DISCUSSION PAPER

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A MODEL OF INTRAURBAN EMPLOYMENT LOCATION: REPLICATING THE BOGOTA EXPERIMENT IN SEOUL

by

Kyu Sik Lee

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Water Supply and Urban Development Department
Operations Policy Staff
The World Bank

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Abstract

A model of employment location, which was developed and applied to Bogota, Colombia, in an earlier World Bank research project, was estimated with a fresh set of data obtained from a sample survey of manufacturing establishments in the Seoul region. The results from the Seoul data are much more robust than those of Bogota and strongly support the empirical evidence obtained from the Bogota study. The patterns of employment location in rapidly growing LDC cities are by no means random. The empirical findings from these two studies should offer the behavioral underpinnings required for sound policy analyses.

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1. Introduction

As part of the World Bank's "City Study" research project on Bogota, Colombia, a model was formulated to study the location behavior of manufacturing firms in urban areas. The theoretical model was extended to a multinomial logit specification and estimated using the results of a sample survey of establishments conducted for Bogota. The model and estimation results (Lee, 1982) are appended as annex to be used as reference in the following discussion.

While the Bogota study dealt mainly with the behavioral underpinnings of firms' location choice, the current research on Seoul has focused on evaluating various spatial policies intended to influence the firms' location behavior. More specifically, in the research project the extent of policy effectiveness was documented quantitatively (Lee, 1985b) and relative efficiencies of alternative policies were simulated (Murray, 1985). As part of the data collection efforts, a sample survey of 500 manufacturing establishments was conducted for the Seoul region. The survey instrument included the modules on the firm's location behavior similar to those used in the Bogota study, as well as the modules on the firms' responses to various policy measures. Therefore, the fresh data from the Seoul survey provided an opportunity to estimate the model with the same specification used in the Bogota study.

After the nature of the survey data is briefly described in the next section, the estimation results are presented; the results obtained using the Seoul data are much more robust than those of Bogota; moreover, the conclusions drawn from the Seoul results strongly support those on Bogota.

2. The Data [1/]

A sample of 499 manufacturing establishments interviewed in the survey was drawn from the 1981 manufacturing establishment survey file of the Korean National Bureau of Statistics. The file contained 33,425 manufacturing establishments with five or more employees, of which 15,119 establishments were located in the Seoul region which includes Seoul and Gyeonggi province. In response to our request, in the 1981 survey NBS obtained information on the founding date of the establishment, the previous location, the date of relocation, and reasons for relocation. This information enabled us to take a random sample stratified by the following four categories: (1) location tenure, i.e., newly established firms (births), relocated firms (movers), and those stayed at the same location (mature firms) [2/]; (2) firm size by employment; (3) the zone system defined by the 45 subareas of Gu's, Si's, and Gun's; and (4) the type of industries defined by the SIC codes.

In order to minimize the cost of sampling while having a sufficient number of observations for econometric estimation, we chose two two-digit industries, the textile and the fabricated metal industries. These industries without much locational idiosyncrasy should be more amenable to policies than some other industries such as cement or steel. Moreover, both industries had a large share of establishments in the region accounting for 52.4 percent of total

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1/ From Lee, Choe, and Pahk (1985).

2/ Births are defined as those established in 1979 or thereafter; movers are those that relocated during 1979-1981; mature firms are those established before 1979 and never moved.

manufacturing. The homogeneity of firms in each industry group makes it possible to test behavioral hypotheses with sufficient degrees of freedom.

The second consideration given in the sampling process was to over-sample large firms so that the number of workers included in the sample could be maximized and also to over-sample those firms relocated in response to government actions such as relocation orders. Finally, an attempt was made to cover a wide geographic area in such a way that spatial analyses could be possible covering the entire region. Our target sample size was 500 with about equal shares of establishments among the three types of location tenure.

The realized sample of 499 establishments consists of 221 mature firms, 137 births, and 141 movers (see Table 1). The average size of newly established firms was smallest (Table 3). The sample coverage across zones was satisfactory; of the 45 subareas in the region, 39 were represented. The geographic distribution of the sample firms was consistent with that of the population. More firms were selected from Rings 2, 3, and 4 (see Table 1 and Figure 1).

In some cases the four-way stratification severely limited the possibility of drawing sample establishments from a specific population category. For example, not enough textile firms were located in certain subareas. It should be noted here that the sample was drawn from the 1981 establishment file and the survey was taken in 1983. Some firms apparently changed their line of production during this period; the final sample included nine establishments in other industries (Table 2).

As shown in Table 3, the average size of sample firms was 115 persons, which was much larger than the average size of all

Table 1: SAMPLE COMPOSITION: NUMBER OF ESTABLISHMENTS BY ZONE AND FIRM TYPE

Zone	Mature	Births	Movers	Total
Ring 1	8 38.10 3.62	11 52.38 8.03	2 9.52 1.42	21 100.00 4.21
Ring 2	55 64.71 24.89	22 25.88 16.06	8 9.41 5.67	85 100.00 17.03
Ring 3	65 58.04 29.41	32 28.57 23.36	15 13.39 10.64	112 100.00 22.44
Ring 4	78 32.37 35.29	59 24.48 43.07	104 43.15 73.76	241 100.00 48.30
Ring 5	15 37.50 6.79	13 32.50 9.49	12 30.00 8.51	40 100.00 8.02
Total	221 44.29 100.00	137 27.45 100.00	141 28.26 100.00	499 100.00 100.00

Source: The Project Sample Establishment Survey.

Figure 1: RING SYSTEM IN THE SEOUL REGION

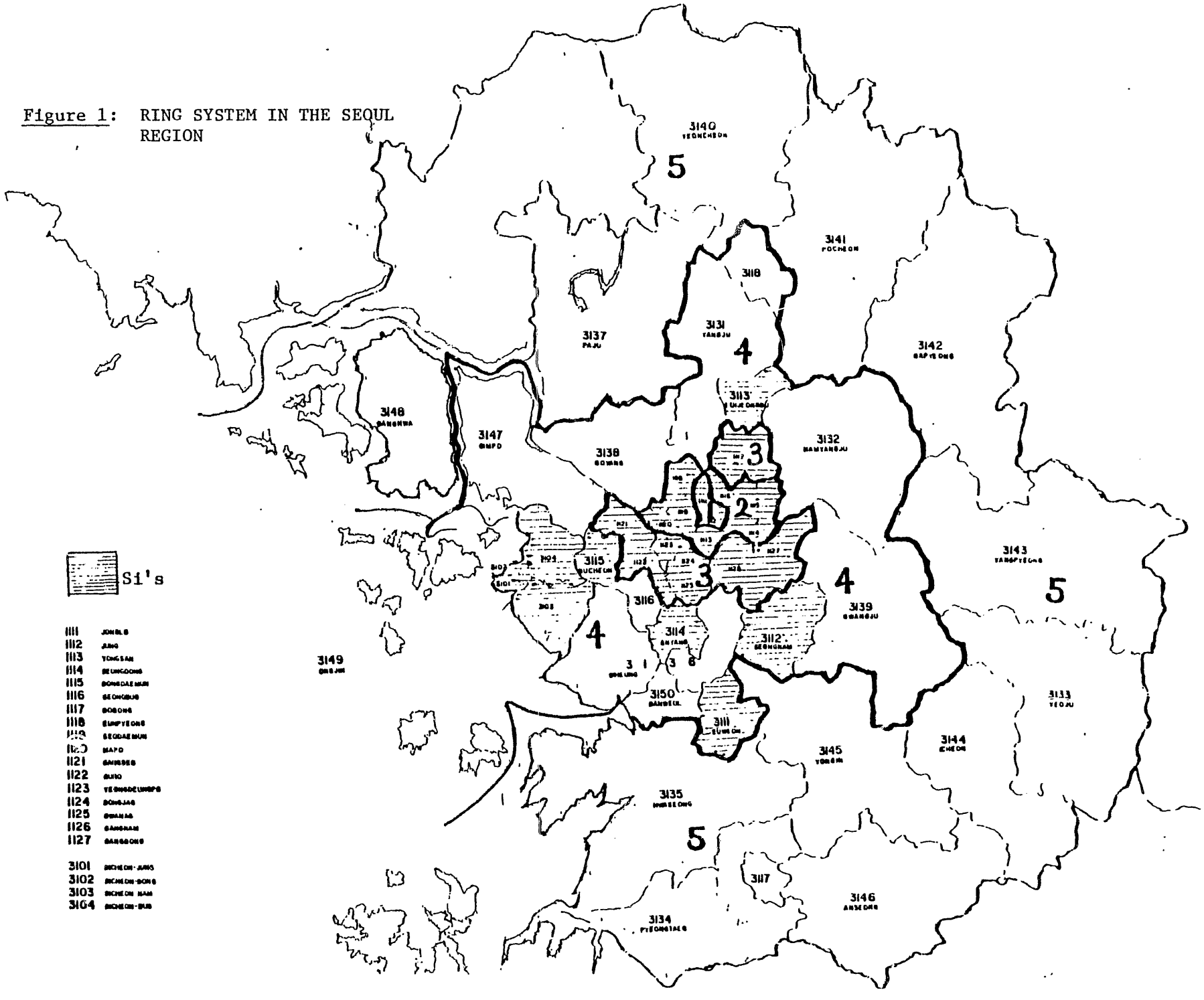

Table 2: SAMPLE COMPOSITION: NUMBER OF ESTABLISHMENTS BY ZONE AND INDUSTRY

Zone	Textile	Fabricated Metal	Other Manufacturing [a]	Total
	17	4	0	21
Ring 1	80.95	19.05	0.00	100.00
	7.83	1.47	0.00	4.21
	57	28	0	85
Ring 2	67.06	32.94	0.00	100.00
	26.27	10.26	0.00	17.03
	46	64	2	112
Ring 3	41.07	57.14	1.79	100.00
	21.20	23.44	22.00	22.44
	76	158	7	241
Ring 4	31.54	65.56	2.90	100.00
	35.02	57.88	78.00	48.30
	21	19	0	40
Ring 5	52.50	47.50	0.00	100.00
	9.68	6.96	0.00	8.02
	217	273	9	499
Total	43.49	54.71	1.80	100.00
	100.00	100.00	100.00	100.00

[a] Includes the printing, the chemical, the mineral, the basic metal industries.

Source: The Project Sample Establishment Survey.

Table 3: SAMPLE COMPOSITION: NUMBER OF ESTABLISHMENTS BY FIRM TYPE AND ESTABLISHMENT SIZE

	1-4[a]	5-9	10-19	20-49	50-99	100-100	200-299	300-Over	Total
Mature	7	31	28	48	50	34	7	16	221
	3.17	14.03	12.67	21.72	22.62	15.38	3.17	7.24	100.00
	87.50	58.49	35.90	35.56	45.45	48.57	33.33	66.67	44.29
	2.86	6.97	14.39	32.19	68.34	130.12	249.14	1650.50	172.75 [b]
Births	1	14	28	46	25	13	5	5	137
	0.73	10.22	20.44	33.58	18.25	9.49	3.65	3.65	100.00
	12.50	26.42	35.90	34.07	22.73	18.57	23.81	20.83	27.45
	2.00	6.14	13.32	31.80	69.84	130.23	207.00	374.80	60.38
Movers	0	8	22	41	35	23	9	3	141
	0.00	5.67	15.60	29.08	24.82	16.31	6.38	2.13	100.00
	0.00	15.09	28.21	30.37	31.82	32.86	42.86	12.50	28.26
	-	7.25	13.00	33.90	73.43	143.22	239.00	378.00	77.18
Total	8	53	78	135	110	70	21	24	499
	1.60	10.62	15.63	27.05	22.04	14.03	4.21	4.81	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	2.75	6.79	13.62	32.58	70.30	134.44	234.76	1225.67	114.89

[a] Persons.
[b] The bottom number in each cell is the mean employment size of firms in that cell.

Source: The Project Sample Establishment Survey.

establishments in the Seoul region (77 persons in 1981 according to NBS). This resulted from the sample design of over-sampling large firms. In particular, it should be noted that the average firm size of births was 60 persons compared to 27 in the population. In the sample the average firm size of movers was slightly larger than that of births, but the average size of mature firms was more than twice these two groups.

3. Estimation Results

The derivation of the theoretical model and its empirical specification appear in the Annex. In short, the model specifies that the firm, as a price taker, locates where it maximizes profits. The locational attributes of a particular plant site as well as the lot size enter into the firm's production decision. A particular plant site is then occupied by the firm that offers the highest bid. In locational equilibrium, no firm will have any incentive to move since all firms make the same profits. Once the bid-rent function is derived from the profit function, multinomial logit specification follows.[3/] This stochastic specification offers a framework for predicting the probability that a firm of particular type will occupy a site with particular attributes.

The survey questionnaire was constructed to capture this theoretical and empirical framework. It was designed to take about one hour to complete and did not require the respondents to look up their accounting books; still the questionnaire contained a large amount of

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3/ Applications of a discrete choice model in urban economic research are reviewed in Lee (1985a).

information with over 400 computer readable variables. The most salient aspects of the survey results are summarized in a descriptive paper by Lee, Choe, and Pahk (1985).

The survey results provide the information required for estimating the multinomial logit specification of the model as described above. Attributes of the firm include product mix, type of production process, building structure, plant space, lot size, and the workforce composition. These variables can be used for stratifying the sample firms by type to define the dependent variable. Attributes of the plant site include variables associated with the accessibility to the product and input markets and those representing the level and the quality of local public services. These variables serve as the independent variables in the logit specification.

The basic model specified for Seoul was the same as that of Bogota; there were only minor differences in defining the measurements of some variables. To define the dependent variable, we chose the same two variables used in the Bogota study: product type (two-digit SIC in the case of Korea) and firm size defined by floor space. Therefore the firms in the two industries are grouped into two plant sizes according to floor space. To examine the sensitivity of estimation results to the threshold value of floor space that determines the firm size categories, we repeated the estimation with different threshold values. This was not possible in the Bogota study where the sample size was small. The results using two values are reported here: floor space of 100 pyeongs (330 square meters) and 200 pyeongs, respectively. The specification of dependent variable is shown in Table 4 using two threshold values when

Table 4: DEFINITION OF DEPENDENT VARIABLE
(Estimating for Seoul Alone)

A. Threshold Floor Space = 100 pyeongs

Group	Industry	Floor Space	Number of Observations
1	SIC 32	Less than 100 pyeongs	56
2	SIC 32	100 pyeongs or more	64
3	SIC 38	Less than 100 pyeongs	49
4	SIC 38	100 pyeongs or more	49
Total			218

B. Threshold Floor Space = 200 pyeongs

Group	Industry	Floor Space	Number of Observations
1	SIC 32	Less than 200 pyeongs	82
2	SIC 32	200 pyeongs or more	38
3	SIC 38	Less than 200 pyeongs	74
4	SIC 38	200 pyeongs or more	24
Total			218

Note: SIC 32 = textile; SIC 38 = fabricated metal.

the model was fitted to Seoul alone. Of the 499 sample establishments, 218 were located in Seoul (Rings 1, 2, and 3 in Table 1).

The independent variables are basically the same as those used in the Bogota study, but in some cases different definitions were used as defined in the Appendix. They include the following: access to the local markets for output and material inputs measured by the proportion of output sold to (PROSOLD) and inputs bought (INPTBT) from Seoul; proximity to residential areas of production workers (RESLOCWKR) and office workers (RESLOCMNG); the quality of local public services measured by the frequency of electricity interruption (ELECINT) and water supply interruption (WATERINT); the extent of scale economies of a particular industry measured by the employment location quotient of individual industries in the zone of location (LOCQT); the intensity of economic activities measured by the population density in the zone of location (POPDENS); and the distance to the CBD (DISTCBD) as a measure of accessibility to the city center. The water interruption rate was the only additional variable included in the Seoul study. As in the case of Bogota, however, we included two firm type stratification variables on the right-hand side of the equation: the year of initial operation (YRINOP) at the present location that discriminates old mature establishments against new ones and recent movers; and the ownership dummy variable (RENTER) to distinguish renters from owners.

Table 5 shows the estimated values of coefficients and the corresponding "t" statistics that are the test of differences between the coefficients of a particular group with respect to those of the reference group. As in the case of Bogota, Group 4 (large metal-fabricating firms) was set as the reference group. The logit

Table 5: LOGIT ESTIMATION OF FIRM LOCATION CHOICE, SEOUL (Dependent Variable: Industry and Floor Space [a])

	CONSTANTS	YRINOP	RESLOCMG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT
Coefficients:												
Group 1	-10.970	0.156	0.009	-0.031	0.006	0.016	-0.811	1.324	-0.161	-0.7311×10^{-4}	0.674	1.285
Group 2	1.840	-0.020	0.019	-0.039	-0.005	0.007	-0.126	1.332	-0.086	-0.4792×10^{-4}	-	
Group 3	-8.216	0.065	0.004	-0.017	0.011	0.018	0.089	0.645	0.060	0.4875×10^{-4}	0.674	0.576
Group 4 [b]	-	-	-	-	-	-	-	-	-	-	-	-
t Statistics:												
Group 1	1.902*	2.241**	1.278	3.587**	0.955	2.476**	1.614	1.344	1.626	1.147	1.884*	2.228**
Group 2	0.497	0.494	2.799**	4.617**	0.799	1.208	0.285	1.468	0.910	0.794	-	
Group 3	1.761*	1.212	0.536	1.996**	1.659*	2.931**	0.214	0.650	0.665	0.746	1.884*	0.851
Group 4	-	-	-	-	-	-	-	-	-	-	-	-

Percent correctly predicted: 49.54
Likelihood ratio index: 0.2417
Likelihood ratio statistics: 146.1

Number of observations: Group 1 = 56
Group 2 = 64
Group 3 = 49
Group 4 = 49
Threshold for floor space = 100 pyeongs

Source: The Project Sample Establishment Survey.

[a] Definitions of variables are given in the Appendix.
[b] Group 4 is used as the base.
* Significant at the 5% level.
** Significant at the 2.5% level.

Table 6: LOGIT ESTIMATION OF FIRM LOCATION CHOICE, SEOUL (Dependent Variable: Industry and Floor Space [a])

	CONSTANTS	YRINOP	RESLOCMG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT
Coefficients:												
Group 1	-17.010	0.252	0.024	-0.061	0.011	0.012	-0.192	2.525	-0.207	0.7782×10^{-4}	0.462	1.310
Group 2	0.960	-0.012	0.039	-0.066	-0.012	0.017	-0.373	3.187	-0.135	0.7041×10^{-4}	-	
Group 3	-14.240	0.177	0.018	-0.042	0.011	0.014	0.281	2.058	-0.029	0.1713×10^{-4}	0.462	0.540
Group 4 [b]	-	-	-	-	-	-	-	-	-	-	-	-
t Statistics:												
Group 1	2.755**	3.474**	2.507**	3.949**	1.209	1.588	0.314	1.690*	1.631	0.936	1.099	2.282**
Group 2	0.193	0.227	3.505**	4.096**	1.193	2.050**	0.560	2.154**	1.002	0.825	-	
Group 3	2.610**	2.868**	1.962*	2.774**	1.364	1.904*	0.500	1.415	0.250	0.215	1.099	0.815
Group 4	-	-	-	-	-	-	-	-	-	-	-	-

Percent correctly predicted: 57.34
Likelihood ratio index: 0.3327
Likelihood ratio statistics: 201.1

Number of observations: Group 1 = 82
Group 2 = 38
Group 3 = 74
Group 4 = 24

Threshold for floor space = 200 pyeongs

Source: The Project Sample Establishment Survey.

[a] Definitions of variables are given in the Appendix.
[b] Group 4 is used as the base.
* Significant at the 5% level.
** Significant at the 2.5% level.

coefficients of group-specific variables should be interpreted as relative differences with respect to Group 4. It should be noted that the signs of coefficients do not necessarily mean the direction of causation; they only show the relative orders of magnitudes of individual coefficients with respect to the reference group for a given independent variable.

In Table 5, we first note that the estimation results using the Seoul data are much more robust than those obtained for Bogota, i.e., more coefficients are statistically significant in the case of Seoul than Bogota. The likelihood ratio index of 0.24 indicates that the overall goodness of fit is good and comparable to the Bogota result. Both the level of significance and goodness of fit improve further when the threshold floor space is raised to 200 pyeongs, but without affecting the relative orders of magnitudes of individual coefficients (Table 6). This means that as specified by the model there are systematic relationships between the firm attributes and the site attributes in determining which types of firms tend to occupy which types of sites. These relationships are analyzed below using the estimated coefficients.

To perform such analyses, the elasticities of probabilities are calculated at sample means and reported in Tables 7 and 8 for the case of Seoul alone. The elasticity value represents the percentage change in the probability of being in the ith group with respect to 1 percent change in a given independent variable for that group. For example, in Table 7 when the measure of access to the local input markets INPTBT increases by 1 percent, the probability of a firm to be in Group 1 increases by more than 3 times that of being in Group 2. In

Table 7: ELASTICITIES OF PROBABILITY: LOGIT ESTIMATION OF LOCATION CHOICE, SEOUL
(Threshold for floor space = 100 pyeongs)

Industry Groups by Floor Space	YRINOP	RESLOCMNG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT	Share
Group 1	9.092	0.429	-1.081	0.243	0.931	-0.786	1.107	-0.787	-1.016	0.295	1.304	0.2569
Group 2	-1.065	1.072	-1.285	-0.103	0.276	-0.136	1.074	-0.495	-0.595	-	1.258	0.2936
Group 3	3.885	0.193	-0.859	0.491	1.126	0.104	0.541	0.419	0.702	0.394	0.380	0.2248
Group 4	-	-	-	-	-	-	-	-	-	-	-	0.2248

Source: The Project Sample Establishment Survey.

NOTES. For definitions of dependent and independent variables, see the Appendix.

The elasticity of probability is defined as $e_{ij} = (1-p_i)\, b_{ij}\, X_{ij}$, where P_i is the share of ith group, b_{ij} the jth logit coefficient of the ith group, and X_{ij} the sample mean of the jth independent variable for the ith group.

It should be noted that the logit coefficients estimated are the differences with respect to the coefficients of the base group. Therefore, the values of elasticities in this table are the results based on $(b_{ij} - b_j^*)$ instead of b_{ij}, where b_j^* in the coefficient of the base group.

Table 8: ELASTICITIES OF PROBABILITY: LOGIT ESTIMATION OF LOCATION CHOICE, SEOUL

(Threshold for floor space = 200 pyeongs)

Industry Groups by Floor Space	YRINOP	RESLOCMG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT	Share
Group 1	12.295	0.999	-1.696	0.357	0.522	-0.167	1.768	-0.906	-0.892	0.162	1.116	0.3761
Group 2	-0.732	2.741	-2.808	-0.171	0.824	-0.462	3.047	-0.923	-1.018	-	1.512	0.1743
Group 3	9.017	0.790	-1.850	0.367	0.654	0.278	1.470	-0.178	0.203	0.194	0.312	0.3394
Group 4	-	-	-	-	-	-	-	-	-	-	-	0.1101

Source: The Project Sample Establishment Survey.

NOTES. For definitions of dependent and independent variables, see the Appendix.

The elasticity of probability is defined as $e_{ij} = (1-p_i)\, b_{ij}\, X_{ij}$, where P_i is the share of ith group, b_{ij} the jth logit coefficient of the ith group, and X_{ij} the sample mean of the jth independent variable for the ith group.

It should be noted that the logit coefficients estimated are the differences with respect to the coefficients of the base group. Therefore, the values of elasticities in this table are the results based on $(b_{ij} - b_j^*)$ instead of b_{ij}, where b_j^* in the coefficient of the base group.

other words, the accessibility to local input markets is more important to small textile firms (Group 1) than large textile firms (Group 2) in their location choice; furthermore, the elasticity value for Group 3 indicates that this site attribute is more important for small metal-fabricating firms (Group 3) than small textile firms (Group 1). More generally, this evidence supports the hypothesis that local market orientation is very important for small firms. The elasticity values for PROSOLD, the measure of access to local product markets, also show the same relative orders of magnitudes among the three groups as was the case with INPTBT.

As in the Bogota study, we find that the proximity to the residential areas of office workers RESLOCMNG is much more important for large firms (Group 2) than small firms (Groups 1 and 3), while the opposite is true for the proximity to production workers' residential areas RESLOCWKR. The distance effects measured by DISTCBD are also the same as in the Bogota case: This variable is least important for small textile firms (Group 1), indicating that they tend to locate near the CBD. As the distance from the CBD increases, the probability of being in Group 2 is larger than that of being in Group 1. Small metal-fabricating firms (Group 3), however, tend to locate farther from the CBD than the textile firms of both sizes.

The Seoul results show that as in the case of Bogota large textle firms are more sensitive to the poor quality of elasticity ELECINT than small textile firms, but metal-fabricating firms are more sensitive than textile firms as a whole. With respect to the poor quality of water WATERINT, however, textile firms are more sensitive than metal-fabricating firms. The scale economies of individual

industries measured by location quotient LOCQT are about three times more important for textile firms than metal-fabricating firms.

Another way of interpreting the elasticity values in Table 7 is to find which variables are more important than others in attracting firms to a particular group. In Table 9 we rank the elasticity values in descending order for each group, and those of the Bogota estimates are also shown for comparisons. The quality of water variable is omitted since it was not included in the Bogota study. The most important variable that influences the probability of being in Group 3 (small metal-fabricating firms) is the measure of access to the local input markets INPTBT, followed by the proximity to production workers' residential areas RESLOCWKR and the population density POPDENS. The electricity variable ELECINT and the commuting distance of office workers RESLOCMNG are least important. This ranking result is similar to that of Group 1 and those of both small firm groups of Bogota. For Group 2 (large textile firms), however, the location quotient LOCQT and the commuting distance of office workers RESLOCMNG are more important than access to local input markets, INPTBT. These results for large firms of Seoul are also consistent with those of Bogota.

Nevertheless, we find one sharp difference between the two cities: In the case of Seoul, the location quotient LOCQT is the most important variable for small textile firms (Group 1) while it ranks second for large textile firms (Group 2). In the case of Bogota, however, this variable was important only for large textile firms (Group 2). In Seoul, the scale economies of the textile industry are important for both small and large firms indicating greater "linkages" between different size groups in Seoul than in Bogota.

Table 9: RANKING OF INDEPENDENT VARIABLES FOR FIRM LOCATION CHOICE: CONTRASTS BETWEEN BOGOTA AND SEOUL

	Bogota			Seoul		
Variable	Small Textile (Group 1)	Small Fab.Metal (Group 3)	Large Textile (Group 2)	Small Textile (Group 1)	Small Fab.Metal (Group 3)	Large Textile (Group 2)
INPUTBT/ a/ INPTBT	1	1	4	4	1	6
WKSOUTH/ a/ RESLOCWKR	2	4	7	2	2	1
POPDENS	3	3	8	3	3	4
ELECINT	4	8	2	6	8	7
LOCQT	5	7	1	1	6	2
PRODSOLD/ a/ PROSOLD	6	2	5	8	4	8
ADMNORTH/ a/ RESLOCMNG	7	5	3	7	7	3
DISTCBD	8	6	6	5	5	5

a/ The notation used in the Bogota study for the same variable.

Source: Table 7 of the text, and Table 6 of Annex (for Bogota).

The model was estimated with the threshold floor value of 200 pyeongs and reported in Tables 6 and 8. The conclusions drawn from the above analysis are not much affected by this specification. When the model was estimated with alternative specifications of the dependent variable, with lot size, and employment size instead of floor space, the general patterns stayed the same. These results are not reported here. The model is also estimated for the Seoul region as a whole. The region has 9 other cities including Incheon which has more than one million people. The theoretical and empirical bases need to be further developed, however, before extending the present model to a multi-center case for a large metropolitan region. For example, the model's applicability will depend on the extent and functioning of the land, labor, and other markets in the region. The estimation results for the region which are quite similar to those obtained for Seoul alone are shown in the Appendix.

4. Conclusions

A model of intraurban employment location estimated earlier for Bogota was estimated for Seoul with a fresh data set obtained from a sample survey of establishments in the Seoul region. The results with the Seoul data are much more robust than those of Bogota; this should be partly attributed to the better quality of the Seoul data in terms of the sample frame, sample size, and sampling procedures followed.

The results for Seoul are analyzed by comparing with those of Bogota. On the whole, the predicted location patterns from the Seoul estimates are consistent with those of Bogota. In sum, for small manufacturing firms accessibilities to local input and output markets

and the commuting distance of production workers are most important. For these firms, the benefits from various externalities tend to compensate for high rent and congestion costs in the central area. Large firms tend to be more export-oriented (from the city) and require more space with modern production technology. For these firms, land and plant space available at lower cost in outer areas is more important than access to local markets. As was the case in Bogota, the Seoul results also show that large firms are more sensitive to the quality of public utility services and the commuting distance of administrative workers than small firms.

The Seoul results, however, reveal one interesting contrast between the two cities. The location quotient which represents scale economies of individual industries is most important for Bogota's large textile firms but unimportant for both small textile and small metal-fabricating firms in that city. In the case of Seoul too this variable is unimportant for small metal-fabricating firms, but it turns out to be most important for both small textile and large textile firms. This implies that in Seoul small textile firms tend to follow its parent industry indicating the need for strong "linkages" within the industry.

The land price gradient estimated with the same data set is as follows:

$$\text{Land price} = 1458\, e^{-0.0811\ \text{Distance}},$$

where $t = 32.11$; $R^2 = 0.6971$.

The fit is much stronger than that of Bogota, while the slope coefficients are comparable between the two (see footnote 5 in Annex). As in the case of Bogota, a strong relationship exists for Seoul between the intensity of input (labor and capital) use and land price. From the

two studies, we may conclude that in rapidly growing cities in developing countries manufacturing firms respond to the substitutability of land with respect to other inputs over space. The successful estimation of the model with the Seoul data provides a stronger base to support the empirical evidence obtained earlier from the Bogota study.

Appendix

1. Definition of Variables

2. Estimation Results for the Region (Tables A1 through A4)

1. DEFINITIONS OF VARIABLES

Dependent Variable

See Table 4.

Independent Variables

CONSTANT: Group specific constants.

PROSOLD: Percent of products sold in Seoul.

INPTBT: Percent of inputs bought in Seoul.

DISTCBD: Airline distance (km) from the CBD to the center of the subarea where the establishment is located.

RESLOCWKR: Percent of production workers living in the neighbornood or city where the establishment is located.

RESLOCMNG: Percent of office workers living in the neighbornood or city where the establishment is located.

ELECINT: Frequency of electricity interruption.
(1, almost never; 2, once a month; 3, once a week; 4, twice a week; 5, twice or more per week.)

WATERINT: Frequency of water interruption.
(1, almost never; 2, once a month; 3, once a week; 4, twice a week; 5, twice or more per week.)

POPDENS: Population per square kilometer of the subarea where the establishment is located (for 1980).

LOCQT: Location quotient defined as subarea j's employment share of industry i relative to its share of total manufacturing employment. (Separate values are used for the two industry groups.)

YRINOP: Year of initial operation at the present location.

RENTER: Ownership dummy: 1 if renter, 0 if owner. (Assigned to establishments with floor space less than the threshold value for both industry groups.)

2. ESTIMATION RESULTS FOR THE REGION

(Tables A1 through A4)

Table A1: LOGIT ESTIMATION OF FIRM LOCATION CHOICE, SEOUL AND GYEONGGI (Dependent Variable: Industry and Floor Space [a/])

	CONSTANTS	YRINOP	RESLOCMG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT
Coefficients:												
Group 1	-5.210	0.057	-0.001	-0.017	0.007	0.009	-0.424	-0.056	-0.009	0.2623×10^{-4}	1.277	1.114
Group 2	-0.160	0.000	0.009	-0.022	-0.001	-0.005	0.143	0.451	-0.009	0.9065×10^{-4}	-	
Group 3	-4.339	0.015	-0.001	-0.003	0.006	0.010	-0.082	0.060	0.014	0.9740×10^{-4}	1.277	0.952
Group 4 [b/]	-	-	-	-	-	-	-	-	-	-	-	-
t Statistics:												
Group 1	1.407	1.280	0.202	3.379**	1.756*	2.212**	1.490	0.137	0.427	0.835	4.854**	3.179**
Group 2	0.064	0.002	2.509**	5.163**	0.211	1.562	0.652	2.213**	0.600	0.341	-	
Group 3	1.473	0.434	0.330	0.547	1.541	2.530**	0.316	0.170	0.697	3.365**	4.854**	3.000**
Group 4	-	-	-	-	-	-	-	-	-	-	-	-

Percent correctly predicted: 54.82
Likelihood ratio index: 0.2516
Likelihood ratio statistics: 347.4

Number of observations: Group 1 = 81
Group 2 = 138
Group 3 = 77
Group 4 = 202
Threshold for floor space = 100 pyeongs

Source: The Project Sample Establishment Survey.

[a/] Definitions of variables are given in the Appendix.
[b/] Group 4 is used as the base.
* Significant at the 5% level.
** Significant at the 2.5% level.

Table A2: LOGIT ESTIMATION OF FIRM LOCATINO CHOICE, SEOUL AND GYEONGGI (Dependent Variable: Industry and Floor Space [a])

	CONSTANTS	YRINOP	RESLOCMNG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT
Coefficients:												
Group 1	-7.663	0.110	0.001	-0.026	0.006	0.004	-0.279	0.151	-0.036	0.5946×10^{4}	1.132	1.152
Group 2	-0.911	0.011	0.010	-0.023	-0.002	-0.004	0.218	0.400	-0.012	0.2766×10^{-4}	-	
Group 3	-6.378	0.078	-0.001	-0.010	0.004	0.005	0.006	-0.059	-0.023	0.1043×10^{-3}	1.132	0.976
Group 4 [b]	-	-	-	-	-	-	-	-	-	-	-	-
t Statistics:												
Group 1	2.199**	2.624**	0.207	5.146**	1.442	0.980	1.036	0.510	1.748*	1.791*	4.285**	3.280**
Group 2	0.330	0.329	2.367**	4.719**	0.547	1.173	0.869	1.842*	0.725	0.870	-	
Group 3	2.225**	2.236**	0.293	2.267**	0.932	1.535	0.025	0.197	1.121	3.474**	4.285**	3.055*
Group 4	-	-	-	-	-	-	-	-	-	-	-	

Percent correctly predicted: 54.02
Likelihood ratio index: 0.2176
Likelihood ratio statistics: 300.5

Number of observations: Group 1 = 117
Group 2 = 102
Group 3 = 128
Group 4 = 151

Threshold for floor space = 200 pyeongs

Source: The Project Sample Establishment Survey.

[a] Definitions of variables are given in the Appendix.
[b] Group 4 is used as the base.
* Significant at the 5% level.
** Significant at the 2.5% level.

Table A3: ELASTICITIES OF PROBABILITY: LOGIT ESTIMATION OF LOCATION CHOICE, SEOUL AND GYEONGGI

(Threshold for floor space = 100 pyeongs)

Industry Groups by Floor Space	YRINOP	RESLOCMNG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT	Share
Group 1	3.733	-0.048	-0.721	0.323	0.573	-0.504	-0.052	-0.108	0.294	0.501	1.254	0.1627
Group 2		0.452	-0.786	-0.026	-0.172	0.176	0.425	-0.125	0.060	-	0.929	0.2771
Group 3	0.982	-0.051	-0.166	0.264	0.628	-0.106	0.058	0.183	0.087	0.715	0.802	0.1546
Group 4	-	-	-	-	—	-	-	-	-	-	-	0.4056

Source: The Project Sample Establishment Survey.

NOTES. For definitions of dependent and independent variables, see the Appendix.

The elasticity of probability is defined as $e_{ij} = (1-p_i)\, b_{ij}\, X_{ij}$, where P_i is the share of ith group, b_{ij} the jth logit coefficient of the ith group, and X_{ij} the sample mean of the jth independent variable for the ith group.

It should be noted that the logit coefficients estimated are the differences with respect to the coefficients of the base group. Therefore, the values of elasticities in this table are the results based on $(b_{ij} - b_j^*)$ instead of b_{ij}, where b_j^* in the coefficient of the base group.

Table A4: ELASTICITIES OF PROBABILITY: LOGIT ESTIMATION OF LOCATION CHOICE, SEOUL AND GYEONGGI

(Threshold for floor space = 200 pyeongs)

Industry Groups by Floor Space	YRINOP	RESLOCMNG	RESLOCWKR	PROSOLD	INPTBT	ELECINT	WATERINT	DISTCBD	POPDENS	RENTER	LOCQT	Share
Group 1	6.681	0.046	-0.948	0.234	0.208	-0.312	0.131	-0.383	0.607	0.392	1.155	0.2349
Group 2	0.670	0.559	-0.958	-0.054	-0.137	0.304	0.424	-0.204	0.173	-	1.030	0.2048
Group 3	4.502	-0.045	-0.512	0.138	0.248	0.007	-0.050	-0.277	0.878	0.434	0.751	0.2570
Group 4	-	-	-	-	-	—	-	-	-	-	-	0.3032

Source: The Project Sample Establishment Survey.

NOTES. For definitions of dependent and independent variables, see the Appendix.

The elasticity of probability is defined as $e_{ij} = (1-p_i)\, b_{ij}\, X_{ij}$, where P_i is the share of ith group, b_{ij} the jth logit coefficient of the ith group, and X_{ij} the sample mean of the jth independent variable for the ith group.

It should be noted that the logit coefficients estimated are the differences with respect to the coefficients of the base group. Therefore, the values of elasticities in this table are the results based on $(b_{ij} - b_j^*)$ instead of b_{ij}, where b_j^* in the coefficient of the base group.

References

Ellickson, B. (1981), "An Alternative Test of the Hedonic Theory of Housing Markets," Journal of Urban Economics.

Lee, K.S. (1981), "Intraurban Location of Manufacturing Employment in Colombia," Journal of Urban Economics.

Lee, K.S. (1982), "A Model of Intraurban Employment Location: An Application to Bogota, Colombia," Journal of Urban Economics.

Lee, K.S. (1985a), "Decentralization Trends of Employment Location and Spatial Policies in LDC Cities," Urban Studies.

Lee, K.S. (1985b), "An Evaluation of Decentralization Policies in Light of Changing Location Patterns of Employment in the Seoul Region," Urban Development Discussion Paper No. UDD-60, The World Bank.

Lee, K.S., Choe, S.C. and K.H. Pahk (1985), "Determinants of Locational Choice of Manufacturing Firms in the Seoul Region: An Analysis of Survey Results," Urban Development Discussion Paper No. UDD-85, The World Bank.

Mills, E.S. (1972), Urban Economics, Sott, Foreman, Glenview, Ill.

Murray, M.P. (1985), "Simulating the Efficiencies of Alternative Industry Location Subsidies in Korea," Urban Development Discussion Paper No. UDD-87, The World Bank.

Solow, R. (1972), "On Equilibrium Models of Urban Location," in Essays in Modern Economics (Parkin, Ed.), Longmans, Green, New York.

Annex: The Bogota Study

(Journal of Urban Economics, Vol. 12, pp. 263-279)

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A Model of Intraurban Employment Location: An Application to Bogota, Colombia[1]

KYU SIK LEE

Urban Development Department,
The World Bank, 1818 H Street NW,
Washington, D.C. 20433

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A micro model is formulated to study the location behavior of manufacturing firms in urban areas. A bid-rent function is derived from the profit function and captures the firms' locational equilibrium situations. The theoretical model is extended to a multinomial logit specification and estimated using establishment survey results for Bogota, Colombia. The survey included information on (1) attributes of the establishment such as plant space, and (2) attributes of the plant site such as access to markets. The estimated model is capable of predicting the location choices of different types of firms.

1. INTRODUCTION

The work reported here is part of a World Bank urban study project. In this paper a theoretical model of employment location is formulated and extended to an empirical specification in the multinomial logit framework.

In the descriptive phase of the study, the employment location patterns of Bogota, Colombia, and their changes were extensively analyzed using industrial directory data. The analysis, performed in terms of births, deaths, and relocation of firms, revealed a high degree of employment location dynamics: both the birth and relocation rates were high and evidence of spatial decentralization of manufacturing employment was strong (Lee [9]).

Although researchers have drawn attention to the need for modeling employment location behavior, the gap in this area remains unattended in the literature. The analytical work reported in the present paper is an

[1]Presented at the Econometric Society Annual Meetings, Denver, Colorado, September 5–7, 1980. Support for the work reported in this paper was provided by the City Study research project (RPO 671-47) funded by the World Bank. The views reported here are those of the author and should not be interpreted as reflecting the views of the World Bank or its affiliated organizations. The author thanks Maria Clara de Posada who conducted the survey of establishments and Jose Fernando Pineda who supervised it, M. Wilhelm Wagner and Leslie Kramer for research assistance, and members of the World Bank research staff for comments with particular appreciation for Gregory K. Ingram and Douglas H. Keare. Discussions with Professor Marc Nerlove and comments received from Professor Edwin Mills' seminar at Princeton University were helpful at the early stage of this work. Roger Schmenner provided valuable suggestions for designing the survey instrument.

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attempt to model the location behavior of the firm and to explain observed patterns of employment location. For this purpose, a survey of manufacturing establishments was conducted in Bogota, a rapidly growing city comparable to such United States cities as Phoenix and Houston. This paper presents estimation results based on the survey. The model is presented in the next section, the survey is then briefly described, and finally, the estimated results are reported.

2. A MODEL OF EMPLOYMENT LOCATION

Consider T types of manufacturing firms in an urban area. The firm maximizes profits as a price taker in both product and factor markets. The firm uses a set of variable and fixed inputs to produce an output. The problem is to determine the optimum combination of inputs, including the lot size and the plant location, to attain locational equilibrium profits in an urban area.

Consider a production function in the general form

$$Q = f(L, X; Z) \tag{1}$$

where Q is the output, L the lot size, X a vector of other inputs such as labor, and plant and equipment; Z a vector of site characteristics that are independent of lot size and can be considered as "local public goods"[2] such as the quality of public utility services, accessibility to markets, and amenities of the zone of plant location.

The profit of the firm is

$$\Pi = pf(L, X; Z) - RL - wX \tag{2}$$

where Π is the profit, p the output price, R land rent per unit, w other input prices, such as wage rate, and price of capital input.

From the first-order conditions for profit maximization, one obtains the following demand equations for variable inputs:

$$\frac{\partial f}{\partial L} = \frac{R}{p} \tag{3}$$

$$\frac{\partial f}{\partial X} = \frac{w}{p}. \tag{4}$$

Solving (3) and (4) for the optimal input quantities L^* and X^*, and substituting them into (2), the "profit function," based on the duality

[2] Burstein [1] included this variable in the household utility function of her housing demand study.

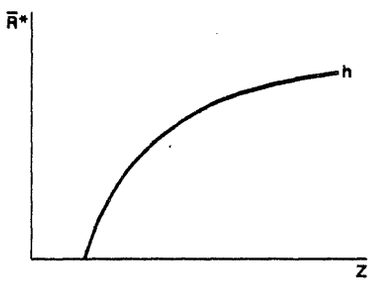

FIG. 1. The firm's bid-rent function.

theorem,[3] is obtained as

$$\begin{aligned}\Pi^* &= pf(L^*, X^*; Z) - RL^* - wX^* \\ &= \bar{\Pi}^*(p, R, w; Z).\end{aligned} \tag{5}$$

Let t be the unit transport cost for shipment of output; then $p - t$ is the factory price of output. Using p as the numeraire and introducing the location subscript (u), (5) becomes

$$\bar{\Pi}^*(u) = g[1 - \bar{t}(u), \bar{R}(u), \bar{w}(u); Z(u)] \tag{6}$$

where $\bar{\Pi}$, $\bar{t}$, $\bar{R}$, and $\bar{w}$ are values normalized by p; u refers to the distance to the product market.

In locational equilibrium, for a given u every firm should have the same profit, and there is no incentive for any firm to relocate. An equilibrium rent profile must satisfy

$$\bar{\Pi}^*(u) = g[1 - \bar{t}(u), \bar{R}(u), \bar{w}(u); Z(u)] = \text{const.}^4 \tag{7}$$

As with residential location, a useful interpretation of this formulation of firm location choice is in terms of the bid-rent function of the firm, giving the price for site with characteristics Z that yields profit $\bar{\Pi}^*$. Let $\bar{R}^*(u)$ denote the bid rent, then (as in Fig. 1)

$$\bar{R}^*(u) = h[1 - \bar{t}(u), \bar{w}(u); Z(u); \bar{\Pi}^*(u)]. \tag{8}$$

For convenience, suppose the unit transport cost is site invariant within an urban area and include it as an element in the constant term. Also

[3]For the duality relations between the production function and the profit function, see Diewert [2] and Lau and Yotopoulos [6].

[4]Solow [12] shows an equilibrium rent profile of households in an urban area.

suppress $\overline{\Pi}^*(u)$ which is constant. Hence (8) can be written

$$\bar{R}^*(u) = h[\bar{w}(u); Z(u)] \tag{9}$$

where

$$\frac{\partial \bar{R}^*}{\partial \bar{w}} < 0; \qquad \frac{\partial \bar{R}^*}{\partial Z} > 0. \tag{10}$$

For illustration, consider the case of labor input. As the labor–land ratio increases the marginal product of land increases relative to that of labor, and the relative price of land with respect to labor also rises. This argument supports the empirically observed rent gradient in an urban area in the sense that as the distance to the CBD becomes shorter, the intensity of a variable input such as labor increases and the land rent rises.[5] In other words, producers respond to input price differentials over space to obtain optimal input combinations including lot size. Also the value of land increases as desirable site characteristics, such as public service provision and accessibility, are improved.

Since $\bar{w}$ is the input price vector normalized by output price, (4) can be rewritten as

$$\frac{\partial f}{\partial X}(u) = \bar{w}(u). \tag{11}$$

Substituting (11) into (9), we have the bid-rent function expressed in terms of firm characteristics $\partial f/\partial X$ and site characteristics Z.

For expository reasons, rewrite (9) as

$$\bar{R}^*(u) = h[x(u), Z(u)], \tag{12}$$

where $x(u)[= (\partial f/\partial X)(u)]$ now represents a vector of firm characteristics, namely input combinations, which in turn depend on technology characterized, for example, by type of production process and building structure. As mentioned earlier $Z(u)$ is a vector of site characteristics.

Now suppose that there are T types of firms defined by x and S types of sites defined by Z. Let N_t be the number of type t firms in the market.

Then using (12), the bid rent for a site with characteristics Z by the nth firm of type t is given by

$$\bar{R}^*_{tn} = h_{tn}(Z_n), \qquad n \in N_t. \tag{13}$$

[5]A measure of the land price gradient using the survey data used in this study resulted in the following: $\ln$ land price $= 8.029 - \underset{(3.17)}{0.1126}$ distance, $R^2 = 0.1093$, which can be written as land price $= 3069e - 0.1126$ distance.

Note that we have now suppressed the vector $x(u)$ that is used to define the firm type t. For example, all firms of type t are similar in terms of output, input combination and technology, that is, they have an identical production function.

Following Ellickson's [3, 4] work on residential location, we can interpret this model in terms of predicting the probability of a certain type of firm t to locate at a site with a specified set of characteristics Z.

The stochastic version of (13) is

$$\bar{R}^{*}_{tn} = h_{tn}(Z_n) + e_{tn}, \qquad n \in N_t. \tag{14}$$

where e_{tn} is a random disturbance term reflecting unaccounted variations of firm characteristics of type t.

Since a given site is occupied by the firm with the highest bid, the relevant variable for determining the probability that a given site is occupied by a firm type t is the maximum bid given by firms of type t.

$$\bar{R}^{\max}_{t} = \max_{n}\left(\bar{R}_{tn}\right) = h_t(Z) + e_t, \qquad t \in T \tag{15}$$

where

$$e_t = \max_{n}\left(e_{tn}\right), \qquad n \in N_t.$$

If the e_t are identically and independently distributed Weibull,[6] the specification of a logit model follows, namely, the probability that a firm of type t occupies a site with characteristics Z takes the logit specification[7]

$$p(t \mid Z) = \frac{\exp\left[h_t(Z)\right]}{\sum_{t' \in T} \exp\left[h_{t'}(Z)\right]}. \tag{16}$$

The above discussion shows that the basic theoretical approach used in the study of residential location can provide a useful analytical framework for the study of employment location.[8] The optimizing behavior of the firm is postulated as location specific, that is, the choice by the firm of a specific site is part of the production decision; furthermore, the location specific

[6]For example, the maximum value of an identically and independently distributed normal variate has the Weibull distribution.

[7]Ellickson [3, 4] derived this variation of the logit model in his residential location study.

[8]Theoretical and empirical work is rare in this area; Mills [10] and Solow [12] offer basic micro foundations; the work by Hoover and Vernon [5], Struyk and James [13], and Schmenner [11], although descriptive, serves as the empirical bases in the field.

equilibrium position of individual firms is extended to the "locational equilibrium" situation of all firms in an urban area. The theoretical model is easily extended to the stochastic specification of the model in an estimable form.

3. THE DATA

The sample of 126 establishments was drawn for the survey from DANE's 2629 distinct firm records in the industrial directory files covering 1970–1975,[9] stratified by the following four categories: (1) location history, that is, stationary firms, movers, and births[10]; (2) the zone system defined by 38 *comunas*; (3) the type of industry defined by 3-digit SIC codes; and (4) firm size by employment.

To minimize the sampling cost while having sufficient observations for econometric estimation, we chose the textile industry and the fabricated-metal industry as the two main industries to be studied. Both industries had a large share of manufacturing establishments in Bogota. The homogeneity of firms in each industry group makes it possible to test behavioral hypotheses with sufficient degrees of freedom. We added as a third group, however, the "other industries" category with which to do mainly descriptive studies about establishments in various other types of industries.

The second consideration given in the sampling process was to oversample large firms so that the number of jobs included in the sample could be maximized. Finally, an attempt was made to cover a wide geographic area in such a way that spatial analyses could be possible, including the estimation of the rent and wage gradients. Our target sample size was 120 with about equal shares of establishments among the three types of location history.

The realized sample of 126 establishments consists of 58 stationary firms, 50 movers (including two firms that moved to Bogota from outside) and 18 births (see Table 1). The newly established firms were mostly small (Table 3). The sample coverage across zones was satisfactory; with 27 *comunas* covered, the spread was fairly even over the 3 Rings that have high manufacturing employment densities (see Table 1 and Fig. 2). On the other hand, only a small number of establishments was selected from Ring 1 (CBD) and Ring 6 (3 residential *comunas* in the north).

[9]The original DANE (National Statistics Department) files had 3388 records for the 6-year period. To maintain consistency in coverage over the period, however, firms with less than 10 employees or those that appeared in the directory for only one year were not included in our master file. The basic structure of the industrial directory data was documented in Lee [7].

[10]Stationary firms are defined as those that appeared in all six annual directories with the same address; births are those that appeared for the first time in any year during 1971–1975; movers are those that relocated within Bogota during 1971–1975. An analysis of the employment location patterns by this classification of establishments was done in Lee [9].

TABLE 1
Sample Composition: Zone by Firm Type

Zone	Stationary	Birth	Mover within Bogota	Mover from outside	Total
Ring 1	0	2	2	0	4
	0.00	50.00	50.00	0.00	100.00
	0.00	11.11	4.17	0.00	3.17
Ring 2	7	3	5	0	15
	46.67	20.00	33.33	0.00	100.00
	12.07	16.67	10.42	0.00	11.90
Ring 3	17	6	13	1	37
	45.95	16.22	35.14	2.70	100.00
	29.31	33.33	27.08	50.00	29.37
Ring 4	16	3	13	1	33
	48.48	9.09	39.39	3.03	100.00
	27.59	16.67	27.08	50.00	26.19
Ring 5	16	4	12	0	32
	50.00	12.50	37.50	0.00	100.00
	27.59	22.22	25.00	0.00	25.40
Ring 6	2	0	3	0	5
	40.00	0.00	60.00	0.00	100.00
	3.45	0.00	6.25	0.00	3.97
Total	58	18	48	2	126
	46.03	14.29	38.10	1.59	100.00
	100.00	100.00	100.00	100.00	100.00

Source. The City Study Establishment Survey.

In some cases the 4-way stratification severely limited the possibility of drawing sample establishments from a specific population category. For example, not enough textile firms were located in certain *comunas*. Therefore, sample establishments were also selected from two other industry categories that are closely related to the two main industries; namely, the textile industry was supplemented by the apparel industry, and the fabricated-metal industry by the nonelectric machinery industry. As shown in Table 2, the final sample has fairly even shares among the three industry groups: about 35% each for the two main industry groups and 30% for the "other" category.

In Table 3, we see that the average size of stationary firms in the sample is almost five times larger than the average size of births, and more than

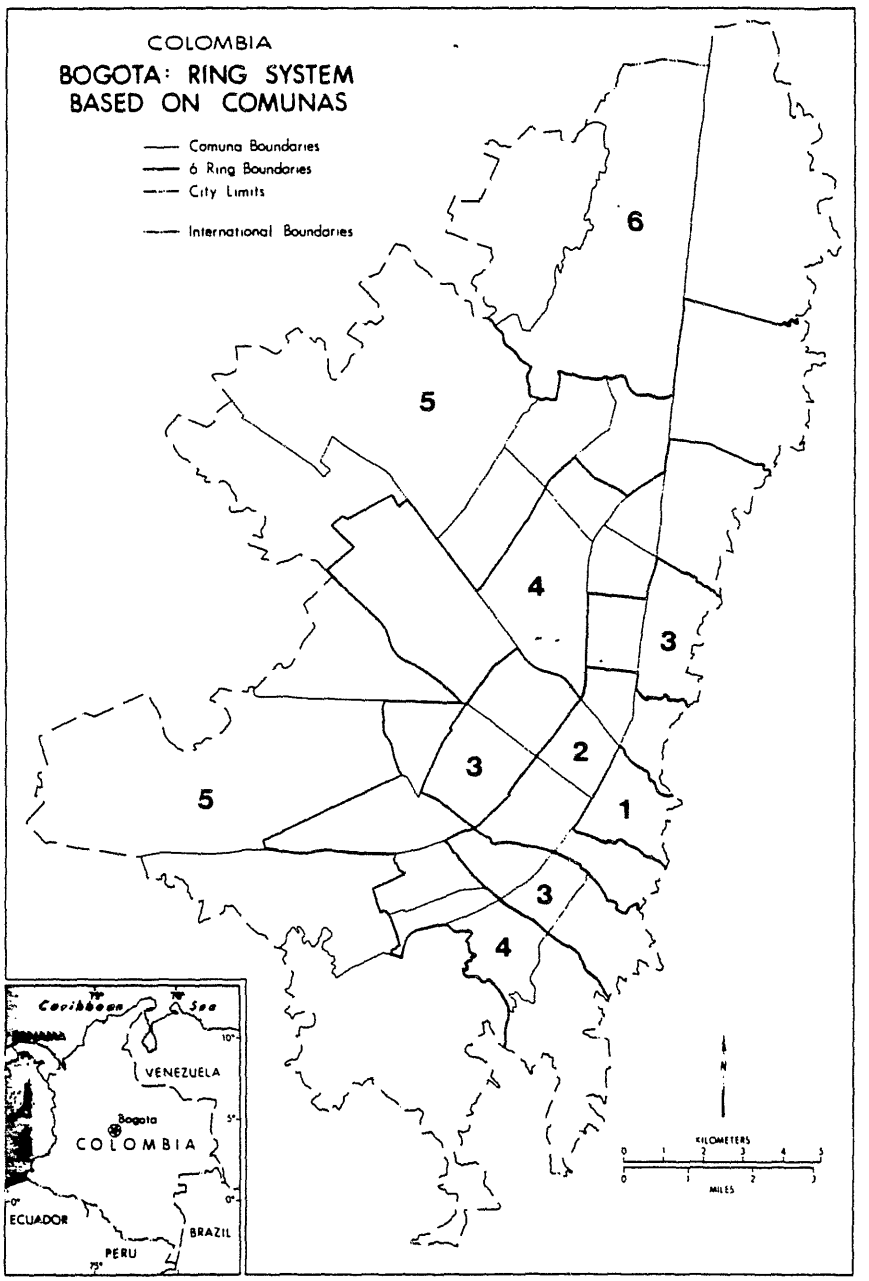
COLOMBIA
BOGOTA: RING SYSTEM
BASED ON COMUNAS
Comuna Boundaries
6 Ring Boundaries
City Limits
International Boundaries
6
5
4
3
2
1
3
5
3
4
Caribbean Sea
VENEZUELA
Bogota
COLOMBIA
ECUADOR
BRAZIL
PERU
N
KILOMETERS
MILES

FIGURE 2

TABLE 2
Sample Composition: Zone by Industry

Zone	Textiles	Apparel	Fabricated metal	Nonelectric machinery	Other	Total
Ring 1	1	1	1	0	1	4
	25.00	25.00	25.00	0.00	25.00	100.00
	3.03	10.00	2.86	0.00	2.56	3.17
Ring 2	3	1	4	1	6	15
	20.00	6.67	26.67	6.67	40.00	100.00
	9.09	10.00	11.43	11.11	15.38	11.90
Ring 3	6	6	13	4	8	37
	16.22	16.22	35.14	10.81	21.62	100.00
	18.18	60.00	37.14	44.44	20.51	29.37
Ring 4	12	1	9	2	9	33
	36.36	3.03	27.27	6.06	27.27	100.00
	36.36	10.00	25.71	22.22	23.08	26.19
Ring 5	10	1	6	2	13	32
	31.25	3.13	18.75	6.25	40.63	100.00
	30.30	10.00	17.14	22.22	33.33	25.40
Ring 6	1	0	2	0	2	5
	20.00	0.00	40.00	0.00	40.00	100.00
	3.03	0.00	5.71	0.00	5.13	3.97
Total	33	10	35	9	39	126
	26.19	7.94	27.78	7.14	30.95	100.00
	100.00	100.00	100.00	100.00	100.00	100.00

Source. The City Study Establishment Survey.

twice that of movers. This resulted from the oversampling of large firms; the sample average firm size of 135 persons is about twice as large as the average firm size of the establishments in the population.[11]

4. SELECTED ESTIMATION RESULTS

We now turn to the estimation of the multinomial logit model (16). Estimation is based on the Bogota establishment survey results and other secondary data sources. Although the survey questionnaire was designed to take no more than 1 hour to complete, it was comprehensive in coverage to include plant characteristics, employment composition, transport access, proximity to markets, local public services, and the respondent's evaluation

[11]According to the industrial directory file of 1975, the average firm size of 1829 establishments with 10 or more employees was 65 persons.

TABLE 3
Sample Composition: Firm Type by Size

Firm type	Employment size[a]						
	(1, 4)	(5, 9)	(10, 19)	(20, 49)	(50, 99)	(100 or more)	Total
Stationary	0	1	8	13	4	32	58
	0.00	1.72	13.79	22.41	6.90	55.17	100.00
	0.00	25.00	38.10	34.21	23.53	72.73	46.03
	—	6.00	16.25	33.54	81.75	324.72	194.66
Birth	1	2	3	9	1	2	18
	5.56	11.11	16.67	50.00	5.56	11.11	100.00
	50.00	50.00	14.29	23.68	5.88	4.55	14.29
	3.00	6.00	13.00	26.56	63.00	174.00	39.11
Mover	1	1	10	16	12	10	50
	2.00	2.00	20.00	32.00	24.00	20.00	100.00
	50.00	25.00	47.52	42.11	70.59	22.73	39.68
	3.00	7.00	13.50	31.94	78.75	335.60	99.14
Total	2	4	21	38	17	44	126
	1.59	3.17	16.67	30.16	13.49	34.92	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	3.00	6.25	14.48	31.21	78.53	320.34	134.53

Source. The City Study Establishment Survey.
[a]The bottom number in each group is the mean employment size of firms in that group.

of the plant location. Particular attention was given to the characteristics of movers[12] and the factors that influence location decisions.

In (16) specification of the dependent variable requires a stratification of firms by type according to the vector of firm characteristics x; the independent variables are the site characteristics Z. The survey instrument contains a number of candidate variables for the stratification of firms to define the dependent variable: variables related to output such as product type and annual sales; variables related to technology such as type of production process and building structure; and variables associated with inputs, for instance, plant space, lot size, and the number of production workers. The site characteristics to be used as independent variables include those associated with accessibility to various types of markets (product, material inputs, and labor), and those related with the quality of local public services.

Of the 126 firms in the sample, 87 are in the textile and the fabricated metal industries, the two major industries included in the study. We report here estimated results obtained with the specifications shown in Table 4.

[12]Detailed analysis of movers appears in Lee [8].

TABLE 4
Stratification of Dependent Variable

Group	Industry	Floor space	Number of Observations
1	SIC 321 and 322	Less than 1000 m^2	17
2	SIC 321 and 322	1000 m^2 or more	26
3	SIC 381 and 382	Less than 1000 m^2	27
4	SIC 381 and 382	1000 m^2 or more	17
Total			87

Note: SIC 321, textile; SIC 322, apparel; SIC 381, fabricated metal; and SIC 382, nonelectric machinery.

For the dependent variable, the 87 firms in the two major industries are grouped into two plant sizes according to floor space. The independent variables are in the following categories: access to the local markets for output and material inputs measured by the proportion of output sold and inputs bought in Bogota, proximity to residential areas of production and administrative workers, an index of the quality of local public services measured by the frequency of electricity interruption, the extent of agglomeration economies measured by the employment-location quotient of individual industries in the zone of location, and the intensity of economic activities and the degree of congestions measured by the population density in the zone of location. The distance to the CBD is included as a measure of accessibility to the city center.

Ideally, stratification for the dependent variable should be achieved by more than the 2-way (and 4-cell) classification used here. The small sample size, however, limits such possibilities. Therefore, we include two firm type stratification variables on the right-hand side of the equation, specifically, the year of initial operation at the present location that discriminates old mature establishments against new ones and recent movers, and the ownership dummy variable to distinguish renters from owners.

All independent variables entered the model as "group-specific"[13] except for the location-quotient variable and the ownership dummy variable; the former being specified as "generic" within the same industry group, and the latter within the same size group. In the estimation of this multinomial logit formulation, Group 4 was used as the reference group. Therefore, the estimated logit coefficients of group-specific variables should be interpreted as relative differences with respect to the reference group. Hence, the signs of the coefficients do not necessarily mean the direction of causation; they

[13]This expression is equivalent to "alternative-specific" in the multinomial-logit literature.

only reflect the relative orders of magnitudes of individual coefficients with respect to the reference group for a given independent variable.

Table 5 reports the estimated logit coefficients and t statistics that are the test of difference between the coefficients of a particular group with respect to those of the reference group. In Table 5, Group 4 (large metal-fabricating firms) was set as the reference group. The t tests indicate that the differences of coefficients are significant between two size groups (large as against small), and are more robust within the same industry (Group 4 vs Group 3). None of the coefficients of Group 2 (large textile firms) was statistically significant. The likelihood ratio index of 0.29 indicates that the overall goodness of fit is good. These patterns held true in the estimation of alternative model specifications with lot size and employment variables in place of the floor space variable.

To interpret the estimated logit coefficients the elasticities of probabilities are calculated at sample means and reported in Table 6. This parameter measures the percentage change in the probability of being in the ith group with respect to 1% change in a given independent variable for that group. In Table 6 we first observe that Group 3 (small metal-fabricating firms) has the highest elasticity values for most of the variables; compared with the other two, however, this group is least sensitive to the electricity interruption rate ELECINT and the location quotient LOCQT. The most important variable that influences the probability of being in Group 3 is the measure of access to the local input markets INPUTBT, followed by the measure of access to the local product markets PRODSOLD. Local market orientation is very important for this group.

For Group 1 (small textile firms), the measure of access to the local input markets is also the most important variable, followed by proximity to production workers' residential areas WKSOUTH. The weakest variable in this case is distance from the CBD, which implies that small textile firms tend to locate near the CBD compared with the other 2 groups. As distance from the CBD increases, the probability of being in Group 2 is three times higher than that of being in Group 1. However, small metal-fabricating firms tend to locate farther from the CBD than do textile firms of both size groups.

In the case of large textile establishments (Group 2), it is interesting to find that the most important variable is the location quotient LOCQT, followed by the electricity interruption rate ELECINT, and the proximity to the residential areas of administrative workers ADMNORTH. For this group of large firms, the measure of access to local markets and the proximity to production workers' residential areas are rather unimportant. Large textile firms tend to be more export-oriented and use capital-intensive production facilities. Also, the fact that large firms have less likelihood of locating in a densely populated area POPDENS is consistent with the finding that they tend to locate farther from the CBD.

TABLE 5

Logit Estimation of Firm Location Choice: Dependent Variable, Industry and Floor Space[a]

	CONSTANT[a]	PRODSOLD	INPUTBT	DISTCBD	WKSOUTH	ADMNORTH	ELECINT	POPDENS	LOCQT	YRINOP	RENTER
Coefficients											
Group 1	−15.680	0.011	0.019	0.012	0.014	−0.010	0.501	0.008	0.749	0.159	2.069
Group 2	−2.128	0.008	−0.010	0.032	0.003	−0.016	0.448	0.002		0.033	—
Group 3	−12.880	0.028	0.027	0.151	0.022	−0.020	0.115	0.012	0.738	0.095	2.069
Group 4[b]	—	—	—	—	—	—	—	—	—	—	—
t Statistics											
Group 1	2.09**	0.74	1.39	0.07	0.80	0.64	1.05	1.11	1.69*	1.63*	2.67**
Group 2	0.57	0.60	0.89	0.21	0.20	1.12	1.11	0.35		0.60	—
Group 3	2.07**	1.83*	2.05**	0.92	1.33	1.40	0.24	1.89*	1.71*	1.20	2.67**
Group 4	—	—	—	—	—	—	—	—		—	—

Percent correctly predicted:	54.02	Number of observations:	Group 1 = 17
Likelihood ratio index:	0.2903		Group 2 = 26
Likelihood ratio statistic:	70.02		Group 3 = 27
			Group 4 = 17

Source. The City Study Establishment Survey.

[a]Definitions of variables are given in the Appendix.

[b]Group 4 is used as the base.

*Significant at the 5% level.

**Significant at the 2.5% level.

TABLE 6

Elasticities of Probability: Logit Estimation of Location Choice

Industry groups by floor space	PRODSOLD	INPUTBT	DISTCBD	WKSOUTH	ADMNORTH	ELECINT	POPDENS	LOCQT	YRINOP	RENTER	Share
Group 1	0.515	1.182	0.052	0.808	−0.496	0.711	0.794	0.544	9.264	1.665	0.1954
Group 2	0.272	−0.293	0.155	0.128	−0.538	0.556	0.124	0.722	1.585	—	0.2989
Group 3	1.367	1.455	0.584	1.120	−0.689	0.123	1.233	0.468	4.630	1.467	0.3103
Group 4	—	—	—	—	—	—	—	—	—	—	0.1954

Source. The City Study Establishment Survey.

Notes. For definitions of dependent and independent variables, see the Appendix.

The elasticity of probability is defined as $e_{ij} = (1 - p_i)b_{ij}\bar{X}_{ij}$, where p_i is the share of ith group, b_{ij} the jth logit coefficient of the ith group, and $\bar{X}_{ij}$ the sample mean of the jth independent variable for the ith group.

It should be noted that the logit coefficients reported in Table 5 are the differences with respect to the coefficients of the base group. Therefore, the values of elasticities in this table are the results based on $(b_{ij} - b_j^*)$ instead of b_{ij}, where b_j^* is the coefficient of the base group.

With such a small sample and a large number of independent variables, the above results look promising. When the model was specified with lot size and employment size as the stratifying variable (in place of the floor space), the estimation results were quite similar to those reported here.

5. CONCLUDING REMARKS

This paper presents an abstract but empirically tractable model of employment location; it shows that the basic theoretical approach used in the housing literature can provide a useful analytical framework for the study of employment location. The results of the establishment survey conducted in Bogota are used to test a multinomial logit specification of bid-rent function following the approach used by Ellickson [4] in his housing study.

The estimation of the model was performed with a 2-way stratification of dependent variable by the use of industry type and floor space, each having two categories. Independent variables included were measures of access to the output and input markets, indexes of concentration of economic activities, and a quality index of public utility services. Even though the sample size was not large, the goodness of fit was satisfactory, and the estimated model was capable of predicting, in probability terms, which types of firms are likely to occupy a site with those characteristics specified by the explanatory variables.

The predicted location patterns resulting from the model are consistent with those expected *a priori*. For small firms the accessibilities to the local input and output markets are most important; the benefits of accessibility to the central area tend to compensate for the high land rent and congestion costs in the high density area. On the other hand, large establishments, which are more export-oriented and require more plant space with modern production technology, tend to locate in outer areas where more space is available at lower cost. The estimated results also show that for large firms, the quality of public utility services is very important, and that the proximity to the residential areas is more important to administrative workers than to production workers.

Separate regression results[14] (using the same data set) indicate a strong relationship between the intensity of input (labor and capital) use and land price; given a well shaped (monocentric) rent gradient in Bogota,[15] these results support the hypothesis that the firms respond to the substitutability of land with respect to other inputs over space, and this evidence is consistent with the predictions obtained from the logit specification in this paper. The patterns of employment location in Bogota are by no means

[14]Reported in the earlier version of this paper presented at the Denver meetings of the Econometric Society.

[15]See footnote 5, and also Villamizar [14].

random; they are quite similar to those observed for large cities in the United States.

APPENDIX: DEFINITIONS OF VARIABLES IN TABLE 5

Dependent Variable

See Table 4

Independent Variables

CONSTANT Group specific constants

PRODSOLD Percent of products sold in Bogota

INPUTBT Percent of inputs bought in Bogota

DISTCBD Airline distance (km) from the CBD (the center of *comuna* 31) to the establishment location (the center of the *comuna* where the establishment is located)

WKSOUTH Percent of production workers living in the south

ADMNORTH Percent of administrative workers living in the north

ELECINT Frequency of electricity interruption; (1, never; 2, once a week; 3, twice a week; 4, more than twice a week)

POPDENS Population per hectare of the *comuna* where the establishment is located

LOCQT Location quotient defined as *comuna j*'s share of industry *i* relative to its share of total manufacturing employment (Separate values are used for the two industry groups.)

YRINOP Year of initial operation at the present location

RENTER Ownership dummy: 1 if renter, 0 if owner. (Assigned to establishments with floor space of less than 1000 m^2 in both industry groups.)

REFERENCES

1. N. R. Burstein, Voluntary income clustering and the demand for housing and local public goods, *J. Urban Econ.* (1980).
2. W. E. Diewert, Applications of duality theory, *in* "Frontiers of Quantitative Economics" (M. D. Intriligator and D. A. Kendrick, Eds.), Vol. 2, North-Holland, Amsterdam (1974).
3. B. Ellickson, "Economic Analysis of Urban Housing Markets: A New Approach," The Rand Corp., R-2024-NSF (1977).
4. B. Ellickson, An alternative test of the hedonic theory of housing markets, *J. Urban Econ.*, **9**, 56–79 (1981).
5. E. M. Hoover and R. Vernon "Anatomy of a Metropolis" Harvard Univ. Press, Cambridge, Mass. (1959).
6. L. J. Lau and P. A. Yotopoulos, A test for relative efficiency and application to Indian agriculture, *Amer. Econ. Rev.* (March 1971).
7. K. S. Lee, "Distribution of Manufacturing Establishments and Employment in Bogota and Cali," City Study Workshop paper (January 16), The World Bank, Washington, D.C. (1978).
8. K. S. Lee, "Determinants of Intra-urban Location of Manufacturing Employment: An Analysis of Survey Results for Bogota, Colombia," Urban and Regional Rep. No. 81-3. The World Bank, Washington, D.C. (1981).
9. K. S. Lee, Intra-urban location of manufacturing employment in Colombia, *J. Urban Econ.*, **9**, 222–241 (1981).

10. E. S. Mills, "Urban Economics," Scott, Foreman, Glenview, Ill. (1972).
11. R. Schmenner, "Making Business Location Decisions," Prentice–Hall, Englewood Cliffs, N.J. (1982).
12. R. Solow, On equilibrium models of urban location, *in* "Essays in Modern Economics" (Parkin, Ed.), Longmans, Green, New York (1972).
13. R. Struyk and F. James "Intrametropolitan Industrial Location," Lexington Books, Lexington, Mass. (1975).
14. R. Villamizar, "Land Prices in Bogota between 1955 and 1978: A Descriptive Analysis," Urban and Regional Rep. No. 80-2. The World Bank, Washington, D.C. (1980).