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Firm location in a polycentric city: the effects of taxes and agglomeration economies on location decisions

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Abstract. The authors explore the determinants of firm location in a polycentric city with the aid of data for the Houston region. Firm location is modeled in a discrete-choice framework, with eight employment centers and outlying areas used as possible choices. Agglomerative and dispersive forces are explicitly treated, as are taxes and other characteristics that vary over space. The findings suggest that property taxes have large deterrent effects on firm locations for the four industrial groups analyzed here: oil and gas; manufacturing; finance, insurance and real estate (FIRE); and services. When agglomeration economies are present, they are weaker than the tax effects and are positive for only the FIRE and services industrial groups.

1 Introduction

Today's cities present an interesting landscape that differs dramatically from the layout presented by traditional monocentric city models. Monocentric models assume that employment is concentrated in the central business district (CBD), with decentralized employment found at low densities at other locations. However, for many large urban areas, like the Greater Houston area, the spatial landscape of firms often shows several other locations or employment subcenters (in addition to the CBD) where relatively high employment densities occur. Such cities are termed 'polycentric' and offer a challenge to researchers not only to understand how, why, and where these subcenters appear, but also to characterize any potential attractive forces generated by the subcenters for firm location.

Recent research on employment subcenters in urban areas has focused on the definition and identification of employment subcenters (Craig and Ng, 2001; McMillen, 2001), the effects of subcenters on land values or real estate values, and the effects of subcenters on the spatial distribution of employment densities and population densities in urban areas (Craig and Kohlhase, 2003; McMillen and MacDonald, 1998; Small and Song, 1994). In contrast, in the present study we model intraurban firm location in a discrete choice framework. In particular, we empirically test the determinants of firm location among eight employment centers in Harris County, Texas—the most populated county in the Houston metropolitan area. Houston is an interesting city in which to study the location decisions of firms for many reasons. Perhaps most importantly, market forces dominate the decision-making process for firm location. The decisions are made in an atmosphere of minimal government regulation on land use: Houston is the only major US city without centralized zoning (Seigan, 1972). Fiscal policies do, however, impact firms in that taxes and services can vary over the many jurisdictions within the area. The presence of several concentrations of employment may be indicative of agglomerative forces operating at the microgeographic level. And relating to transportation, Houston lies on a flat, homogeneous plane, has a well-developed highway network for transporting goods and people, and has a well-defined export node at Port of Houston (the Houston Ship Channel).

Our study focuses on two important questions about firm location within a polycentric city: whether or not there is empirical evidence of the presence of agglomerative forces in and near to the subcenters; and whether or not fiscal variables are important determinants of firm location. To examine the role of fiscal variables and potential agglomerative forces, the location preferences of firms locating within subcenters as well as firms locating outside subcenters are examined. Both logit and mixed-multinomial logit models are estimated to provide empirical evidence for the arguments.

Previous empirical research on agglomeration economies has been conducted using a variety of approaches for various levels of spatial aggregation and industrial aggregation (for excellent survey articles see Duranton and Puga, 2004; Quigley, 1998; Rosenthal and Strange, 2004). Several studies have been conducted at the intermetropolitan-area level by examining aggregate urban area production functions. For example, Moomaw (1986; 1998), Henderson (1986), and Segal (1976) present evidence that productivity differences among urban areas exist and are a function of the size of the urban area. Agglomeration variables have been specified either as the total population of the city, or as the total employment in the city. Rich detail at the local geographic level is lost in such aggregate approaches. Other recent research has focused on smaller spatial units, such as firms aggregated to the zipcode level (Rosenthal and Strange, 2003, 2005; Shukla and Waddell, 1991) or at the census-tract level (Rosenthal and Strange, 2005). A few studies have been able to exploit detailed individual plant data in the UK (Duranton and Overman, 2002) and the US (Henderson, 2003).

Our study looks at location decisions made by individual firms within a single urban area. The present study is one of a few to use a discrete choice model which attempts to explicitly account for agglomeration economies and fiscal variables. Extensive use is made of geographic information systems (GIS) software to code addresses and to create spatially disaggregated variables. Another important feature is a comparative analysis of four major industrial groups, rather than the traditional focus on only the manufacturing sector.

The paper is organized as follows. In part 2 we present two alternative qualitative choice models in which to model a firm's location decision. In part 3 we discuss the data and the unique agglomeration proxy variables created for the study. Empirical results from estimating a logit and a mixed-multinomial logit model are presented in part 4, and results compared by the four industrial groups: oil and gas; manufacturing; finance, insurance and real estate (FIRE); and the services sector. Conclusions and policy implications are offered in part 5.

2 Discrete choice approach to firm location decisions

We assume firms have already decided to locate in a given metropolitan area and are faced with the current decision of where to locate within the region. To model the firm's location choice, a qualitative choice framework is developed in which the firm is able to choose among a number of discrete sites on the basis of expected future profit levels at the alternative sites. Following the development in Greene (2003, chapter 21) and Wooldridge (2002, chapter 15) we can specify a model of the probability of choosing amongst a set of L sites. Let firm m's expected profit equation at site i be:

$$V_{mi} = \mathrm{f}(S_{ki}, F_{mj}) + \varepsilon_{mi}, \qquad k = 1, \ldots, K, \ i = 1, \ldots, \mathrm{L}, \ m = 1, \ldots, \mathrm{M}, \ j = 1, \ldots, \mathrm{J}, \quad (1)$$

where V_{mi} is the present discounted value of firm m's expected future profits at site i over its lifetime. The vector $\boldsymbol{S}$ represents site-specific variables, indexed by k, which impact firm m's expected present value at location i. It is through the site-specific variables that potential agglomeration economies operate, as do the fiscal variables. The vector $\boldsymbol{F}$ represents firm-specific variables, indexed by j, which influence firm m's present value expectation at location i. The function $f(S_{ki}, F_{mj})$ makes up the deterministic portion of firm m's present value expectation at site i. The error term, ε_{mi}, is that part of firms m's present value expectation at site i not explained by the function.

The firm is assumed to have unbiased expectations of the profitability of each site: the firm simply chooses the site with the highest expected present value. The probabilities generated in the discrete choice model arise because the researcher does not have all the information the firm uses to assess the profitability of alternative sites.

Equation (1) represents the expected present value that firm m will generate if it locates at site i. However, the only V_{mi} observed for each locating firm is the value of the realized choice. Firm m will follow the decision rule:

$$N_{mi} = \begin{cases} 1, & \text{if } V_{mi} > V_{mt}, \quad t \in T_m, \ \forall\, t \neq i, \\ 0, & \text{otherwise,} \end{cases} \tag{2}$$

where N_{mi} is an index of L site choices open to firm m and T_m is the set of L alternatives, of which t is a subset.

The firm is assumed to know the part of the profit equation (1) determined by the researcher, f(.), as well as the error term. In contrast, to the researcher, the error term in equation (1) represents the missing firm or site characteristics. Substituting equation (1) into the decision rule, equation (2), gives:

$$N_{mi} = 1, \quad \text{iff } (S_{ki}, F_{mj}) + \varepsilon_{mi} > \mathrm{f}(S_{kt}, F_{mj}) + \varepsilon_{mt}, \quad t \in T_m \ \forall\, t \neq i, \tag{3a}$$

which can be rewritten as

$$N_{mi} = \begin{cases} 1, & \text{iff } (S_{ki}, F_{mj}) - \mathrm{f}(S_{kt}, F_{mj}) > (\varepsilon_{mt} - \varepsilon_{mi}), \quad t \in T_m \ \forall\, t \neq i, & \text{(3b)} \\ 0, & \text{otherwise,} & \text{(3c)} \end{cases}$$

Assuming the difference $(\varepsilon_{mt} - \varepsilon_{mi})$ follows a probability distribution, the probability that firm m will choose site $i\,(N_{mi} = 1)$ for each alternative i can be estimated using the logit function. We express the function as being composed of characteristics of the choices (sites) as well as the chooser (firms)—a variant often termed the 'mixed-multinomial logit' (see the discussion in Long and Freese, 2003, section 6.7.5):

$$\mathrm{P}(N_{mi} = 1 | S_{ki}, F_{mj}) = \frac{\exp[\mathrm{f}(S_{ki}, F_{mj})]}{\sum_{i=1}^{L} \exp[\mathrm{f}(S_{ki}, F_{mj})]}, \tag{4}$$

where $\mathrm{P}(N_{mi} = 1)$ is the probability that firm m will choose site i.

A related discrete choice model is the simple logit, where we model the choice between a 'concentrated' or a dispersed location. In such a specification, the choice of location can be viewed as a zero–one choice, where $N = 1$ if firm m locates inside any one of the eight employment centers, and $N = 0$ if firm m locates in the rest of Harris County. Then the probability that firm m locates in a concentrated location becomes:

$$\mathrm{P}(N_m = 1 | z_m) = \frac{\exp[\mathrm{f}(z_m)]}{1 + \exp[\mathrm{f}(z_m)]}, \tag{5}$$

where $\boldsymbol{z}$ is a vector of variables associated with each firm m.

3 Dataset and created variables

The focus of our study is the Houston metropolitan area—in particular, firm locations within its central county, Harris.(1) Figure 1 shows cumulative population and employment distributions for the Houston MSA (Metropolitan Statistical Area) in 1990 as a function of distance from the CBD. The figure shows that employment is more centralized than population—more than 50% of employment lies within 10 miles of the CBD whereas only about 30% of the population does. This relative spatial distribution is intriguing in itself and motivates one of our research questions: what are the forces that bind firms together, even in the presence of a decentralizing population? To explore the issues, we analyze firm location in the context of a set of discrete concentrations of employment, that is, the CBD and other employment 'subcenters'. We use the seven employment subcenters in the Houston region, identified by the method of quantile smoothing splines described in a paper by Craig and Ng (2001): Baytown, Pasadena, LaPorte, Clear Lake, the Galleria, Carrilon, and Greenspoint.(2) Figure 2 shows the eight employment centers defined by their respective 1990 census tract. (Hereafter we use the term 'employment centers' as an inclusive term to indicate the CBD and the other employment subcenters.)

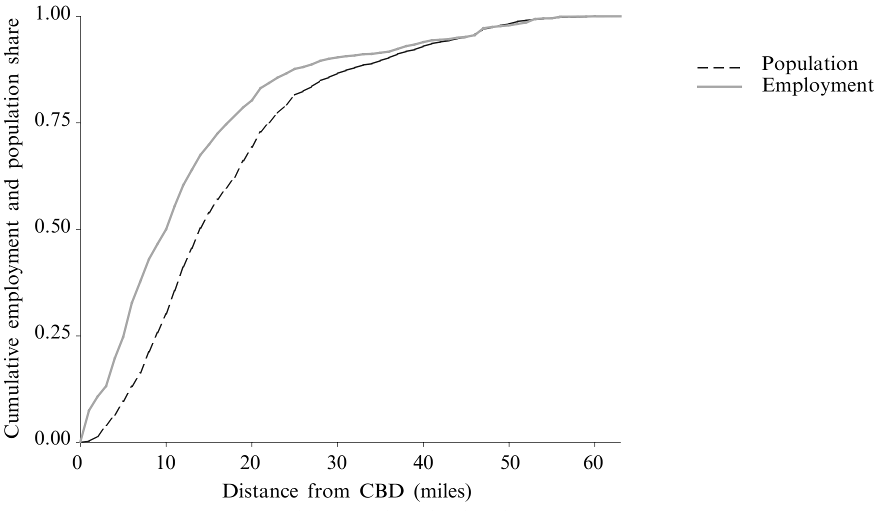

Figure 1. Houston metropolitan spatial distributions, 1990.

Aside from the CBD, Houston's strongest employment subcenter is the Galleria area, called 'Uptown' by some real estate professionals. This is a retail and office area bordering on the innermost circumferential highway (I-610) and the main southwest freeway (US 59). Clear Lake is the area south and east of the CBD that contains NASA. Carillon is an area about 5 miles west of the Galleria. Greenspoint is near

(1) The land area of Harris County is about 1730 square miles. About 30% of the county's land area is covered by the 540 square mile city of Houston.

(2) Even though the Houston MSA is made up of five counties, the CBD and all employment subcenters identified by Craig and Ng (2001) lie within its central county, Harris County. To determine the location of the employment subcenters, Craig and Ng use a nonparametric specification (quantile smoothing splines) to evaluate the upper tail of employment densities. Their seven subcenters lie on three concentric rings (defined at 6, 13, and 21 miles) around the CBD. In their method, areas with employment densities at the 95th percentile or above, conditional on the distance from the CBD, that also appear to influence neighboring areas, are identified as employment subcenters. The geography of the eight employment centers are small areas, defined by the boundary of an appropriate 1990 census tract.

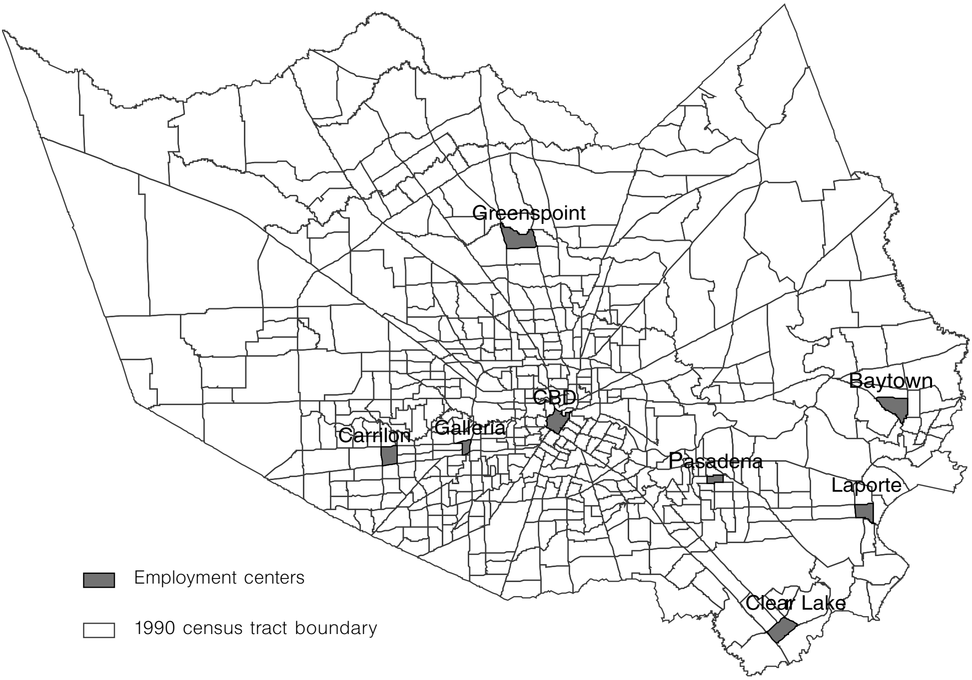

Figure 2. Houston area employment centers and 1990 census tract boundaries.

the major airport, on an arterial freeway north of the CBD. Baytown, Pasadena, and LaPorte are all industrial areas in the neighborhood of the Houston Ship Channel.

Individual establishment-level data used for this study were taken from a commissioned Dun & Bradstreet MarketPlace file for Harris County, Texas 1990. The full dataset contains 72 variables and 123 313 observations. The data are at the establishment level or plant level, but we choose to use the term 'firm' for ease of exposition in the rest of the paper (in our data, most of the establishments are stand-alone firms). Firm-specific characteristics in the dataset include name and address of firm, number of employees, annual sales, Duns number, 1990 census tract number, four-digit SIC codes, and year established.

Sixteen industries at the two-digit SIC level were selected for analysis and then broadly grouped into four industrial groups, as reported in table 1. The groupings were constructed to capture industries that are likely to produce complementary products or services. The underlying assumption is that advantages of agglomeration could be detected more easily in these broadly interrelated sectors. For example, industries with complementary products may tend to locate near each other in order to save on transportation costs of inputs and outputs, or to enhance information transmission

Table 1. Major industrial groups by standard industry classification (SIC) (source: Standard Industrial Classification Manual, 1987).

Group	Name	SIC code
1	Oil and gas	13, 28, 29, 30
2	Manufacturing	33, 35, 37, 38
3	FIRE[a]	60, 63, 65, 67
4	Services	73, 75, 80, 87

[a] Finance, insurance, and real estate.

through frequent face-to-face contact. Potential sources of the external economies may include labor-market pooling, input sharing, knowledge spillovers, availability of consumption externalities, and others (see the survey by Duranton and Puga, 2004).

The first broad sector contains oil-related and gas-related industries. They are oil and gas extraction (SIC 13), chemical and allied products (SIC 28); petroleum refining (SIC 29); and rubber and miscellaneous plastics products (SIC 30). The second group, manufacturing, includes: primary metal industries (SIC 33); commercial machinery and computer equipment (SIC 35); transportation equipment (SIC 37); and measuring, analyzing, and controlling instruments (SIC 38). The third group—FIRE—contains: depository institutions (SIC 60); insurance carriers (SIC 63); real estate (SIC 65); and holding and other investment companies (SIC 67). The fourth group was designed for service industries; it contains: business services (SIC 73); automotive repair, services, and parking (SIC 75); health services (SIC 80); and engineering, accounting, research, management, and related services (SIC 87).

In order to create spatially detailed variables, the addresses of the individual firms were geocoded, but not all firms' addresses were able to be geocoded, for a myriad of reasons. The overall matching rate was about 67%, ranging from 56% (SIC 63, insurance carriers) to 77% (SIC 37, transportation equipment), bringing the original sample size of 34 683 down to 22 485 for the sixteen industries. The sample size was further reduced to 19 748 after firms with zero employees were deleted from the sample.[(3)]

For the empirical work, two samples of firms were examined in two different discrete choice frameworks. First, the entire sample of about 20 000 firms (hereafter referred to as the 'full' sample) was used to estimate the choice between concentrated location (any of the eight employment centers) or dispersed location (anywhere else in the rest of Harris County, Texas). Second, a smaller sample of firms, about 4600, was used to investigate further those firms choosing concentrated locations in one of Houston's eight employment centers—hereafter these are referred to as the 'centers' sample.

Several variables, both dependent and independent, were constructed for the data analysis. Based on the geocoded address of each firm, firms were assigned a particular location category: one of the eight employment centers or the 'rest of Harris County'. Any firm lying within the census tract containing an employment center was assigned that center as a location. Two types of discrete dependent variables were created. The first dependent variable was a binary variable, where zero is assigned to firms locating in the rest of Harris County and one was assigned to firms locating in any one of the eight employment centers. The second dependent variable assigned firms a location category numbered from 1 to 8, with the CBD assigned location 1. We then used the CBD as the base (omitted) category for estimating the mixed-multinomial logit on the centers sample. Table 2 shows the distribution of the number of firms by location category.

For the mixed-multinomial logit, two types of independent variables were constructed: those that are characteristic of the eight choices, and those that are characteristic of the individual firm. Table 3 reports means and standard deviations for the two datasets used in the estimation—the full dataset and the centers dataset. Seven choice-specific independent variables were constructed whereby the values of the variables differ for each of the discrete choices. The variables include three measures of agglomeration, three tax variables, population density, an accessibility variable, and the distance to the centroid of each center from the nearest firm of a particular industry group.

(3) For the sixteen industries, the percentage of observations with zero reported employees ranged from a low of 4% for SIC 30—rubber and plastics—to a high of 41% for SIC 67—holding companies.

Table 2. Location patterns of firms in the 'full' and 'centers' samples.

	Numbers of firms				
	manufacturing	oil and gas	FIRE[a]	services	all 4 groups
Full sample					
Rest of Harris County	813	1 095	3 011	10 182	15 101
Subcenters	146	654	1 178	2 669	4 647
Total	959	1 749	4 189	12 851	19 748
Centers sample					
CBD[b]	47	331	341	876	1 595
Baytown	0	3	19	75	97
Pasadena	7	9	38	188	242
LaPorte	3	8	9	11	231
Clear Lake	5	9	45	191	250
Galleria	39	205	546	829	1 619
Carrilon	24	40	119	383	566
Greenspoint	21	49	61	116	247
Total	146	654	1 178	2 669	4 647

[a] FIRE—finance, insurance, and real estate.
[b] CBD—central business district.

We focus on the geography of agglomerative forces within the city, and proxy potential agglomerative forces with three different measures. One variable focuses on the number of nearby firms, and the other two on nearby employment. The first variable, FIRMS, is defined as the number of firms in the same industrial group within a 1-mile radius of the census tract containing an employment center. This was constructed to capture the attractiveness of a firm to other firms in the same broad industrial category. This measure is intended to capture the microgeography of localization economies and is most closely related to some of the work of Rosenthal and Strange (2005) for New York City, who found that the impact agglomeration economies attenuate with distance and are strongest for a 1-mile radius. We hypothesize that links to other like firms and other complementary firms are what characterizes the basis for agglomeration economies within cities.

We also constructed two other proxy measures of agglomerative forces. As an alternative to the number of nearby firms to proxy for localization economies, we define the variable IND_EMP to be the total number of employees in the same industry. Counting the number of employees rather than the number of firms should control for industrial organization characteristics. For example, a few large firms may have many employees, and the source of the agglomeration economy may be from potential labor-market pooling as proxied by the entire employee base. The final measure is our attempt to capture the idea of urbanization economies on a microgeographical scale. Traditionally, urbanization economies are thought of as the benefits that a given firm receives from the expansion of the entire industrial base of an urban area. In our case, however, we define a spatially limited measure: the benefits a firm gets from the expansion of the entire industrial base within a given subregion of the metropolitan area. To do so, we define the third agglomeration variable, TOT_EMP, to be the total number of employees in *all* industrial sectors (not just the four studied in detail here) within a 1-mile radius of the census tract center. The data for this variable were created by the Houston–Galveston Area Council, and are also based on Dun and Bradstreet data.

Table 3. Mean characteristics (with standard deviations shown in parentheses) of 'full' and 'centers' samples.

	Manufacturing	Oil and gas	FIRE[a]	Services
Full sample				
Firm size[b]	36.76 (153.39)	31.75 (126.62)	15.01 (119.69)	13.26 (153.30)
Number of firms	959	1 749	4 189	12 851
Subcenters sample				
Firm characteristics				
Firm size[b]	72.65 (309.92)	42.13 (164.57)	16.61 (101.97)	14.89 (82.63)
Number of firms	146	654	1 178	2 669
Choice characteristics[c] *varying by industry*[c]				
Agglomeration				
number of firms in same industry	16.286 (14.93)	51.714 (78.063)	141.857 (228.462)	134.143 (165.72)
number of employees in same industry (thousands)	0.515 (0.602)	2.895 (3.766)	1.391 (2.252)	3.660 (4.361)
Total number of employees in all industries (thousands)	53.622 (49.109)	53.623 (49.109)	53.623 (49.109)	53.623 (49.109)
Distance to firm, same industry (miles)	0.414 (0.253)	0.411 (0.253)	0.284 (0.200)	0.256 (0.162)
common to all industries[c]				
Tax ($ per $100 value)	1.803 (0.223)	1.803 (0.223)	1.803 (0.223)	1.803 (0.223)
Population density (thousands)	3.983 (3.033)	3.983 (3.033)	3.983 (3.033)	3.983 (3.033)
Distance to highway (miles)	2.020 (2.970)	2.020 (2.970)	2.020 (2.970)	2.020 (2.970)

[a] FIRE—finance, insurance, and real estate.
[b] Averaged over all firms.

The fiscal variable we use, TAX, measures the local tax burden imposed by various government and quasi-government bodies. Property-tax variables were collected for twenty-three Independent School Districts (ISDs), twenty-five cities, and over 300 Municipal Utility Districts (MUDs) within Harris County, Texas, for the year 1990. County property taxes are not included since all observations lie within Harris County. The tax rates are effective property tax rates measured in dollars per $100 property valuation. The ISD and city-tax data were gathered from the Harris County Appraisal District. The MUD tax data were retrieved from Municipal Service's data file. Each tax variable was geographically coded by census tract and assigned to the appropriate site-specific variable.

The Houston area is unusual in its method of providing several local public services, such as water and gas. Areas outside the city limits often are provided with local services by special districts called Municipal Utility Districts, or MUDs. MUDs are created for specific purposes within a limited geographical area. In 1990, 313 MUDs existed within Harris County outside city boundaries. One unique feature of the empirical study described here is that it is the first (to the best of the authors' knowledge) to incorporate the MUD tax rates into a firm location decision study. MUD tax rates were typically excluded in previous studies of Houston, due to a lack of a geocoded data source.[4]

We created three variables to describe the economic environment of each employment center. These variables serve to capture elements of any comparative advantage a given center may have within the spatial structure of the metropolitan area. The first variable, DENSITY, measures the population density of each of the employment centers and is calculated by dividing the 1990 population by land area for each employment center. The variable is assumed to capture the general economic environment of the center. The mean population density is 3983 persons per square mile. The highest value of population density is 15 048 persons per square mile, located near the Galleria.

The second variable, DHIGHWAY, is used to account for the relative accessibility of each employment center within the general highway transportation network of the metropolitan area. The measure of the highway access of an employment center is defined as the distance from the centroid of each center to the nearest freeway entrance, and measured using ArcView GIS. The selected freeways in this study are Interstate Highway 10 (I-10), Interstate Highway 45 (I-45), State Highway 59 (US-59), Interstate Highway Loop 610 (I-610), and Beltway 8.

The third variable is intended to capture an indication of within-center land prices or rents. A typical land-rent function would have peaks in the centroids of each employment center and decline with distance from each center. As a proxy for the expected land-price premium near employment centers, we define the variable, DNEAR, to be the distance from the centroid of each subcenter to the nearest firm of a given industrial group. This measure is admittedly very crude but, in the absence of land rent data, it seems a reasonable alternative.

There is one firm-specific independent variable included in this dataset, EMPLOYEES, which is obtained from Dun and Bradstreet's data file directly. The variable reflects the size of each firm and is measured by the number of employees at each plant location. This measure is used to control for differences among firms that might be due to internal scale economies. The Dun and Bradstreet dataset reports the quality of the employee data, so in constructing our dataset we used only firms whose employment data were reported as an actual (not estimated) value that was not zero.

4 Empirical results

Two classes of discrete choice models are estimated: for the choice of dispersed versus concentrated location; and for the choice among the eight employment centers. Coefficient estimates are reported in tables 4 and 5–8 and elasticities are reported in tables 4, 9, and 10. The elasticities were measured at the observation level and then averaged. Table 11 reports a comparison of the predicted and actual number of firms for model 1 (described below). Results are presented for the four industrial groups—oil and gas, manufacturing, FIRE, and services.

Initially, our intention was to estimate a discrete choice model with nine choices: the first eight choices being among the eight employment subcenters and the ninth choice being the 'rest of Harris County'. However, the definition of the choice-specific variables such as tax rate and population density were problematic for this ninth choice as it had such a large land area and variety of values. Therefore we present two sets of estimates: one set isolates the dispersed–concentrated choice while the second set looks in particular at concentrated location choices.

[4] We would like to thank Dr Ronald Welch of Welch Associates for providing us with a geocoded boundary file for the Harris County MUDs. In a recent paper, Palmon and Smith (1998) use MUD tax rates in a study of housing-price capitalization.

Table 4. Concentrated versus dispersed location: logit-estimation results (with z-statistics shown in parentheses) for the 'full sample'.

Estimated model variable	Manufacturing	Oil and gas	FIRE[a]	Services
Employees	0.001205	0.001108	0.000144	0.000078
	(2.49)*	(2.37)*	(0.54)	(0.61)
Constant	−1.770946	−0.550604	−0.940672	−1.339987
	(−19.00)**	(−10.69)**	(−27.17)**	(−61.41)
Log likelihood	−406	−1 153	−2 489	−6 565
Likelihood ratio χ^2 (1)[b]	6.69	7.04	0.28	0.35
Probability $> \chi^2$	0.01	0.01	0.60	0.55
n	959	1 749	4 189	12 851
Correctly classified (%)	85	63	72	79
Calculated elasticity				
Employees	0.031	0.018	0.001	0.001

*significant at the 5% level, two-tailed test; **significant at the 1% level, two-tailed test.
Note: Dependent variable is dichotomous: 1 = locate in any of the 8 employment centers, 0 = locate in rest of Harris County.
[a] FIRE—financial, insurance, and real estate.
[b] Likelihood ratio test, calculated test statistic with 1 degree of freedom.

4.1 Dispersed versus concentrated location

To estimate a firm's choice between concentrated versus dispersed locations, we use a simple logit with firm-specific variables as regressors. By necessity our model is modest: because of dataset limitations, the only firm-specific variable available for the analysis is the number of employees at the establishment. Given these limitations, the function from equation (5) can be expressed as follows:

$$\mathrm{f}(z_m) = a_0 + a_2\,\mathsf{EMPLOYEES}, \tag{6}$$

where EMPLOYEES is the total number of employees at a single plant location. The coefficients and elasticities reported in table 4 show that location choices by firms differ by industrial sector. Both for manufacturing and for oil and gas, larger firms are more likely to choose concentrated locations. In contrast, firm size is not a source of location preference for firms in the FIRE and services sectors. The finding of the heterogeneity of location choices to firm size results carries over into the more detailed model estimated below.

4.2 Choice of employment center

Location preferences of firms that choose a location that can be characterized by concentrated employment densities were examined in a mixed-multinomial logit framework. Firms locating outside employment centers are excluded from the following estimations, and because no MUDs exist in the employment centers, the tax variable is composed only of ISD and city tax rates. Results are reported for the four broad industrial groups in tables 5 – 10: tables 5 – 8 present coefficient estimates for three models differentiated by agglomeration measure; tables 9 and 10 present elasticities, calculated at the observation level and then averaged.

Table 5. Choice of employment center for manufacturing firms (with z-statistics shown in parentheses.

Variable	Model 1		Model 2		Model 3	
Choice-specific variable						
Number of firms in same industry	−0.0192746	(−1.57)				
Number of employees in same industry (thousands)			−0.1633216	(−3.22)**		
Total number of employees in all industries (thousands)					−0.0039835	(−1.88)$^+$
Population density (thousands)	0.365410	(5.52)**	0.373267	(6.08)**	0.361445	(5.80)**
Tax	−3.704655	(−6.12)**	−4.088944	(−6.82)**	−3.718523	(−6.33)**
Distance to highway (miles)	−0.253064	(−2.52)*	−0.161775	(−1.81)$^+$	−0.224458	(−2.36)**
Distance to firm (miles)	−4.297168	(−4.13)**	−5.156923	(−5.56)**	−4.223860	(−4.69)**
Firm-specific variable[a]						
Employees						
Pasadena	−0.009009	(−0.71)	−0.005918	(−0.63)	−0.008881	(−0.71)
LaPorte	−0.022305	(−0.45)	−0.052595	(−0.77)	−0.025374	(−0.48)
Clear Lake	0.000159	(0.19)	0.000304	(0.38)	0.000216	(0.26)
Galleria	−0.000447	(−0.50)	−0.000924	(−0.82)	−0.000512	(−0.56)
Carrilon	−0.001523	(−0.55)	−0.002140	(−0.65)	−0.001673	(−0.58)
Greenspoint	−0.022727	(−1.68)$^+$	−0.031252	(−2.12)*	−0.026518	(−1.79)$^+$
Number of firms[b]	146		146		146	
Log likelihood	−213		−208		−212	
Likelihood ratio χ^2 (12)[c]	181		190		182	

$^+$significant at 10% level, two-tailed test; *significant at 5% level, two-tailed test; **significant at 1% level, two-tailed test.
Note: Base category is CBD.
[a] Baytown omitted due to lack of data.
[b] Number of observations equals 8× (number of firms).
[c] Likelihood ratio test, calculated test statistic with 12 degrees of freedom.

The function f(.) of the mixed-multinomial logit equation, equation (4), can be expressed in the following three models, differentiated by measure of agglomeration:

Model 1

$$f(S_{ki}, F_{mj}) = a_1\,\mathsf{DENSITY} + a_2\mathsf{TAX} + a_3\mathsf{FIRMS} + a_4\,\mathsf{DHIGHWAY} + a_5\,\mathsf{DNEAR} + \sum_{i=1}^{8} a_{(i+5)}(\mathsf{EMPLOYEES} \times \mathsf{CENTER}_i), \quad (7)$$

Model 2

$$f(S_{ki}, F_{mj}) = a_1\,\mathsf{DENSITY} + a_2\mathsf{TAX} + a_3\mathsf{IND\_EMP} + a_4\,\mathsf{DHIGHWAY} + a_5\,\mathsf{DNEAR} + \sum_{i=1}^{8} a_{(i+5)}(\mathsf{EMPLOYEES} \times \mathsf{CENTER}_i), \quad (8)$$

Table 6. Choice of employment center for oil and gas firms (with z-statistics shown in parentheses.

Variable	Model 1		Model 2		Model 3	
Choice-specific variable						
Number of firms in same industry	−0.0034192	(−3.43)**				
Number of employees in same industry (thousands)			−0.0144	(−0.71)		
Total number of employees in all industries (thousands)					−0.0027401	(−1.59)
Population density (thousands)	0.449787	(10.50)**	0.407823	(9.37)**	0.422013	(9.73)**
Tax	−7.270857	(−12.33)**	−6.128798	(−12.16)**	−6.350100	(−12.64)**
Distance to highway (miles)	−0.324829	(−3.89)**	−0.403701	(−4.23)**	−0.385419	(−4.19)**
Distance to firm (miles)	−6.875260	(−8.22)**	−4.648261	(−6.96)**	−5.339965	(−6.95)**
Firm-specific variable						
Employees						
Baytown	0.003968	(1.78)$^+$	0.003619	(1.51)	0.003704	(1.57)
Pasadena	0.001557	(0.93)	0.001482	(0.87)	0.001500	(0.89)
LaPorte	0.003318	(1.33)	0.003927	(1.86)$^+$	0.003750	(1.71)$^+$
Clear Lake	0.001005	(0.16)	−0.002315	(−0.22)	−0.000613	(−0.07)
Galleria	0.002720	(3.17)**	0.002670	(3.09)**	0.002696	(3.12)**
Carrilon	0.003589	(3.71)**	0.003708	(3.80)**	0.003680	(3.78)**
Greenspoint	−0.000233	(−0.13)	0.000474	(−0.30)	0.000213	(0.13)
Number of firms[a]	654		654		654	
Log likelihood	−725		−731		−730	
Likelihood ratio $\chi^2(12)$[b]	1 269		1 257		1 259	

$^+$significant at 10% level, two-tailed test; **significant at 1% level, two-tailed test.
Note: Base category is CBD.
[a] Number of observations equals 8 × (number of firms).
[b] Likelihood ratio test, calculated test statistic with 12 degrees of freedom.

Model 3

$$f(S_{ki}, F_{mj}) = a_1\,\mathsf{DENSITY} + a_2\mathsf{TAX} + a_3\mathsf{TOT\_EMP} + a_4\,\mathsf{DHIGHWAY} + a_5\,\mathsf{DNEAR} + \sum_{i=1}^{8} a_{(i+5)}(\mathsf{EMPLOYEES} \times \mathsf{CENTER}_i), \qquad (9)$$

where the index is over the eight employment centers. The CBD ($i = 1$) is used as the base category, so that $a_6 = 0$. The agglomeration variables (FIRMS, IND_EMP, and TOT_EMP) measure potentially attractive forces within a 1-mile band of the census tract containing each center. The variable FIRMS is the number of firms from the same broad industrial group, IND_EMP is the number of employees in the same industry, and TOT_EMP is the total number of employees in all industries. The variable TAX is the sum of city and school district tax rates, DNEAR is the distance from the centroid of each subcenter to the nearest firm in the industrial group, and DHIGHWAY is the straight-line distance from the centroid of each subcenter to the nearest freeway. In the estimation procedure, each site-specific variable generates one parameter estimate and each chooser-specific variable generates seven parameter estimates because the CBD choice

Table 7. Choice of employment center for FIRE (finance, insurance, and real estate) firms (with *z*-statistics shown in parentheses).

Variable	Model 1		Model 2		Model 3	
Choice-specific variable						
Number of firms in same industry	0.0030087	(15.51)**				
Number of employees in same industry (thousands)			0.1941547	(10.02)**		
Total number of employees in all industries (thousands)					0.0119534	(10.67)**
Population density (thousands)	0.298432	(10.50)**	0.485851	(16.11)**	0.489789	(16.21)**
Tax	−0.840258	(−3.66)**	−1.306666	(−5.69)**	−1.651667	(−7.88)**
Distance to highway (miles)	−0.417378	(−6.94)**	−0.773365	(−13.13)**	−0.711958	(−12.23)**
Distance to firm (miles)	0.364117	(0.90)	4.588079	(7.10)**	5.401366	(7.89)**
Firm-specific variable						
Employees						
Baytown	−0.002793	(−0.4)	−0.014824	(−0.92)	−0.018524	(−1.03)
Pasadena	−0.080260	(−2.68)**	−0.050508	(−1.98)*	−0.045291	(−1.87)
LaPorte	0.000062	(0.01)	0.001355	(0.42)	0.001244	(0.38)
Clear Lake	−0.004909	(−0.82)	−0.003686	(−0.61)	−0.003272	(−0.56)
Galleria	−0.005760	(−2.53)*	−0.000277	(−0.40)	−0.000289	(−0.42)
Carrilon	−0.004147	(−1.23)	−0.002533	(−0.81)	−0.002501	(−0.80)
Greenspoint	−0.001724	(−0.70)	−0.009147	(−1.71)+	−0.008170	(−1.60)
Number of firms[a]	1 178		1 178		1 178	
Log likelihood	−1 624		−1 702		−1 696	
Likelihood ratio χ^2 (12)[b]	1 650		1 495		1 507	

+significant at 10% level, two-tailed test; *significant at 5% level, two-tailed test; **significant at 1% level, two-tailed test.
Note: Base category is CBD.
[a] Number of observations equals 8 × (number of firms).
[b] Likelihood ratio test, calculated test statistic with 12 degrees of freedom.

parameter is normalized to zero. For the chooser-specific variable (firm size), we specified the variable as an interaction term, EMPLOYEES × CENTER, as is common practice in mixed-multinomial models (Long and Freese, 2003).

4.2.1 *Agglomeration economies*

We found evidence that both agglomeration economies and agglomeration diseconomies exist in Houston and that the results differ by broad industrial group (table 11). Furthermore, we found evidence consistent with the operation of different types of agglomeration economies—our particular version of localization and urbanization economies. We interpret the signs of the significant coefficients on the agglomeration variables as being indicative of the presence or absence of agglomerative forces. This is because the signs of the coefficients of the choice-specific variables are the same as the signs of the marginal effects in a mixed-multinomial logit (Greene, 2003). The coefficients of the three agglomeration proxy variables, FIRMS, IND_EMP, and TOT_EMP are significant at the 12% level or better, with the exception of the coefficient on IND_EMP for the oil and

Table 8. Choice of employment center for services firms (with z-statistics shown in parentheses).

Variable	Model 1	Model 2	Model 3
Choice-specific variable			
Number of firms in same industry	0.0026844 (16.10)**		
Number of employees in same industry (thousands)		0.0973553 (15.77)**	
Total number of employees in all industries (thousands)			0.0067102 (13.26)**
Population density (thousands)	0.198374 (15.15)**	0.218383 (16.64)**	0.251951 (19.10)**
Tax	−1.457915 (−12.01)**	−1.324157 (−10.58)**	−1.345919 (−10.48)**
Distance to highway (miles)	−0.315123 (−10.91)*	−0.362036 (−12.66)**	−0.434769 (−15.24)**
Distance to firm (miles)	−1.225991 (−6.40)**	0.427251 (2.03)**	1.283658 (4.94)**
Firm-specific variable			
Employees			
Baytown	0.000770 (0.79)	0.000251 (0.21)	0.000021 (0.02)
Pasadena	−0.005102 (−1.55)	0.004044 (−1.36)	−0.003986 (−1.34)
LaPorte	0.000119 (0.04)	0.000714 (0.29)	0.001269 (0.59)
Clear Lake	−0.000640 (−0.53)	−0.000220 (−0.21)	−0.000208 (−0.19)
Galleria	−0.000671 (−1.05)	−0.000387 (−0.64)	−0.000026 (−0.05)
Carrilon	0.000030 (0.05)	0.000182 (0.29)	0.000254 (0.39)
Greenspoint	−0.005816 (−1.54)	0.006972 (−1.66)*	−0.016066 (−2.64)**
Number of firms[a]	2 669	2 669	2 669
Log likelihood	−4 271	−4 272	−4 310
Likelihood ratio χ^2 (12)[b]	2 558	2 557	2 480

*significant at 5% level, two-tailed test; **significant at 1% level, two-tailed test.
Note: Base category is CBD.
[a] Number of observations equals 8 × (number of firms).
[b] Likelihood ratio test, calculated test statistic with 12 degrees of freedom.

gas sector. Moreover, the results are remarkably consistent across the three measures of agglomerative forces. Localization economies appear to operate in two of the four sectors. Nearby firms and employees in the same industrial groups appear to be an attractive force for only the FIRE and services industrial groups. In contrast, nearby firms and employees of the same industrial group appear to be repelling forces for firms in the oil and gas group as well as for the manufacturing group. The results are similar when we examine our measure for urbanization economies—the total number of employees across all industries. There appears to be evidence of urbanization economies for firms in FIRE and services, but diseconomies for firms in manufacturing, and oil and gas.

The magnitude of the attractive and dispersive effects can be examined in the context of the elasticities reported in table 9. Quantitatively, most responses are small—as evidenced by most elasticities being < 1. Exceptions are for firms in the FIRE sector which are relatively sensitive to the makeup of the Galleria and CBD (several elasticities > 1). For example, a 10% increase in the total number of employees in all industries increases the probability of a FIRE firm locating in the CBD by about 17%, and locating in Galleria by about 12%. In contrast, repelling and attracting forces can be found by comparing the elasticities of the oil and gas group to the service group.

Table 9. Elasticities for agglomeration variables by center.

Agglomeration variable	Manufacturing	Oil and gas	FIRE[a]	Services
Number of firms in same industry				
CBD	−0.645	−0.574	0.965	0.653
Baytown		−0.017	0.062	0.064
Pasadena	−0.127	−0.036	0.126	0.165
LaPorte	−0.057	−0.027	0.030	0.016
Clear Lake	−0.165	−0.034	0.155	0.211
Galleria	−0.063	−0.592	1.015	0.874
Carrilon	−0.498	−0.153	0.375	0.500
Greenspoint	−0.361	−0.175	0.212	0.169
Number of employees in same industry				
CBD	−0.773	−0.097	1.277	0.901
Baytown		−0.027	0.037	0.093
Pasadena	−0.023	−0.015	0.049	0.174
LaPorte	−0.004	−0.003	0.009	0.016
Clear Lake	−0.163	−0.001	0.075	0.203
Galleria	−0.199	−0.120	0.847	0.847
Carrilon	−0.068	−0.057	0.248	0.543
Greenspoint	−0.039	−0.026	0.179	0.138
Total number of employees in all industries				
CBD	−0.562	−0.270	1.675	0.965
Baytown		−0.049	0.210	0.118
Pasadena	−0.103	−0.072	0.313	0.169
LaPorte	−0.031	−0.022	0.094	0.053
Clear Lake	−0.160	−0.115	0.487	0.266
Galleria	−0.472	−0.316	1.217	0.730
Carrilon	−0.304	−0.225	0.918	0.511
Greenspoint	−0.144	−0.108	0.480	0.272

Note: Elasticities were evaluated at the observation level and then averaged by choice.
[a]FIRE—finance, insurance, and real estate.

A 10% increase in the number of same-group firms in the CBD *decreases* the probability of an oil and gas firm locating there by 6%; but, a 10% increase in the total number of same-group firms in the CBD *increases* the probability that a service firm locates in CBD by over 6%, and a firm in the FIRE sector by about 10%.

4.2.2 *Property taxes*

Results in table 10 (and summarized in table 12) indicate that, although proximity variables do play a role in determining firm location, firms are more significantly impacted by public policy in their location decisions. The significance at the 1% level and the negative signs of the property-tax coefficients imply that firms treat the property taxes as location deterrents. The magnitudes of tax elasticities differ by industrial group, but are elastic in most cases. Previous research by others has found evidence that taxing jurisdictions can influence the amount of activities taking place within them (see the summary in Bartik, 1991; Charney, 1983; Finney, 1994; Fox, 1981; McGuire, 1985; McHone, 1986; Wasylenko, 1980a; 1980b). The question is that of how, and to what degree, do taxes affect firm location.

Table 10. Elasticities for other variables by center.

Variable	Manufacturing			Oil and gas			FIRE[a]			Services		
	1	2	3	1	2	3	1	2	3	1	2	3
Choice-specific variable												
Tax												
CBD	−3.740	−4.488	−3.819	−5.293	−4.370	−4.554	−1.015	−1.335	−1.685	−1.602	−1.413	−1.410
Baytown				−13.928	−11.736	−12.161	−1.590	−2.448	−3.090	−2.761	−2.486	−2.517
Pasadena	−5.945	−6.648	−5.975	−11.933	−10.037	−10.404	−1.365	−2.137	−2.705	−2.280	−2.081	−2.118
LaPorte	−6.882	−7.551	−6.904	−13.671	−11.534	−11.948	−1.583	−2.464	−3.114	−2.741	−2.492	−2.535
Clear Lake	−5.859	−6.575	−5.916	−11.992	−10.080	−10.457	−1.350	−2.096	−2.652	−2.267	−2.073	−2.104
Galleria	−4.821	−5.002	−4.809	−9.234	−7.673	−7.994	−0.710	−1.458	−1.835	−1.615	−1.502	−1.597
Carrilon	−7.289	−7.952	−7.297	−15.336	−13.017	−13.463	−1.672	−2.599	−3.285	−2.834	−2.584	−2.627
Greenspoint	−4.746	−5.140	−4.710	−10.109	−8.677	−8.927	−1.257	−1.957	−2.356	−2.148	−1.942	−1.938
Population density												
CBD	0.939	1.045	0.945	0.883	0.785	0.817	0.986	1.473	1.352	0.600	0.640	0.721
Baytown				1.210	1.097	1.135	0.793	1.278	1.286	0.532	0.581	0.667
Pasadena	3.294	3.410	3.263	4.205	3.805	3.940	2.736	4.482	4.525	1.716	1.898	2.193
LaPorte	0.532	0.540	0.526	0.662	0.601	0.622	0.441	0.719	0.724	0.294	0.324	0.374
Clear Lake	0.418	0.434	0.416	0.543	0.491	0.509	0.359	0.582	0.588	0.245	0.271	0.312
Galleria	1.211	1.148	1.190	1.437	1.289	1.340	0.655	1.389	1.392	0.557	0.626	0.754
Carrilon	2.025	2.039	1.998	2.622	2.398	2.476	1.643	2.669	2.691	1.064	1.176	1.356
Greenspoint	0.843	0.845	0.824	1.126	1.040	1.068	0.814	1.257	1.272	0.536	0.588	0.666
Distance to highway												
CBD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Baytown				−0.902	−1.121	−1.070	−1.146	−2.100	−1.931	−0.865	−0.986	−1.179
Pasadena	−0.840	−0.544	−0.746	−1.102	−1.366	−1.305	−1.400	−2.610	−2.407	−1.102	−1.175	−1.412
LaPorte	−1.952	−1.240	−1.730	−2.538	−3.158	−3.013	−3.265	−6.054	−5.573	−2.460	−2.829	−3.400
Clear Lake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Galleria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carrilon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Greenspoint	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 10 (continued).

	Manufacturing			Oil and gas			FIRE[a]			Services		
	1	2	3	1	2	3	1	2	3	1	2	3
Distance to firm												
CBD	−0.346	−0.451	−0.346	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Baytown				−4.534	−3.066	−3.521	0.216	2.690	3.162	−0.727	0.251	0.751
Pasadena	−3.635	−4.419	−3.577	−4.425	−2.985	−3.431	0.038	0.483	0.569	−0.224	0.078	0.236
LaPorte	−0.423	−0.505	−0.416	−1.509	−1.022	−1.173	0.182	2.294	2.700	−0.244	0.085	0.257
Clear Lake	−2.165	−2.642	−2.141	−4.727	−3.187	−3.666	0.088	1.110	1.308	−0.207	0.073	0.218
Galleria	−1.270	−1.433	−1.241	−1.232	−0.821	−0.949	0.023	0.377	0.442	−0.183	0.065	0.206
Carrilon	−0.996	−1.180	−0.977	−0.653	−0.445	−0.511	0.033	0.411	0.484	−0.108	0.038	0.114
Greenspoint	−1.085	−1.275	−1.054	−1.853	−1.277	−1.456	0.106	1.268	1.498	−0.329	0.114	0.337
Firm-specific variable												
Employees												
CBD	0.067	0.093	0.077	−0.069	−0.071	−0.071	0.055	0.028	0.026	0.010	0.008	0.012
Baytown				0.098	0.081	0.085	0.008	−0.219	−0.282	0.021	0.012	0.012
Pasadena	−0.587	−0.337	−0.569	−0.004	−0.009	−0.007	−0.967	−0.617	−0.551	−0.066	−0.052	−0.048
LaPorte	−1.553	−1.953	−1.767	0.071	0.094	0.087	0.056	0.050	0.047	0.012	0.019	0.031
Clear Lake	0.079	0.116	0.092	−0.027	−0.169	−0.096	−0.027	−0.034	−0.028	0.00038	0.005	0.009
Galleria	0.035	0.026	0.039	0.045	0.041	0.043	−0.041	0.023	0.021	−0.00009	0.002	0.011
Carrilon	−0.043	−0.062	−0.045	0.082	0.085	0.084	−0.014	−0.015	−0.016	0.010	0.011	0.016
Greenspoint	−1.583	−2.177	−1.850	−0.079	−0.051	−0.062	0.026	−0.124	−0.110	−0.077	−0.096	−0.227

Notes: Models differ by measure of agglomeration: model 1 uses number of firms in the same industry; model 2, the number of employees in the same industry; and model 3, the total number of employees in all industries. Elasticities are evaluated at the observation level and then averaged by choice.
[a] FIRE—finance, insurance, and real estate.

Table 11. Evidence of agglomeration economies in the centers model.

Industry	Sign of agglomeration effect			Type agglomerative force
	FIRMS	IND_EMP	TOT_EMP	
Manufacturing	neg	neg***	neg*	dispersive
Oil and gas	neg***	neg	neg	weak dispersive
FIRE[a]	pos***	pos***	pos***	attractive
Services	pos***	pos***	pos***	attractive

*significant at 10% level; ***significant at 1% level.
[a] Fire, insurance, and real estate.

Table 12. Evidence of property-tax effects in the centers model.

Industry	Tax-effect sign	elasticities range (absolute values)	Location impact
Manufacturing	neg***	3.7– 7.6	deterrent
Oil and gas	neg***	4.4–15.3	deterrent
FIRE[a]	neg***	0.7– 3.3	deterrent
Services	neg***	1.4– 2.8	deterrent

*** significant at 1% level.
[a] Fire, insurance, and real estate

Oil and gas firms show the most elastic responses to taxes, with elasticities ranging from approximately -4 to -15, followed by manufacturing, with elasticities ranging from about -4 to -8. Firms in FIRE and services also view property taxes as a location deterrent but are somewhat less sensitive to changes, with most elasticities falling between -1 and -3. The single inelastic response is for the Galleria choice for firms in the FIRE sector, where the elasticity is -0.7. The inelastic response makes sense in that this location has the highest predicted probability. If the choice probabilities are unbiased estimates of the proportion of firms in each center, the change in choice probabilities due to the tax changes may be thought of as a prediction of the change in the proportion of new firms locating in the centers. Therefore, the elasticities could be interpreted as the percentage changes in the expected relative frequency of a sample of new firms opening in the centers resulting from percentage change in the tax rate of the respective center. For example, comparing the CBD and Galleria choices for model 1, a 1% increase in property taxes in those centers would lead to about a 9% decrease in the relative frequency of oil and gas firms locating in Galleria and a 5% decrease for them in the CBD. In contrast, for FIRE firms, the tax effects are much smaller. A 1% increase in property taxes would lead to a 0.7% decrease in the relative frequency of locating in Galleria and 1% for the CBD.

Comparing our findings to other studies based on differing methodologies, we find further support for elastic responses to taxes. Charney's (1983) elasticity of 2.52, or Fox's (1981) elasticity of 4.43, are close to many of the tax elasticities in this study in magnitudes. Since Charney's (1983) dependent variable is firm density, her calculated tax elasticity is perhaps more comparable to that of the present study than is Fox's elasticity; Fox's dependent variable is the land area by jurisdiction devoted to industrial production.

4.2.3 *Other independent variables*

As a determinant of firm location, population density is significant at the 1% level for all industrial groups. The signs of the coefficients on DENSITY are all positive and imply that firms choosing employment center locations are attracted to locations with higher population densities. To the extent that population densities reflect general economic outcomes, it can be concluded that firms choose to locate in economically vibrant areas.

The coefficients of all the highway-distance variables, DHIGHWAY, have negative signs, and are significant at the 5% or 1% level for all models. The exception is for the manufacturing sector, where the coefficient is significant at the 10% level in model 2. From the elasticity results reported in table 10, we are able to predict how responses differ by sector. For example, based on model 1, a 10% increase in distance to the nearest highway would reduce the probability of a firm locating in Pasadena by about 8% for manufacturing firms, by about 11% for the oil and gas firms, by about 14% for FIRE, and 11% for the service firms.

The variable DNEAR measures the relative attractiveness of proximity to the centroid of each employment center. The signs of the distance variables vary by model and sector. Expected negative signs occur for all three models estimated for manufacturing and oil and gas. But for FIRE and services several positive coefficients are found, especially when the employee-count measures of agglomerative forces are used. Responses by FIRE and services firms are in general inelastic and are the least responsive to changes in distance. The many positive inelastic results could indicate that these types of firms prefer to locate away from the centroid of employment centers, in order to take advantage of potentially lower rents. An alternative explanation may be that many of the FIRE and services firms prefer to locate far from the centroid of the employment centers in order to capture a larger local market area for their products.(5) For example, based on model 3, a 10% increase in distance from the centroid of a center to a firm in the same industry would reduce the probability of firms locating in Galleria by 10% for oil and gas and 12% for manufacturing, but increase the probability by 4% for FIRE and 2% for services.

The one firm-specific variable, EMPLOYEES $\times$ CENTER, is our proxy of firm size, and is included to measure internal economies of scale. If an increase in the number of employees per firm significantly reduces the probability of the marginal firm locating in that subcenter, then larger firms do not favor that subcenter. The results show mixed results for the firm-size effect and, as indicated earlier, the results for the mixed-multinomial logit mirror earlier results found in the dispersed model. Firm size is more likely to be an important determinant of location for firms in the manufacturing, and oil and gas sectors than for firms in the FIRE and services sectors. Many of the signs of the coefficients are indeterminate [and the marginal effects and elasticities need not be of the same sign as the coefficient for the firm-specific variables in a mixed-multinomial setting (Greene, 2003)] and only a few of them are significant at the 5% or 10% level. The statistical significance of the firm-size variable is industry-specific and choice-specific and elasticities are quite small. The one exception to the inelastic pattern occurs for the manufacturing sector, for which responses are elastic: for example, if a manufacturing firm's own employment increased by 10%, the probability that the firm would locate in the Greenspoint subcenter would decline by between 16% and 22%.

5 Summary and conclusion

Our research is one of a few attempts to model the workings of within-city agglomerative forces using firm-level data in a discrete-choice model. Moreover, fiscal variables operate at a fine level of spatial detail, so that our results are likely to be an improvement on previous work that has been done at higher levels of spatial aggregation.

(5) We would like to thank a referee for this insight.

Two models have been estimated and the results discussed. First, logit estimates of the general choice of dispersed versus concentrated location show some evidence that firm size affects that choice. We found that larger firms in manufacturing, and oil and gas are more likely to locate in centers of employment concentration than are smaller firms in those sectors. But we found no firm-size effect for the industrial groups where major employment growth has been occurring, services and FIRE.

Second, results based on the estimation of a mixed-multinomial logit for the choice of centers allow more complicated stories to be modeled. We are particularly interested in measuring potential agglomerative forces and verifying whether or not agglomeration economies work at the within-city level (rather than the between-city level). Thus our focus is on the discrete choice of employment center. It is important to determine if different sectors have different pathways linking to other firms: if differences are found, potential projections can be made for the future of urban growth as industrial composition changes to a more service-oriented economy. Our findings are important for this story. We find that agglomeration economies—measured by the use of three proxies for spatially limited localization and urbanization economies—do exist within Houston.(6) The benefits of proximity appear to be important only for the FIRE and service groups, and we find evidence for the workings both of localization and of urbanization economies. In contrast, firms in both the oil and gas group and the manufacturing group appear not to benefit from proximity to other firms, as is evidenced by the negative elasticities for the agglomeration variables. However, the magnitudes of the effects—positive or negative—are relatively small as evidenced by most elasticities being less than one in absolute value. The exception occurs for the FIRE sector, which shows elastic responses to changes in all three agglomeration measures for the CBD and the Galleria.

Fiscal variables also have significant impacts on firm location decisions for all sectors. The negative sign and relatively large elasticities (most greater than one in absolute value) show that local property taxes are viewed as a deterrent to location in an employment center. Tax effects are especially strong for heavy industry: oil and gas, and manufacturing. Moreover, it is possible that tax effects may mitigate any of the positive attractive forces in a center. For example, only FIRE and service firms are attracted to similar firms, and for those firms increases in local property taxes may overwhelm any benefits from proximity.

Overall, the results suggest that models such as the ones presented here have considerable explanatory power concerning the location decisions of business establishments. Many economic development studies involve identifying potential drivers of economic growth, as well as the prediction of the effects of a new plant opening in the region. In addition to providing useful information for potential firms that may locate in the local area and in providing an assessment of the implications of those decisions on the local economy, models such as the one incorporated here could be used for policy analysis. The role of fiscal variables must be analyzed in a context allowing for internal and external economies and diseconomies to affect individual firms.

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(6) There remains the possibility that what we call 'agglomerative forces' are merely the outcome of individual decisions based on comparing the benefits from natural advantages of various sites (or a combination of agglomeration economies and natural advantage)—such decisions can also result in concentrated patterns of location—so our results may most appropriately be interpreted as an upper bound (see Rosenthal and Strange, 2004).

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