EMPIRICAL MODEL OF FIRM LOCATION FOR CLUSTERED CITIES: 
THE CASE OF ISTANBUL

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ABSTRACT
Multi-centric urban structure is more complicated than mono-centric, making modeling of change and policy-making issues more complex and challenging. Theoretical and empirical location models are reviewed to explore forces for formation of job agglomerations outside of CBD: localization benefits; labor-force accessibility; lack of cheap and available land. We present an intra-urban firm location model over discrete space appropriate to explain clustered growth of firm locations and to test significance of given explanatory variables in the case city. We also contribute to literature for understanding of sub-center employment in rapidly growing cities by analyzing Istanbul which has not been examined before.

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1. Introduction

Multi-centric employment is defined as the decentralized, but clustered, formation of work agglomerations in sub-centers in contrast to employment concentrating predominantly into one central business district (CBD) or being dispersed throughout the metropolitan region. In many cities, centralized employment has given way to a substantial amount of job growth and/or relocation in employment centers other than the CBD.

Early location theorists considered the properties of the mono-centric city (Alonso, 1964) but this was replaced with the observation of a new form of metropolitan structure where the firms tend to cluster into sub-centers (Wheaton, 1979; Gordon et al., 1986). Theoretical urban location and empirical models (mainly in large US cities) were proposed to explain employment distribution, sub-center formation, and land rent gradients as driving forces of poly-centrism. Most of these have employed equilibrium models defining the firms’ profit function as Cobb-Douglas type production function and household utility function characterized by land rent profile, wage profile, commuting, and agglomeration economies (Fujita and Ogawa, 1982; Helsley and Sullivan, 1991; Fujita and Krugman, 1995).

Anas et al., (1998) and White, (1999) suggest that empirical findings from different cities with specific characteristics are required to better explain the decentralized urban dynamics. With this challenge as a background, the metropolitan area of Istanbul is taken as a case city of a rapidly growing city in a dynamic economy. The case study provides a good example since it is the biggest settlement of Turkey, with more than 10 million population and the economic center. It has taken on a multi-centric form, especially since 1973, with the construction of the first Bosporus highway bridge connecting the continents of Asia and Europe. Also, restrictive policies for large-scale, new developments in the old city center to preserve the historical identity of the core have been another driving force for the outer city agglomeration formation.

This paper presents a model of intra-urban firm location decisions as a discrete choice problem over discrete space appropriate to explain the clustered growth of firm locations. The empirical intra-urban firm location model for Istanbul explores the job stock increase in the clusters outside the old CBD between 1985 and 1997, when data from two metropolitan transportation studies were available to the researchers. The question as to “how does the accessibility and land availability/unavailability shape the urban configuration?” is explored to interpret the validity of underlying reasons of multi-centric structure, well referred in...
literature, for the decentralized job agglomerations pattern observed in Istanbul. Section 2 reviews briefly previous research on non mono-centric employment distribution. Section 3 proposes an empirical model for Istanbul and defines the variables of the model with sources of data. Section 4 tests the model and alternative model specifications with data collected for Istanbul in 1985 and in 1997. Further research that is needed is identified in section 5.

2. Previous Work on Non Mono-centric Employment Distribution

There is ample evidence, not reviewed here, that, in the last four decades, significant outward movement of jobs from the old downtown has been occurring in large American cities. For example, Gary (1990) explored six metropolitan areas; Los Angeles, San Francisco, Seattle, Houston, Denver, and Toronto between 1960 and 1988. For all, there was an important decrease in CBD share of the total office stock. He found the three cities of Los Angeles, Houston, San Francisco approximately 90% of the job agglomerations were clustered, and the number of non-CBD clusters that increased was substantial. Clusters near a transit station in metropolitan Toronto were nearly eight times as large and twice as intense as other clusters, and contained 25% of the non-CBD office stock. Clusters near a transit station in San Francisco Bay Area were 1.4 times as large and equally intense and contained 10% of the non-CBD stock.

2.1 Empirical Models

In the last two decades, an increasing number of descriptive models for empirical analysis of firm location choices in poly-centric cities have appeared – again, mostly for USA metropolises (McDonald and Prather, 1994; Giuliano and Small, 1999; Hansen, 1987; McMillen, 2001; Lee, 1982; Shukla and Waddell, 1991). For example, applying multivariate regression analysis, McMillen and McDonald (1998) analyzed the Chicago Metropolitan Area to test how statistically significant a number of likely factors were in explaining employment density gradients from the city center. The most significant variables were the distance to sub-center and distance to the airport, having an effect within a given distance from the airport. Distances to highway interchanges and train stations were also found to be significant.

Discrete programming models have also been applied to the firm location preferences in a non mono-centric urban form (Carlton, 1983; McMillen, 1989; Shukla and Waddell 1991; Hansen 1987; and Lee, 1982). Despite the errors of zonal aggregation in such type of models,
they are practical, and give a sound representation of firms’ location preferences by involving spatial variables that are highly influential in the choice process (Anas, 1982; Richardson, 1988).

Applying a multi-nomial logit model, Shukla and Waddell (1991) explored the firm location choices over 141 traffic analysis zones in Dallas-Fort Worth for a number of variables (distance to CBD, distance to airport, distance to major highway intersections, percentage of developed area, total population within a decay radius of 1 zone, median household income, and finally four different sectors of employment stock). All the distance variables explained less than one third of the variations for manufacturing employment. Freeway and airport access and scale economies variables were all valued in importance by almost all the firm types.

3. Empirical Model for Firm Location in Istanbul

Accessibility has a long history in urban transport studies (Hansen, 1959). Thus, the empirical intra-urban firm location model for Istanbul (Figure 1) explores the job stock increase in the clusters outside the old CBD between 1985 and 1997 considering three main job location-based accessibility measures. Between these years, the city has shown a considerable population and employment growth increasing from 5,379,026 to 9,060,005 and from 1,885,646 to 2,794,224, respectively.

Figure 1: The Greater Metropolitan Area of Istanbul and Highway Network

3.1 Firm’s Utility Function

Firms are grouped into three industry types: commercial and services; light industry; and heavy industry. Separate utility functions were estimated for each type. Almost one third of the total employment is in the commercial and service sector, so only the results for this type will be presented in this paper. The model estimates the increase in firm stock between 1985 and 1997 over five spatial alternatives that were specified as five sub-groups of 209 traffic analysis zones for metropolitan Istanbul. The five clusters were determined by the rank size distribution of logarithmic employment density of employment distribution in 1985 (Figure 2).

Figure 2: Spatial Alternatives of Clusters by Rank Size Distribution (1985)
The cut-offs were chosen based on the values on y-axis (logarithmic employment density) as 5, 4, 3, 2, and 1. The plausibility of five clusters was explored by separate model tests for three, four and five clusters grouping zones as three, four and five spatial alternatives. The statistical significance was found to be the highest for a configuration with five clusters. (The zones either with zero employment or a logarithmic employment density less than one are excluded from the analysis). Table 1 gives the increase in the number of workers in each five clusters. There was almost no increase between 1985 and 1997 in cluster zones that are in the old CBD zones of the historical peninsula of Istanbul (Constantinople).

Table 1: Distribution of Employment Increase among Five Clusters, Istanbul

The model considers the initial location preferences of newly established firms presuming no location changes of already existing firms. Scale economies are only incorporated in terms of external scale economies. Internal scale economies (benefits that are attained due to the growth of production scale within a firm) are not considered. Finally, the transport cost of input and output goods and labor force attributes are considered to be spatially invariant.

The indirect utility function $\prod_{q_y,i}$ for $q_y$ industry sector locating in a zone of cluster $m$ type is given by below equation 1. The vector of the utility coefficients is estimated by the Gumbel derived logit model ($k = k_j$).

$$\prod_{q_y,m} = k_1A_i^L + k_2P_i + k_3A_G^{q_y,i} + k_4C_i + k_5Z_i + \varepsilon_{q_y,m}$$

(1)

All variables are defined in section 3.2.

3.2 Explanatory Variables

♦ Labor force accessibility and public transport service level “A$^L$ and P”

For the labor force highway accessibility by automobile, $A_i^L$ of zone i in question, the Hansen gravity-type accessibility given by equation 2 is appropriate to compute the accessibility, where $L_j$ is the labor force (that is the working population in zone j); and $t_{ij}$ is the peak hour trip time in minutes between zones i and j.

$$A_i^L = \sum_j L_j e^{-\beta_{ij}}$$

(2)
For public transportation, one suitable way of calculating the potential accessibility is to use the accessibility indices pioneered by the London Borough of Hammersmith and Fulham (1995). The model provides the basis for calculations of public transportation frequencies and the level of public transportation provision across any specified study area given by equations 3 and 4.

\[
X = \text{walking time} + \frac{60K}{2S}
\]  

(3)

\[
M_j = \frac{30}{X_1} + \frac{15}{X_2} + \ldots + \frac{15}{X_m} + \frac{30}{Y_1} + \frac{15}{Y_2} + \ldots + \frac{15}{Y_n}
\]  

(4)

\(X\) is the access time that is from the doorstep to public transportation; \(X_1\) and \(Y_1\) are access time to the most accessible bus route and rail station; \(m\) and \(n\) are the number of accessible bus routes and train stations; \(S\) is the number of scheduled services per hour; and \(K\) is the reliability factor (peak travel times in inner London \(K\) was taken as 1 for rail and 2 for bus).

The \(M_i\) accessibility index, in its original form, is a measure of frequency, involving the reliability and availability of the services. However, the peak-hour, in-vehicle time is not embodied in this index. In order to incorporate the congestion effects it is possible to calculate different means of accessibility by adding the peak-hour trip time to the access time in equation 3 and calculating a gravity type accessibility index as given by equation 5. Then, the trip time between each pair of zones becomes the sum of the \(t_{ij}\) - in-vehicle trip time; and \(X_{ij}\) - access time to the public transportation network for the trips starting at zone \(i\) and ending at zone \(j\).

\[
A'^L_i = \sum_j L_{ij} e^{-\beta t_0 + X_{ij}}
\]  

(5)

Both the original frequency indices or the gravity type accessibility computed for public transportation are applicable to the case city since the whole metropolitan area of Istanbul is served by an extensive bus network serving almost 60% of the total daily trips.

† **Agglomeration economies “AG”**

Agglomeration economies \((A^G)\) are generally accepted as an important factor for the
emergence of high density business centers. In a study by Fujita and Ogawa (1982) such localization benefits are measured by equation 6 of potential function \( F(x) \) at location “\( x \)” as a measure of agglomeration economies; \( b(y) \) is density of business firms at \( y \); \( \theta \) is a parameter; and \( d(x,y) \) is the distance between firms locating at \( x \) and \( y \).

\[
F(x) = \int b(y)e^{-\theta d(x,y)} dy
\]

(6)

A more generalizable way of measuring the benefits from the proxies of firms is by using a macro economic input-output table. In the case of Istanbul this was applied to derive weights of interactions among intra-industry and inter-industry transactional relationship (Figure 3).

First, the input-output tables are aggregated into the number of the business types. Each monetary element \( (x_{qyz}) \) of the table is converted into units of the number of the workers, as depicted by Figure 3 (b). The number of workers that are necessary for business type \( q_y \) to employ for supplying or serving to business type \( q_z \) is given by \( w_{qyz} \), and is calculated by below equations; where \( a^{qyz} \) is the production coefficient; \( E_{qy} \) and is the total number of workers employed in business type \( q_y \).

Figure 3: Illustrative Input Output Tables

The coefficient \( K^{qyz} \) that is used to reflect the inter- and industry relationship is calculated with equations 7 to 9. Finally, the benefits of spatial proximity is given by the exponential decay function by equation 10 where: \( A^{G}_{qy,i} \) is the agglomeration benefits of business type \( q_y \) locating in zone \( i \); \( E_{qy,j} \) is the number of employment for business type \( q_y \) locating in zone \( j \); \( \beta \) is the distance decay parameter; \( z \) is the number of business type considered; and \( k \) is the number of zones.

\[
a^{qyz} = \frac{x_{qyz}}{X_{qy}}
\]

(7)

\[
w_{qyz} = a^{qyz}E_{qy}
\]

(8)

\[
K^{qyz} = \frac{w_{qyz}}{W_{qyz}}
\]

(9)

\[
A^{G}_{qy,i} = \sum_{j=1}^{n} \sum_{z=1}^{k} K^{qyz}E_{qy,j}e^{-\beta d_{ij}}
\]

(10)
♦ Land availability vise versa insufficiency “C”

The land availability outside of the CBD central area, and the insufficiency of vacant or re-developable land inside the CBD/downtown, which is closely linked to land prices, is also an important factor to be incorporated into the model. If reliable land price data are available (as in Japan), instead of land availability, directly including land values may also well explain the firms’ behavior. However, by including the potential of zones to accommodate more stock as an explanatory variable is a common way of examining the bid rent functions derived from the maximization of firm’s or residence’s utility function (hedonic pricing). Following this assumption, and also land value data limitation in Istanbul, it is assumed that the land prices are capitalized by the other independent variables given in this section, and are excluded from the utility function.

Land insufficiency was included as the percentage of developed area to the percentage of undeveloped area. Excluding the land used for residential purposes, the lack of available lots for new development was estimated with equation 11; where \( empden \) is the number of jobs by all firms; and \( maxempden \) is the maximum allowable density. This makes it possible to use the variable as a policy-sensitive attribute.

\[
C_i = \frac{empden_i}{max empden} \tag{11}
\]

♦ The zonal attributes “Z”

The fourth potential explanatory variable is the spatial attributes of each zone. This has been rarely considered, especially in the more economic theoretical models. Recent work has analyzed land use zoning policies, closeness to main highway junctions or railway stations as zonal spatial features and has revealed significant relationships. The zones that are restricted for any development, or zones that are promoted as sub-centers, may be incorporated as dummy variables if there exists any real, and enforceable, zoning policies.

4. Testing Alternative Model Specifications

Three alternative models were tested. For all three, zoning policies were only taken into
account as restrictive policies, because these have been clearly promulgated, especially to
preserve the identity of the city of Istanbul on the historical peninsula and the coastal side
along the Bosporus Strait.

The Land-use Master Plan designated urban nodes as sub-centers but the master-plan lacks
enforceable policies and programs, except for a few examples of transferring some
large-scale light and heavy industries to the outskirts of the city. When adding a dummy
variable for the nodes that are promoted as sub-centers, an undesirable minus sign of public
transportation service level in clusters II, III and IV for light and heavy industries appeared.
Consequently, only the dummy variables were included as zoning policies restricting any
new developments.

Agglomeration benefits of spatial proximity for intra- and inter-sectoral business interactions
defined by equation 10 were included in three of the models. Distance \(D_{ij}\) was calculated
over the road network coded in the transport model. Assuming that the firms are distributed
homogenously in each zone, the firm stock was added cumulatively with the increasing
distance of 1 km. For the zone \((i)\), the consideration is only the zones \((j)\) within a diameter of
10 km to be included in the calculations because the further zones are assumed to have no
influence by means of external scale economies. For the parameter \(\beta\), values varying
between 0.10 and 0.20 were tested to find the value that gives the best fit by looking at its t
statistics and likelihood value. Although there were small variations, 0.18 gave the best
results as the distance decay parameter.

For automobile-user labor force accessibility, the gravity-type accessibility model was tested
in all of the various model formulations. For the distance decay parameter “\(\beta\)” in equation 2,
the decay parameter derived for home-based work trips trip length distribution from the 1997
origin destination surveys was taken to be \(\beta=0.13\).

Two types of accessibility measures for public transportation were considered: the
Hammersmith and Fulham frequency indices by equation 4 (Model I); and the Hammersmith
and Fulham based gravity type accessibility by equation 5 (Model II). Frequencies were
computed for buses, minibuses and railways in Istanbul. The reliability factors were taken as
1.5 and 1.2 for the inner and outer parts of the city only for buses and minibuses. To compute
gravity type indices over the total trip time, peak hour trip time \((t_{ij})\) was derived from the
coded transport network.
For the land insufficiency, three different values of $\text{maxempden}$ were suggested along with the land-use permits and proposed degree of growth as designated by the Land Istanbul Metropolitan Area Sub-Region Master Plan (1/50,000 scale) for 1M, 2M and 3M centers. In model I and model II, the land insufficiency variable was included but only in model III variable was not considered in order to test the explanatory power of the only three accessibility measures.

### 4.1 Estimation Results

Tables 2 to 4 summarize and compare the results of the three model estimations for commercial and service type of firms. The test statistics, maximum likelihood ratios and the percentages estimated correctly, are given to verify the statistical significance of the models. The t-statistics given in parenthesis were calculated for a 5% significance and the reference category was chosen as cluster V.

| Table 2: Model I Estimation Results for Commercial and Service Type of Firms |
| Table 3: Model II Estimation Results for Commercial and Service Type of Firms |
| Table 4: Model III Estimation Results for Commercial and Service Type of Firms |

Model I and model II approximately predicted half of the commercial and service type firm location choices between 1985 and 1997 with the percentages estimated correctly 54.4% and 51.5%:, and with maximum likelihood ratios 0.25 and 0.25, respectively. When examining the percentages estimated correctly, for each of the five alternatives, the lowest hit ratios were for the cluster I type of zones (most of which are CBD zones) and the cluster II, III and IV zones were best estimated in all the three models. This may be one important reason that the real location dynamics occurred in these clusters between 1985 and 1997.

Highway private automobile accessibility indices, where both population distribution and highway network characteristics in the peak hour are embodied, are found to be significant in all the three models for all business sectors. The t-statistics for highway accessibility are slightly higher than those for the public transport accessibility in model II. The lower t-statistics of the variable for bus and railway frequencies in model I is because of very small variations of bus frequencies among the zones, since the whole metropolitan area is served with an extensive bus and minibus network. The two gravity type of accessibility indices for highway and public transport (model II) produced a high correlation (0.79) because both are
calculated for the same labor force distribution and over the same highway network as bus and minibuses dominate the public transport network.

In conclusion, the decentralization of population and the transportation network improvements proved to be significant for the clustering of firms. However, it should be noted that the public transportation service, mainly the provision of buses, increased with the emergence of the sub-centers simultaneously. Evidently, construction of the two Bosphorus bridges and the beltways were important driving forces in the decentralization of employment in Istanbul.

The dummy variable of the restrictive zoning policy variable was highly significant for cluster I and II type of zones and especially for the commercial and service type of firms - this is along with the strong restrictive policies of new developments in the high density zones in downtown. The most significant variable was the land scarcity variable indicating that the ease of finding floor space has been a very important factor for firm location choices. The t-statistics were even higher for light and heavy industry sectors in both models I and II.

The agglomeration economies, or in other words the accessibility between the firms, also was found to be important, but is less effective than land insufficiency and highway accessibility variables in explaining employment decentralization. Although, the agglomeration economic benefits variable was correlated with the land scarcity variable (-0.58), it was kept in the model because it is generally accepted in urban economic theory that, for poly-centric employment development, both localization and urbanization benefits, as explained earlier, should be influential location factors. The land scarcity variable well explained the high increase of job agglomerations in clusters II and III, especially for commercial and service sector. (It was less significant for the light and heavy industry suggesting that scale economies have been more evident for the commercial and service sectors.)

In model III, the agglomeration economies variable produced a negative sign – an undesirable and implausible sign – with the exclusion of land insufficiency variable from the model, but the significance of both highway and public transportation accessibility indices increased slightly, although the overall explanatory power of the model decreased (maximum likelihood ratio is 0.17).

The overall conclusion when examining the five clusters of employment in Istanbul is that,
in general, the relative magnitude of accessibility indices in cluster II and III type of zones suggest that greater accessibility will increase the probability that the firms will choose to locate in these zones. Similarly, for the results for the land scarcity coefficient, in absolute terms, a decreasing value of the parameter for cluster IV can be interpreted as the importance of land scarcity that the firms places tends to decrease with an increase in the ease of finding office space.

5. Conclusions

As urban structure diverges from a mono-centric form, the urban dynamics and policy-making issues become more complex subject to many factors and complicated relationships. For cities with poly-centric employment structures, urban location theory needs to be advanced. More empirical studies are required in order to better explain the trend and deriving forces of such an evolving urban form of decentralized concentration. This paper has presented the results of an empirical model on firm location choices for Istanbul, where a considerable number of jobs have located outside the old CBD during the last two decades.

The increase in clusters of employment was explored by a multinomial logit specification over the discrete space of traffic analysis zones. The five spatial location alternatives were determined as the five clusters of zones, grouped for their employment density. Firm’s utility functions were defined separately for the three different industry types: commercial and service; light industry; and heavy industry. Although the level of aggregation is high, the model has some assumptions, and there are data limitations, investigations into the firms’ behavior have given insights into the process of sub-center formation. In a growing city, where market-driven forces predominate, spatial dynamics have produced a clustered pattern for employment distribution that can be partially explained by an empirical model.

The key driving forces have been identified. Three job-location based accessibility measures; proximity among the firms for external scale benefits; highway accessibility of labor force; accessibility provided by public transport service; and the land insufficiency in the old city center, were found to be important in firm’s location decisions. The ease of finding floor space outside the CBD, and highway accessibility, were the most significant variables, especially for the medium density employment zones.

Further research is necessary because the lack of available, and reliable, data on land price in 1985 and 1997 in Istanbul did not allow analysis of the interactions between land gradients
and clustering of employment. A further issue to investigate would be empirical evidence of both the residential and business land rent functions. These need to be explored with the emergence of the sub-centers in order to help explain the rent peaks outside the CBD that are occurring in Istanbul.

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References


Figure 1: The Greater Metropolitan Area of Istanbul and Highway Network

Figure 2: Spatial Alternatives of Clusters by Rank Size Distribution (1985)
Figure 3: Illustrative Input Output Tables

(a) Input output table (monetary)          (b) Input output table (number of workers)

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<th>Heavy Industry</th>
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Table 2: Model I Estimation Results for Commercial and Service Type of Firms

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**TEST STATISTICS**

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Table 3: Model II Estimation Results for Commercial and Service Type of Firms

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**TEST STATISTICS**

- Maximum likelihood ratio: 0.245
- Percentage estimated correctly: 51.5%

Table 4: Model III Estimation Results for Commercial and Service Type of Firms

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**TEST STATISTICS**

- Maximum likelihood ratio: 0.168
- Percentage estimated correctly: 42.1%