Accessibility and Agglomeration:
Discrete-Choice Models of Employment Location by Industry Sector

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ABSTRACT
This paper reports on the design, specification and empirical results of a discrete choice employment location model for the Greater Wasatch Front Region of Utah, which includes Salt Lake City, using 150 by 150 meter grid cells as the units of analysis. The employment location model is a component of the UrbanSim model system, which also includes model components for residential location, real estate development, and land prices. The employment location model simulates employers choosing locations to place new jobs or jobs that are moving using location characteristics. Parcel and business establishment data were geo-coded to grid cells in order to derive spatial measures describing the real estate and land use composition of the location and its neighborhood, site characteristics such as proximity to highways and arterials, local agglomeration effects of proximity to employment by sector, and regional access measures incorporating the composite utility of travel to population. Estimation results confirm the significance of site characteristics such as density and proximity to freeways, accessibility to labor force and consumers, and to nodes of regional significance such as the central business district of Salt Lake City and the regional airport. Results also show complex patterns of agglomeration, or clustering of employment within and between industry sectors.

INTRODUCTION

Understanding the factors influencing the spatial distribution of employment is critical in the development of sound regional transportation plans, insofar as the locations of retail stores, manufacturing firms, service firms, governmental agencies and schools determine the destinations of most intra-urban travel. Investments in transportation, by the same token, alter patterns of accessibility and influence the costs firms face in accessing inputs and labor and distributing outputs to consumers. These changes in turn alter the spatial distribution of opportunities for employment location and expansion, raising implications for the economic structure and competitiveness of regions and their evolving polycentric spatial structure. Within the context of integrated transportation and land use planning there is a pressing need for employment location models that are sensitive to multi-modal transportation investments and policies, and which can distinguish between the behavioral patterns of location choices made by firms in different industrial sectors within modern multi-nucleated urban forms.

This paper presents the design and specification of a multi-sectoral employment location model and its application to the Salt Lake City, Utah area. The work is part of a larger project to implement an integrated transportation and land use model system for regional planning, linking UrbanSim and a regional four-step travel model system operated by the Wasatch Front Regional Council (WFRC) and the Mountainlands Association of Governments (MAG). The project was coordinated by the Governor's Office of Planning and Budget, in close coordination with Envision Utah, a regional visioning process, and with the WFRC and MAG. A description of and estimation results from the Greater Wasatch Front application of the residential location, real estate development and land price components of UrbanSim are reported in (*1, 2*). Further references provide an overview of the UrbanSim model and validation results of its application in Eugene-Springfield (*3*), empirical results from the original specification of UrbanSim (*4*), a detailed description of the current model system implementation (*5*), its theoretical foundations (*6, 7*), and the underlying software infrastructure (*8*). In the following sections, we briefly review the theory and approach used in designing the models, and we describe the methodology and results from estimation using data for the Greater Wasatch Front Region.

THEORY

Theoretical models of employment location date at least to the seminal work of von Thünen (*9*), which described a negatively sloped agricultural land rent gradient in which land prices fall with distance from a central market, to offset transportation costs to the market. This early work on bid-rent later stimulated the development of the monocentric model of urban structure (*10, 11, 12*). Early applications of spatial theory of urban firm location can be traced to Christaller's work on central place theory and the hierarchy of cities (*13*), and that of Losch, who derived an idealized hexagonal representation of market areas based on spatial competition between firms (*14*). While these early contributions provided conceptual foundations for understanding the competitive bidding for sites with higher accessibility, which produces declining land rent gradients from high access locations, and the spatial separation of firms competing for market share, the framework would be insufficient to explain the rise of central business districts in the 19th century, and the rapid rise of secondary suburban centers in the latter third of the 20th century.

A third major theoretical contribution is the concept of agglomeration economies, which help to explain the existence of employment clusters on the basis of externalities associated with spatial proximity. These agglomeration economies have been described as arising from information spillovers, local non-traded inputs, and a local skilled labor pool (*15*). An important theoretical problem in urban economic models is that neo-classical economic assumptions include constant returns to scale, but the essence of agglomeration economies is the idea of increasing returns to scale for firms that cluster with other firms in their own or related industrial sectors (*16*). There are offsetting forces that neutralize the agglomeration advantages of clustering as centers become large, producing opportunities for the creation and growth of suburban centers. Other relevant work on employment location has focused on transportation costs (*17*), the influence of amenities and governmental services and taxes (*18, 19*).

The model developed in this paper draws on these antecedents, bringing together the concepts of bid-rent theory, agglomeration economies, and the effects of transportation and local government policy in a discrete choice model. The following section develops the model specification, and is followed by a discussion of the data and the estimation results from application of the model to the metropolitan region of Salt Lake City, Utah.

METHODOLOGY

Model Design

The employment location choice model simulates location choices for new jobs created as a byproduct of economic expansion, predicted by an external macroeconomic model, and for jobs that have been predicted to move by the employment relocation model component of UrbanSim. The employment location model is a discrete choice model from the vantage point of an employer locating a job anywhere in the city. All jobs that do not have a space in a current year, i.e. all new jobs and all jobs that are moving, are faced with alternative locations to choose from. The choice set of location alternatives is defined by *job spaces* (quantities of vacant nonresidential square footage of sufficient size to accommodate a job, and some fraction of the housing units, to accommodate home-based employment) within 150 by 150 meter grid cells.

The probability of each alternative (the different job spaces open to a particular job) being chosen is calculated using a discrete choice model. We draw on discrete choice theory and random utility maximizing models, following the work of McFadden (*20, 21*), to specify a multinomial logit model.

To arrive at a choice model for employment location we assume that 1) each job belongs to a firm (whose characteristics other than industry sector remain latent) which is faced with a choice between alternative locations for the job, 2) that each location, indexed by i, has attached to it some utility, U_i, for the firm, and 3) that the location with the highest utility has been chosen (maximization of utility). We refer to the more general concept of utility maximization rather than profit maximization, since the utility may be based largely or exclusively on expectations of profit for some sectors, but profit may represent a small or nonexistent part of the utility for other sectors, such as governmental and educational establishments. We only observe the current location of jobs, and do not observe the alternative locations open to the employer before locating the job, nor do we observe the utility. We proceed by assuming that the utility of alternative i for the employer of a particular job can be separated into a systematic part and a random part:

$$U_i = u_i + \varepsilon_i \tag{1}$$

where $u_i = \beta_i \cdot x$ is a linear-in-parameters function, β_i is a vector of k estimable coefficients, x is a vector of k observed, exogenous, independent variables, and ε_i is an unobserved random error. The systematic component of the utility of location i is specified as a function of an array of characteristics at the *site* (S_i), including the real estate characteristics and proximity of the site to freeways and arterials; characteristics of the land use mix and value in the immediate *neighborhood* surrounding the site (N_i); agglomeration economies from geographic *clustering* of firms of the same and each of the other sectors (C_i); and multi-modal *accessibility* to labor, consumers, the Central Business District (CBD), and the regional airport (A_i):

$$u_i = \alpha + \beta S_i + \delta N_i + \lambda C_i + \gamma A_i . \qquad (2)$$

Assuming the errors in (1) to be distributed with a Gumbel distribution (Type I extreme value distribution) leads to the familiar multinomial logit model (*20, 21*):

$$P_i = \frac{e^{\beta_i \cdot x}}{\sum_{\forall i'} e^{\beta_{i'} \cdot x}} . \qquad (3)$$

The probability, P_i, represents the probability of the firm choosing location alternative i for a particular job. The estimable coefficients, β_i, of (3) are estimated with the method of maximum likelihood (see for example (*22*)).

We estimate one choice model (i.e. one set of coefficients) for each of the 14 industry sectors shown in Table 1. To estimate the model coefficients we use data for business establishments in 1997, geo-coded to a grid of 150 by 150 meter cells. To arrive at a set of alternatives we allow each job in a sector the choice of all locations in the universe open to that industry sector. This generates a very large choice set. We use a uniform distribution to randomly sample a set of nine alternatives in addition to the chosen location and estimate a model using this random sample of alternatives. This makes it impossible to estimate alternative-specific effects or alternative-specific constants. However, it can be proven that the coefficients of a choice model estimated from a random sample of alternatives, selected with a uniform distribution, are consistent, as explained by McFadden (*23*) in his paper on residential location choice, which faces a similar issue.

Data

The input data used to construct the UrbanSim *database* include parcel data from tax assessor offices, business establishment files from the state unemployment insurance database, census data, GIS overlays representing environmental, political and planning boundaries, and a location grid. These data are diagnosed and analyzed for missing, erroneous or inconsistent values. Each household in the metropolitan area is represented as an individual entity, with the primary characteristics relevant to modeling location and travel behavior: household income, size, age of head, presence of children, and number of workers. Employment is represented as individual records for each job and its industry sector. Locations are represented using grid cells of 150 by 150 meters (just over 5.5 acres). This location grid allows explicit cross-referencing of spatial features such as planning and political boundaries, including city, county, traffic zones, urban growth boundaries; and environmental features such as wetlands, floodways, stream buffers, steep slopes, or other environmentally sensitive areas.

The database links individual jobs to job spaces. The job spaces can be either nonresidential square footage, or a residential housing unit to account for home-based employment. When jobs are predicted to move, the space they occupy becomes vacant, and when jobs are assigned to a particular job space, that space is reclassified as occupied.

The employment location choice model coefficients must first be estimated using a set of observed employment locations. Each location has associated with it characteristics, which become the exogenous variables in the model. The characteristics used by the employment location model include real estate characteristics in the grid cell (land value, residential units, commercial sq. ft., land use), neighborhood characteristics and local accessibility measures (quantity of residential units, average land values, average improvement values, distance to highway, employment by sector within 600 m), and regional accessibility (travel time to central business district, travel time to airport, access to population, and access to employment).

The neighborhood characteristics and local accessibility measures depend on a neighborhood scale, chosen to represent walking distance. There is no agreement in the literature on the most appropriate walking distance. For the purpose of this study, we define a neighborhood scale as a radius of 600 meters (roughly 1/3 of a mile). This radius is used to calculate neighborhood averages and measures of quantity of employment by sector. This captures the effect of local agglomeration on employment location.

Regional accessibility is also important in employment location choice. We use travel time to central business district and travel time to airport as two of our regional accessibility measures. The other two measures are accessibility to population and accessibility to employment. These measures are calculated for each location, i, as:

$$A_i = \sum_{\forall j} D_j e^{L_{ij}} , \qquad (3)$$

where A_i is a regional accessibility measure, D_j is the quantity of activity (to which accessibility is measured, i.e. population or employment in our case), L_{ij} is a composite utility, calculated as a logsum, from location i to j, scaled to a maximum value of zero for the highest utility and with negative values for all other utilities. These accessibility measures are calculated by a separate UrbanSim model component, the accessibility component, which reads the composite utilities, L_{ij}, from the travel model.

Given these data, we estimate multinomial logit, discrete choice models for employment location for each industry sector, with a random sample of nine alternative locations in addition to the chosen location, on a random sample of 5000 observed jobs in each sector. The models are estimated using maximum likelihood. See for example Greene (*22*) for a description of maximum likelihood estimation and multinomial logit models. The estimation results for all sectors are presented in Tables 2–3.

Simulating Employment Location Choice

During every simulation year, jobs are created and jobs are predicted to move by UrbanSim. The employment location choice model is used to simulate the choice of a location for each job that has no location. For each such job, a sample of locations with vacant non-residential space, or space in housing units for home-based jobs, is randomly selected from the set of all possible alternatives. The estimated logit model for the job's industry sector is then used to calculate the probabilities of each alternative location being chosen.

Once the probabilities of all allowed location choice alternatives are calculated for a job, the location choice is simulated using a Monte Carlo sampling process. After cells have been selected as the chosen locations for all jobs, the cells' characteristics are updated, i.e. the previously vacant job spaces becomes occupied, the number of jobs in the cells is updated, etc.

RESULTS

Estimation results for the employment location choice logit models for all industry sectors in the Greater Wasatch Front region are presented in Tables 2–3. Since the coefficients are based on random sampling of alternatives, there are no alternative-specific constants, and no base alternative. The coefficients are therefore interpretable in terms of the direction of the influence of a variable on the utility and the probability of a location choice. In addition, coefficients can be compared across industry sectors, since the same specification is used for all sectors, with the exception of insignificant variables, which were restricted to zero. Interpreting the coefficients is complex, however, due to the interaction between correlated variables. This is particularly true of the access to population and access to employment variables, and the travel time to the CBD and to the regional airport, since these are fairly close to each other within the broader region. Nevertheless, including these correlated variables improved the goodness of fit of the model.

Beginning with site characteristics, the total commercial square footage within a cell measured a local density effect, with all sectors showing a negative and significant effect, and the strongest aversion being shown by the resource extraction and auto sales and service sectors, while the lowest aversion was shown by manufacturing; transportation, communications and public utilities; finance; and government and education. Housing units within a cell indicate the affinity for sites that include residential uses. Construction showed the only positive effect among the sectors identified as basic; with Transport, Communications, and Utilities, along with Trucking, showing significant negative results; and retail and service sectors 7-13 all had positive and significant coefficients. Total value in the cell refers to the combination of all land value and building (improvement) value in the cell, and is not normalized per square foot of land or building. Most sectors had a positive coefficient on this, with the highest magnitudes for the service sectors 9-13. The development type of the cell was included in the models as a set of binary indicator variables representing mixed use, low-density commercial, mid-density commercial, high-density commercial, industrial, or governmental types. The base of comparison for these are cells of principally residential type, and these variables must be interpreted holding constant the other variables in the model. No clear interpretation of patterns in these development type variables is apparent, though they were generally significant.

Neighborhood characteristics include the housing density within 600 meters, the average land value per acre in the area, and the quality of housing within the area as measured by improvement value per unit. The sectors showing positive coefficients on neighborhood housing density were all the retail and service sectors, in addition to construction, with the highest effects for retail sectors and health services. Higher quality of housing in the neighborhood had positive effects on location probabilities for most sectors, with the exceptions of general retail, finance and health services. Higher land values in the neighborhood reduced the probability of location for almost all sectors, with only insurance and real estate actually showing a positive effect, indicating the relative propensity of this sector to bid successfully for the most prized locations.

Accessibility characteristics include regional multi-modal accessibility of population and employment, as well as travel times to the CBD and airport. The accessibility to population and employment were generally significant and with offsetting signs, with variation across sectors in terms of the relative weights of these two effects. The sectors attracted to sites with relatively high access to population as compared to employment are construction and insurance and real estate. Sectors showing aversion of sites with relatively high accessibility to population as compared to employment are manufacturing; transportation, communications and public utilities; and auto sales and service. Sectors attracted to sites with relatively high access to employment relative to population are trucking, warehousing and wholesale trade; and general retail. Sectors showing aversion to sites with relatively high employment access relative to population are resource extraction, health services and government and education. Travel time to the CBD, controlling for access to the airport and all the preceding accessibility effects, was positive for most sectors, but remained negative for health services, general services, and government and education. By contrast, travel time to the airport, a few miles to the west of the Salt Lake City CBD, was negative for most basic and retail sectors, and positive only for service sectors 11-14.

The agglomeration effects were measured by estimating the effect on location probabilities of the number of jobs in each sector that are within 600 meters, representing a degree of spatial clustering that facilitates face-to-face interaction and walk access within employment centers. Some general patterns are apparent from the summary of these industry interactions, shown in Table 4. All the agglomeration effects for the same industry were positive (indicated by the plus-sign on the diagonal in Table 4), showing a positive externality for clustering of employment within the same industry. Since this is a job-based location choice model specification, and not a firm-based model, this outcome may indicate more about average establishment size than about clustering of different establishments of the same industry. The patterns of agglomeration across industry sectors show complex positive and negative geographic associations between industry sectors. For example, general retail shows a positive effect on location probability in locations with more employment in the immediate vicinity in the construction; transportation, communications and utilities; restaurants and food stores; and general services. Location probability of jobs in the finance sector is positively influenced by agglomerations of insurance and real estate and general services. These results are derived from empirical estimation of the affinities for spatial proximity between jobs in each sector, rather than imposed on the data using an input-output matrix, as is done in spatial input-output models such as MEPLAN or TRANUS (*24*).

The employment location model developed here extends previous models of employment location by integrating within a general discrete choice model structure the effects of site, neighborhood, accessibility, and agglomeration on location choice. The level of spatial detail is unprecedented in intra-urban modeling of employment location, using 150 by 150 meters as the representation of location. Further development of the approach will explore dynamics of business establishment creation, closure, expansion and contraction, and the labor market matching of jobs and workers.

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LIST OF TABLES

TABLE 1 Industry Sectors

Sector number	Sector description	Sector type
1	Resource Extraction	Basic
2	Construction	Basic
3	Manufacturing	Basic
4	Transport, Communications and Utilities	Basic
5	Trucking and Warehousing, Wholesale Trade	Basic
6	General Retail	Retail
7	Restaurants and Food Stores	Retail
8	Auto Sales and Services	Retail
9	Finance	Service
10	Insurance and Real Estate	Service
11	Business and Professional Services	Service
12	Health Services	Service
13	General Services	Service
14	Government and Education	Service

TABLE 2 Estimation Results for Employment Location Models by Industry Sectors 1–7

Employment Sectors:	1	2	3	4	5	6	7
Ln(Total commercial sqft in cell)	-0.554	-0.434	-0.196	-0.214	-0.321	-0.335	-0.374
	(0.0151)‡	(0.0117)‡	(0.0151)‡	(0.0230)‡	(0.0168)‡	(0.0140)‡	(0.0146)‡
Ln(Total number of residential units in cell)	–	0.0725	–	-0.0992	-0.0829	–	0.0699
		(0.0230)‡		(0.0259)‡	(0.0247)‡		(0.0213)‡
Ln(Total value of cell)	0.172	–	–	0.201	–	0.247	0.181
	(0.0294)‡			(0.0365)‡		(0.0298)‡	(0.0316)‡
Ln(Access to population)	2.337	1.491	-1.355	-6.778	-6.433	-1.444	–
	(0.437)‡	(0.362)‡	(0.392)‡	(0.444)‡	(0.471)‡	(0.432)‡	
Ln(Access to employment)	-2.388	-1.490	0.950	6.219	7.040	1.729	–
	(0.481)‡	(0.337)‡	(0.421)‡	(0.493)‡	(0.525)‡	(0.479)‡	
Ln(Distance to highway)	0.0256	–	0.0167	-0.0240	-0.0142	-0.0242	-0.0225
	(0.00877)‡		(0.00782)‡	(0.00824)‡	(0.00812)†	(0.00691)‡	(0.00674)‡
Travel time to central business district (min.)	0.0172	–	0.0161	–	0.0681	0.0533	0.0185
	(0.00869)‡		(0.00705)‡		(0.00752)‡	(0.00772)‡	(0.00690)‡
Travel time to airport (min.)	-0.0127	–	-0.0180	-0.0176	-0.0465	-0.0348	-0.0123
	(0.00885)		(0.00703)‡	(0.00481)‡	(0.00735)‡	(0.00790)‡	(0.00696)†
Ln(Number of units within 600 m)	–	0.0312	-0.0307	–	-0.0410	0.158	0.219
		(0.0153)‡	(0.0112)‡		(0.0129)‡	(0.0145)‡	(0.0136)‡
Ln(Land value per acre within 600 m)	-0.0991	-0.0950	-0.131	-0.133	-0.0698	-0.167	–
	(0.0189)‡	(0.0182)‡	(0.0154)‡	(0.0220)‡	(0.0187)‡	(0.0207)‡	
Ln(Improvement value per unit within 600 m)	0.0419	0.0202	0.0247	0.0284	0.0178	-0.0168	–
	(0.00699)‡	(0.00743)‡	(0.00582)‡	(0.00431)‡	(0.00588)‡	(0.00811)‡	
Mixed use, residential / commercial, cell	0.689	–	-0.789	-0.803	-0.683	–	–
	(0.0513)‡		(0.148)‡	(0.199)‡	(0.158)‡		
Low density commercial cell	–	-0.196	-1.086	-1.520	-1.042	–	0.313
		(0.0742)‡	(0.153)‡	(0.213)‡	(0.177)‡		(0.0740)‡
Middle density commercial cell	0.519	-0.315	-0.862	-1.611	-1.122	0.259	0.475
	(0.0655)‡	(0.0796)‡	(0.158)‡	(0.216)‡	(0.185)‡	(0.0534)‡	(0.0718)‡
High density commercial cell	0.925	-0.190	-0.789	-1.279	-0.994	0.235	0.355
	(0.0573)‡	(0.0782)‡	(0.164)‡	(0.215)‡	(0.192)‡	(0.0493)‡	(0.0756)‡
Industrial / Governmental cell	–	-0.540	-1.272	-1.701	-1.310	-0.508	-0.314
		(0.0683)‡	(0.158)‡	(0.217)‡	(0.185)‡	(0.0533)‡	(0.0748)‡

(Continued)

TABLE 2 Estimation Results for Employment Location Models by Industry Sectors 1–7 (Continued)

Employment Sectors:	1	2	3	4	5	6	7
Employment in sector 1 within 600 m	0.0217 (0.000545)‡	0.00389 (0.000856)‡	0.00351 (0.000541)‡	-0.00267 (0.000529)‡	0.00107 (0.000488)‡	-0.00645 (0.000563)‡	0.00133 (0.000607)‡
Employment in sector 2 within 600 m	0.000533 (0.000201)‡	0.00421 (0.000138)‡	0.000561 (0.000143)‡	–	0.000937 (0.000129)‡	0.000504 (0.000158)‡	-0.00111 (0.000204)‡
Employment in sector 3 within 600 m	-0.00105 (0.907e-4)‡	–	0.00142 (0.364e-4)‡	–	0.000129 (0.489e-4)‡	–	-0.000444 (0.693e-4)‡
Employment in sector 4 within 600 m	–	–	–	0.000983 (0.219e-4)‡	-0.000325 (0.560e-4)‡	0.000150 (0.399e-4)‡	–
Employment in sector 5 within 600 m	–	-0.000233 (0.891e-4)‡	-0.000171 (0.533e-4)‡	0.000239 (0.442e-4)‡	0.00108 (0.425e-4)‡	-0.000201 (0.774e-4)‡	-0.987e-4 (0.762e-4)
Employment in sector 6 within 600 m	-0.00206 (0.000112)‡	-0.000415 (0.000108)‡	-0.000767 (0.768e-4)‡	0.000340 (0.634e-4)‡	–	0.00159 (0.503e-4)‡	-0.000216 (0.660e-4)‡
Employment in sector 7 within 600 m	0.000686 (0.000119)‡	-0.000525 (0.000148)‡	–	-0.000810 (0.963e-4)‡	-0.000697 (0.000116)‡	0.000581 (0.881e-4)‡	0.00233 (0.857e-4)‡
Employment in sector 8 within 600 m	-0.000813 (0.000280)‡	–	-0.00109 (0.000238)‡	-0.00247 (0.000218)‡	0.000549 (0.000178)‡	–	–
Employment in sector 9 within 600 m	-0.00107 (0.000118)‡	–	-0.000328 (0.916e-4)‡	–	-0.000671 (0.000116)‡	–	0.000256 (0.000102)‡
Employment in sector 10 within 600 m	–	–	–	–	0.000688 (0.000123)‡	-0.000367 (0.872e-4)‡	-0.000705 (0.782e-4)‡
Employment in sector 11 within 600 m	0.000389 (0.724e-4)‡	-0.000126 (0.581e-4)‡	0.000191 (0.596e-4)‡	0.000447 (0.429e-4)‡	0.000360 (0.640e-4)‡	-0.000230 (0.458e-4)‡	-0.000366 (0.591e-4)‡
Employment in sector 12 within 600 m	–	-0.000291 (0.915e-4)‡	-0.000230 (0.715e-4)‡	-0.000172 (0.519e-4)‡	-0.000298 (0.805e-4)‡	–	-0.000318 (0.592e-4)‡
Employment in sector 13 within 600 m	–	-0.000428 (0.000127)‡	–	-0.000138 (0.362e-4)‡	–	0.000236 (0.363e-4)‡	-0.000247 (0.356e-4)‡
Employment in sector 14 within 600 m	-0.000312 (0.431e-4)‡	-0.000183 (0.373e-4)‡	-0.000252 (0.317e-4)‡	-0.000381 (0.330e-4)‡	-0.000269 (0.358e-4)‡	-0.000210 (0.305e-4)‡	-0.000172 (0.284e-4)‡
Number of observations	5000	5000	5000	5000	5000	5000	5000
Log-likelihood at 0	-11512.9	-11512.9	-11512.9	-11512.9	-11512.9	-11512.9	-11512.9
Log-likelihood at β	-6697.29	-7203.56	-9610.51	-8456.81	-9090.76	-9409.45	-8760.73
ρ^2	0.41828	0.37431	0.16524	0.26545	0.21039	0.18271	0.23905

Logit model coefficient estimates with standard errors of the estimates in parentheses.
Significance of coefficients from zero is indicated by † (90%) and ‡ (95%), for a two-tailed t-test.
– Indicates the coefficient was restricted to zero because of lack of significance.

TABLE 3 Estimation Results for Employment Location Models for Industry Sectors 8–14

Employment Sectors:	8	9	10	11	12	13	14
Ln(Total commercial sqft in cell)	-0.493 (0.0245)‡	-0.267 (0.0147)‡	-0.318 (0.0215)‡	-0.299 (0.0214)‡	-0.290 (0.0128)‡	-0.396 (0.0133)‡	-0.243 (0.0213)‡
Ln(Total number of residential units in cell)	0.123 (0.0227)‡	0.182 (0.0220)‡	0.135 (0.0222)‡	0.0428 (0.0222)†	0.114 (0.0192)‡	0.0598 (0.0138)‡	–
Ln(Total value of cell)	0.173 (0.0379)‡	0.384 (0.0324)‡	0.292 (0.0404)‡	0.534 (0.0333)‡	0.385 (0.0309)‡	0.308 (0.0274)‡	0.271 (0.0311)‡
Ln(Access to population)	-2.996 (0.453)‡	-2.730 (0.460)‡	0.758 (0.375)‡	-3.555 (0.451)‡	1.121 (0.494)‡	–	4.633 (0.453)‡
Ln(Access to employment)	2.805 (0.496)‡	2.991 (0.516)‡	-0.637 (0.351)†	5.226 (0.503)‡	-1.726 (0.534)‡	–	-5.359 (0.470)‡
Ln(Distance to highway)	-0.0490 (0.00693)‡	-0.0695 (0.00736)‡	-0.0924 (0.00733)‡	-0.0345 (0.00719)‡	0.0334 (0.00835)‡	-0.0214 (0.00701)‡	0.0219 (0.00810)‡
Travel time to central business district (min.)	0.0478 (0.00832)‡	0.125 (0.00810)‡	–	0.0183 (0.00802)‡	-0.0870 (0.00879)‡	-0.0758 (0.00666)‡	-0.0826 (0.00857)‡
Travel time to airport (min.)	-0.0419 (0.00846)‡	-0.112 (0.00821)‡	–	0.0455 (0.00827)‡	0.0713 (0.00909)‡	0.0691 (0.00694)‡	0.0448 (0.00914)‡
Ln(Number of units within 600 m)	0.0518 (0.0144)‡	0.129 (0.0178)‡	–	0.0506 (0.0120)‡	0.356 (0.0223)‡	–	0.0939 (0.0145)‡
Ln(Land value per acre within 600 m)	–	–	0.719 (0.0548)‡	-0.20 (0.0176)‡	-0.0649 (0.0310)‡	-0.0836 (0.0196)‡	-0.0580 (0.0210)‡
Ln(Improvement value per unit within 600 m)	0.0685 (0.00893)‡	-0.040 (0.0101)‡	0.0382 (0.00842)‡	–	-0.0454 (0.0134)‡	0.0467 (0.00618)‡	0.0641 (0.00805)‡
Mixed use, residential / commercial, cell	0.488 (0.182)‡	-0.467 (0.0717)‡	-0.686 (0.170)‡	-0.802 (0.185)‡	–	–	-0.904 (0.183)‡
Low density commercial cell	0.973 (0.190)‡	-0.568 (0.0819)‡	-1.058 (0.186)‡	-1.105 (0.196)‡	–	–	-1.307 (0.196)‡
Middle density commercial cell	0.844 (0.195)‡	–	-0.682 (0.186)‡	-0.921 (0.195)‡	-0.154 (0.0764)‡	–	-1.413 (0.198)‡
High density commercial cell	0.727 (0.203)‡	–	-0.767 (0.190)‡	-0.529 (0.196)‡	0.382 (0.0625)‡	–	-0.820 (0.194)‡
Industrial / Governmental cell	0.379 (0.201)†	-1.145 (0.0574)‡	-1.796 (0.196)‡	-1.215 (0.199)‡	–	-0.344 (0.0434)‡	–

(Continued)

TABLE 3 Estimation Results for Employment Location Models by Industry Sectors 8–14 (Continued)

Employment Sectors:	8	9	10	11	12	13	14
Employment in sector 1 within 600 m	0.00394 (0.000716)‡	-0.00749 (0.000418)‡	-0.00179 (0.000388)‡	-0.000970 (0.000460)‡	0.00663 (0.000697)‡	0.00109 (0.000492)‡	0.00239 (0.000534)‡
Employment in sector 2 within 600 m	0.000337 (0.000154)‡	–	–	–	–	-0.00121 (0.000174)‡	-0.00122 (0.000191)‡
Employment in sector 3 within 600 m	-0.000412 (0.653e-4)‡	-0.000504 (0.641e-4)‡	-0.000516 (0.731e-4)‡	–	-0.000775 (0.942e-4)‡	-0.000539 (0.655e-4)‡	-0.000507 (0.733e-4)‡
Employment in sector 4 within 600 m	0.915e-4 (0.382e-4)‡	-0.000369 (0.503e-4)‡	–	–	–	-0.000353 (0.550e-4)‡	-0.000502 (0.621e-4)‡
Employment in sector 5 within 600 m	–	-0.000747 (0.000100)‡	-0.000363 (0.998e-4)‡	–	-0.00156 (0.000176)‡	0.000402 (0.631e-4)‡	–
Employment in sector 6 within 600 m	-0.000310 (0.715e-4)‡	–	-0.000345 (0.680e-4)‡	–	-0.000711 (0.000101)‡	0.000241 (0.658e-4)‡	–
Employment in sector 7 within 600 m	–	–	–	-0.000346 (0.770e-4)‡	-0.000454 (0.000108)‡	-0.000322 (0.939e-4)‡	-0.00108 (0.998e-4)‡
Employment in sector 8 within 600 m	0.00515 (0.000137)‡	–	-0.00103 (0.000189)‡	0.000668 (0.000144)‡	0.000851 (0.000188)‡	–	–
Employment in sector 9 within 600 m	0.000251 (0.000108)‡	0.00193 (0.567e-4)‡	–	-0.000549 (0.706e-4)‡	–	–	–
Employment in sector 10 within 600 m	-0.000469 (0.000126)‡	0.000127 (0.611e-4)‡	0.00130 (0.50e-4)‡	0.000140 (0.673e-4)‡	-0.00124 (0.000111)‡	-0.000338 (0.846e-4)‡	-0.000302 (0.948e-4)‡
Employment in sector 11 within 600 m	-0.000173 (0.622e-4)‡	–	–	0.00106 (0.430e-4)‡	0.000320 (0.464e-4)‡	0.000156 (0.435e-4)‡	0.000577 (0.403e-4)‡
Employment in sector 12 within 600 m	–	-0.000359 (0.552e-4)‡	-0.000215 (0.448e-4)‡	-0.000158 (0.478e-4)‡	0.000905 (0.320e-4)‡	-0.000264 (0.484e-4)‡	-0.000420 (0.371e-4)‡
Employment in sector 13 within 600 m	-0.000420 (0.708e-4)‡	0.000169 (0.239e-4)‡	–	-0.000153 (0.310e-4)‡	-0.000198 (0.416e-4)‡	0.000408 (0.317e-4)‡	-0.000131 (0.397e-4)‡
Employment in sector 14 within 600 m	-0.000291 (0.346e-4)‡	-0.000257 (0.305e-4)‡	-0.000225 (0.247e-4)‡	-0.00030 (0.270e-4)‡	-0.000332 (0.306e-4)‡	-0.793e-4 (0.226e-4)‡	0.000363 (0.133e-4)‡
Number of observations	5000	5000	5000	5000	5000	5000	5000
Log-likelihood at 0	-11512.9	-11512.9	-11512.9	-11512.9	-11512.9	-11512.9	-11512.9
Log-likelihood at β	-8455.54	-8358.04	-7475.63	-9255.06	-7345.06	-9270.29	-8326.63
ρ^2	0.26556	0.27403	0.35067	0.19612	0.36202	0.19479	0.27676

Logit model coefficient estimates with standard errors of the estimates in parentheses.
Significance of coefficients from zero is indicated by † (90%) and ‡ (95%), for a two-tailed t-test.
– Indicates the coefficient was restricted to zero because of lack of significance.

TABLE 4 Agglomeration Effects by Industry Sector

Employment within 600 m. by Sector:	Industry Sector of Job Being Located:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Basic	1	+	+	+	-	+	-	+	+	-	-	-	+	+	+
	2	-	+	+	·	+	+	-	+	·	·	·	·	-	-
	3	-	·	+	·	+	·	-	-	-	-	·	-	-	-
	4	·	·	·	+	-	+		+	-	·	·	·	-	-
	5	·	-	-	+	+	-	-	·	-	-	·	-	+	·
Retail	6	-	-	-	+	·	+	-	-	·	-	·	-	+	·
	7	+	-	·	-	-	+	+	·	·	·	-	-	-	-
	8	-	·	-	-	+	·	·	+	·	-	+	+	·	·
Service	9	-	·	-	·	-	·	+	+	+	·	-	·	·	·
	10	·	·	·	·	+	-	-	-	+	+	+	-	-	-
	11	+	-	+	+	+	-	-	-	·	·	+	+	+	+
	12	·	-	-	-	-	·	-	·	-	-	-	+	-	-
	13	·	-	·	-	·	+	-	-	+	·	-	-	+	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	+

+ indicates positive coefficient, **-** indicates negative coefficient, · indicates insignificant coefficient