	0.699 (0.89)	0.354 (0.52)	2.063 (1.94)	1.747 (1.81)
Proportion of elderly (65+)	0.482 (0.81)	0.0002 (0.00)	0.804 (0.96)	-0.611 (0.73)	-0.660 (0.69)	-0.299 (0.35)	0.677 (0.72)	2.557 (1.69)	1.239 (0.90)
Proportion of children (0-14)	0.506 (1.10)	0.675 (1.13)	1.170 (1.81)	0.170 (0.26)	-0.092 (0.13)	0.203 (0.30)	0.658 (1.00)	1.161 (1.08)	1.539 (1.58)
Adjusted R^2	0.1431	0.2274	0.1649	0.2393	0.2230	0.1083	0.1207	0.1400	0.0517
Number of Observations	99	98	98	87	86	86	95	80	80

A strong and generally consistent result is that the further a station is from downtown the more price elastic is the ridership. The only exception is for weekend travel after the 2009 fare increase. The American Community Survey also asks people about their primary mode of travel to work, and there is a negative correlation of -0.35 between the distance from downtown and the proportion of working adults who take transit to work. So it is probably not surprising that more distant stations have riders who have alternative modes available to them and consequently are more price elastic.

Population density, which we have already commented is uncorrelated with distance from downtown, does not explain price elasticity in 2004 and 2006, but is strongly related at the 1% significance level in 2009. The greater the population density, the more inelastic is the price elasticity. The 2009 result is not surprising as dense neighborhoods make switching to automobile less attractive due to congestion and parking difficulties. The surprising feature is that this result was not found for the two earlier fare increases.

6.2 Effect of Neighborhood Income per Capita

Turning to the main focus of the paper, we find the unsettling result that while higher-income neighborhoods appear to be more price inelastic after the 2004 and 2009 fare increases, the reverse is true for the 2006 increase. In 2006 demand for transit was generally increasing both on weekdays and at the weekends and the proportionate increase seems to be higher at stations in lower-income neighborhoods. While income did not significantly affect the price elasticity for weekend travel after the 2009 increase, in 2004 weekend travel was increasing and stations in higher-income neighborhoods seem to have had the largest increase.

To obtain more insights, the regressions equations are used to forecast the "price elasticity" at a station with neighborhood income at the 25th percentile in our data ($14,000 per capita) and at the 75th percentile ($42,000 per capita). To do so the non-income variables are held at their mean values. The estimates are shown in table 4.

Table 4: "Price Elasticity" Estimates at the 25th and 75th Percentile of Income per Capita assuming that other Variables are held at their Mean Values

Fare Increase Year	Type of Day	At 25th Percentile of Income per Capita ($14,000)	At 75th Percentile of Income per Capita ($42,000)
2004	Weekdays	-0.21	-0.09
	Saturdays	-0.05	0.09
	Sundays / holidays	0.28	0.48
2006	Weekdays	0.44	0.26
	Saturdays	0.58	0.34
	Sundays / holidays *	0.04	-0.08
2009	Weekdays	-0.28	-0.12
	Saturdays *	0.03	0.09
	Sundays / holidays *	0.27	0.43

* indicates that the effect of income is not statistically significant

The reader is reminded that the “elasticities” reported in table 4 represent two combined effects. The first is the effect of the fare increase, which is a shift along the demand curve, and the second is any shifts in the demand curve due to macroeconomic conditions, the price of gasoline and other exogenous effects. Therefore the values shown in this table should not be regarded as additional observations that should be added to the meta-studies of transit price elasticities.

In all three time periods, the elasticities on weekends are generally positive. The backdrop to this finding is that the renaissance of ridership on mass transit rail in Chicago in the past two decades has primarily manifested itself with strong increases in weekend ridership. CTA annual traffic reports, available on the RTAMS website, show that that between 2000 and 2014 average Sundays and holidays rail boardings increased by 82%, Saturdays by 59%, and weekdays by “only” 21%. Reasons for this may include the transition to electronic ticketing that makes casual use of the system easier, improved perceptions of personal safety at off-peak times, and increased service provision on the weekends.

Perhaps the most conventional and consistent results are found for weekdays in 2004 and 2009. Stations in neighborhoods in the 25th percentile of income are price inelastic with elasticity estimates of -0.21 in 2003-04 and -0.28 in 2009. Stations in neighborhoods at the 75th percentile of income are even more inelastic with elasticity estimates of -0.09 in 2004 and -0.12 in 2009.

Overall one is struck by the consistency of the current findings with those of Cummings et al. (1989) in Chicago in the 1980s. They also found that higher-income groups were more price inelastic for work trips (which presumably primarily occur on weekdays) whereas there were not any significant differences in fare sensitivity for non-work trips that presumably dominate on the weekends.

An alternative explanation of the weekday result might be that stations in higher-income areas are primarily used for the journey to work, which tends to be a relatively price inelastic trip purpose, whereas stations in lower-income areas have a mix of work and the more price elastic non-work trips. The present dataset does not provide information on journey purpose to pursue investigating this line of reasoning directly. However it can be indirectly investigated by analyzing whether the ratio of weekend boardings (which one would imagine are more for leisure trips) to weekday boardings varies systematically with neighborhood income. If riders in higher-income areas only use the rail system for work trips then we would expect the ratio of weekend boardings to weekday boards to be much lower than in lower-income neighborhoods. In fact there appears to be no such systematic relationship. The correlation between the ratio of Saturday to weekday boardings and neighborhood per capita income is just +0.05, and the correlation between the ratio of Sunday to weekday boardings and neighborhood per capita income is of an opposite sign and just -0.04.

7. Discussion and Conclusions

Changes in ridership following three fare increases are compared with the average per capita income, and other characteristics, of the neighborhoods surrounding 110 mass transit rail stations in Chicago that are outside of the downtown area. These stations serve neighborhoods of widely differing per capita income, with a range from $10,000 a year to $75,000 a year.

The prior literature has been rather inconclusive as to whether higher-income riders are more or less insensitive to fare increases. On one hand higher-income groups are less constrained in their budget, but on the other hand they have more options for switching to automobiles. Many readers may feel that the current results confirm this ambivalence.

The fare increases in 2004 and 2009 suggest that ridership at stations in higher-income neighborhoods is more inelastic than at stations in lower-income neighborhoods. Yet the reverse was found for the fare increase of 2006. In general ridership changes from 2005 to 2006 are quite bizarre with the strongest ridership gains, despite a fare increase, in some of the lowest income parts of the city. There have been strong increases in ridership on the weekends in recent decades, and it would seem that these ridership gains have been drawn from all parts of the city.

The most conventional results are for weekday trips after the 2004 and 2009 fare increases. The fare elasticity was -0.25 for the stations in neighborhoods at the 25th percentile of income and -0.10 for those stations in neighborhoods at the 75th percentile of income. On the face of it this would suggest that the less constrained budget of higher-income travelers trumps the increased availability of alternative modes for the journey to work.

References

Balcombe, Richard et al. (2004). *The Demand for Public Transport: A Practical Guide*. Report TRL593, Crowthorne, UK: TRL Limited.
http://www.demandforpublictransport.co.uk/

Cummings, C. Philip. et al. (1989). "Market segmentation of transit fare elasticities." *Transportation Quarterly* 43(3):407-421.

Guerra, Erick, Cervero, Robert, and Tischler, Daniel (2012). "Half-mile circle: Does it best represent transit station catchments?" *Transportation Research Record* 2276:101-109.

Halcrow Fox and Associates (1993). *London Congestion Charging: Review and Specification of Model Elasticities*. Report by Halcrow Fox and Associates, Accent Marketing Research, and the University of Leeds for the United Kingdom Department of Transport. London: U.K. Department of Transport.

Lassow, William (1968). "Effect of the fare increase of July 1966 on the number of passengers carried on the New York City Transit System." *Highway Research Record* 213:1-7.

Molnar, Joszef and Nesheim, Lars (2011). *A Disaggregate Analysis of Demand for Local Bus Service in Great Britain (excluding London) using the National Travel Survey*. Report prepared for the UK Competition Commission.
http://www.eea-esem.com/files/papers/eea-esem/2012/2382/StaticTransportModel_2011_12_15.pdf

Mackett, Roger (1990). "Exploratory analysis of long-term travel demand and policy impacts using micro-analytical simulation." In Jones, Peter (ed.), *Developments in Dynamic and Activity-Based Approaches to Travel Analysis*. Brookfield, VT.: Avebury, pages 285-405.

Mayworm, Patrick, Lago, Armando M., and McEnroe, J. Matthew (1980). *Patronage Impacts of Changes in Transit Fares and Services*. Bethesda, MD: Ecosometrics Incorporated.

Nash, Christopher A. (1978). "Management objectives, fares and service in bus transport." *Journal of Transport Economics and Policy* 12(1):70-85.

Obanini, Felix C. (1977). "Analysis of user response to the 1975 New York City transit-fare increase." *Transportation Research Record* 625:12-14.

Paulley, Neil et al (2006). "The demand for public transport: The effects of fares, quality of service, income and car ownership." *Transport Policy* 13(4):295-306.
http://dx.doi.org/10.1016/j.tranpol.2005.12.004

Savage, Ian (2004). "Management objectives and the causes of mass transit deficits." *Transportation Research Part A: Policy and Practice* 38(3):181-199.
http://dx.doi.org/10.1016/j.tra.2003.10.003

Swan, Sherril, and Knight, Robert (1979). *Denver Off-Peak Free Fare Public Transit Experiment* Washington, DC: U.S. Dept. of Transportation, Urban Mass Transportation Administration.

Transportation Research Board (2004). *Traveler Response to System Changes*, Transit Cooperative Research Project Report 95. Washington, DC: Transportation Research Board (see especially Chapter 12 "Transit Pricing and Fares").
http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_webdoc_12.pdf

Wardman, Mark (2014). "Price elasticities of surface travel demand: A meta-analysis of UK evidence" *Journal of Transport Economics and Policy* 48(3):367–384.
http://www.ingentaconnect.com/content/lse/jtep/2014/00000048/00000003/art00002