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# The Impact of Rapid Rail Transit on Economic Development: The Case of Atlanta's MARTA*

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This paper uses a simultaneous model of census tract population and employment to study the economic impacts of Atlanta's MARTA rail transit system. The results indicated that MARTA has had no discernible impact on total population or employment in station areas, but it has altered the composition of employment in these areas in favor of the public sector. 

## I. INTRODUCTION

One possible benefit of fixed rail transit systems is population and employment densification in the vicinity of rail stations resulting from the access advantage provided by these areas. Densification is considered socially beneficial because it increases transit patronage, curbs urban sprawl, generates higher tax revenues for fiscally stressed central cities, and expands the employment opportunities of people who are transit dependent. If the social benefits resulting from transit-related economic development are sufficiently large, they may offset or exceed the documented higher social cost of rail in comparison to bus transit systems (Meyer *et al.* [22]; Keeler *et al.* [19]; Straszheim [26]).

Despite the importance of quantifying the economic development effects of rail transit in conducting cost/benefit analyses, there have been

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few studies of these effects. The work that has been done has largely been descriptive in nature. No econometric model has been estimated.

The purpose of this paper is to report our findings of the effects that Atlanta's MARTA rail line (henceforth MARTA) has had on population and employment in station areas. MARTA provides a unique opportunity for studying the development effects of rail stations, since Atlanta area governments have adopted no significant public policies, other than rezoning, to encourage development in station areas. This makes it much easier to isolate the true economic effects of rail stations.

The models estimated allow the joint determination of population and employment change at the census tract level. In addition to the results on the effects that stations have had on total population and employment, separate equations are estimated for blacks and whites and nine different industry groups. Evidence on whether MARTA has altered the composition of population or employment in station areas is therefore also presented.

The results indicate that (1) MARTA has had neither a positive nor a negative impact on total population and total employment in station areas, and (2) MARTA has altered the composition of employment in favor of the public sector, but only in those areas with high levels of commercial activity.

## II. LITERATURE REVIEW

The economic development effects of a rapid rail system may occur at either the regional or the local level. Regional growth may be stimulated if the transit system improves the productivity of the region. Local impacts around stations may result if stations provide improved accessibility to locations of interest within the region. This section reviews only those studies that have attempted to quantify local impacts, since this is the exclusive focus of the present study. Moreover, except for subjective rankings of interregional locational factors obtained from firm questionnaires, there is really nothing of substance to review on regional impacts.

To investigate the local economic development impacts of rail transit, previous studies have related station proximity to either land value or population and/or employment. Given the focus here and the fact that Landis *et al.* [21] have recently reviewed the land value studies, this section examines only those studies that deal with the densification of population and employment in station areas. The focus is also limited to those studies that have been done on the newer rapid rail systems. For a review of the studies that have analyzed data on older systems, see Knight and Trygg [20].

The first study of the local development impacts of a newer rapid rail system was done by Dvett *et al.* [13] as part of the BART Impact Program

(BIP). Based upon data from BART's first 4 years of operation, this study concluded that BART had small but not inconsequential effects on land use in station areas. BART's strongest effects were found to be on office and housing construction. Regarding the former, almost all of the new office space attributed to BART was built in downtown San Francisco.

Dvett *et al.*'s methodology involved time series analyses of building permit data and aerial photographs. Before and after comparisons were made to document absolute changes. The permit data were also employed to determine whether station areas were able to capture a larger share of the region's building construction. To better assess BART's contribution to the development that occurred around stations, ''knowledgeable informants'' were interviewed.

Before and after analyses of the type conducted by Dvett, even with the input of experts' opinions, are unlikely to yield reliable quantitative evidence on the developmental impacts of rail stations. Without appropriate statistical controls, it is impossible to isolate BART's contribution. Perhaps of greatest concern is the possibility that the causality runs in the opposite direction, since stations may be placed to serve areas of major economic activity.

Recently, the land use impacts of BART have been restudied by Cervero *et al.* [10]. Their chief motivation was that the analysis conducted by Dvett was too soon after the opening of BART. Land use effects of any consequence are generally believed to take more than 4 years after the opening of a station. Cervero *et al.* analyze data covering the first 20 years of BART's existence. In comparison to Dvett, they found that BART had a stronger but still modest impact on station area development. Most of the development resulting from BART was found to be in the form of multi-family housing. They also found, like Dvett, that BART positively affected employment in downtown station areas.

Like its predecessor, much of the Cervero *et al.* study consisted of simple comparisons of population and employment changes in BART and non-BART areas. The unique part of their study involved matched pair analysis of freeway nodes and station areas. The chief matching criteria were that the pairs be within 1 to $2\frac{1}{2}$ miles of each other and be connected to the same arterial. As its name implies, matched pair analysis is an attempt to control for other factors that may obscure comparisons between station and non-station areas. However, there is no easy method of determining how closely matched selected pairs are with respect to the many factors that can influence the growth of small areas. Another problem is that the analysis of Cervero *et al.* provides information only on the developmental impacts of stations *relative* to those of highway intersections.

Another study of the local impacts of rail transit was conducted a few years after the initial BART study as part of a comprehensive analysis of Atlanta's rapid transit system. This study, identified as the Transit Impact Monitoring Program (TIMP), had several characteristics in common with the earlier BIP. First, both BIP and TIMP were conducted soon after their respective systems opened. Second, TIMP followed BIP's methodological approach of making before and after comparisons of station areas, using building permit data and aerial photographs. Third, to sort out MARTA's contribution to the development that had occurred around stations, knowledgeable informants were again consulted. TIMP also included simple comparisons of aggregate and industry level employment changes between station and non-station areas.

Two of the principal conclusions of TIMP mirrored those of BIP: (1) MARTA's developmental impacts have been far less than anticipated, and (2) impacts have been concentrated within the CBD and adjacent to several stations located on MARTA's North Line. TIMP also found that the share of the region's employment located in station areas declined during the 1970s.

The local economic development impacts of Washington, DC's rapid transit system (METRO) have been investigated by Green and James [14]. This study used employment data for 1337 traffic zones covering the years 1972, 1976, and 1980. Since METRO first opened in 1976, this study, like BIP and TIMP, may have been premature. Nevertheless, comparisons of employment levels and changes between station and non-station areas showed large differences in favor of station areas. On average, zones with stations contained $2\frac{1}{2}$ times more jobs and had employment growth that was $2\frac{1}{2}$ times greater than zones without stations. These differences were found to be statistically significant.

The procedure of testing for whether station versus non-station differences are statistically significant is an improvement over the comparisons conducted in the other studies reviewed above. However, given the timing of the Green and James study and the failure to control for other variables affecting development, the results of this study may also be of limited value.

In summary, studies of the local economic impacts of rail stations have yielded mixed results. The BART and MARTA studies found weak to modest effects, while the METRO study found more substantial effects. Since none of the studies control for non-station influences on development or address the possibility that stations are placed in areas with historically high or low population or employment density, the question of a link between transit investment and economic development remains largely unanswered. This study controls for many non-station influences.

Moreover, while a full-blown model of endogenous station location is not estimated, this study controls for endogenous placement of stations in areas with historically high or low population or employment density.

## III. THE MODEL

The local economic development impacts of MARTA are investigated by estimating simultaneous models of population and employment. A unique characteristic of the present study is that such models have never been estimated at the neighborhood (i.e., census tract) level. Steinnes and Fisher [25] were the first to estimate a simultaneous model of population and employment. Their estimates were made using a sample of 100 scattered corporate suburbs and community areas of the Chicago SMSA. Since then such models have been used to explain population and employment suburbanization (Steinnes [24]) and the growth of counties (Carlino and Mills [8]), metropolitan areas (Mills and Lubuele [23]), and municipalities (Boarnet [4, 5]). A simultaneous model has also been used to investigate the Pareto optimality of the Tiebout model (Grubb [15]). A primary theme of this literature is whether ''jobs follow people'' or ''people follow jobs.'' The evidence provided on this issue by the above studies has been mixed.

### *Simultaneous Model*

The model estimated in this study is closely related to the one Boarnet [4, 5] developed and estimated to study the determinants of municipal growth in northern New Jersey. The unique characteristic of both Boarnet's and the present model that distinguishes them from earlier simultaneous models of population and employment is that gravity or potential variables are used to measure the tract's proximity to population and employment. Such variables are necessary when the unit of observation is too small in geographical area to be considered a separate labor market. The gravity variables are endogenous in the econometric model and result in spatially lagged endogenous variables that require the use of spatial econometric techniques.

The model is a general equilibrium model that allows population and employment to be mutually affected. The location choices of households and firms are based on the standard assumptions of utility and profit maximization, respectively. Intrametropolitan relocations occur until utility and profits are equalized at alternative locations. Population and employment density will be higher where utility and profits are higher prior to complete capitalization of locational differentials into land values. Both profits and utility are assumed to be functions of MARTA proximity and other local characteristics. The advantages of MARTA to households are the savings in travel time and travel cost (both pecuniary and nonpecuniary, e.g., avoiding the disutility of driving an automobile in congested traffic). For firms, MARTA is expected to reduce labor costs by increasing labor supply, expand revenues by increasing accessibility to customers, and reduce land and/or construction costs by decreasing the need for parking spaces.

Considering the exogenous control variables in two groups, those affecting profits and those affecting utility, yields the following population and employment equations:[1]

$$\mathrm{POP}_i^* = f\left(M_i, P_i, \overline{\mathrm{EMP}}_i^*\right) \tag{1}$$

$$\mathrm{EMP}_i^* = g\left(M_i, E_i, \overline{\mathrm{POP}}_i^*\right), \tag{2}$$

where

$\mathrm{POP}_i^*$ = equilibrium population at $i$

$\mathrm{EMP}_i^*$ = equilibrium employment at $i$

$M_i$ = MARTA proximity at $i$

$P_i$ = values of variables affecting utility at $i$

$E_i$ = values of variables affecting profits at $i$

$\overline{\mathrm{EMP}}_i^*$ = equilibrium employment in a commuter shed or labor market centered on $i$

$\overline{\mathrm{POP}}_i^*$ = equilibrium population in a commuter shed or labor market centered on $i$.

Carlino and Mills [8] and Boarnet [4, 5] assume that population and employment adjust to equilibrium values with substantial lags. Both assume the same distributed-lag adjustment process,

$$\mathrm{POP}\Delta_{i,t} = \mathrm{POP}_{i,t} - \mathrm{POP}_{i,t-1} = \lambda_{\mathrm{p}}(\mathrm{POP}_{i,t}^* - \mathrm{POP}_{i,t-1}) \tag{3}$$

$$\mathrm{EMP}\Delta_{i,t} = \mathrm{EMP}_{i,t} - \mathrm{EMP}_{i,t-1} = \lambda_{\mathrm{e}}(\mathrm{EMP}_{i,t}^* - \mathrm{EMP}_{i,t-1}), \tag{4}$$

where

$\mathrm{POP}_{i,t}$ = actual population in census tract $i$ at time $t$

$\mathrm{POP}_{i,t-1}$ = actual population in census tract $i$ at time $t-1$

$\mathrm{POP}_{i,t}^*$ = equilibrium population in census tract $i$ at time $t$

where $\mathrm{EMP}_{i,t}$, $\mathrm{EMP}_{i,t-1}$, and $\mathrm{EMP}_{i,t}^*$ defined similarly. $\lambda_{\mathrm{p}}$ and $\lambda_{\mathrm{e}}$ are the estimated adjustment parameters, with values that range between 0 and 1.

[1] Our Eqs. (1)–(13), while containing different exogenous variables, otherwise reproduce equations (1)–(15) of Boarnet [4].

The validity of assuming the above lagged adjustment process can be tested by determining whether the estimates of $\lambda_p$ and $\lambda_e$ imply dynamic stability. Carlino and Mills found that their model is dynamically stable, while Boarnet found that his model is not. However, as discussed more fully below, regardless of whether dynamic stability is found, the econometric model that results from assuming the adjustment process in (3) and (4) includes the set of control variables that are necessary to isolate the MARTA effect. Equations (3) and (4) are therefore adopted.

Assuming that the equilibrium relationships expressed in (1) and (2) are linear, the substitution of (1) and (2) into (3) and (4) (and the suppression of the $i$ subscript) results in the model

$$\begin{aligned} \mathrm{POP}\,\Delta_t &= \mathrm{POP}_t - \mathrm{POP}_{t-1} \\ &= \gamma_0 + M_t\gamma_1 + P_t\gamma_2 + \gamma_3\overline{\mathrm{EMP}}_t^{*} - \lambda_p\,\mathrm{POP}_{t-1} + u \qquad (5) \\ \mathrm{EMP}\,\Delta_t &= \mathrm{EMP}_t - \mathrm{EMP}_{t-1} \\ &= \delta_0 + M_t\delta_1 + E_t\delta_2 + \delta_3\overline{\mathrm{POP}}_t^{*} - \lambda_e\,\mathrm{EMP}_{t-1} + v, \qquad (6) \end{aligned}$$

where $u$ and $v$ are mean zero random variables uncorrelated with $P_t$ and $E_t$.[2]

In order to estimate (5) and (6), the unobservable variables $\overline{\mathrm{EMP}}_t^{*}$ and $\overline{\mathrm{POP}}_t^{*}$ must be related to observable variables. Once again, a distributed-lag adjustment is introduced:

$$\overline{\mathrm{POP}}_t - \overline{\mathrm{POP}}_{t-1} = \lambda_p\left(\overline{\mathrm{POP}}_t^{*} - \overline{\mathrm{POP}}_{t-1}\right) \qquad (7)$$

$$\overline{\mathrm{EMP}}_t - \overline{\mathrm{EMP}}_{t-1} = \lambda_e\left(\overline{\mathrm{EMP}}_t^{*} - \overline{\mathrm{EMP}}_{t-1}\right). \qquad (8)$$

As Boarnet [4] notes, since the labor market variables are sums of census tract variables, they will adjust with the same lag as census tract variables.

By rewriting (7) and (8), $\overline{\mathrm{POP}}_t^{*}$ and $\overline{\mathrm{EMP}}_t^{*}$ can be expressed as functions of observable labor market variables:

$$\overline{\mathrm{POP}}_t^{*} = \overline{\mathrm{POP}}_{t-1} + \lambda_p^{-1}\left(\overline{\mathrm{POP}}_t - \overline{\mathrm{POP}}_{t-1}\right) \qquad (9)$$

$$\overline{\mathrm{EMP}}_t^{*} = \overline{\mathrm{EMP}}_{t-1} + \lambda_e^{-1}\left(\overline{\mathrm{EMP}}_t - \overline{\mathrm{EMP}}_{t-1}\right). \qquad (10)$$

[2]An alternative model can be derived by assuming that Eqs. (1) and (2) are log linear. Equations (5) and (6) would then measure percentage change in population and employment. Estimates of this model were qualitatively similar to those presented below.

Substituting (9) and (10) into (5) and (6) yields an estimable system of equations:

$$\mathrm{POP}\Delta_t = \gamma_0 + M_t\gamma_1 + P_t\gamma_2 + \gamma_3\overline{\mathrm{EMP}}_{t-1} + \gamma_4\overline{\mathrm{EMP}}\Delta_t - \lambda_{\mathrm{p}}\mathrm{POP}_{t-1} + u \tag{11}$$

$$\mathrm{EMP}\Delta_t = \delta_0 + M_t\delta_1 + E_t\delta_2 + \delta_3\overline{\mathrm{POP}}_{t-1} + \delta_4\overline{\mathrm{POP}}\Delta_t - \lambda_{\mathrm{e}}\mathrm{EMP}_{t-1} + v, \tag{12}$$

where $\gamma_4 = (\gamma_3/\lambda_{\mathrm{e}})$, $\delta_4 = (\delta_3/\lambda_{\mathrm{p}})$, $\overline{\mathrm{EMP}}\Delta_t = \overline{\mathrm{EMP}}_t - \overline{\mathrm{EMP}}_{t-1}$, and $\overline{\mathrm{POP}}\Delta_t = \overline{\mathrm{POP}}_t - \overline{\mathrm{POP}}_{t-1}$.

The labor market variables ($\overline{\mathrm{POP}}_t$, $\overline{\mathrm{EMP}}_t$, $\overline{\mathrm{POP}}_{t-1}$, and $\overline{\mathrm{EMP}}_{t-1}$) measure the census tract's proximity to jobs and population within the metropolitan area. To construct these variables, gravity formulae are employed,

$$\overline{\mathrm{POP}}_i = \sum_{j \neq i} \frac{\mathrm{POP}_j}{(d_{ij})^{\alpha}} + \mathrm{POP}_i$$

$$\overline{\mathrm{EMP}}_i = \sum_{j \neq i} \frac{\mathrm{EMP}_j}{(d_{ij})^{\alpha}} + \mathrm{EMP}_i, \tag{13}$$

where $d_{ij}$ is the distance between the centroids of census tracts $i$ and $j$. The distance exponent, $\alpha$, measures the willingness of workers to travel over greater distances. $\alpha$ is set equal to 0.67, based upon Boarnet's [6] estimate of $\alpha$ obtained from census commuting data.[3]

Estimation of Eqs. (11) and (12) must address the issue of the endogenity (or simultaneity) of the variables $\overline{\mathrm{POP}}\Delta$ and $\overline{\mathrm{EMP}}\Delta$. Anselin [1] suggests a simultaneous equations approach, which is adopted by Boarnet [4, 5]. In this approach, reduced form population and employment change equations are estimated using the exogenous regressors from both equations. The predicted values of population change ($\widehat{\mathrm{POP}\Delta}_i$) and employment change ($\widehat{\mathrm{EMP}\Delta}_i$) are then used to construct gravity variables which

[3] Values of $\alpha$ equal to 0.5, 1.0, 1.5, and 2.0 were also tried. The results are not sensitive to the choice of $\alpha$.

serve as instruments:

$$\widehat{\overline{\text{POP}}}\Delta_i = \sum_{j \neq i} \frac{\widehat{\text{POP}}\Delta_j}{(d_{ij})^{\alpha}} + \widehat{\text{POP}}\Delta_i$$

$$\widehat{\overline{\text{EMP}}}\Delta_i = \sum_{j \neq i} \frac{\widehat{\text{EMP}}\Delta_j}{(d_{ij})^{\alpha}} + \widehat{\text{EMP}}\Delta_i. \tag{14}$$

While this approach is intuitive, it may not be appropriate. If the data are drawn from a population using random sampling, then the construction of the gravity variables in the fashion suggested by Anselin is appropriate; that is, the instruments are orthogonal to the error terms in the equations. However, given the spatial characteristics of the data, it is possible that $\widehat{\text{POP}}\Delta_i$ is correlated with $(\text{POP}\Delta_j - \widehat{\text{POP}}\Delta_j)$, resulting in biased estimates. This correlation is likely to arise given the structure of the system.[4]

Fortunately, this problem can be resolved. Rather than projecting POPΔ and EMPΔ on the exogenous variables, project $\overline{\text{POP}}\Delta$ and $\overline{\text{EMP}}\Delta$ on gravity variables $(\overline{X})$ representing each of the exogenous variables:

$$\overline{X} = \sum_{j \neq i} \frac{X_j}{(d_{ij})^{\alpha}} + X_i. \tag{15}$$

The values predicted from this projection are used as instruments. This ensures, by construction, that the instrumented gravity variable is orthogonal to the residuals in the estimation equation. Note that if (14) is a legitimate instrument, the approach taken here is algebraically equivalent since the gravity variables are linear transforms.

Equations (11) and (12) estimate MARTA's impact on the long-run equilibrium levels of population and employment. MARTA may also affect the mix of employment and population in station areas. As noted above, MARTA may affect firms' profits by either reducing labor costs or expanding revenues. Firms in basic industries (e.g., manufacturing) would benefit only from lower labor costs, while firms in non-basic industries (e.g., services) would benefit from both lower labor costs and greater revenues.

[4] This can be seen by solving the system of equations represented by (11) and (12) for a reduced form specification involving only the exogeneous variables $M_t$, $P_t$, $E_t$, $\text{EMP}_{t-i}$, and $\text{POP}_{t-1}$. The equation for each census tract will necessarily involve exogenous variables from the other census tracts (through the gravity variables $\overline{\text{EMP}}_t$ and $\overline{\text{POP}}_t$). Hence, regressing $\text{EMP}_t$ and $\text{POP}_t$ only on exogeneous variables from their own census tract omits additional exogeneous variables in the reduced form. These will lead, necessarily, to the correlation identified in the text.

This suggests that MARTA may exert a greater pull on firms in the latter industries. MARTA may also alter the mix of public and private employment. Public officials may locate government establishments in the vicinity of rail stations to increase ridership and encourage private development.

Regarding MARTA's affect on population mix, blacks are known to be more dependent than whites on public transit, presumably because blacks have lower incomes and public transit is an inferior good.[5] Blacks may therefore be more attracted to station areas.

To investigate how MARTA has effected the mix of employment and population in station areas, an 11-equation system of population and employment was estimated. There are 9 employment equations, 1 for each industry, and 2 population equations, 1 for whites and 1 for blacks. The specifications of the equations are consistent with those estimated for total population and employment:

$$\mathrm{EMP}\Delta_{t,b} = \alpha_0 + M_t\alpha_1 + \sum_{b=1}^{9} \beta_b \mathrm{EMP}_{t-1,b} + \sum_{c=1}^{2} \gamma_c \overline{\mathrm{POP}}_{t-1,c} + \sum_{c=1}^{2} \delta_c \overline{\mathrm{POP}}\Delta_c + E\lambda + \varepsilon, \quad (16)$$

$$\mathrm{POP}\Delta_{t,c} = \omega_0 + M_t\omega_1 + \sum_{c=1}^{2} \sigma_c \mathrm{POP}_{t-1,c} + \sum_{b=1}^{9} \theta_b \overline{\mathrm{EMP}}_{t-1,b} + \sum_{b=1}^{9} \chi_b \overline{\mathrm{EMP}}\Delta_b + P\Phi + \nu, \quad (17)$$

where

$\mathrm{EMP}\Delta_b$ = change in tract's employment in industry $b$

$\mathrm{POP}\Delta_c$ = change in tract's population for group $c$

$\mathrm{EMP}_{t-1,b}$ = employment in the $b$th industry located in the tract in $t-1$

$\mathrm{POP}_{t-1,c}$ = population of group $c$ located in the tract in $t-1$

$\overline{\mathrm{EMP}}_{t-1,b}$ = proximity of the tract to employment in the $b$th industry in $t-1$

$\overline{\mathrm{POP}}_{t-1,c}$ = proximity of the tract to population in group $c$ in $t-1$

$\overline{\mathrm{EMP}}\Delta_b$ = change in the proximity of the tract to employment in industry $b$ (instrumental variable)

[5]According to the 1990 Census of Population and Housing, the percentage of black and white households living within the Atlanta MSA who have no auto, van, or truck at home for use by household members is 23% and 4.2%, respectively.

$\overline{\text{POP}}\Delta_c$ = change in the proximity of the tract to population group $c$ (instrumental variable)

$E$ = control variables affecting employment change

$P$ = control variables affecting population change.

## IV. DATA

The study area is the seven-county Atlanta Region. This Region includes the central city of Atlanta and the counties comprising the inner suburbs of the Atlanta MSA.[6] Population and employment changes are measured from 1980 to 1990 for the 299 census tracts that existed in the Region in 1980. The population data come from the 1980 and 1990 Censuses of Population and Housing. The employment data are from the Atlanta Regional Commission (ARC). ARC's employment estimates were initially based on a complete census of employers conducted in 1970. Since then employment figures have been updated by surveying a sample of firms and relying upon secondary resources such as commercially available business lists and information from the Georgia Department of Labor.[7]

The first 13 stations of the MARTA rapid transit system opened in 1979 (see Table 1). During the first half of the 1980s, another 12 stations opened. Four stations opened after 1985, bringing the system total to 29 stations in 1990. These 29 stations are the focus of the present study. Since 1990, 4 stations have been added to the system to bring the total number to 33. MARTA's service area includes only two of the seven counties in the Region—Fulton County and Dekalb County. The rail system is structured in a cruciform arrangement, with the East/West and North/South lines intersecting in downtown Atlanta, at the center of the Region.

The MARTA independent variable was constructed by using a digitized map. A quarter-mile ring was drawn around each station. A quarter mile (2.5 blocks) is used as the radius of the MARTA impact area for two reasons. First, walking distance is most commonly defined as being within a quarter mile of a station (Bernick and Carroll [3]; Cervero [9]; Untermann [27]).[8] Second, a quarter-mile radius results in a minimum of ring overlap for the nine stations located in downtown Atlanta. These stations average 0.5 mile apart in contrast to the roughly 2.5 miles separating outlying stations.

[6] The Region accounted for 82% of the MSA's population in 1980 and 80% of the MSA's growth in population between 1980 and 1990.

[7] A complete description of ARC's methodology can be found in any of their annual employment reports (e.g., *Employment 1992*, Atlanta Regional Commission [2]).

[8] Evidence in favor of the notion that a quarter of a mile represents a reasonable walk is provided by Holzer and Ihlanfeldt [16]. Based on a sample of 800 Atlanta firms, they find that the probability that the last person hired by the firm is black is higher if the firm is no more than a quarter of a mile from a public transit stop.

TABLE 1
MARTA Rapid Rail Stations

| North/South line | | | East/West line | | |
|---|---|---|---|---|---|
| Station name | Opening date | Type | Station name | Opening date | Type |
| Doraville | Dec. 1992 | Commuter | Indian Creek | June 1993 | Commuter |
| Chamblee | Dec. 1987 | Commuter | Kensington | June 1993 | Community center |
| Brookhaven | Dec. 1984 | Community center | Avondale | June 1979 | Community center |
| Lenox | Dec. 1984 | Mixed use | Decatur | June 1979 | Mixed use |
| Lindberg Ctr. | Dec. 1984 | Mixed use | East Lake | June 1979 | Neighborhood |
| Arts Center | Dec. 1982 | High intensity | Edgewood/ Candler Park | June 1979 | Neighborhood |
| Midtown | Dec. 1982 | High intensity | | | |
| North Avenue | Dec. 1981 | High intensity | Inman Park/ Reynoldstown | June 1979 | Neighborhood |
| Civic Center | Dec. 1981 | High intensity | | | |
| Peachtree Ctr. | Sept. 1982 | High intensity | King Memorial | June 1979 | Neighborhood |
| Five Points | Dec. 1979 | High intensity | Georgia State | June 1979 | High intensity |
| Garnett | Dec. 1981 | High intensity | Omni/Dome/ GWCC | Dec. 1979 | High intensity |
| West End | Sept. 1982 | Community center | | | |
| Oakland City | Dec. 1984 | Neighborhood | Vine City | Dec. 1979 | Neighborhood |
| Lakewood/ Ft. McPherson | Dec. 1984 | Commuter | Ashby | Dec. 1979 | Mixed use |
| | | | West Lake | Dec. 1979 | Neighborhood |
| East Point | Aug. 1986 | Community center | Hightower | Dec. 1979 | Commuter |
| College Park | June 1988 | Community center | | | |
| Airport | June 1988 | Commuter | | | |

| Proctor/Creek Line | | |
|---|---|---|
| Station name | Opening date | Type |
| Bankhead | Dec. 1992 | Neighborhood |

The next step in constructing the MARTA variable was to determine the census tracts with some portion falling within each of the station impact areas. The percentage of each impact area found in each of these tracts was then estimated by careful visual inspection. The MARTA variable is therefore defined as the percentage of the station impact area falling within the tract (COV). *Ceteris paribus*, tracts with higher values of COV are expected to experience greater growth in population and employment than tracts with smaller values or tracts lying outside station impact areas (COV = 0).

In addition to using COV as the MARTA variable, COV is interacted with a set of five dummy variables representing station type. A station typology was developed as part of the Transit Station Area Development Studies (TSADS) that were conducted in the early 1970s prior to the opening of MARTA. The purposes of the TSADS were to develop land use plans for each station area and recommend public policies that would work toward the implementation of the plans. The five types of stations are:

High-intensity urban node (TYPE1)

Mixed-use regional node (TYPE2)

Commuter station (TYPE3)

Community center (TYPE4)

Neighborhood station (TYPE5).

The amount of economic development envisioned in the TSADS varies across station types, with the emphasis on development systematically declining from the top to the bottom of the above list (see Table 2). With few exceptions, the only policy action taken in response to the TSADS has been the rezoning of station areas. Multiplying COV by each of the station type dummy variables allows the MARTA impact to vary across station types.

In addition to COV and its interaction with station type, three alternative MARTA variables were employed. First, rather than the percentage of the MARTA impact area located in a tract, the percentage of the tract falling within an impact area was tried.[9] Like COV, this variable was used by itself as well as interacted with the station type dummies. Second, a set of dummy variables was used to indicate whether a census tract fell within a particular station type impact area. Finally, another set of dummy variables indicating whether the tract was within a particular station profile area was used. These areas are defined for each station type and are somewhat larger than our 1/4-mile impact areas, ranging between 1/3 and 1/2 mile in radius. Station profile areas were defined by the TSADS for planning purposes. Since the results obtained with these alternative MARTA variables are qualitatively consistent with the results obtained with COV, they are not reported here. They are, however, contained in Appendix A, which is available from the authors.

In addition to the MARTA variables, the population and employment change equations included other variables, $P_i$ and $E_i$, hypothesized to

[9]COV is the preferred measure since it is not sensitive to the area of the census tract. Consider a case where a station impact zone falls entirely within a census tract. The value of COV would be one regardless of the census tract and station. The percentage of the census tract within the impact zone would vary depending on the size of the census tract.

TABLE 2
Station Types

| | |
|---|---|
| High-intensity urban node | *High-intensity urban node stations* are found primarily in the Atlanta Central Business District and areas with related high-intensity commercial uses. The development objects guiding planning at the stations include the promotion of the highest intensities of mutually supportive uses in close proximity to the MARTA stations while providing for light and air at street level. Aesthetic and functional relationships are sought among structures, utilities, and the rapid transit system. Private automobiles are discouraged, are mass transit facilities encouraged. Pedestrian networkers separated from vehicular traffic between buildings and public ways through buildings are planned. Mixed uses of land are stressed. |
| Mixed-use regional node | In areas where stations are near existing or prospective community or regional shopping and office centers, *mixed-use regional node stations* are planned. Enlargement of or addition to such centers as planned development rather than strip commercialism is encouraged. New housing is planned at medium and high densities. At suitable locations office users are encouraged. Protection of adjacent low-density residential uses is stressed for many such station areas. |
| Commuter station | In areas where *commuter stations* are located, policies encourage development or expansion of local employment opportunities wherever possible to allow for reverse commuter patterns, thereby more fully utilizing the rapid transit system. |
| Community center | *Community center stations* function as centers of activity for several surrounding neighborhoods. A ‘‘feeling of community’’ is pursued in these station area plans. Development plans for these areas designate places to live, work, and shop with a variety of community facilities and services. Residential preservation and redevelopment are encouraged with supportive office and distribution activities. |
| Neighborhood station | *Neighborhood stations* serve established low- or medium-density neighborhoods. The plans for these station areas stress the protection of such neighborhoods by prohibiting new commercial or industrial development in the vicinity of stations except where compatible. Where there are opportunities for development or redevelopment, low- or medium-density residential uses are usually recommended. |

*Source*. ‘‘Transit Station Area Development Studies Summary,’’ September 1977.

cause spatial variation in household utility and firm profits, respectively. Common to the $P_i$ and $E_i$ sets of variables are whether an expressway runs through the tract (FREEWAY); whether the tract contains Hartsfield International Airport (AIRPORT); the percentage of the tract's land area that is developable (VACANT), low-density housing (LDRESID), high-density housing (HDRESID), and commercial, industrial, and institutional (PRODUCT); and the per capita expenditures on police (PCPOL) and highways (PCHIGH) of the jurisdiction within which the tract is located. Both equations also include the size of the tract in acres to control for differences in the size of tracts (ACRES).[10]

Variables in $P_i$ that are not in $E_i$ include eighth grade test scores for the school district in which the tract is located (TEST); per capita expenditures on parks (PCPARK); and the tract's percentage black (RACE), percentage poor (POV), and percentage of the housing stock built before 1950 (HOUSE50).[11]

One variable is unique to $E_i$, namely, the tract's proximity to employment in financial, legal, business, and miscellaneous services (BSERV). This is measured as a gravity variable in the same manner as in Eq. (13).[12]

Following Carlino and Mills [8] and Boarnet [4, 5] the $M$, $P$, and $E$ variables are assigned beginning of the period values. Except for the government expenditure variables, which come from the 1982 Census of Governments, variables take on 1980 values. Beginning of the period values are employed to better identify the system, since these values should not be affected by the endogenous variables of the model.

As expressed by Eq. (11), in addition to $\overline{P_i}$, the population change equation includes the exogenous variables $\overline{\text{EMP}}_{80}$ and $\text{POP}_{80}$ and the endogenous variable $(\overline{\text{EMP}}\Delta)$. Similarly, the employment change equation includes, along with $E_i$, $\overline{\text{POP}}_{80}$, $\text{EMP}_{80}$, and $(\overline{\text{POP}}\Delta)$.

While the rationale for the inclusion of most of the above variables in the equation in which they appear is obvious, a number of the variables warrants additional comment. First, the percentages of a tract's land area in alternative uses at the beginning of the period are included in both equations to proxy constraints on further economic development resulting from zoning and/or land development costs. For example, if a high percentage of a tract's land is allocated to housing in 1980, there may be little land left that is suitable for or zoned for additional housing. Future growth in population may therefore be limited. A high percentage of land in housing may also constrain employment growth to the extent that households oppose non-residential development. Second, BSERV is included in the employment change equation since the cost of face-to-face

[10] A number of other variables were included in preliminary runs but were dropped from the final estimations because of very low $t$ statistics. These included per capita expenditures on fire protection, per capita expenditures on sanitation, and property tax rates.

[11] TEST was based on the percentage of students who achieved at least 15 of 20 objectives in reading and mathematics. The reading and math percentages were averaged to form TEST.

[12] An $\alpha$ value of 2 is used in the construction of BSERV since the benefits which accrue to firms from locating close to these services decline rapidly with distance (Ihlanfeldt and Raper [17]).

meetings and the cost of labor per unit of output will be lower if suppliers of support services are located nearby. In an earlier study, BSERV was found to have a strong influence on the location of office employment in Atlanta (Ihlanfeldt and Raper [17]). Finally, it is worth noting that the inclusion of $POP_{80}$ in the population change equation and the inclusion of $EMP_{80}$ in the employment change equation can be justified on two accounts. As shown above, these variables are in the econometric model because a distributed-lag adjustment process is assumed. But another important reason for including them is that there are likely to be unobservables that affect both the levels and the changes in population and employment in the same direction. When the unit of observation is as small as a census tract, there are many factors (such as geological and surface characteristics) that may affect development that cannot be measured.[13]

## V. RESULTS

### *Summary Measures*

The dependent variables in the simultaneous models are changes in population and employment for the census tract measured from 1980 to 1990. Before presenting the regression results, it is of interest to consider the mean values of these variables for station and non-station areas (see Table 3). Tracts containing a portion of the 1/4-mile impact area are labeled station tracts.

The mean change in population for station tracts is −274, while the mean change for non-station tracts is 2291. A similar contrast is found for employment, although here it is not so stark. The mean employment changes for station and non-station tracts are 731 and 1768, respectively.

The racial breakdown shows that population changes are considerably larger for both blacks and whites in non-station areas than in station areas. The industry breakdown shows that the mean employment change is larger for non-station than for station tracts for seven of the eight industry groups. Only the mean change in government employment is found to be larger for station tracts.

The data are also broken down by station type. The mean change in total population is substantially smaller for all station types in comparison to non-station areas. This also holds true for blacks and whites. However,

[13]An anonymous referee suggested including distance to the CBD as a regressor. Distance to the CBD is often used as proxy for proximity to the high employment region of the city. In our specification, the employment gravity variables measure this proximity more accurately. Additionally, there are actually three areas in Atlanta with dense employment—the CBD, the Midtown area, and the North Perimeter area. The employment gravity variable accounts for these additional regions while distance to the CBD would not.

TABLE 3

Mean Change in Population and Employment, 1980−1990

| | Non-station tracts | Station tracts | Station types[a] 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Total population | 2291 | −274 | 88 | −197 | −400 | −396 | −473 |
| Whites | 1263 | −408 | −179 | −41 | −843 | −966 | −111 |
| Blacks | 835 | 50 | 226 | −208 | 187 | 425 | −370 |
| Total employment | 1768 | 731 | 1643 | 2090 | −192 | 324 | 28 |
| Private employment | 1625 | 446 | 1210 | 1021 | −137 | 172 | −18 |
| Government | 144 | 285 | 433 | 1068 | −55 | 152 | 45 |
| Retail | 432 | 28 | −101 | 320 | 119 | −5 | −2 |
| Wholesale | 216 | 46 | 215 | −34 | 36 | −19 | −1 |
| Manufacturing | 91 | −123 | −155 | −23 | −358 | −65 | −95 |
| FIRE[b] | 150 | 42 | 154 | 74 | −24 | −29 | 19 |
| TCU[c] | 96 | 11 | 169 | −129 | −133 | 60 | −43 |
| Services | 556 | 455 | 1034 | 816 | 180 | 204 | 111 |
| Construction | 63 | −18 | −99 | −10 | 26 | 24 | −6 |
| Miscellaneous | 17 | 2 | −7 | 8 | 15 | 2 | 1 |
| Observations | 236 | 62 | 15 | 8 | 7 | 15 | 17 |

[a] Station types: 1, high-intensity urban node; 2, mixed-use regional node; 3, commuter station; 4, community center; 5, neighborhood station.

[b] FIRE, Finance, insurance, and real estate.

[c] TCU, Transportation, communication, and utilities.

while the mean change in the white population is negative for all station types, for three of the five types of stations the mean change for blacks is greater than zero. For employment, tracts that are part of the impact areas of stations classified as mixed-use regional nodes (TYPE2) had a mean employment change of 2090, which is larger than the mean employment change of 1768 for non-station tracts. Tracts identified with the other four types of stations had a smaller mean change in employment than non-station tracts.

The industry by station type breakdown reveals that growth in government employment explains the relatively greater growth experienced by TYPE2 station tracts. The change in private employment is smaller across all station types in comparison to non-station areas.

The industry by station type breakdowns also show that the changes experienced by TYPE1 (high-intensity urban node) station tracts compare most favorably to non-station areas. For government, FIRE, TCU, and services the mean change in employment is greater for TYPE1 station tracts than non-station tracts. The next most favorable comparison is for

TYPE2 station tracts. The mean changes in government and services employment are greater for the latter tracts in comparison to non-station tracts. None of the other station types had individual industry changes that are larger than those experienced by non-station areas.

The above comparisons of means between station and non-station tracts suggest that MARTA has had little, if any, effect on total employment or population in station areas. It appears, however, that MARTA has had some effect on the industry and population mix within these areas.

### *Regression Results*

The employment equation results for the two-equation system (Eqs. (11) and (12)) are reported in Table 4. In the first column COV is the MARTA variable. In the second column COV is interacted with station type. The estimated coefficient on COV has a positive sign but it is not statistically significant ($t$ statistic = 0.28). When COV is interacted with station type, only the estimated coefficient on TYPE2 is significantly different from zero. The positive sign on this coefficient indicates that MARTA positively affects employment in those tracts that fall within the impact areas of TYPE2 stations (mixed-use regional nodes). As noted above, TYPE2 station areas have experienced relatively strong growth in government employment. This growth may explain the positive effect that MARTA has on total employment in these areas. This is confirmed by the industry level results reported in Table 6.

The control variables that enter the employment equation behave as expected. FREEWAY, AIRPORT, LDRESID, PRODUCT, PCHIGH, PCPOL, $EMP_{80}$, and $\overline{POP\Delta}$ are significant at the 5% level by a two-tailed test. As the percentage of the tract's land devoted to low-density housing or commercial, industrial, and institutional usage increases, the change in employment is smaller. Greater per capita expenditures on highways are found to increase employment change, while expenditures on police are found to reduce employment change. An explanation for the latter result is that greater police expenditures per capita are required where crime is a more serious problem. Employment in 1980 is positively associated with the change in employment. This implies that the lagged adjustment parameter ($\lambda_e$) lies outside the acceptable 0 to 1 range. Apparently, as noted above, $EMP_{80}$ is serving as a proxy for unobservables that directly effect both the level and the change in census tract employment. Finally, the estimated coefficient on the change in proximity to population variable $\overline{POP\Delta}$ is positive and highly significant, which indicates that jobs follow people.

The population equation results are reported in Table 5. Again, COV is the MARTA variable in column one and the interactions of COV and station type are the MARTA variables in column two. The estimated

TABLE 4
Estimation Results, Employment Equation

| | | |
|---|---|---|
| FREEWAY | 787 | 829 |
| | (302)[a] | (300) |
| AIRPORT | 28,878 | 31,956 |
| | (2,670) | (3,290) |
| ACRES | −0.0089 | −0.011 |
| | (0.032) | (0.031) |
| VACANT | −33 | −42 |
| | (24) | (24) |
| LDRESID | −50 | −58 |
| | (22) | (22) |
| HDRESID | −22 | −28 |
| | (29) | (29) |
| PRODUCT | −56 | −61 |
| | (22) | (22) |
| PCHIGH | 57 | 59 |
| | (15) | (15) |
| PCPOL | −25 | −28 |
| | (13) | (13) |
| BSERV | 0.0064 | 0.0076 |
| | (0.0064) | (0.0073) |
| COV | 206 | — |
| | (734) | |
| TYPE1 | — | −476 |
| | | (1,223) |
| TYPE2 | — | 3,219 |
| | | (1,518) |
| TYPE3 | — | −3,217 |
| | | (2,092) |
| TYPE4 | — | −514 |
| | | (1,765) |
| TYPE5 | — | 1,076 |
| | | (1,305) |
| $\overline{\text{POP}}_{80}$ | 0.0002 | −0.0006 |
| | (0.004) | (0.004) |
| $\overline{\text{POP}}\Delta$[b] | 0.057 | 0.055 |
| | (0.009) | (0.009) |
| $\text{EMP}_{80}$ | 0.170 | 0.176 |
| | (0.046) | (0.050) |
| CONSTANT | −1,188 | 207 |
| | (3,065) | (3,072) |
| $N$ | 299 | 299 |
| $R^2$ | 0.504 | 0.516 |

[a] Standard error in parentheses.
[b] Instrumental variable.

TABLE 5
Estimation Results, Population Equation

| | | |
|---|---|---|
| FREEWAY | −362 | −355 |
| | (394)[a] | (393) |
| AIRPORT | −162 | 1863 |
| | (3,287) | (4,078) |
| ACRES | 0.004 | 0.005 |
| | (0.040) | (0.040) |
| VACANT | 23 | 18 |
| | (30) | (30) |
| LDRESID | −54 | −58 |
| | (26) | (27) |
| HDRESID | −55 | −54 |
| | (35) | (36) |
| PRODUCT | −45 | −48 |
| | (27) | (28) |
| PCHIGH | 40 | 40 |
| | (19) | (19) |
| PCPOL | 11 | 11 |
| | (22) | (21) |
| PCPARK | 49 | 46 |
| | (32) | (32) |
| POV | 21 | 22 |
| | (20) | (20) |
| RACE | −13 | −12 |
| | (9) | (9) |
| HOUSE50 | 13 | 14 |
| | (14) | (14) |
| TEST | 82 | 79 |
| | (32) | (32) |
| COV | −26 | — |
| | (805) | |
| TYPE1 | — | 406 |
| | | (1,128) |
| TYPE2 | — | −747 |
| | | (1,870) |
| TYPE3 | — | −2,003 |
| | | (2,577) |
| TYPE4 | — | −1,367 |
| | | (2,166) |
| TYPE5 | — | 1,377 |
| | | (1,605) |
| $\overline{EMP}_{80}$ | 0.002 | 0.0001 |
| | (0.008) | (0.0080) |
| $\overline{EMP}\Delta^b$ | 0.021 | 0.025 |
| | (0.016) | (0.016) |
| $POP_{80}$ | 0.292 | 0.289 |
| | (0.069) | (0.069) |
| CONSTANT | −8,809 | −8,242 |
| | (4,352) | (4,371) |
| $N$ | 299 | 299 |
| $R^2$ | 0.455 | 0.460 |

[a]Standard error in parentheses.
[b]Instrumental variable.

coefficient on COV has a negative sign, but it is not statistically significant ($t$ statistic = 0.032). All of the MARTA variables are also significant in the specification containing the interaction variables.

The control variables again generally behave as expected, although many fail to attain significance at the 5% level. Statistically significant variables include TEST, LDRESID, PCHIGH, and $POP_{80}$. Higher test scores, a lower percentage of low-density housing, greater highway expenditures per capita, and higher population in 1980 result in a greater change in the census tract's population. The sign on $POP_{80}$ is once again inconsistent with lagged adjustment but is consistent with the hypothesis that levels and changes are similarly affected by unobservable variables. The estimated coefficient on the change in proximity to employment variable $\overline{EMP}\Delta$ is positive, which suggests that people follow jobs. But it is significant only at the 20% level. A comparison of the magnitudes of the estimated coefficients on $\overline{POP}\Delta$ in the employment equation (0.055) and $\overline{EMP}\Delta$ in the population equation (0.025) indicates that people have a stronger pull on jobs than vice versa.[14, 15]

The estimated coefficients on the MARTA variables from the 11-equation system (Eqs. (16) and (17)) are presented in Table 6. (In these equations the MARTA variables are those that interact COV with station type.) The complete set of results is in Appendix B which is available from the authors. In the employment equations, only three of the MARTA variables are statistically significant (by a two-tailed test at the 5% level). MARTA increases government employment (+2979) and decreases TCU employment (−657) around stations that are classified as mixed-use regional nodes. Manufacturing employment is reduced by MARTA (−825) around stations classified as commuter stations. In the black and white equations, none of the MARTA variables attains significance.

[14] Tests for spatial autocorrelation were performed on both the population and the employment equations in each of the specifications. The Cliff–Ord test was utilized (Cliff and Ord [11]; Anselin [1]). The test statistic is constructed as an asymptotic standard normal deviate (Burridge [7]; Cressie [12]). The test was performed on the structural residuals of the system. All test statistics are below the usual 1.96 rejection value. The employment equations have test values ranging from 0.20 to 0.48, while the population equations have test values ranging from 1.60 to 1.70. Standard tests for heteroskedasticity were also performed. No evidence of heteroskedasticity was found.

[15] To more fully assess the robustness of the results, two additional experiments were conducted using the two-equation system. First, MARTA's effects on population and employment were allowed to vary with the length of time the station had been open. Separate estimates were obtained for stations opening before 1980, between 1980 and 1985, and after 1985. The results are qualitatively the same as those discussed in the text. Second, equations were estimated just for the tracts located in the two counties (Fulton and Dekalb) containing MARTA. Again, these results are consistent with those reported in the text.

TABLE 6
Results for Industry and Racial Groups

| | Station type | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Employment | | | | | |
| Government | 414.18[a] | 2979.40 | −285.17 | 228.75 | −41.04 |
| | (440.62)[b] | (477.47) | (648.11) | (544.64) | (410.4) |
| Retail | −651.97 | 97.85 | −296.15 | −422.18 | 224.24 |
| | (341.35) | (376.34) | (501.44) | (422.18) | (315.83) |
| Wholesale | −7.46 | −357.55 | −616.35 | −6.10 | 218.09 |
| | (373.0) | (331.06) | (440.25) | (305.0) | (279.6) |
| Manufacturing | −484.63 | −57.82 | −825.16 | 119.11 | 43.56 |
| | (257.78) | (275.33) | (375.07) | (313.45) | (242.0) |
| FIRE[c] | −241.39 | −458.03 | −362.39 | −200.93 | 215.96 |
| | (236.66) | (257.32) | (345.13) | (291.2) | (218.14) |
| TCU[d] | −108.81 | −657.57 | −736.76 | −156.79 | −118.28 |
| | (302.25) | (330.43) | (443.83) | (373.31) | (281.62) |
| Services | 306.00 | −138.76 | −560.96 | −94.67 | 471.20 |
| | (430.99) | (462.53) | (623.29) | (525.94) | (395.97) |
| Construction | −103.28 | −23.80 | −108.00 | −7.79 | −2.61 |
| | (84.66) | (91.54) | (122.73) | (111.29) | (87.0) |
| Miscellaneous | −15.72 | 6.81 | 1.87 | 2.08 | 7.42 |
| | (17.27) | (18.92) | (26.71) | (20.8) | (16.13) |
| Population | | | | | |
| White | 1076.29 | 546.02 | 118.52 | 2140.70 | 139.14 |
| | (1134.94) | (1761.35) | (2370.4) | (2001.0) | (1391.4) |
| Black | −634.82 | −304.29 | −222.41 | −408.05 | −90.70 |
| | (520.34) | (800.76) | (1059.1) | (927.39) | (647.86) |

[a] Estimated coefficient on TYPE * COV in the government employment equation.
[b] Standard errors in parentheses.
[c] FIRE, Finance, insurance, and real estate.
[d] TCU, Transportation, communication, and utilities.

To further assess whether MARTA alters either the total or the mix of employment and population in station areas, results from the 11-equation system were used to conduct joint and sum significance tests for each station type. For example, for station type 1 the joint employment test is

$$H_0 : \begin{bmatrix} {}_{\text{gov}}\alpha_1 \\ {}_{\text{ret}}\alpha_1 \\ \vdots \\ {}_{\text{misc}}\alpha_1 \end{bmatrix} = 0,$$

and the employment sum test is

$$H_0: {}_{\text{gov}}\alpha_1 + {}_{\text{ret}}\alpha_1 \cdots {}_{\text{misc}}\alpha_1 = 0.$$

The joint significance tests are $\chi^2$ tests with 9 and 2 degrees of freedom for employment and population, respectively. The sum significance tests are standard normal tests. The results are reported in Table 7.

In the case of employment, the null hypothesis is rejected for the joint test at the 10% level for TYPE1 stations and at the 1% level for TYPE2 stations, but cannot be rejected for the other types of stations. For the sum tests, the null hypothesis cannot be rejected for station types 1, 2, 4, and 5. For station type 3, the sum is significant at the 5% level, but the sign of the sum is negative.

The joint and sum test results for employment confirm that MARTA has not had a positive effect on total employment in station areas. There is also confirmation of the result that MARTA has affected the mix of employment in station areas classified as mixed-use regional nodes. In addition, the results weakly suggest that the mix of employment has also been affected in station areas classified as high-intensity urban nodes. However, MARTA's impact on employment mix differs between the latter type of station and mixed-use regional nodes. For high-intensity urban nodes, the signs and magnitudes of the MARTA variables in Table 6

TABLE 7

Joint and Sum Significance Tests

| | Joint test ($\chi^2$) | Sum test (standard normal) |
|---|---|---|
| Employment | | |
| Station type | | |
| 1 | 16.09* | −0.69 |
| 2 | 48.48*** | 0.98 |
| 3 | 8.84 | −2.00** |
| 4 | 1.98 | −0.34 |
| 5 | 2.80 | 0.85 |
| Population | | |
| Station type | | |
| 1 | 1.97 | 0.39 |
| 2 | 0.20 | 0.14 |
| 3 | 0.05 | −0.05 |
| 4 | 1.20 | 0.87 |
| 5 | 0.02 | 0.03 |

*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

suggest that retail and manufacturing jobs are displaced by government and, to a lesser extent, services jobs. For mixed-use regional nodes, government jobs displace these in TCU, FIRE, and wholesale industries.

In the case of population, the null hypothesis cannot be rejected for any of the station types for either the joint or the sum test. These results confirm that MARTA has affected neither total population nor the racial mix of population in station areas.

## VI. CONCLUSIONS

Two conclusions can be drawn from the results of this study. First, MARTA has had neither a positive nor a negative impact on total population and total employment in station areas. Second, MARTA has altered the composition of employment in favor of the public sector, but only in those areas with high levels of commercial activity.

An explanation for the first conclusion was suggested nearly 20 years ago by Knight and Trygg [20]: ‘‘modern urban transit systems rarely, if ever, provide a major effective increase in accessibility, because the areas served tend to be already more accessible by auto.’’ This may be particularly true for MARTA, since it provides service within only 2 of the 20 counties that comprise the Atlanta metropolitan area. However, even if MARTA were more widespread, it is unlikely that the results would change. Atlanta is a highly decentralized automobile-dominated metropolitan area whose development has been primarily shaped by highway construction. That is, it is a typical American city.

Our conclusion that MARTA has had no discernible effect on total employment or population in station areas is consistent with its inability to attract ridership. While it is frequently claimed that the addition of rapid rail to Atlanta’s transit system significantly increased transit ridership, Kain [18] has documented that this is not true. Transit ridership, as measured by linked trips, was only 2.5% higher in 1993 than in 1979, the year before Atlanta initiated rail service.[16]

The second conclusion is consistent with the hypothesis that public officials target station areas for government employment. Presumably, the intent of this targeting is to increase ridership and encourage private development. However, the results provide no evidence that these benefits have been realized, since public employment is found to fully displace private employment.

[16] Kain argues that the perception that Atlanta’s rail system has been more successful in attracting ridership than other rail systems built in the United States since the end of World War II results from the mistaken use of total boardings to measure transit ridership. Boardings grew rapidly after the opening of the rail system because many direct bus services that did not require transfers where replaced by feeder bus−rail services that did require transfers.

Taken together with earlier evidence that the social costs of rapid transit are higher than those for buses, the results suggest that it may be difficult to justify rapid rail investment on the basis of a benefit−cost analysis. In the absence of local economic development around stations, the benefits of rail are limited to those that might occur at the regional level. Future work should seek to quantify these benefits.

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