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Accessibility Improvements and Local Employment: An Empirical Analysis

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ABSTRACT

In this paper we hypothesize that the local supply of labor (i.e., labor force participation) is affected, among other things, by the level of accessibility to employment locations. Specifically, we conjecture that improved accessibility in a given area, resulting from transportation infrastructure investment, will enhance labor participation, given intervening factors such as socioeconomic and locational characteristics. We further conjecture that this effect will be more pronounced in low-income areas where costs of labor-market participation, including transportation costs, constitute a real barrier to market entry. Using a simultaneous equation model, this paper empirically explores the impact of accessibility changes on the supply of labor in specific job types in the South Bronx, New York, an economically distressed area. The major sources of data for this study are three U.S. Census Bureau data files from the 1990 Census Transportation Planning Package.

INTRODUCTION

Can accessibility improved through infrastructure development actually affect the level of local employment? If so, what is the nature and extent of this change? In this paper, we hypothesize that if travel time and costs represent a significant barrier to labor-market participation, improved accessibil-

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ity, in terms of reduced travel times and costs, can affect the propensity of potential employees to enter labor markets, given their residential and employment locations and socio-economic attributes. We further hypothesize that this effect is more prominent, and, therefore, more discernible, in economically distressed areas where enhanced accessibility is likely to have a larger impact on labor-market participation. This paper examines these hypotheses with the results from an empirical analysis of accessibility-improvement impacts on employment using data from a low income, high unemployment area in the South Bronx of New York City.

This analysis stems from the fact that many transportation improvement projects are justified by their alleged positive effect on the local economy, primarily an increase in employment beyond that generated by construction of the project. Specifically, transportation investments are suggested for poor areas as a form of economic stimuli under the presumption that increased employment will follow. On the other hand, if improved accessibility does indeed have a tangible effect on employment, it is necessary to understand the nature of this impact relative to the types of employment and socioeconomic groups benefiting from such investments.

It is obvious that accessibility is only one of a number of factors influencing labor-market participation. Factors such as work skills, education, and family size and makeup may have an even greater impact on the employability of potential workers than does accessibility. Therefore, a main objective of this analysis is to discern the degree to which the reduction in the cost of travel to specified work sites can influence an increase in labor supply, given other intervening factors.

It can also be argued that whereas improved accessibility may have a positive effect on labor supply, in affluent areas where income and car ownership levels are high, this effect is likely to be insignificant and quite difficult to detect.[1] If it is at all effective as a means to promote employment, improved accessibility will have a greater impact in poor areas where skill and education levels are lower than in affluent areas.[2] For this reason, we have conducted our empirical analysis in the South Bronx, a distressed urban area in New York City.

On a more general level, improved accessibility has several potential long-term consequences possibly affecting the overall welfare of the area's residents and should be regarded in a general equilibrium framework. First, changes in accessibility can affect property values, possibly rising with increased accessibility, thereby making present nonowner residents worse off by increasing their rent level or even forcing them to relocate to fringe areas where rents are lower. Second, improved accessibility affects location decisions by both firms and households. As a result, the argument that improved accessibility can induce labor-market entry may not hold since spatial rearrangement may, in turn, alter accessibility levels to the disadvantage of low-income residents unable to relocate. A related issue is that improved accessibility can cause migration of residents of adjacent regions with inferior accessibility level into the impacted area.

Still another element to consider when developing a methodology for analyzing the effects of accessibility changes on employment is that transportation improvements are the result of public decisions, possibly not independent of external factors, such as the wealth levels of different areas. Transportation capital improvement projects are neither ubiquitous nor random since local pressure by affluent constituents can result in greater investments made in their locales relative to areas that lack such influence. Hence, a more accurate comparison of areas with and without improved accessibility, relative to their impact on employment, requires a consideration of this and similar factors.

In this paper we do not address these issues, even though we consider them quite important for the overall understanding of the relationship between transportation improvements and employment. Mainly due to data reasons (see the data in

[1] On the other hand, the value of time tends to increase with income so that the value of accessibility also rises with income. A counter argument is that at higher income, trip-makers can influence their travel time by purchasing the services of high-speed modes, such as a private car, express bus or rail, or travel on toll roads, and that these means are beyond the reach of low-income commuters.

[2] Vickerman et al. (1995) argue that ". . . a lack of labor skills can be compensated for by the provision of a cheap and efficient public transport system. . . ."

Appendix B) and the specific characteristics of the South Bronx, our analysis is a nontemporal and nonspatial equilibrium analysis, which assumes fixed residential and employment locations and a given population level. It focuses on the more immediate response of potential workers to changes in accessibility. We notice that, in general, the changes noted above in property value, location, and population shifts are rather complex phenomena extending over many years and carrying mixed effects on employment. As such, they require complicated modeling and an elaborate database. On the other hand, potential shorter-term adjustments in the level of employment from transportation improvements carry significant implications for policy making, particularly in economically distressed areas with high unemployment rates.

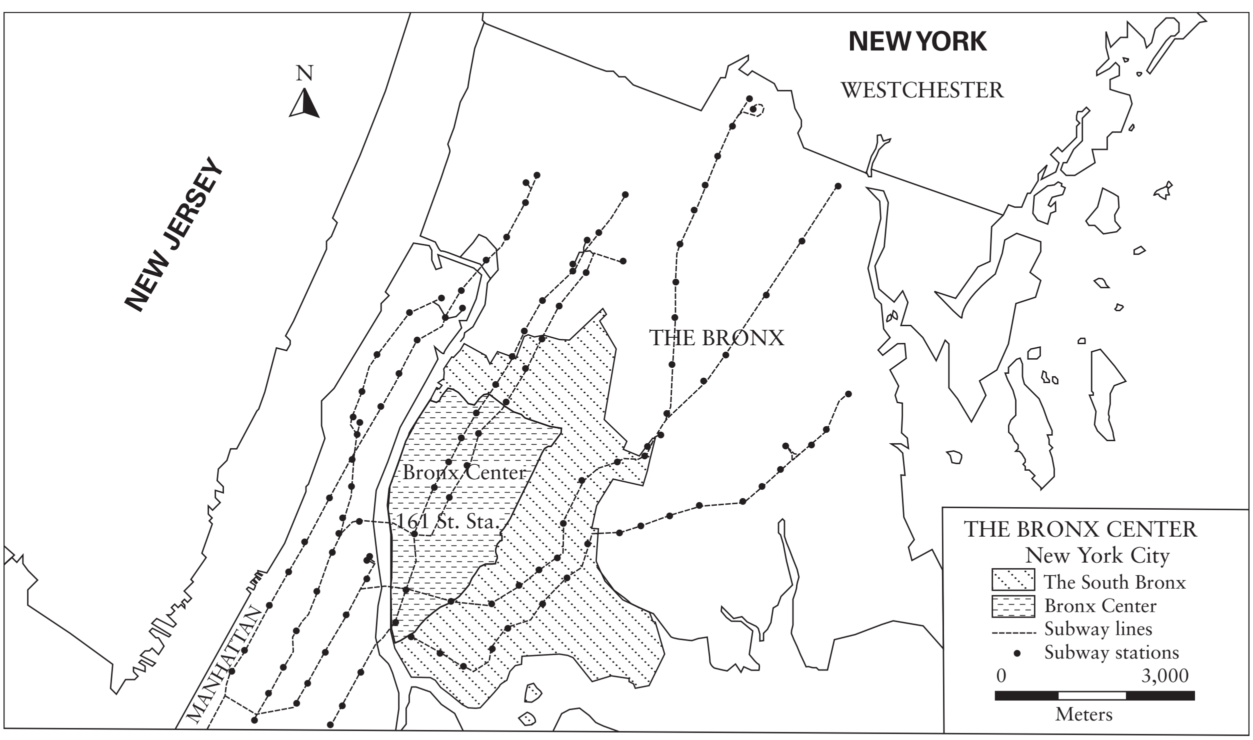
In the following section we describe the socioeconomic and transportation-related characteristics of the South Bronx. The estimated results can best be understood when considered against these factors. In the third section, we briefly present findings from studies that measured the effects of accessibility improvements on the local economy, mainly on employment. Section four presents our theoretical considerations and modeling approach. Empirical results and discussion appear in section five, and major conclusions are in the final section.

THE SOUTH BRONX: SOCIOECONOMIC AND TRANSPORTATION-RELATED CHARACTERISTICS

While Berechman and Paaswell (1996) offers a detailed description, we begin this analysis with a brief description of the studied area. The South Bronx, a 336-square block area in the borough of the Bronx, New York, is a 30-minute subway trip from Midtown Manhattan. Figure 1 displays the boundaries of the South Bronx within the Bronx. A major transportation investment project, labeled the Bronx Center project, was considered for this area. Its location is also marked in figure 1.

Although the area contains a community college, a major hospital, courthouses, and borough offices, it houses a population whose demographics and socioeconomic profile show that the region is economically disadvantaged. The economic decline came about through the closing of manufacturing in the 1960s and through the departure of the middle class to suburban regions. A key factor underlying much of the economic reality of the South Bronx is its high level of unemployment. As shown

FIGURE 1 Location of the Bronx Center



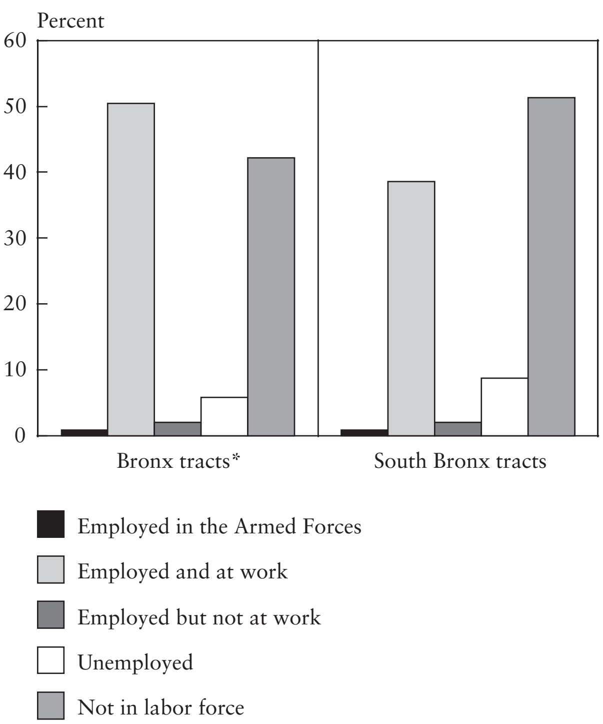
in figure 2, in 1990, while 50% of the residents of the Bronx (excluding the South Bronx) are defined as "employed and at work," the corresponding figure for the South Bronx is only 39%. The participation rate, defined here as the number of employed people out of the total labor force, was 91% in 1990 in New York City, 88% in the Bronx, and 84% in the South Bronx.

As table 1 shows, even in later years the unemployment rate (not seasonally adjusted) in the Bronx, including the South Bronx, is quite high relative to the other boroughs in New York City.

The median income in the South Bronx is only about 69% of that of the Bronx as a whole and about 50% of that of New York City.[3] The poverty rate (the number of persons in poverty out of total persons) is the highest in the New York area, about 40% in 1996.

Level of education greatly affects employability. Presently, about 80% of the residents of the South Bronx have only a high school diploma or fewer years of schooling compared with 67% in the rest of the Bronx. This situation is reflected in the occupation profile of the South Bronx residents. The majority of the labor force is employed in administrative support and service occupations. As the estimated results presented later indicate, labor-market participation in these particular occupations is markedly sensitive to changes in accessibility.

FIGURE 2 Employment Status (1990)



*Excluding South Bronx tracts

TABLE 1 Unemployment Rates in New York's Five Boroughs, 1996–1998 (percent)

	1996	1998
New York City (all boroughs)	8.5	8.1
Bronx (including the South Bronx)	11.0	10.2
Brooklyn	9.5	9.4
Manhattan	7.4	6.9
Queens	7.5	6.9
Staten Island	7.5	7.6

Source: New York State Bureau of Labor Statistics (November 1996, July 1998)

Transportation options for the area include commuter rail, rapid rail, and metropolitan bus lines. These, however, are geared to trips ending in mid- to lower-Manhattan. Based on markets existing some decades ago, they do not necessarily represent market demands created by the decline of manufacturing in the Bronx and the growth of services in Manhattan. A close inspection of South Bronx transportation conditions reveals that they are quite deficient in terms of high travel costs, long commute times, and inferior service quality. As shown in figure 1, within the South Bronx many areas are relatively far from a subway station, and bus service is infrequent and expensive. Furthermore, the car-ownership rate in the South Bronx is quite low, about 21% as compared with 49% for the entire Bronx borough and 57% for New York City. It is not surprising, therefore, that residents of the South Bronx rely heavily on public transit for travel to work. About 63% use public modes (subway, elevated train, railroad, or bus), and only 19% use a private car. For the Bronx borough (excluding the South Bronx), the corresponding figures are 54% and 33%, respectively. The remainder is made up by foot travel and other transportation means.[4]

Two other important indicators of travel behavior are time of departure and length of travel time. Thus, whereas the distribution of time of departure

[3] See Berechman and Paaswell (1996) for a detailed description. Data sources are listed in Appendix B.

[4] See Appendix B for the source of these data.

for the Bronx residents (excluding the South Bronx) displays an almost normal curve, the distribution of time of departure for the South Bronx residents is heavy-tailed with many early and late departures. On the other hand, the majority of trips by South Bronx residents are within the middle range, 30 to 60 minutes, whereas those of Bronx residents are in the shorter, 0 to 30 minute, and longer, 60 to 90 minute, ranges.

In summary, these data demonstrate that the socioeconomic profile of South Bronx residents is quite different from that of Bronx residents as a whole and of the other New York boroughs. They are poorer and less mobile and also have lower levels of formal education and work skills. These qualities effectively reduce their potential employability. This observation has two major ramifications for our analysis. The first is that residents of the South Bronx appear more susceptible to changes in travel time and costs relative to labor force participation than residents of more affluent areas. The second is that estimated results from empirical analysis will be best understood if socioeconomic and transportation characteristics are considered.

EFFECT OF ACCESSIBILITY CHANGES ON EMPLOYMENT

In recent years, interest in the question of whether transportation improvements generate economic growth, mainly employment, has grown (Banister and Berechman 2000). Beeson (1992) argued that in urban areas the degree of labor specialization and division (e.g., diversity of employment), which affects labor productivity and use, depends mainly on the size of the market determined, in turn, by population density and transportation costs. Paaswell and Zupan (1998) showed that increased densities in the core (Manhattan) require the high accessibility provided primarily by rail rapid transit systems. Quite simply, in such extremely high-density areas, an employer can benefit not only from nearby important support services and amenities but also from a diverse labor force within a reasonable commuting distance. The authors showed that few cities in the world, London and Tokyo being exceptions, had that relationship between employment density and accessibility. In contrast, in Chicago, a city with a highly developed rail rapid transit system, opportunities are less than optimal. The more than 50% of the region's population living in the suburbs are served by well-developed highway networks, which also encourage dispersion of employment. In the last decade, this dispersion has taken jobs away from the core, redistributed them throughout the suburbs, and made them accessible only by car, effectively reducing overall accessibility for potential employees (Sen et al. 1998). The costs to enter or participate in the job market for the low-income worker in Chicago, then, are higher than for his New York counterpart.

The empirical literature pertinent to these arguments can be categorized into two broad groups. The first is the Spatial Mismatch Hypothesis (SMH); it focuses on labor force participation of inner city minority residents. The second, labeled here the "production function" approach, focuses on the causality between transportation improvements and growth as well as the degree to which such association actually exists.

Starting with the pioneering work of Kain (1968), the SMH states that inner city minority residents suffer from high rates of unemployment, caused by poor accessibility to employment, which has decentralized to suburbs. These minorities, who have low income and low rates of car ownership, are unable to relocate to these suburbs due to discrimination in the suburban housing markets. Under these conditions, improved accessibility can bring about an increase in market participation rates of inner city minorities.

A recent comprehensive review of empirical results from SMH studies has concluded that the lack of spatial accessibility to employment can explain poor labor-market participation rates of inner city, low-income inhabitants in large metropolitan areas (Ihlanfeldt and Sjoquist 1998). However, this review also suggests that in addition to accessibility, other factors can bring about similar effects. These factors range from the lack of information on job availability at distant employment sites to job discrimination factors. Furthermore, it is also suggested that the lack of important job skills is at least as important as accessibility in affecting employment levels among inner city, low-income groups. A similar argument can be made for the effect of childcare costs, which for low-income groups can be significant. Hence, for policy purposes it is important to discern the relative importance of each factor on spatial mismatch since, in themselves, commuting programs may not appreciably affect deficient market participation among inner city minorities. Still another empirical issue is whether all low-skilled workers, mainly adults, actually are accessibility-deficient. This issue is troublesome since most SMH studies have focused on the analysis of inner city youth.

This study does not intend to examine the SMH. We look at labor-force participation within New York City, a unique urban area atypical of U.S. urban areas, and address impacts of costs of travel in boroughs where accessibility may be high and traditional job markets within reach. Thus, in terms of transportation, the South Bronx is not typical as compared with many inner city areas. Workers in the South Bronx have access to transportation systems that provide high levels of accessibility to the prime locations of employment, the core of Manhattan. In addition, they have access to a highly developed expressway network that can bring them to nearby suburban counties. The problem discussed here is more local. Because the rail network was designed to access the core of Manhattan and the bus network to serve the rail stations, public transport within the South Bronx does not adequately serve local workers. Thus, while a commute to the core of Manhattan or to the suburbs can be achieved in a reasonable time, a commute across the South Bronx becomes quite costly. For this reason, this paper does not attempt to confirm or disprove the SMH.

However, the present analysis accounts for several factors, also necessary for validating the SMH. In particular, it controls for labor skills, for the level of education, and for household variables including age of children. In addition, in this analysis we use an accessibility measure, a function of network-based modal travel times and costs, of time of departure, of car ownership, and of household income. We believe that this measure is comprehensive enough to adequately measure accessibility to employment in the studied area. Moreover, our analysis distinguishes between residents who live *and* work in the Bronx and those who live in the Bronx but work elsewhere.

Within "production function" literature, several empirical studies have found that changes in accessibility (broadly defined) have an insignificant effect on employment growth (Danielson and Wolpert 1991) or on travel-to-work behavior (Ewing 1995). Thus, it was concluded that employment growth took place mainly in outer suburbs and was largely insensitive to highway accessibility (Giluliano and Small 1999). On the other hand, household characteristics such as size, number of workers, and income have a stronger impact on work trip patterns.

Cervero and Landis (1995), who investigated the employment effects from the San Francisco Bay Area Rapid Transit (BART) system, found that most employment growth took place in corridors not served by BART and that BART's locational advantage was confined primarily to the service sector (mainly finance, insurance, and real estate). Employment densities near BART stations were higher than match-paired freeway interchanges (+12% for suburban and +28% for urban).

Results from these studies do not clearly delineate employment changes from accessibility improvements. Transportation development generates efficiency gains, transfer effects, and activity relocation effects (Banister and Edwards 1995; Berechman 1995; Forkenbrock and Foster 1990). Together these effects influence the demand for employment in conflicting ways. But what about labor supply changes from accessibility improvements? Do people, especially in poor areas, respond to accessibility changes by offering more labor? How do labor skills and labor-market experience affect their willingness to enter the labor market relative to the effect of reduced transportation costs? Are potential employees in some occupations more susceptible to accessibility changes than employees in other occupations? Next we address these questions.

MODELING ACCESSIBILITY AND MARKET ENTRY DECISIONS

When examining the relationships between accessibility improvements and changes in the local supply of labor, it is necessary to distinguish between two types of change. The first is a change in the amount of labor actually provided by existing employees and measured by, for example, the number of daily hours worked. The second is a change in the actual number of people in the labor force, resulting from new market entry.

A common approach to assessing changes in actual labor supplied by existing employees is to consider work/nonwork activity substitution. Individuals divide their total daily hours between work and nonwork activities, and the latter can further be divided between travel and other nonwork (leisure time) activities. Travel time, in turn, which confers negative utility, is a function of accessibility (by mode). Hence, reduced travel time resulting from improved accessibility will leave more time available for work and leisure time activities. Given some reasonable assumptions on work/leisure time substitution as well as on the effect on income of reduced travel times and costs, improved accessibility is likely to have a positive effect on the actual amount of labor individuals can supply (Berechman 1994). At equilibrium, the allocation of time between work and nonwork activities will depend on the reservation wage rate, the lowest wage an unemployed worker will accept; individual preferences with respect to work/leisure substitution; and travel time to work, a measure of accessibility.[5] Since the focus here is on market entry due to accessibility improvements, we do not examine the possibilities of part-time work or working more or fewer hours. Also the database used here (see Appendix B) does not report such information.

A plausible explanation for new labor-market entry due to improved accessibility is the net-pay entry threshold argument. Net pay is defined as the after-tax total earnings minus the costs associated with labor-market participation. Accordingly, individuals regard their expected net pay as a key determinant in their labor-market entry decisions. The costs of participation include the costs of child-care arrangements as well as the time and out-of-pocket expenses associated with travel to work. With other key factors, such as skills and family size, kept constant, the net-pay argument implies that when given after-tax expected earned income, lowering the time and money costs of travel will also lower entry thresholds, thereby positively affecting the propensity of individuals to enter the labor market. It also follows that the larger the entry cost share is of total after-tax expected income, certainly the case for low-income individuals,[6] the larger the elasticity of the labor supply with respect to travel cost reduction will be. Again, we emphasize the short-term and partial equilibrium nature of this analysis since, in the longer run, changes in the labor supply function will affect equilibrium wage rates which, in turn, will affect the actual level of employment.

Empirically, changes in the labor-participation rate can be observed only if individuals willing to enter the labor market, following accessibility improvements, actually become employed. For this to happen, it is necessary for some firms to employ these individuals. In this short-term analysis, we assume a quite elastic labor-demand function so that an increase in labor supply following accessibility improvements will indeed result in employment of workers at present wage rates for firms' location and production technology.

In his well-known study, Cogan (1980) developed a methodology for assessing the effect of the costs of labor-market participation on entry decisions by women. Using 1976 household-panel data from the Michigan Panel Income Dynamics survey and applying a probit model to estimate a reduced-form index of women's labor force participation, Cogan found that the effect of time and monetary costs (unrelated to travel) associated with labor-market entry was rather substantial. Specifically, he

[5] One caveat to this conclusion: many employees are constrained by employment rules, making it unfeasible for them to be paid for more than a fixed number of hours per day, week, or month. These work rules vary between firms and occupations as well as by seniority and labor union contracts. In the Bronx, a large number of employees are part-time workers, who, for various reasons, such as lack of skills, cannot increase the number of hours they work; if they could, they would have done so, considering their income level.

[6] It might be argued that low wages also imply low value of time and, hence, low travel costs. In the New York area, however, direct monetary costs of travel are quite high, so their effect on low wage earners probably outweighs the effect of low value of time.

found that estimated at the sample mean, these costs were equivalent to 1,151 annual hours to the worker. Overall, his results indicate that the annual cost of participation in the labor market amounts to 16% of women's average earned income. These results, however, were not categorized by employment type and did not account for transportation costs associated with market entry.

In this study, we have followed Cogan's approach to examine the effect of lowering travel times and money costs on the supply of labor. Here we test two main hypotheses: 1) improved accessibility, all else unchanged, will positively affect individuals' propensity to enter the labor market and 2) this effect will vary across employment types and industries. Appendix A provides a discussion of the analytical underpinnings of our modeling approach, primarily on the nature of the supply function, which represents participation decisions in the wage-travel costs space.

We measure accessibility as a combination of travel time and monetary costs, known as generalized travel costs, adjusted for the type of mode used. It is important to point out that, to a certain extent, accessibility costs are endogenous variables in the decision process of potential employees. That is, given their location, factors such as mode choice, time of departure, car ownership, and car utilization are used by individuals to effectuate their travel times and costs. On the other hand, mode availability, bus and train headways, fares, and road tolls are largely exogenous. In the analytical model, we regarded accessibility as an endogenous variable but have also introduced into the accessibility function some exogenous travel variables.

The level of accessibility between residential and employment locations i and j, respectively, measured in units of weighted travel time and costs, denoted by T_{ij}, is specified as a function of the following five components:[7] c_{ij}^{m} is the monetary costs of travel by mode, weighted by the proportion of people using that mode between these locations, w_{ij}^{m}; t_{ij}^{m} is travel times by mode, also weighted; d_{ij} is time of departure; C_i^H is car ownership by households (at residential location i); and Y_i^H is households' income level.

$$T_{ij} = f\left(w_{ij}^{m} c_{ij}^{m}, w_{ij}^{m} t_{ij}^{m}, d_{ij}, C_i^H, Y_i^H\right) \qquad (1)$$

The specific accessibility function used in this study is given by

$$T_{ij} = \eta_0 + \sum_m \eta_1^m \left(w_{ij}^{m} c_{ij}^{m}\right) + \sum_m \eta_2^m \left(w_{ij}^{m} t_{ij}^{m}\right) + \eta_3 d_{ij} + \eta_4 C_i^H + \eta_5 \ln Y_i^H + \varepsilon_1 \qquad (2)$$

The weights $w_{ij}^{m} = \frac{L_{ij}^{m}}{L_{ij}}$, where L_{ij}^{m} is the number of people using mode m (m = car, transit, walk) for home-to-work travel between i and j; L_{ij} is the total number of people traveling between i and j.

Equation (2) does not represent a transportation choice model. That is, often after the implementation of a transportation improvement, for example, a new express bus, travelers may shift route or mode, thereby affecting accessibility. While equation (2) does not account for route or mode choices, it explicitly asserts that whatever transportation improvements are made, their accessibility impact is captured through changes in travel time and costs and time of departure, given car availability and income.[8]

Next, we specify the labor-supply function, where $Q_{ij}^{k,s}$ denotes the number of employees in job type k, employed in industry type s, residing in location i, and working in location j, respectively. See Appendix A for definitions.

$$Q_{ij}^{k,s} = \lambda_0 + \lambda_1^k \exp(-\upsilon T_{ij}) + \lambda_2 \ln Y_i^H + \lambda_{3,k} \ln W_j^{k,s} + \lambda_4 E_i + \sum_{I=1}^{3} \lambda_{5,I} F_{I,i} + \lambda_6 SB + \varepsilon_2 \qquad (3)$$

where ε_1 (equation (2)) and ε_2 are the error terms. For the empirical analysis, the accessibility function's decay factor, υ, is set to 1.0. Experi-

[7] We have also used a travel time and cost matrix calculated from actual bus and subway information relative to headways, in-vehicle time, and average walk time to/from nearest stations. These two matrices are highly correlated though on some specific routes there were some significant variations. We did not find significant differences when we tested the empirical model for each of these matrices.

[8] In any case, conducting route and mode choice analysis requires an individual choice database, largely unavailable.

ments with other values for υ did not yield significantly different results.

Equations (2) and (3) were estimated simultaneously using a two-stage least squares (2SLS) procedure. In the first stage, equation (2), the level of accessibility, T_{ij}, between residential location i and employment location j is estimated.[9] In the second stage $Q_{ij}^{k,s}$, the number of employees living in i, working in j, and working in job type k in industry type s is assumed to be a function of several factors: 1) inverse of the accessibility level, T_{ij}, estimated from the first stage; 2) income Y_i^H ; 3) the actual wage rate paid in job type k in industry type s $\left(W_j^{k,s}\right)$; 4) the level of education, measured in units of school years, E_i; and 5) the number of children in 3 age groups ($F_{l,i}$;l = 1,2,3): 0-5, 6-13, 14-18. We have also used a dummy variable, *SB*, to indicate whether a person who lives in the South Bronx also works there (*SB* = 1) or not (*SB* = 0).

The database used for this analysis is composed of 1990 U.S. Census Bureau data. The major data files used contain data at the census block group level and not at the individual household level. The observations pertain to employment, travel behavior, and socioeconomic attributes of residents of the South Bronx, New York. Employment is categorized into 13 job types in 17 employment sectors. In the study area, there are approximately 56,000 census-block-based origin-destination pairs, including persons living and working in the Bronx and people living in the Bronx but working anywhere. As already mentioned, this database does not account for part-time employees or for changes in the number of weekly work-hours actually worked by already employed workers. A detailed description of the database and its organization, including variables definition, appears in Appendix B.

RESULTS AND DISCUSSION

Our principal hypothesis is that with all else constant, reductions in accessibility costs between places of residence and places of employment will enhance the propensity of individuals in the South Bronx to participate in the labor force. Thus, the main thrust of the empirical analysis is the estimation of point elasticities of labor-force supply in specific job categories with respect to travel costs, given a set of other intervening variables. The main results from the estimation are presented in table 2.

As already mentioned, there are 13 job types. Table 2, however, shows results for four types only. One reason is that some employment types (e.g., farming) are not well represented in the South Bronx and thus can be omitted. Another reason is that not all job types proved sensitive to accessibility changes, that is, the relevant estimated parameters were insignificant at 0.05.[10] For brevity, table 2 lists all variables for each equation but shows only those parameters that are significant at the 0.05 level or better. For the accessibility and employment equations, the reported parameters are scale-adjusted coefficients as the units of measurement of variables in these equations are noncomparable.[11]

As can be expected, the results of the accessibility function, equation (2), indicate that overall accessibility is positively and significantly affected by public transit, car, and walk travel times. Reductions in transit travel times have the greatest impact ($\eta_2^{Transit} = 0.807$), while reductions in car travel times have the least effect ($\eta_2^{Car} = 0.212$). The importance of these results is that in the South Bronx, considering the low levels of car ownership, improvements in transit service will have the greatest impact on accessibility.

Interesting results pertain to time of departure. As the number of people leaving home for work at the early and late time periods increases, accessibility improves (the negative sign of the 6:30–7:30 and 8:30–12:00 departure time variables). Apparently, a rush hour departure time is associated with poorer accessibility as factors such as crowding, unreliability, and general inconvenience

[9] In the South Bronx, 68.3% of trip-makers travel by public transit for which monetary cost (fare) is constant relative to trip length and time of day. Therefore, in some runs of the model, the travel cost variable, C_{ij}^m, was omitted from the accessibility equation due to lack of variability.

[10] It remains to be examined why these sectors are not affected by travel costs reduction. This is the subject of a follow-up analysis.

[11] See Montgomery and Peck (1992, chapter 4) for a statistical explanation.

TABLE 2 A Two-Stage Least Squares Estimation of the Accessibility and Employment Functions

Accessibility (equation 2)		Employment (equation 3)				
			Type of job			
Variable	Parameter	Variable	Executive parameter	Technician parameter	Administrative parameter	Transport parameter
Mode		**Accessibility**	–.237740	–.187414	–.096016	–.079812
car	.212161	**Wage rate**				
transit	.806815	(3) Construction	NS	.283052	NS	NS
walk	.413026	(4) Manufacture 1	.129783	.136822	.048485	NS
others	NS	(5) Manufacture 2	NS	.090696	NS	.235875
Departure						
12:00–5:59	NS	(6) Transport	.338492	NS	.235395	.575081
6:00–6:29	NS	(7) Communication	NS	NS	NS	NS
6:30–6:59	–.140844	(8) Wholesale	NS	–.145514	.163956	.256606
7:00–7:29	–.198046	(9) Retail	.285929	NS	NS	NS
7:30–7:59	.286117	(10) FIRE	.485281	.447685	.422971	NS
8:00–8:29	.103212	(11) Business and repair	NS	.347708	NS	–.353465
8:30–8:59	–.126580	(12) Personal Services	NS	–.142507	.068464	NS
9:00–9:59	–.137373	(13) Entertainment	.210809	NS	.052301	NS
10:00–11:59	–.149063	(14) Health	NS	.858439	.172036	.384054
Car ownership						
0 cars	–.042637	(15) Education	NS	.122671	.074335	.179501
1 car	–.004050	(16) Other	.140571	–.143720	NS	.454775
2+ cars	.017643	(17) Public administration	–.141837	.00407	.161577	NS
Income, in $ thousands		**Education:**				
0–9.9	.571909	Less than 9th grade	NS	–.275950	NS	NS
10–19.9	.521587	Less than 12th grade	–.235460	.408651	NS	–.684124
20–29.9	NS	High school diploma	NS	–.326228	.168903	NS
30–34.9	.340198	No college degree	NS	NS	.179568	.212217
35–49.9	.367278	Associate degree	.146286	NS	.166667	–.268634
50–74.9	.189123	Bachelor degree	NS	–.224551	NS	–.288028
75.0+	–.012188	Graduate degree	NS	.187507	NS	–.538609
Constant	44.3827	**Childrens' age:**				
R-Squared	.362	Under 3	NS	NS	NS	–.258383
		3–5	NS	–.235078	NS	–.275407
		6–11	NS	–.159645	–.132387	.455364
		12–17	NS	–.425830	.130015	NS
		Income, in $ thousands				
		0–9.9	NS	.089148	–.055030	NS
		10–19.9	NS	.155627	NS	NS
		20–29.9	.058064	NS	–.043658	NS
		30–34.9	.093460	NS	NS	NS
		35–49.9	NS	NS	NS	NS
		50–74.9	0.082358	NS	–.158341	NS
		75.0+	NS	NS	NS	.121987
		Constant	–4.286843	6.516566	–25.94905	–.841860
		R-Squared	.866	.869	.953	.765

Note: Parameters shown are adjusted coefficients (see text) and significant at 0.05 level or better.
NS = not significant.

affect accessibility.[12] Since New York City public transit is priced uniformly over time and space, improved transit in vehicle travel times, headway, and capacity is likely to have a profound impact on overall accessibility.

The relatively low value of the car ownership parameter ($\eta_4 = -0.04050$) reflects the basic reality of the South Bronx of a very low level of car ownership. Another analysis (Berechman and Paaswell 1997) showed that the car occupancy variable has an indirect effect on accessibility, as higher levels of occupancy are associated with

[12] Early departure may also suggest a multi-purpose trip pattern. Dropping a child at a day-care center is an obvious example.

reduced travel times. Car ownership by itself, however, does not seem to have such an effect.

Income has an interesting effect on measured accessibility. In 1990, in the South Bronx over 65% of the population earned less than $20,000 per year, and over 45% earned less than $10,000. There is no doubt that at these income levels public transit is the mode of choice which, compared with car use, is a slow mode offering lesser accessibility. This explains why we find a significant and positive (i.e., higher travel times) relationship between accessibility and low-income variables (parameter value is $\eta_5 = 0.571$ for $10,000 or less, and $\eta_5 = 0.521$ for $10,000–$20,000 income level). As income increases, there is a gradual shift to private modes, associated with greater accessibility, hence the smaller value of the relevant parameters. When income is at its highest level ($75,000+), its effect on accessibility actually peaks ($\eta_5 = -0.012188$).

Turning now to the employment function, equation (3), a key result is that only for some job types are the accessibility parameters (λ_1^k) statistically significant and with the correct sign. For example, in table 2, the accessibility parameters of Executive, Technician, Administrative, and Transport types of jobs are significant and have a negative sign (i.e., improved accessibility, in terms of *reduced* costs of access, will *increase* employment in these job categories). Why is this result important? Actual accessibility improvements in the South Bronx seem to affect labor supply in some job types only but not in others. In assessing the policy impacts of accessibility improvements on employment in this area, not all job types should be treated similarly. We return to this issue when we discuss the policy implications of this analysis.

As expected, the estimated parameters indicate that a higher wage rate is associated with a greater propensity for workers to enter the labor market. This is particularly true for Executive and Administrative support type jobs in the 17 industries. For Technician and Transport occupations, however, the wage rate effect is positive for only some employment sectors and is negative for others (e.g., for Technicians employed in Personal Services, $\lambda_3 = -0.142507$). It is not quite clear how to explain this result. We surmise that wage differentials in various industries can suppress the willingness of one member of a two-employee household to enter the job market when the other member earns a much higher wage. Another possible explanation is that the increase in accessibility expands the search area. People who were unemployable at present wage rates in their previous search area can now find jobs at a lower wage in the expanded area.

The parameters pertaining to the variable "level of education" have a positive effect on labor-market participation though their magnitude is less than the impact of other variables. For some job types, Executive and Administrative, the estimated parameters indicate that having some formal college education positively contributes to employability, whereas for Technician and Transport, the opposite is true ($\lambda_4 < 0$).[13]

Underlying our analysis is the hypothesis that the costs of travel and other nontravel expenses an individual incurs when entering the labor force represent an actual barrier to labor-force participation. Thus, the costs associated with childcare represent a major market-entry barrier. A negative sign for the pertinent (and significant) parameter (i.e., $\lambda_5 < 0$) indicates that for a given job type having more children of a given age group poses higher market-entry costs. And these, in turn, negatively affect the propensity of individuals to be employed in this occupation. A positive (and significant) parameter indicates the opposite. By and large, the significant parameters of the children-age variable in the employment equation have the expected negative sign (e.g., for job type "Technician" having children in the age group 3–5, $\lambda_5 = -0.235078$). One probable explanation for the few parameters with a positive sign is that, for these particular job types, having children of a certain age does not represent actual costs while, concurrently, it does induce a greater labor-market participation due to income needs.

Except for Executive type jobs and the very low income levels of Technician and highest level of Transport, the income parameter of all other job types (λ_2) was either insignificant or had a nega-

[13] We are unable to explain $\lambda_4 = 0.187507$ for Technician with a graduate degree. Perhaps in this job type overqualification has an offsetting impact on employment.

tive effect on participation decisions. The main reason seems to be the general low level of income in the South Bronx that, save for a small percentage of jobs (Executive being 5.9% of all jobs), is a result of low wages paid in all other job categories. Above, we saw that the wage rate parameters, by and large, have a positive and a sizable impact on participation. Since in the South Bronx wages and income are highly correlated, participation rates are largely captured by changes in the wage level.

How can these parameter estimates be used to assess the impact of improved accessibility on labor supply in the South Bronx? When assessing the size of the employment effect from a given improvement in accessibility, it is necessary to recall that our employment model assumes locations as given. Therefore, a specific reduction in travel costs (equation 2) will affect the propensity of potential employees at their present residential location *i*, to enter job type *k* in industry type *s* at location *j*, by the magnitude of the estimated parameters (λ_1^k in equation 3) *and* the actual change in accessibility. Thus, if we assume a certain percentage increase in accessibility between locations, *i* and *j*, ΔT_{ij}, the total change in labor supply at location *j*, ΔQ_{ij} is

$$\Delta Q_{ij} = \Delta T_{ij} \sum_{k,s} \lambda_1^k \cdot P_{ij}^{k,s} \qquad (4)$$

where $P_{ij}^{k,s}$ is the number of potential employees (the number of employable adults) residing in the zones affected by the accessibility change (*i* and *j*) who work in job type *k* in industry type *s*.

To illustrate, consider a particular transportation development, such as the introduction of an express bus to a major employment area *j*, which improves accessibility (i.e., lowers the composite travel costs measure, T_{ij}) by 10% relative to present accessibility level (thus, $\Delta T_{ij} = 0.1$) for all potential employees who reside in *i* and would travel to work at *j*. From table 2, there are four job types whose accessibility parameters are statistically significant. Within the South Bronx, the observed distribution of these four job types is as follows: Executive (executive, administrative, and managerial) makes up 5.9% of the labor force; Technician (technicians and related support occupations), 2.1%; Administrative (administrative support occupations), 22.4%; and Transport (transportation and material moving occupations), 5.2%. Jointly, they make up 35.6% of the total labor force in the South Bronx.[14] Hence, for every 1,000 potential employees in the relevant *i* and *j* area, 356 are employed in job types that are positively and significantly affected by accessibility changes. For these calculations we assume that this observed distribution of job types applies also to every *i* and *j*.

Given these figures, from equation (4) we get that for each 1,000 potential employees, this accessibility improvement will induce 4.4 new market entries in these job categories. That is:

$$\Delta Q_{ij} = \Delta T_{ij} \sum_{k,s} \lambda_1^k \cdot (1{,}000 \cdot w^{k,s}) = 4.4 \qquad (5)^{15}$$

where $w^{k,s}$ is the above proportion of employees in each job type *k* in industry *s*. Thus, under these conditions a 10% improvement in accessibility, which affects 1,000 potential employees, will stimulate 1.23% new market entry in these 4 job types.[16] The accuracy of these calculations depends, of course, on the degree to which the working assumptions above are valid. It is safe to conclude, however, that overall the net effect of accessibility improvements on employment in the South Bronx is rather small. In this regard, the results obtained in this study agree with those reported in the Spatial Mismatch Hypothesis literature.

CONCLUSIONS

The main objective of this paper was to examine the effect of improved accessibility from transport investment on the local supply of labor in an economically distressed area. The South Bronx, which, according to key socioeconomic indicators, is such an area, has been considering a major transportation improvement investment, known as the Bronx

[14] The proportions of job types cited here represent observed figures and not supply figures, which are unavailable. Therefore, in this example we use the observed percentages as approximations for the supply figures.

[15] $\Delta Q_{ij} = 0.1 \times (0.059 \times 0.23774 + 0.021 \times 0.187414 + 0.224 \times 0.096016 + 0.052 \times 0.079812) \times 1{,}000 = 4.4$

[16] $(\frac{4.4}{356} \times 100)$.

Center project. The increases in employment that derive from transportation investments designed to improve accessibility also result in a more positive economic future for the area. The question then is, if implemented, will this project indeed bring about an increase in employment?

Fundamentally, increased employment from transportation investments results from the interaction of two main factors. The first is the impact on the willingness of a potential worker to enter the job market and travel to a specific employment site once generalized travel costs have been lessened. The second relates to employers' demand for labor, which, among other things, is predicated on the level of access to a properly skilled labor force. In this paper we have examined the first factor, which essentially amounts to an investigation of the effect of a transportation-cost reduction on labor-market participation, assuming that additional employment will be made available by present employers at present wage rates. We have also explicitly assumed a short- to medium-run framework in which households and firms do not relocate in response to the improved accessibility.

Using an analytical framework similar to that of Cogan (1980) to model market-entry decisions by potential employees facing significant entry costs, we have estimated a two simultaneous equations regression model of accessibility and employment. Accessibility is modeled as a function of modal travel time and costs, of time of departure, of car ownership and use, and of income. The employment equation is specified as a function of accessibility costs, wage rate by industry, work skills, level of education, and household demographic characteristics. Our database included 1990 census travel and employment data from the South Bronx, New York. The empirical estimation has yielded point estimates that indicate the effects of accessibility improvements on labor-force participation by job type and employment categories, given residential and employment locations.

The central conclusion from the empirical results is that changes in accessibility costs have a discernible effect on labor-market participation in the studied area. However, with respect to job type, the effect of accessibility is not ubiquitous, both in terms of magnitude and (statistical) significance. Depending on skill requirements, offered wage rates, household income, and children of specific age groups, participation in employment sectors such as Executive, Technician, Administrative, and Transport are more responsive to travel cost reduction than are other employment types. In fact, the empirical estimation shows that labor supply in some employment types such as Retail and Wholesale and Personal Services (statistically) is largely not amenable to changes in accessibility costs.

Another important result is that the magnitude of the estimated net employment effect is rather modest. However, in an economically distressed area like the South Bronx, even a relatively small employment increase can provide an important boost to the welfare of area residents. In particular, this is the case for improving women's labor-market participation following travel costs reductions. In places like the South Bronx, where the proportion of all households headed by a woman is rather large, a reduction in female unemployment is, undoubtedly, of major interest.

Although it was not the intent of the authors to carry out SMH analysis, the results shown in the paper do not negate the principal results of the spatial mismatch literature. For example, for occupations in which there are a large number of low-skill workers (and low wages) such as service occupations or sales occupations, for the most part accessibility coefficients are insignificant. For administrative and transport type jobs, they are significant but quite small. Thus, as the SMH literature confirms, accessibility is not a major factor explaining labor-force participation in areas like the South Bronx.

Within the framework of this analysis it is important to observe that, even in the short run, location can matter when assessing labor-supply changes from accessibility improvements. That is, a large-scale transportation investment, like the Bronx Center Project, is likely to strongly affect some locations but not others, as only a subset of all origin-destination pairs will experience a consequential travel-cost reduction. As a result, only those households located within the impacted area of the planned new rail and bus routes will potentially change their labor-market participation, given all other intervening factors.

A second caveat is that in the empirical analysis we have used "number of employees" as the labor supply variable rather than "number of hours worked." This practice may have affected the estimated results since, in a low-income area like the South-Bronx, many people may be employed in part-time jobs. Therefore, the increase in the supply of labor can be in the form of more hours worked rather than new entry into the labor market. It also does not tell us whether new workers are part-time or full-time employees. If data on the number of hours worked were available, an alternative approach would be to investigate the trade off between work and nonwork activities from a reduction in travel time and cost. It would also permit the investigation of the full change in employment resulting from overall equilibrium adjustment of hours of work.

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REFERENCES

Banister, D. and M. Edwards. 1995. Measuring the Development and Social Impacts from Transport Infrastructure Investment: The Case of the Jubilee Line Extension in London. Available f rom the authors at The Bartlett School of Planning, UCL, Wates House, 22 Gordon Street, London WC1H 0QB.

Banister, D. and J. Berechman. 2000. *Transport Investment and Economic Development.* London: University College London Press.

Beeson, P.E. 1992. Agglomeration Economies and Productivity Growth. *Sources of Metropolitan Growth.* Camden: Rutgers University.

Berechman, J. 1994. Urban and Regional Economic Impacts of Transportation Investment: A Critical Assessment and Proposed Methodology. *Transportation Research A* 28, no. 4:351–162.

____. 1995. Transport Infrastructure Investment and Economic Development: A Review of Key Analytical and Empirical Issues. *Transport and Urban Development.* London: Chapman and Hall.

Berechman, J. and R. Paaswell. 1996. Socio-Economic Profile of the South Bronx, New York. Working Paper 1996-2, University Transportation Research Center, The City College, New York.

____. 1997. The Implications of Travel Profiles for Transportation Investment: The Bronx Center Project. *Transportation* 24, no. 1:51–77.

Cervero, R. and J. Landis. 1995. Development Impacts of Urban Transport: A U.S. Perspective. *Transport and Urban Development.* London: Chapman and Hall.

Cogan, J. 1980. Labor Supply with Costs of Labor Market Entry. *Female Labor Supply: Theory and Estimation.* Princeton: Princeton University Press. 327–59.

Danielson, M.N. and J. Wolpert. 1991. Distributing the Benefits of Economic Growth. *Urban Studies* 28:393–412.

Ewing, R. 1995. Beyond Density, Mode Choice, and Single Purpose Trips. *Transportation Quarterly*. 49, no. 4:15–24.

Forkenbrock, D.J. and N.S. Foster. 1990. Economic Benefits of a Corridor Highway Investment. *Transportation Research* 24A:303–12.

Giuliano, G. and K. Small. 1999. The Determinants of Growth of Employment Centers. *Journal of Transport Geography* 7:189–201.

Ihlanfeldt, K. and D. Sjoquist. 1998. The Spatial Mismatch Hypothesis: A Review of Recent Studies and Their Implications for Welfare Reform. *Housing Policy Debate,* 9, no 4.

Kain, J. 1968. Housing Segregation, Negro Employment, and Metropolitan Decentralization. *Quarterly Journal of Economics*. 82, no. 2:175–97.

Montgomery, D. and E. Peck. 1992. *Introduction to Linear Regression Analysis*. New York: John Wiley and Sons, Inc.

New York City. 1994. Economic Statistics, ES-202 Data, Economic Development Corporation, NY.

New York State. 1998. New York State Bureau of Labor Statistics, Employment in the State of New York. November 1996 and July 1998. Available at www.labor.state.ny.us.

Paaswell, R. and J. Zupan. 1998. Transportation Infrastructure Investments: New York and its Peer Cities. Report, prepared for the Citizens Budget Commission, New York.

Sen, A., S. Soot, V. Thakuriah, P. Metaxatos, V. Prasad, G. Yanos, D. Yang, V. Rivas, L. Dirks, K. Stauffer, P. Freese, and T. Sternberg. 1998. Highway and Urban Decentralization. Final Report. Urban Transportation Center, University of Illinois at Chicago.

U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS). 1990. Census Transportation Planning Package: Urban Element. BTS-CD-15-06. Washington, DC.

Vickerman, R., K. Spiekermann, and M. Wegener. 1995. Accessibility and Economic Development in Europe. Paper presented at the ESF Euro-conference on European Transport and Communication Networks: Policies on European Networks, Espinho, Portugal, April 17–23.

APPENDIX A: A MODEL OF LABOR-MARKET ENTRY DECISIONS

In assessing the effect of reduced travel costs on labor supply, a key analytical issue is that existing costs of labor-market entry introduce discontinuity in the labor-supply function. The reason is that an increase in entry costs will raise reservation wages, thereby reducing the probability that a person will work. To test these ideas within the context of women's labor-market participation, Cogan (1980) introduced the concepts of *reservation hours* and *notional hours* of work. The former is defined as the minimum number of hours a person is willing to work. The latter is the number of hours a person would choose to work if required to spend at least a (positive) number of hours in the labor market. We follow a similar approach by formulating the reservation and notional work-hours functions and the reservation and notional wage-rate functions. To each of these functions we also add an accessibility component, our central explanatory factor, estimated from a separate accessibility function.

Within this analytical framework, the labor-market participation decision is defined as the case when the amount of a person's notional hours exceeds his reservation hours. Let the notional work hours be denoted by $h^N_{k,j}$ and the reservation work hours by $h^R_{k,j}$. Labor-force participation requires that $h^N_{k,j} > h^R_{k,j}$.

We conjecture that labor-market participation decisions by potential employees are based on three major variables: 1) her/his notional work hours relative to her/his reservation work hours, 2) her/his reservation wage rate relative to the offered wage rate, and 3) the costs of travel to work she/he faces if deciding to participate. To simplify the analysis, we assume that each of these variables can be expressed as a linear function of its determinant variables but that the supply function must be upward rising throughout, with respect to the relevant variables.[17] These variables (indexed for locations) are the wage rate offered by job type k, at location j, W_j^k; household income at location i, Y_i^H; level of employee education in units of number of school years E_i; employee age, A_i; number of children, by age category l, at residential location i, $F_{l,i}$; labor-market experience (years employed) X_i; and travel costs, T_{ij}, between residential and employment locations ($i,j = 1,\ldots,M$). Next we define the notional and reservation work hours functions, the reservation wage function, and the travel cost function. We assume that the random disturbance term, associated with each of these functions (u), distributes with mean vector zero and an unknown but constant variance-covariance matrix.

For each household in a residential zone i, employed in employment zone j, the notional work-hours equation, given the employment sector k, $h^{k,N}_{i\neq j}$, is expressed as a function of the market wage rate, W_j^k, the accessibility costs T_{ij}, and a vector of socioeconomic variables:

$$h^{k,N}_{ij} = \gamma_0 + \gamma_1 \ln W_j^k + \gamma_2 \ln Y_i^H + \gamma_3 E_i + \gamma_4 A_i + \sum_i \gamma_{5,l} F_{l,i} + \gamma_6 T_{ij} + u_1 \qquad (A1)$$

Since accessibility costs are regarded here as endogenous choice variables, the parameter γ_6 measures only the *partial effect* of a small change in travel cost on work hours.[18] A further caveat is that since participation is a discrete choice variable, the parameter γ_i actually measures the partial changes in the propensity of potential employees to change work hours.

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[17] The labor-supply function represents participation decisions in the wage-travel costs space. Hence, the above variables (a) and (b), in fact, are a one-choice variable.

[18] If accessibility costs were completely exogenous and fixed for each *ij* pair, the effect of a change in these costs could be interpreted as a *full* change in hours of work as employees adjust to their new equilibrium levels.

The reservation work-hours equation is described as a function of the above variables. That is,

$$h_{k,ij}^{R} = \delta_0 + \delta_1 \ln Y_i^H + \delta_2 E_i + \delta_3 A_i + \sum_l \delta_{4,l} F_{l,i} + \delta_5 T_{ij} + u_2 \qquad (A2)$$

From equations (A1) and (A2), the following reservation wage function is derived.[19]

$$\ln W_{ji}^{R} = \beta_0 + \beta_1 \ln Y_i^H + \beta_2 E_i + \beta_3 A_i + \sum_l \beta_{4,l} F_{l,i} + \beta_5 T_{ij} + u_3 \qquad (A3)$$

where: $\beta_\rho = \frac{1}{\gamma_l}(\delta_\rho - \gamma_\rho)$; $\rho = 0.5$; and $u_3 \sim N(0, \sigma^2)$

For a potential employee residing in origin zone *i*, the wage offer equation at location *j* is specified as a function of level of education, E_i; age, A_i; and labor-market experience, X_i (not included in the empirical analysis since the relevant information was unavailable). Thus,

$$\ln W_{ji}^{O} = \alpha_0 + \alpha_1 X_i + \alpha_2 E_i + \alpha_3 A_i + u_4 \qquad (A4)$$

To empirically assess the impact of reduced transportation costs on the propensity of potential employees to participate in the labor force, we can follow two alternative approaches. Following Cogan, we have defined the participation condition as $h_{k,j}^{N} > h_{k,j}^{R}$. In terms of the wage functions (A3) and (A4), this condition is expressed as $\ln W^{O}_{j} > \ln W^{R}_{j}$ (given *i*). Using these functions, we can derive an explicit form for this condition by properly grouping all variables in the left-hand side and the disturbance terms in the right-hand side. The result would be an index describing the probability of labor-force participation. Given the above assumption of the distribution of the disturbance factors, it is possible to estimate the parameters of this participation index using a probit analysis. Such an analysis is quite useful since the participation index, in fact, provides a reduced-form measure for the participation function, the combination of equations (A3) and (A4).

An alternative approach is to use the condition $h = \max(h^N, h^R)$ and the wage-offer equation (A4) to obtain the following expression for the actual hours worked:

$$h_{ij} = \rho_0 + \rho_1 \ln W_j^{k,O} + \rho_2 \ln Y_i^H + \rho_3 E_i + \rho_4 A_i + \sum_i \rho_{5,l} F_{l,i} + \rho_6 X_i + \rho_7 T_{ij} + u_5 \qquad (A5)$$

where $W_j^{k,O}$ is the wage rate offered in sector *k* in location *j*.

To carry out empirical analysis following the first approach, it is necessary to have a database composed of survey information on specific households relative to their labor-market participation decisions, their labor-market experience, and their socioeconomic attributes.[20] Such a database was unavailable for this study. Therefore, in what follows we use the second approach and simultaneously estimate equation (A5) with the accessibility function (equation 2 above), using a two-stage least squares procedure. In this estimation we assumed that each new market entry is a full-time employee because part-time employment is not considered. Given the database (see Appendix B), such an approach is quite useful as it directly elicits the impact of accessibility and its components on labor-market participation.

APPENDIX B: SOURCE AND STRUCTURE OF THE DATABASE

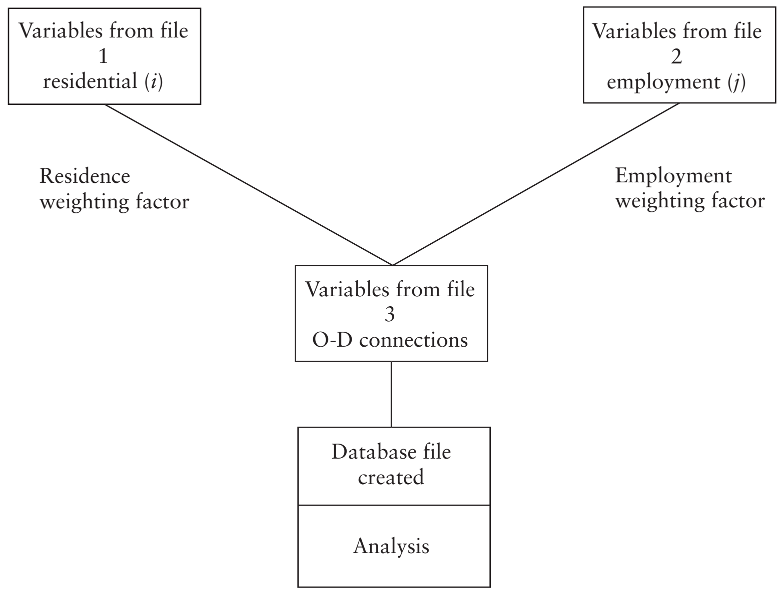
The major sources of data for this study are three U.S. Census Bureau data files: 1) the 1990 Census Transportation Planning Package—Urban Element (CTPP), 2) the Summary Tape File 1 (STF 1a), and 3) Summary Tape File 3 (STF 3a) (USDOC 1990). The prime source of data used for the analysis in this paper comes from the CTPP, which contains data at the census block group level. There are approximately 56,000 census block group origin-destination pairs used in the analysis: persons living in the Bronx and working anywhere.

The CTPP data is actually a data set broken into three different files (see figure A-1). The first file is demographic data for place of residence (*i* loca-

[19] For this derivation, $h = \max(h^N, h^R)$, where h is actual hours worked.

[20] Using data on residential and employment locations and their origin-destination (O-D) interactions introduces statistical complexities into the estimation of a probit model.

FIGURE A.1 Structure of Database



tion). The second file is demographic data for place of employment (*j* location). The third file is the origin-destination matrix for every block group in the New York metropolitan area (a 14-county region of New York, 14 counties of New Jersey, and 3 counties of Connecticut). The matrix contains all modes of travel, peak and off-peak travel, as well as the number of persons traveling between locations *i* and *j*.

The principal variables used in the analysis and their ranges are as follows:

I. **Mean travel time by mode:** mean travel time between *i* and *j* in minutes by mode

II. **Household range of income:** number of households within an income range:

1) $0–$9,999
2) $10,000–$19,999
3) $20,000–$29,999
4) $30,000–$34,999
5) $35,000–$49,999
6) $50,000–$74,999
7) $75,000 and above

III. **Mode use:** number of employed people, 16 years of age or older, who use a mode to travel to work:

1) car
2) public transit (bus, street car, trolley, subway, rail, ferry)
3) other (bike, taxi, motorbike)
4) walk

IV. **Car ownership:** number of households that own *x* cars:

1) 0 cars
2) 1 car
3) 2 or more cars

V. **Time of departure:** number of employed people, 16 years of age or older, during 1 week prior to the census, who leave to work at

1) 12 AM–5:59 AM
2) 6:00 AM–6:29 AM
3) 6:30 AM–6:59 AM
4) 7 AM–7:29 AM
5) 7:30 AM–7:59 AM
6) 8 AM–8:29 AM
7) 8:30 AM–8:59 AM
8) 9 AM–9:59 AM
9) 10 AM–11:59 AM

VI. **Type of industry:** number of people, 16 years of age or older, during 1 week prior to the census, who work in

1) agriculture, forestry, and fisheries
2) mining
3) construction
4) manufacturing, non-durable goods
5) manufacturing, durable goods
6) transportation

7) communications and other public utilities
8) wholesale trade
9) retail trade
10) finance, insurance, and real estate (FIRE)
11) business and repair services
12) personal services
13) entertainment and recreation services
14) health services
15) educational services
16) other professional and related services
17) public administration

VII. **Wage rate by industry:** wage rate for each of the above industries, based on NYC ES202 1994 data.

VIII. **Type of job:** number of people, 16 years of age or older, during 1 week prior to the census, who work at the following job types

1) executive, administrative, and managerial
2) professional specialty occupations
3) technicians and related support occupations
4) sales
5) administrative support occupations, including clerical
6) private household occupations
7) protective service occupations
8) service occupations, except protective and household
9) farming, forestry, and fishing occupations
10) precision production, craft, and repair occupations
11) machine operators, assemblers, and inspectors
12) transportation and material moving occupations
13) handlers, equipment cleaners, helpers, and laborers

IX. **Educational level:** number of persons who have attained a given educational level

1) less than a 9th grade high school level
2) less than a 12th grade level
3) high school diploma
4) attended college but no degree
5) Associates degree
6) Bachelors degree
7) graduate degree

X. **Presence and age of children:** number of children present of different age groups

1) number of children less than 3 years old
2) number of children 3 to 5 years old
3) number of children 6 to 11 years old
4) number of children 12 to 17 years old

The above database contains two interzonal accessibility matrices, one based on travel time and costs reported by travelers making home-to-work trips and the second based on travel time and costs calculated from actual bus and subway information relative to headway, in-vehicle time, and average walk time to or from the nearest stations. Comparisons of these two accessibility matrices showed some variations. Therefore, we carried out the empirical analysis separately for each of these two accessibility matrices though no major differences were found for the estimated parameters.