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The Relationship between Transit Ridership and Urban Decentralization: Insights from Atlanta

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Abstract

Conventional wisdom suggests that the increasing decentralization of population and employment in U.S. metropolitan areas is to blame for declining public transit mode shares and deteriorating system productivity. Proponents of this view assert that transit performs best when it connects suburbs to central business districts in more centralized urban environments. Our time-series analysis of transit patronage in Atlanta suggests that the previously reported secular decline in transit patronage is attributable to employment decentralization outside the MARTA service area but that this can be reduced if the transit system makes decentralizing employment reachable.
Introduction

This paper examines transit ridership change in a rapidly growing, but decentralizing, urban area to determine transit’s relevance in such an urban environment. The traditional view holds that transit service is effective primarily in linking suburbs to central business districts (CBD) in industrial-era metropolises whose core structure is a function of the streetcar. However, there is increasing evidence that transit can perform just as well in rapidly growing, decentralized urban areas that grew up around the automobile. In this paper, we examine the relationship between transit ridership and decentralization, over time, in Atlanta in order to derive lessons that might inform transit policy and planning. We find that transit ridership growth, in addition to being associated with service and fares, is related to the vagaries of employment growth and decline outside the Atlanta CBD. Ridership is highly sensitive to suburban employment growth within the Metropolitan Atlanta Rapid Transit Authority (MARTA) service area, suggesting that users can reach suburban jobs using MARTA trains and buses.

Literature Review

Many scholars have pointed to the decentralization of population and employment in U.S. metropolitan areas as a primary cause of the decline in transit mode share (Ferreri, 1992; Jones, 1985; Meyer, Kain, and Wohl, 1965; Pisarski, 1996). These authors imply that transit is tied to a traditional, mono-centric urban form, and that, as this urban form disappears, transit will decline. But there are exceptions, as Pisarski (1996) notes in the cases of Orlando, Tampa, Phoenix, San Diego, Houston, and Los Angeles.
A number of policy analysts have concerned themselves with determining how much demand exists for transit as urban form is restructured around the automobile. The consensus holds that transit demand is tightly connected to the link between suburb and CBD in industrial-era metropolises (Pucher and Renne, 2001; Pushkarev and Zupan, 1977; Pushkarev and Zupan, 1980). The policy implication of this view is that transit agencies should structure their service to connect neighborhoods to the CBD, as shown in the left panel of Figure 1. Further, many scholars hold that attempts to serve decentralized, auto-oriented suburbs are futile because, not only are population and employment dispersed, but the urban form mitigates against walking from transit vehicles to or from origins and destinations (Ferreri, 1992; Meyer, Kain, and Wohl, 1965; Meyer and Gomez-Ibanez, 1981; Pucher, Markstedt, and Hirschman, 1983; Taylor, 1991).

(Figure 1)

Despite this scholarly consensus, evidence is mounting that transit can be as vital in many auto-oriented areas that lack strong CBDs as it is in more traditional urban environments. Our own research has shown that not only transit use but also productivity has improved in auto-oriented metropolitan areas where transit managers have decentralized service to reach dispersed employment centers (Brown and Thompson, 2005; Thompson and Brown, 2006). This multidestination approach to transit service structure is shown in the right panel of Figure 1. In many urban areas that have adopted a multidestination approach, both ridership (adjusted for population) and productivity have overtaken that for transit systems serving more traditional urban settings. These findings have prompted us to take a closer look at the relationship between transit ridership and decentralization in individual metropolitan areas.
The Study

This paper examines trends in public transit usage in a major metropolitan area that has been undergoing rapid growth accompanied by decentralization of population and employment. The technique that we use is time-series analysis, with which we compare patterns of transit patronage change over time with patterns of growth and decentralization of population and employment. From the time-series comparisons, we make inferences about the strength of transit service demand in the face of decentralization. We do not examine issues related to transit finance or service productivity in this paper.

The metropolitan area that we study is Atlanta and the transit agency that we examine is the Metropolitan Atlanta Rapid Transit Authority (MARTA). We selected Atlanta and MARTA because we were able to obtain data going sufficiently far back in time to permit the use of time-series analysis. In our analysis, we estimate two time-series models containing measures of employment and population decentralization with controls for fare, service, motor fuel price, and income. The time frame of our analysis is 1978 to 2003, the earliest and most recent years, respectively, for which we could obtain information for all the variables we examine.

Our objective is to explain observed transit patronage in terms of explanatory variables that other authors have used in similar investigations. We determine whether there is any indication that transit patronage is influenced by decentralizing population and employment. We distinguish between population and employment that are within the geographic area served by transit versus outside it. In addition, we look within the transit service area at the distribution of employment between CBD and non-CBD locations.
Our approach follows that of Gomez-Ibanez (1996) for Boston and Kain (1997) for an earlier analysis of Atlanta. From their work, these authors drew inferences about the relationship between transit patronage and decentralization, even though they did not make use of variables measuring, for example, the percent of population or employment within walking distance of transit stops or the speed of individual transit routes. While such variables could be developed for today’s circumstance using geographic information systems analysis or transportation demand modeling, they are unavailable for time-series analysis and hence were not used by these authors. They are also unavailable for our study, and thus our approach is identical to theirs. Like Gomez-Ibanez (1996) and Kain (1997), we make spatial inferences from more aggregate measures of decentralization. This is a standard approach to examining these issues.

The Decentralization of Atlanta

The twenty-county Atlanta Metropolitan Statistical Area (MSA) is a rapidly growing and increasingly decentralized urban region. (The sources for the data cited in this section and the following one are discussed in the data section of the paper.) Between 1970 and 2000, the MSA population grew from 1.76 million to 4.11 million, an increase of 133 percent (see Table 1). Population has grown faster outside the core of Fulton and De Kalb counties. In 1970, fifty-eight percent of the MSA population lived in Fulton and De Kalb counties. In 2000, only thirty-six percent of the MSA population lived in these two counties.

(Table 1)
Employment grew even faster than population, nearly 260 percent between 1970 and 2000. In 1970, the Atlanta MSA contained 610,000 jobs (346 jobs per 1,000 residents). In 2000, the Atlanta MSA contained nearly 2,200,000 jobs (535 jobs per 1,000 residents). As was the case with population growth, employment growth has been most rapid outside the core counties of Fulton and De Kalb, although employment remains more centralized than does population.

Figure 2 illustrates the gradual decentralization of employment between 1970 and 2000. In 1970, employment in the Atlanta MSA was highly centralized in Fulton County which contained more than sixty percent of the region’s 610,000 jobs (375,000 jobs). By 2000, Fulton County’s share of MSA employment fell to thirty-three percent of the region’s 2,200,000 jobs (731,000 jobs). During this period, De Kalb County, located east of Fulton County, emerged as a major employment center. De Kalb County’s share of MSA employment increased from just under fourteen percent in 1970 (84,000 jobs) to just under sixteen percent in 2000 (347,000 jobs). Combined, the two core counties accounted for about forty-nine percent of MSA employment in 2000.

(Figure 2)

By 2000, three other counties adjacent to the core counties emerged as major employment centers: Cobb County (located west of Fulton County) had nearly 314,000 jobs, Gwinnett County (located east of Fulton and De Kalb Counties) had 292,000 jobs, and Clayton County (located south of Fulton County and the site of Hartsfield-Jackson Atlanta International Airport) had 136,000 jobs. By 2000, all these counties had more than 600 jobs per 1,000 residents, indicating that they are employment centers as opposed
to bedroom suburbs. All other counties had fewer than 40,000 jobs each and a relatively low level of employment per 1000 residents (see Figure 2).

Figure 2 overlays the then-current MARTA rail system atop the distribution of employment in the panels for 1980, 1990, and 2000. The figure shows that MARTA rail service is restricted to a small portion of the two core counties, and that its expansion between 1980 and 2000 has not paced the decentralization of MSA employment. This is largely a function of MARTA’s history, which we discuss later.

Figure 3 shows the distribution of employment, by super district, within Fulton and De Kalb counties in 2003, the latest year for which data are available. Super districts are aggregations of census tracts used for planning purposes (Atlanta Regional Commission, 2006a). The present MARTA rail system and its stations are overlaid atop the distribution of employment. The figure shows that employment within the core counties is concentrated in the super districts that lie north of the Atlanta CBD and very little employment lies south of the Atlanta CBD. Between 1980 and 2003, employment within the CBD grew by 17.8 percent to 109,637 jobs. At the same time, employment within the MARTA service area but outside of the CBD grew by 60.1 percent, reaching 913,363 jobs in 2003. Most of the core counties’ employment growth has been north of the Atlanta CBD, in the Buckhead, Sandy Springs, and North Fulton super districts within Fulton County and the Chamblee super district within De Kalb County. Each of these super districts had more than 80,000 jobs in 2000 (see Figure 3). MARTA provides rail service to all these super districts except North Fulton. The annual growth of employment within the MARTA service area outside of the CBD is an indicator of decentralization with the transit service area.
The decentralization of population and employment poses challenges to transit managers seeking to provide service that connects riders to the increasingly dispersed destinations they wish to reach. Our particular interest is the influence of employment decentralization on ridership, because (as is done in transportation demand models) the distribution of employment can be viewed as a proxy for other travel destinations whose distribution tends to follow that of employment, including entertainment, shopping, personal business, and educational sites. These sites represent most of the places transit riders wish to reach. Only one category of travel, visiting friends and relatives, is not related to employment location. In the next section, we turn our attention to MARTA and examine its ridership trend during this period of decentralization in the Atlanta MSA.

MARTA’s Performance in a Decentralizing Metropolis
MARTA is the primary transit provider in the Atlanta MSA. MARTA was the only public transit service provider in the region until July 1989 when Cobb Community Transit (CCT) began service. In the past few years, three other agencies began to offer transit service: Clayton County Transit (C-Tran), Gwinnett County Transit (GCT), and the Georgia Regional Transportation Authority (GRTA) XPRESS commuter service. Much of the service provided by these agencies feeds into MARTA rail stations or runs directly into the Atlanta CBD. Of these four newer agencies, only CCT provides a significant amount of service. Even so, it accounts for a mere four percent of transit patronage (passenger kilometers). By contrast, MARTA carried more than ninety-three percent of all Atlanta MSA transit riders (passenger kilometers) in 2003.
As Figure 4 shows, MARTA’s bus and rail service is largely restricted to the two core counties, Fulton and De Kalb. This is a result of the region’s transit history (Skinner, 2006). During the 1940s Atlanta CBD business leaders first conceived of building a new rail rapid transit system linking the suburbanizing and affluent northern counties with the CBD as a means of preserving the CBD’s dominant economic position and offering office workers an alternative to the automobile for what was becoming an increasingly congested auto commute. By the 1960s, poorer inner-city areas to the east, west, and south of the CBD made appeals to equity in arguing for a seat at the table planning rapid transit, and their efforts resulted in the inclusion of an east-west line and a southward extension in the region’s rail transit plans. Ultimately when the creation of the district to build the rail system came up for a vote in 1971, Cobb and Gwinnett Counties in the northwest and northeast dropped out, leaving a service area for what became known as MARTA composed of only Fulton and De Kalb Counties.

(Figure 4)

As part of the successful 1971 vote, MARTA acquired the Atlanta Transit System (ATS), which operated a large number of bus routes that connected neighborhoods in Fulton and De Kalb Counties with the Atlanta CBD, and reduced fares to 15 cents for a period of seven years. This fare reduction program ended in 1979 when fares rose to 25 cents, by which time the rail construction program begun in 1975 was well under way. As new rail stations opened, MARTA rerouted bus lines into them and discontinued the parts of some bus routes that previously ran into the CBD. The purpose here was to improve transit productivity by replacing as many bus kilometers with as few train kilometers as possible.
MARTA patronage grew steadily during the mid 1970s as riders took advantage of the reduced fare program (see Figure 5). Patronage growth then slowed, only to rebound strongly during the energy crisis of 1979-80 just as the first rail line opened. A recession on the heels of the energy crisis brought ridership down, but ridership began climbing again in the mid-1980s. Another patronage spike occurred with the 1996 Olympics and the economic boom of the late 1990s. Patronage decline after 2001 corresponds with declining employment inside the MARTA service area after that date.

(Figure 5)

Passenger kilometers followed a similar trend (see Figure 6), with the significant exception that the average distance traveled by rail passengers began to grow soon after the first rail line opened, and continues to increase to the present time (see Figure 7). In contrast, the average trip length of bus passengers has remained roughly constant throughout this period. According to conversations with MARTA staff, the lengthening of rail trips is a function of two suburban travel phenomena, which can be understood with reference to the spatial pattern illustrated in Figure 8 (MARTA, 2006). First, several rail stations in the northern suburbs of Fulton County have become major destination stations, including Buckhead, Dunwoody, Lindbergh, and Sandy Springs, and a number of people from southern Fulton and De Kalb counties travel long distances via MARTA to reach the increasing number of employment and other destinations near these stations. Second, since the line reached the airport in 1988, passengers from the northern parts of Fulton and De Kalb Counties have used special parking lots adjacent to stations in those areas to park their cars and ride trains to the airport.

(Figure 6)
Another relatively new passenger movement that may be occurring as an outgrowth of truncating bus lines in rail stations is bus passengers riding from suburban residences to jobs in the suburbs. When buses enter a suburban station to feed or be fed by trains, they have the potential of feeding or being fed by each other as well. While not planned, this type of bus-to-bus passenger movement appeared at the northern stations of the Dallas light rail system (Thompson, 2006). In some northern stations in Dallas its magnitude exceeds bus-to-rail passenger movements. The phenomenon occurs where buses serve large concentrations of jobs near suburban stations, which happens throughout north Dallas but not in south Dallas. Unfortunately, MARTA does not have transfer data to confirm whether such movements are occurring at its northern stations where concentrations of jobs are near bus lines serving northern stations, but because such movements are occurring in similar settings in Dallas, it is likely that they are occurring in Atlanta as well.

In examining MARTA’s ridership over the past three decades, it appears to us that it is linked to employment growth within the area it serves and is constrained because it does not serve employment in the rapidly growing outer counties. We decided to statistically examine the relationship between ridership and employment both inside and outside the area MARTA serves.

Analysis of the Relationship between Transit Ridership and Decentralization
We estimate two time-series models that explain ridership as a function of employment decentralization as well as variables that control for fares, service levels, motor fuel prices, income, and the decentralization of population. The first model incorporates a trend variable, while the second model excludes it in order to determine whether the remaining explanatory variables are sufficiently powerful predictors of ridership. Our models cover the time period 1978 to 2003. The next sections of the paper discuss: 1) ridership measures, 2) data and sources, 3) hypotheses, 4) model specification, and 5) model results.

Ridership Measures

Transit ridership can be measured several ways, including using unlinked passenger trips, linked passenger trips, and passenger kilometers. Unlinked passenger trips, or boardings, are problematic measures because they double count transfers and thus inflate patronage figures for transit systems with high levels of transfer activity. Linked passenger trips represent the number of linked trips taken by transit. Linked trips include transfers as encompassing portions of a single trip, and do not double count them. Passenger kilometers measure the distances riders travel in a transit vehicle. One passenger riding one kilometer consumes one passenger kilometer of service.

For our time-series analysis, we use linked passenger trips per capita as our measure of transit ridership, because this is the best ridership measure for which we could obtain data for our entire study period. Table 2 reports linked passenger trips per capita from 1978 to 2003. The table shows a long-term decline in per-capita ridership, slightly less than 3 percent annually over the entire study period. Figure 5 showed that linked
passenger trips increased slightly (around 6 percent) between 1978 and 2003, but ridership has not kept pace with rapid population growth in the Atlanta metropolitan area. We would have also liked to estimate models using passenger kilometers, but passenger kilometer data are only available back to 1984.

(Table 2)

Data and Sources

We obtained data from the Atlanta Regional Commission, U.S. Bureau of Labor Statistics, U.S. Bureau of Economic Analysis, U.S. Census Bureau, Metropolitan Atlanta Rapid Transit Authority, and National Transit Database. The upper half of Table 3 lists the set of employment, population, price index, and transit variables we collected for the study. The lower half of the table lists ten variables that we calculated using these variables.

(Table 3)

We used the combination of two variables to measure employment decentralization. These two variables are: (1) number of employees inside the MARTA service area outside the Atlanta CBD (De Kalb County employment plus Fulton County employment minus Atlanta CBD employment), and (2) ratio of employment outside the MARTA service area to employment inside the MARTA service area (including the Atlanta CBD). The first variable measures the amount of non-CBD employment in the MARTA service area, and thus reflects the magnitude of employment. As discussed earlier, this variable is also a measure of decentralization within the MARTA service area. The second variable measures the relative distribution of employment inside versus outside the MARTA service area, and is thus a measure of decentralization at the
metropolitan scale. We also estimated a model treating this variable as a magnitude variable, but there was no difference in the variable’s effect on model results. We measure population decentralization using the ratio of population outside the MARTA service area to population inside the MARTA service area.

Hypotheses

We developed hypotheses about the effects of each of our explanatory variables on transit ridership. The hypothesized effects are discussed below:

(1) Vehicle service kilometers. We expect that ridership will increase as MARTA adds service.

(2) Percent of vehicle service kilometers by rail. We expect to find a positive relationship, because increased rail service provides more opportunities for bus-to-bus, as well as bus-to-rail, transferring, as discussed earlier.

(3) Average fare per linked passenger trip (adjusted to 2005 dollars). We expect that ridership will fall as the fare increases.

(4) Atlanta MSA motor fuel price index. We expect that as the real price of fuel increases, transit ridership will grow.

(5) Per capita income (adjusted to 2005 dollars). We expect that as income rises, ridership will increase as a reflection of increased economic activity. Even if transit riders are low income people, their propensity to use transit will increase as their incomes rise and they seek to reach employment and other travel destinations.
(6) Number of employees inside MARTA service area (outside the CBD). We use this as one of our two employment decentralization variables. Based on the ridership discussion earlier in the paper, we suspect that MARTA’s service is reaching non-CBD employment inside its service area. Thus, we expect that as MARTA service area employment decentralizes (i.e. the number of jobs inside the MARTA service area but outside the CBD increases), MARTA ridership increases.

(7) Ratio of employment outside the MARTA service area to employment inside the MARTA service area. We expect that as MSA employment decentralizes (i.e. the ratio increases), MARTA ridership falls, because of the competitive pull that major new destinations outside of the service area exerts on persons living within the service area when they are deciding to which destinations within the region that they wish to travel. A person riding a bus to an aging K-Mart within the transit service area might wish to abandon the K-Mart destination and bus mode of travel after a glamorous new Super Wal-Mart opens outside of the service area and is reachable only by auto. If the person has no car, they may prevail on a friend to give them a ride to the Super Wal-Mart.

(8) Ratio of population outside the MARTA service area to population inside the MARTA service area. We expect that as MSA population decentralizes (i.e. the ratio increases), MARTA ridership falls.

(9) Olympics. We expect to see a positive effect on ridership due to the 1996 Olympics in Atlanta.
Trend variable. The trend variable functions as follows: in 1978 it takes a value of 0, in 1979 it takes a value of 1, and in each subsequent year its value increases by 1 for each year. The parameter of the trend variable will tell us how much transit ridership will change each year if all other variables are held constant. If the parameter is positive, transit ridership will rise; if it is negative, ridership will fall. We expect the parameter to be zero because our a priori expectation is that the two employment variables capture this phenomenon. We therefore expect the second time-series model, which excludes the trend variable, to be as powerful a predictor of ridership as the first model that includes the trend variable.

We also tested models using CBD employment as an explanatory variable, but found that it was not a significant influence on ridership when we controlled for the set of other explanatory variables. This is perhaps not surprising given the very modest change in CBD employment over our study period compared to the rapid growth in employment outside the CBD.

One variable that we do not include in our model is travel time (or, alternately, speed). While this variable could be obtained for the present time, it is not available over the entire time series. By excluding it, we assume that travel time does not vary enough over space or over time to make a statistical difference in our analysis. Respected transportation analysts such as Gomez-Ibanez (1996) and Kain (1997) have made this assumption in their own work. They have investigated transit demand over time using constant elasticity or ordinary least squares regression models that do not include a travel time (or speed) variable. Our approach thus follows these other scholars.
**Model Specification**

Using the variables discussed above, we specified our models. We began with the commonly used constant elasticity model, which we modified for use with our time-series dataset. Equation 1 presents the original formulation of our first time-series model:

**Equation 1**

\[
LPT_t = \beta_0 \cdot VKM_t^{\beta_1} \cdot PCTRAIL_t^{\beta_2} \cdot FARE_t^{\beta_3} \cdot FUEL_t^{\beta_4} \cdot PCI_t^{\beta_5} \cdot EMPMARTA_t^{\beta_6} \cdot RATIO\_EMP_t^{\beta_7} \cdot RATIO\_POP_t^{\beta_8} \cdot \exp(\beta_9 \cdot OLYMPICS_t) \cdot \exp(\beta_{10} \cdot TREND_t)
\]

where \(LPT_t\) = annual linked passenger trips per capita for year \(t\), where \(t = 0\) for 1978 and increases by 1 unit for each year thereafter;

\(VKM_t\) = annual vehicle kilometers of service for year \(t\);

\(PCTRAIL_t\) = percent of vehicle kilometers for year \(t\) that are railcar miles;

\(FARE_t\) = average fare per linked trip (2005 dollars) for year \(t\);

\(FUEL_t\) = an index of motor fuel prices for year \(t\);

\(PCI_t\) = per capita income (2005 dollars) for year \(t\);

\(EMPMARTA_t\) = the level of employment within the MARTA service area, excluding the CBD, for year \(t\);

\(RATIO\_EMP_t\) = ratio of employment outside of MARTA service area to the employment inside of MARTA service area (including CBD) for year \(t\);

\(RATIO\_POP_t\) = ratio of population outside of MARTA service area to the population inside of MARTA service area (including CBD) for year \(t\).
OLYMPICS\(_t\) = a dummy variable indicating whether the Olympics occurred that year (for 1996 it equals 1; for all other years it equals 0); and,

TREND\(_t\) = trend variable, which is 0 for 1978 and which increases by 1 for each succeeding year.

The \(\beta\) terms are parameters to be estimated.

We examined the variables in Equation 1, and discovered that the data were not stationary. The variables exhibited clear trends. To obtain a stationary model, we modified equation 1 by dividing it by the same equation for the preceding year. The result is equation 2.

\hspace{1cm} \textbf{Equation 2}

\[
\frac{LPT\(_t\)}{LPT\(_{t-1}\)} = \left[ \frac{VKM\(_t\)}{VKM\(_{t-1}\)} \right]^\beta_1 \left[ \frac{PCTRAIL\(_t\)}{PCTRAIL\(_{t-1}\)} \right]^\beta_2 \left[ \frac{FARES\(_t\)}{FARES\(_{t-1}\)} \right]^\beta_3 \left[ \frac{FUEL\(_t\)}{FUEL\(_{t-1}\)} \right]^\beta_4 \left[ \frac{PCI\(_t\)}{PCI\(_{t-1}\)} \right]^\beta_5 \left[ \frac{EMPMARTA\(_t\)}{EMPMARTA\(_{t-1}\)} \right]^\beta_6 \\
\left[ \frac{RATIO\_EMP\(_t\)}{RATIO\_EMP\(_{t-1}\)} \right]^\beta_7 \left[ \frac{RATIO\_POP\(_t\)}{RATIO\_POP\(_{t-1}\)} \right]^\beta_8 \exp(\beta_9 \ast (OLYMPICS\(_t\) - OLYMPICS\(_{t-1}\))) \ast \exp(\beta_{10}) .
\]

The modification results in the loss of the constant, \(\beta_0\), but it creates a new constant, which is the exponential of \(\beta_{10}\). The new constant arises, because the difference in the TREND variable between all pairs of years is 1.

Equation 2 is a widely used model for assessing demand for public transit (TRL, 2004). To estimate it, we transformed the model by taking natural logs of both sides of the equation. Our new dependent variable is the difference in natural logs of linked passenger trips per capita. Our independent variables are differences in the natural logs for each of the variables except for OLYMPICS, which is the difference in the variable
itself from one time period to the next. (This is because the natural log of an exponential is one.) The new constant in the transformed model is $\beta_{10}$, which is the parameter for the TREND variable. Our second model specification, which excludes the trend parameter (the constant), is nearly identical to Equation 2. It simply excludes $\beta_{10}$.

We estimated this model using ordinary least squares regression, and found that the Durbin-Watson statistic indicated the presence of autocorrelation. Autocorrelation means that the residuals at different time periods are correlated (SPSS, 2004). Residual plots indicated the presence of first-order auto correlated residuals. To correct for autocorrelation, we estimated our model using the Prais-Winsten auto regression procedure, which corrects for first-order auto correlated residuals (SPSS, 2004).

**Model Results**

We estimated two time-series models that explain MARTA transit ridership between 1978 and 2003. Both models are presented in Table 4. The first model includes the constant, which is the parameter for the trend variable, while the second model excludes the constant. Because our model variables represent the differences in the natural logs of the original variables, we can interpret the coefficients directly as elasticities of the variables with respect to transit ridership. In the first model, the constant can be interpreted directly as the coefficient of the trend variable, as a result of the transformation shown in Equation 2.

(Table 4)

The first model is displayed in the left panel of Table 4. This model includes nine explanatory variables, plus a constant which is the exponential of the coefficient for the
trend variable. The Durbin-Watson statistic (DW = 2.079) indicates no autocorrelation. (This finding was also confirmed through the use of residual plots.) The adjusted R squared (.904) indicates that this is a powerful model with a statistically significant collection of explanatory variables. Eight of the nine explanatory variables behave as hypothesized, with the exception being the variable for population decentralization, which is not statistically significant.

Three explanatory variables are statistically significant in model 1. As expected, the service and fare variables are significant influences on transit ridership, with elasticities that are consistent with values reported in the scholarly literature (.55 and -.35, respectively) (TRL, 2004). Both variables reflect policy decisions about fare and service that are under the control of transit agency managers.

Model 1 indicates that employment beyond the MARTA service area does not have a statistically significant effect on ridership, although the sign on the coefficient is in the expected direction. By contrast, employment that is outside the Atlanta CBD but inside the MARTA service area positively influences transit ridership, also as expected. The implication, based on both the statistical analysis presented here and the descriptive discussion earlier in the paper, is that MARTA is successfully serving dispersed employment centers within De Kalb and Fulton counties. The population decentralization variable is not statistically significant.

The constant is the exponential of the trend variable parameter ($\beta_{10}$). The results show $\beta_{10}$ to be -0.051, and its exponential is .95. The constant indicates, all else equal, that predicted linked trips per capita in any given year will be .95 times those in the preceding year; that is, the model indicates a secular decline in linked trips per capita of 5
percent per year compounded. Because MARTA’s observed linked trips per capita have declined at roughly three percent per year compounded since 1995, much less than the secular trend of five percent (see Table 2), other variables must be exerting a compensating effect on patronage per capita. The model indicates that the variable which has been having this countervailing effect is employment growth within the MARTA service area but outside of the CBD.

Model 2 is displayed in the right panel of Table 4. This model removes the trend variable. The Durbin-Watson statistic (1.849), in conjunction with the use of residual plots, indicates no autocorrelation. This model is also a statistically powerful model (adjusted R square = .890), although it is slightly less powerful than the first model. The same three explanatory variables that are significant in the first model are also significant in this model, although their elasticities are slightly reduced. One key difference between model 1 and model 2 is that the removal of the constant (which represents the trend variable) results in the employment decentralization variable (ratio of employment outside the MARTA service area to employment inside the MARTA service area) becoming highly elastic and statistically significant.

Clearly, the trend variable is a reflection of several negative influences on transit patronage over time. One of these is the decentralization of employment, as indicated by its significance in the model that excludes the trend variable. Other variables in model 1, while not statistically significant in model 2, are also clearly related to the trend variable. These variables include motor fuel price, which changes signs, and per capita income, which becomes more significant.
Both models shown in Table 4 reinforce earlier findings on the importance of transit serving decentralized employment. In previous work, we discovered that a multidestination service orientation, through which agencies orient their service to connect riders to non-CBD destinations, was an important factor underlying changes in ridership and service productivity in large U.S. metropolitan areas (Brown and Thompson 2005; Thompson and Brown 2006; Thompson, et al 2006). Statistical analysis corroborates our hypothesis that ridership fluctuates as a function of employment in the service area, but is not linked to employment fluctuation in the Atlanta CBD. Thus, our analysis confirms our original suspicion that MARTA is successfully reaching non-CBD employment in Fulton and De Kalb counties. As employment grows outside the CBD, but within the service area, MARTA ridership increases.

Discussion

Our Atlanta model results support many widely held notions from the transit literature. The models show that more service and lower fares increase patronage. The second model also shows that employment growth outside the transit service area has a large and negative impact on transit ridership, all else held equal. The trend variable obscures this variable’s influence in model 1. The implication here is that MARTA needs to serve employment outside its service area if it is to grow its per-capita ridership.

Both models indicate that the other employment decentralization variable, suburban employment within MARTA’s service area, is also strong and statistically significant. This variable’s growth has slowed dramatically in recent years, as employment growth has shifted to areas now beyond MARTA’s service reach.
The combination of the two variables points to a single service strategy: provide access to dispersed employment clusters. If more employment growth had occurred inside the MARTA service area, instead of outside it, both models suggest that per-capita ridership would have increased. Or, if MARTA had extended service to reach employment growth outside the service area, both models indicate per-capita ridership would have increased. Serving decentralized employment is thus integral to MARTA’s ridership success.

Many readers may find this relationship surprising, given the literature’s widely-stated assertion that suburban employment is too scattered to be served effectively by conventional fixed-route transit. In some places this might be true, but in others it clearly is not. In fact, many transit systems in the United States are increasing their ridership per capita and this increase is coming from the service they provide to suburban employment concentrations (Thompson and Brown, 2006; Thompson and Matoff, 2003). For example, the most heavily traveled bus route in Portland, Oregon operates along an arterial road lined with strip malls, big-box retail outlets, regional malls, and the like five miles east of the CBD (Kimpel, 2001). This route connects to a light rail station, allowing patrons of the bus route to access all destinations served by the transit network and patrons on the network to access the destinations along the bus route. When Portland extended its light rail line to its western suburbs, total patronage on the entire transit system increased 16 percent, with only a 9 percent increase in service, because the transit network now connected moderate income households in the eastern part of the region to concentrations of suburban jobs in the western part of the region, some of which are directly accessible from light rail stations and others which require bus transfers (Tri-Met, 2007). Portland is
one of a handful of metropolitan areas in the country that have increased ridership and increased productivity through their strategy of providing better connections to suburban jobs (Brown and Thompson, 2007). Thus, as we contemplate the evidence from Atlanta, we see that it fits into a larger pattern of transit systems successfully serving suburban employment concentrations.

These findings are also consistent with Downs (2004) who reports that transit agencies can increase their ridership by serving employment concentrations. Furthermore, Downs (2004, citing Pushkarev and Zupan, 1977 and 1980) states that serving suburban employment concentrations is a more important determinant of transit ridership than serving suburban population clusters. Our model clearly suggests that structuring service to reach employment concentrations is more important than serving population concentrations, and is thus consistent with this earlier observation.

If MARTA is serving suburban employment within its service area well enough for the growth of such employment to increase its patronage, would it not be possible for MARTA to cost-effectively increase its ridership by serving employment clusters now outside of its service area? Until we know more about how MARTA is serving its suburban employment, we cannot answer this question. Obviously, MARTA’s service area has been legally defined. However, if it could change its service area boundaries, the task of serving these additional decentralized employment concentrations may not be daunting. As Figure 2 shows, most employment growth is in the inner four counties of the twenty-county region, and it may be sufficient to confine a core network of trunk routes to employment clusters within those four counties rather than spreading it over the entire region. This is a very different approach than that now being taken in many urban
areas, which is to attempt to connect far-flung suburbs throughout the extended metropolitan region to the CBD. The latter concept is indeed a daunting (and expensive) task, and likely of limited effectiveness given the stagnant nature of CBD employment. Obviously, more research is needed to determine whether a destination-based concept of interlinked trunk routes targeted on employment clusters in the major employment-rich counties would be more effective than the typical origin-based route structure concept, but we think that the evidence that we have from Atlanta is tantalizing enough to warrant that investigation.

References
Atlanta Regional Commission. (2006a) ARC Employment Data. Personal e-mail communications with Mike Carnathan of ARC on May 31, 2006 and June 1, 2006.

Atlanta Regional Commission. (2006b) Transit Shapefiles. Personal e-mail communications with Jim Bohn of ARC on June 20, 2006.


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Traditional approach: Connecting neighborhoods to CBD, but jobs outside of CBD difficult to reach

Multi-destination approach: Connecting destinations to each other
Figure 2. Employment (by County) in Atlanta MSA: Number of Jobs (1970-2000)

Figure 3. MARTA Rail System in Relation to Super District Employment in MARTA Core Counties (2005)

Legend
- Rail Stations
- MARTA Rail

Jobs
- Under 40,000
- 40,001 - 80,000
- Over 80,000

Sources: Atlanta Regional Commission (2006a, 2006b)
Figure 4. MARTA Bus and Rail System (2006)

Legend

- MARTA Rail System
- MARTA Bus Routes
- MARTA Core Counties

Source: Atlanta Regional Commission (2006b).
Figure 5. Transit Ridership Trend in Atlanta (MARTA): Linked Passenger Trips (1972 - 2003)

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Figure 7. Change in Average Length of Linked Passenger Trips (MARTA) (1984-2003)

Source: Calculated from FDOT (2005) and MARTA (2006).
Figure 8. Schematic of Employment Patterns in Atlanta
Table 1. Population Growth in the Atlanta MSA (1970-2000)

<table>
<thead>
<tr>
<th>County</th>
<th>1970</th>
<th>2000</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrow</td>
<td>16,859</td>
<td>46,144</td>
<td>174%</td>
</tr>
<tr>
<td>Bartow</td>
<td>32,911</td>
<td>76,019</td>
<td>131%</td>
</tr>
<tr>
<td>Carroll</td>
<td>45,404</td>
<td>87,268</td>
<td>92%</td>
</tr>
<tr>
<td>Cherokee</td>
<td>31,059</td>
<td>141,903</td>
<td>357%</td>
</tr>
<tr>
<td>Clayton</td>
<td>98,126</td>
<td>236,517</td>
<td>141%</td>
</tr>
<tr>
<td>Cobb</td>
<td>196,793</td>
<td>607,751</td>
<td>209%</td>
</tr>
<tr>
<td>Coweta</td>
<td>32,310</td>
<td>89,215</td>
<td>176%</td>
</tr>
<tr>
<td>De Kalb</td>
<td>415,387</td>
<td>665,865</td>
<td>60%</td>
</tr>
<tr>
<td>Douglas</td>
<td>28,659</td>
<td>92,174</td>
<td>222%</td>
</tr>
<tr>
<td>Fayette</td>
<td>11,364</td>
<td>91,263</td>
<td>703%</td>
</tr>
<tr>
<td>Forsyth</td>
<td>16,928</td>
<td>98,407</td>
<td>481%</td>
</tr>
<tr>
<td>Fulton</td>
<td>605,210</td>
<td>816,006</td>
<td>35%</td>
</tr>
<tr>
<td>Gwinnett</td>
<td>72,349</td>
<td>588,448</td>
<td>713%</td>
</tr>
<tr>
<td>Henry</td>
<td>23,724</td>
<td>119,341</td>
<td>403%</td>
</tr>
<tr>
<td>Newton</td>
<td>26,282</td>
<td>62,001</td>
<td>136%</td>
</tr>
<tr>
<td>Paulding</td>
<td>17,520</td>
<td>81,678</td>
<td>366%</td>
</tr>
<tr>
<td>Pickens</td>
<td>9,620</td>
<td>22,983</td>
<td>139%</td>
</tr>
<tr>
<td>Rockdale</td>
<td>18,152</td>
<td>70,111</td>
<td>286%</td>
</tr>
<tr>
<td>Spalding</td>
<td>39,514</td>
<td>58,417</td>
<td>48%</td>
</tr>
<tr>
<td>Walwon</td>
<td>23,404</td>
<td>60,687</td>
<td>159%</td>
</tr>
</tbody>
</table>

Atlanta MSA Total 1,761,575 4,112,198 133%

*Source: US Census Bureau (2006).*
Table 2. Linked Passenger Trips (LPT) per Capita (1978-2003)

<table>
<thead>
<tr>
<th>Year</th>
<th>LPT per Capita</th>
<th>Year</th>
<th>LPT per Capita</th>
</tr>
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<tbody>
<tr>
<td>1978</td>
<td>28.89</td>
<td>1991</td>
<td>22.76</td>
</tr>
<tr>
<td>1979</td>
<td>28.76</td>
<td>1992</td>
<td>21.48</td>
</tr>
<tr>
<td>1980</td>
<td>33.00</td>
<td>1993</td>
<td>19.74</td>
</tr>
<tr>
<td>1981</td>
<td>27.27</td>
<td>1994</td>
<td>19.65</td>
</tr>
<tr>
<td>1983</td>
<td>24.62</td>
<td>1996</td>
<td>18.56</td>
</tr>
<tr>
<td>1984</td>
<td>25.23</td>
<td>1997</td>
<td>20.90</td>
</tr>
<tr>
<td>1985</td>
<td>27.07</td>
<td>1998</td>
<td>19.46</td>
</tr>
<tr>
<td>1986</td>
<td>28.40</td>
<td>1999</td>
<td>19.37</td>
</tr>
<tr>
<td>1987</td>
<td>27.27</td>
<td>2000</td>
<td>18.95</td>
</tr>
<tr>
<td>1988</td>
<td>25.28</td>
<td>2001</td>
<td>17.93</td>
</tr>
<tr>
<td>1989</td>
<td>24.59</td>
<td>2002</td>
<td>15.65</td>
</tr>
<tr>
<td>1990</td>
<td>24.86</td>
<td>2003</td>
<td>14.47</td>
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Table 3. Data and Sources

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Variable</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Atlanta metropolitan statistical area (MSA) employment (by county) (1980-2003)</td>
<td>Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td></td>
<td>Fulton county and DeKalb county employment (by planning super district) (1980-2003)</td>
<td>Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td>Transit variables</td>
<td>MARTA linked passenger trips (by mode) (1972-2003)</td>
<td>MARTA, 2006</td>
</tr>
<tr>
<td></td>
<td>MARTA passenger kilometers (by mode) (1984-2003)</td>
<td>Florida Department of Transportation, 2005</td>
</tr>
<tr>
<td>Author-calculated variables</td>
<td>Average length of MARTA bus linked passenger trips (1984-2003)</td>
<td>Calculated from variables provided by FDOT, 2005 and US Census Bureau, 2006</td>
</tr>
<tr>
<td></td>
<td>Average length of MARTA rail linked passenger trips (1984-2003)</td>
<td>Calculated from variables provided by FDOT, 2005 and US Census Bureau, 2006</td>
</tr>
<tr>
<td></td>
<td>Average MARTA fare revenue per linked passenger trip (1973-2003, in constant 2005 dollars)</td>
<td>Calculated from variables provided by MARTA, 2006, as adjusted using consumer price index to 2005 dollars</td>
</tr>
<tr>
<td></td>
<td>MARTA linked passenger trips per capita (1972-2003)</td>
<td>Calculated from variables provided by Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td></td>
<td>Number of employees in MARTA service area outside the Atlanta CBD (Fulton county employment plus DeKalb county employment minus Atlanta CBD employment)</td>
<td>Calculated from variables provided by Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td></td>
<td>Number of employees outside MARTA service area (MSA employment minus MARTA service area employment)</td>
<td>Calculated from variables provided by Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td></td>
<td>Ratio of number of employees outside MARTA service area to employees inside MARTA service area</td>
<td>Calculated from variables provided by Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td></td>
<td>Ratio of population outside MARTA service area to population inside MARTA service area</td>
<td>Calculated from variables provided by Atlanta Regional Commission, 2006a</td>
</tr>
<tr>
<td></td>
<td>Share of MARTA vehicle service kilometers by rail (1979-2003)</td>
<td>Calculated from variables provided by MARTA, 2006</td>
</tr>
</tbody>
</table>
Table 4. Atlanta (MARTA) Ridership Models

Dependent Variable: Difference in natural log of linked passenger trips per capita

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1: Model with trend variable</th>
<th>Model 2: Model without trend variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient Std. Error T statistic Significance</td>
<td>Coefficient Std. Error T statistic Significance</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.051 0.020 -2.504 0.026</td>
<td>0.564 0.189 2.988 0.009</td>
</tr>
<tr>
<td>Difference in natural log of vehicle service kilometers</td>
<td>0.553 0.168 3.303 0.006</td>
<td>0.564 0.189 2.988 0.009</td>
</tr>
<tr>
<td>Difference in natural log of percent of vehicle service kilometers by rail</td>
<td>0.000 0.009 0.045 0.965</td>
<td>0.000 0.010 0.016 0.988</td>
</tr>
<tr>
<td>Difference in natural log of average fare per linked passenger trip (2005 dollars)</td>
<td>-0.354 0.055 -6.483 0.000</td>
<td>-0.305 0.056 -5.490 0.000</td>
</tr>
<tr>
<td>Difference in natural log of Atlanta MSA motor fuel price index</td>
<td>0.001 0.042 0.012 0.990</td>
<td>-0.025 0.046 -0.542 0.596</td>
</tr>
<tr>
<td>Difference in natural log of per capita income (2005 dollars)</td>
<td>0.162 0.341 0.475 0.643</td>
<td>0.514 0.337 1.525 0.148</td>
</tr>
<tr>
<td>Difference in natural log of number of employees inside MARTA service area (outside CBD)</td>
<td>1.331 0.424 3.140 0.008</td>
<td>1.241 0.493 2.517 0.024</td>
</tr>
<tr>
<td>Difference in natural log of ratio of employment outside MARTA service area to employment inside MARTA service area</td>
<td>-0.844 0.679 -1.242 0.236</td>
<td>-1.944 0.614 -3.164 0.006</td>
</tr>
<tr>
<td>Difference in natural log of ratio of population outside MARTA service area to population inside MARTA service area</td>
<td>0.777 0.688 1.130 0.279</td>
<td>0.168 0.760 0.222 0.828</td>
</tr>
<tr>
<td>Olympics</td>
<td>0.032 0.025 1.311 0.212</td>
<td>0.040 0.026 1.553 0.141</td>
</tr>
<tr>
<td>R squared</td>
<td>0.946</td>
<td>0.936</td>
</tr>
<tr>
<td>Adjusted R squared</td>
<td>0.904</td>
<td>0.890</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.023</td>
<td>0.026</td>
</tr>
<tr>
<td>Durbin-Watson statistic</td>
<td>2.079</td>
<td>1.849</td>
</tr>
<tr>
<td>RHO (AR1)</td>
<td>-0.136</td>
<td>0.226</td>
</tr>
</tbody>
</table>