Suburbanization of Office Space: A Case Study of Houston, Texas.

Dmitry Vadimovich Mesyanzhinov

Louisiana State University and Agricultural & Mechanical College

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SUBURBANIZATION OF OFFICE SPACE:
A CASE STUDY OF HOUSTON, TEXAS

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in
The Department of Geography and Anthropology

by
Dmitry Mesyanzhinov
M.A., Lomonosov Moscow State University, 1992
December, 1997
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ABSTRACT

Since the 1950s, the service sector of the U.S. economy has experienced remarkable growth. Significantly, new jobs in business and professional services and in similar information-processing occupations required new workplaces. Consequently, thousands of office complexes were built in American cities. Displaying a clean break with the past trend, the majority of the new office complexes were constructed in suburban locations, outside the CBDs of most major cities.

The purpose of this research is to investigate the relationships between office complexes and urban labor markets/urban spatial structure. The scope of the empirical work is confined to office suburbanization in Houston, Texas PMSA (Harris County) and covers the period from 1970 to 1990.

The research utilizes census-tract level socioeconomic data from the U.S. Census of Population and Housing (1970, 1980, and 1990) and data on individual office buildings from Black's Office Guide to examine, by means of statistical modeling, the relationships between the location of the intrametropolitan workforce and the location of office space.
Three sets of spatial regression models are formulated in this research: (A) the amount of office space as a function of workforce characteristics; (B) the length of commute as a function of workforce characteristics; and (C) the change in housing values as a function of changes in office stock.

Results of statistical modeling indicate that in Houston, during the period from 1970 to 1990, suburbanizing office complexes targeted the residential areas of white-collar office workers. As a result of this trend, residential areas with high concentrations of white-collar office workers are found to be characterized now with shorter commutes to work. Finally, positive effects of office space on housing values, particularly in the 1980s, were detected.

Results of the study suggest that suburbanization of office complexes leads to polarization of urban space and creates dangerous imbalances in the urban spatial structure. Examples of such imbalances include job-housing mismatch and difficulties associated with access to suburban jobs for low-income workers. Therefore, successful urban planning and urban social policies must necessarily be geographically-informed.
CHAPTER ONE: THE ROLE OF OFFICE COMPLEXES IN URBAN CHANGE

In the last decades of the twentieth century, American cities have experienced remarkable transformations (e.g., Beauregard, 1990; Hart, 1991; Mills and McDonald, 1992). These transformations not only affect the basic structure of urban economic activities (Noyelle and Stanback, 1984; Stanback, 1991), but also the spatial form of the city (Berry, 1993), the fundamental relationships between geographical arrangements of residences and job sites (Cervero, 1986 and 1989), and political and social processes in urban and suburban neighborhoods (Baldassare, 1986). Many of these changes are reasonably incorporated within the broad processes associated with suburbanization. Suburbanization typically refers to the relocation of people and jobs from the central city to the outlying areas. However, suburbanization also encompasses the endogenous growth of population and businesses in non-central city locations, not only the processes associated with the redistribution of population and employment throughout the urbanized areas.

In the first decades following World War II, urban systems in America experienced unprecedented increases in suburban residential development both with respect to scale and areal development (Jackson, 1985). Starting in the 1970s, as suburbanization of the population proceeded at a
high pace, new non-residential land uses such as integrated retail centers and, most importantly, office complexes increasingly emerged as elements of the suburban landscape (Muller, 1981). These developments could be credited to the process of capital accumulation (Harvey, 1985), which, conditioned by state regulation, brought massive private domestic and foreign capital to suburbia where it was profitably invested in the built environment. Low land values, attractive surroundings, and cooperative local governments were all important factors associated with this transformation. Principally, however, the high returns on real estate investment stimulated this unprecedented surge of office building construction on the metropolitan periphery of most, if not all, American cities (Feagin, 1983).

The driving force behind the positive investment environment for office space in suburbia was a rapid growth in demand in the 1970s, 1980s, and 1990s for office buildings induced by expanding service, financial, and new technology manufacturing sectors (Sui and Wheeler, 1993). As a result of sectoral economic restructuring, progressively more Americans find employment in office-based activities such as business and financial services, corporate management, and research and development (Noyelle and Stanback, 1984). Accordingly, office complexes have become
the dominant work places in the contemporary economy (Warf, 1993).

Office space in the typical pre-1970 American city can be characterized as a very highly concentrated urban land use found almost exclusively within Central Business Districts (CBDs) (Matthew, 1993b). Close informational and business ties among companies' headquarters with each other and with financial institutions assured tight spatial clustering of white-collar jobs in the downtown areas of major American cities (Hartshorn, 1992).

However, the conditions which fostered these typical concentrations, have been changing for several decades. By the early 1970s, a new set of factors emerged which, for the first time, were favorable for suburban office expansion and development. First, technological innovations (telex, fax machines, integrated computer systems) considerably relaxed spatial proximity requirements for intra-office communications. Through these improvements to communication technology, the functional need for offices to cluster lessened (Nelson, 1986). Second, the rising demand for office space could not be effectively accommodated, for infrastructural and investment reasons, solely within the CBD's of most American cities (Warf, 1993). Third, the development, as a part of the federally-sponsored Interstate Highway System, of radial and circumferential urban freeways
significantly altered patterns of intrametropolitan accessibility and provided physical "channels" for outward urban growth in general and for office space suburbanization in particular (Hughes and Sternlieb, 1988b).

The fourth condition which stimulated the development of suburban office complexes is closely linked to changes in residential patterns of the urban labor force. Beginning in the 1950s, but continuing through the 1970s, many office workers, especially in middle- and high-income categories, increasingly relocated to the suburbs. A progressive spatial expansion of residential zones away from the urban center made the journey-to-work an increasingly long and stressful endeavor which was required of many suburban residents in order to get to downtown-located office work places. The relative locational "footlooseness" of office industries (Cervero, 1986) and the rising absolute demand for office workers (Pivo, 1988a) led to a greater attention to the "geography" of intrametropolitan labor markets on the part of office-based industries. In other words, commuting convenience began to be addressed by new and expanding firms (Kutay, 1986; Nelson, 1986).

These conditions, first emerging in the 1970s, coupled with abundant capital available in the secondary circuit, i.e., production of the built environment (Harvey, 1985), eventually resulted in the growth of large-scale office
complexes in suburbia (Feagin, 1983). This trend has remained persistent throughout the past twenty years (Fulton, 1986; Garreau, 1991).

The central thesis of this research is that the emergence of office complexes and the jobs associated with these complexes on the metropolitan periphery constituted a dramatic change for office workers, for all other urban residents, and for suburban land use.

The growth of, and the locational changes in, office industries, however, affect other businesses and jobs as well. Shops, restaurants, and various other service establishments then were drawn into this suburbanization process in order to serve the broad needs of this new market of suburban office workers. Given the structural and spatial interdependencies between the metropolitan economy and the residential sector, it is logical to expect that this office location "revolution" would foster significant changes in the lives of many of the people who live and/or work in suburbia. However, the particular ways in which these effects are manifested are not yet clear.

The purpose of this research is to address a set of interrelated issues associated with the suburbanization of office complexes with respect to the relation of this trend to the changing urban spatial structure. Necessarily, the expansion of office space into suburban residential areas
induces physical and economic transformations to the areas adjacent to office complexes. Examples of these transformations include rising land prices (Heikkila et al. 1989), changing housing structures (Byrne 1989), and the displacement of low income residents (Feagin 1983).

The Houston, Texas Primary Metropolitan Statistical Area, that is Harris County, TX, will serve as a study area for this research. As will be discussed later, Houston’s growth and history makes the city an appropriate and interesting place for the analysis.

This study, then, will attempt a systematic analysis of changes in urban spatial structure which resulted from office suburbanization during the period from 1970 to 1990.

Office complexes and office suburbanization have been studied from a variety of different perspectives, including political economy (e.g., Feagin, 1982, 1985b), urban planning (e.g., Pivo, 1988b, 1990), the landscape tradition in geography (e.g., Relph, 1987), and microeconomics (e.g., Kutay, 1986; Ihlanfeldt and Raper, 1990). A survey of the literature, however, has revealed that most studies, relevant to this research problem, do not integrate issues of office space development and socioeconomic transformations. While logically closely related, unfortunately, the links between the two spheres have not received much attention.
This study will try to fill the existing gap in research by bridging locational issues of office development with the related issues associated with the changes in urban spatial structure. This research will adopt an economico-geographical perspective on office suburbanization. Accordingly, the city will be treated as a spatial system, and both labor and capital (built environment) will be analyzed in the context of real geographical space.

How are office complexes as workplaces related to residential urban spatial structure? What are the consequences of suburban office space expansion for urban residents? How has this new expansion of office complexes restructured and differentiated the contemporary urban landscape? These are the types of questions which will be explored in this research.

With respect to the methods of analysis, this research is fundamentally quantitative as it relies heavily on statistical analysis. The research is conditioned in substance, time, space, and scale because it presents a study of the consequences of office suburbanization in Houston during the 1970-1990 time period, and because census tracts are used as units of analysis.

The research will be systematically presented in the following chapter format. Chapter Two presents a discussion of theoretical approaches and previous empirical findings.
related to the broadly-defined issues of the suburbanization of office space, intrametropolitan commuting patterns, and urban land values. Research questions and specific hypotheses are developed and formulated in Chapter Three. Chapter Four provides contextual background information on the historical, geographic, and economic conditions for the study area—Houston, Texas. The research methodology and sources of data which are employed in this research are discussed in Chapter Five. Results of statistical analysis appear as Chapter Six. Chapter Seven contains a discussion of conclusions and the broader implications of this research.
2.1 Introduction

The post-WWII U.S. economy has undergone dramatic restructuring, the essence of which has been the trend towards the increasing dominance of the service sector with respect to employment and also the value of production output (Bluestone and Harrison, 1982). Figure 2.1 illustrates this trend. As a result of this trend, the American economy has entered into what many have called the post-industrial stage (Clark, 1985). This stage represents a radical departure from the industrial stage, characterized by the pivotal role of material production in manufacturing industries, which preceded it. Apart from a significant redistribution of the workforce between these two sectors, the transition from manufacturing to services also entails massive restructuring and the development of new workplaces, i.e., office complexes, to accommodate the growing numbers of service sector workers (Daniels, 1985). Within only a few decades, thousands of office complexes sprang up throughout American metropolitan areas, fostering entirely different urban landscapes and instigating dramatic changes in the spatial structure of American cities (Armstrong, 1979; Pivo, 1990). As some measure of the significance of this shift,
Figure 2.1 Structural Changes in the U.S. Economy in the Twentieth Century
the nation's office stock doubled between 1960 and 1980, and nearly doubled again from 1980 and 1990 (Pivo, 1990). Understanding the mechanics of these changes as well as short-term and long-term consequences which these changes bring about poses a great challenge for urban geography and all related disciplines (Bateman, 1985).

Although problems associated with the numerical growth of office space and spatial proliferation of office complexes are numerous and diverse, the present study is focused on a set of questions concerning explicit and latent interactions between office space and intrametropolitan labor markets.

There are three separate, yet interdependent, strands of inquiry in the present research. The first strand of inquiry deals with issues of intrametropolitan location of office space. The second strand of inquiry concerns one of the immediate consequences of office space growth, specifically, the structure of, and changes in, commuting patterns. The third strand of inquiry addresses long term effects of office space growth on housing values. The research questions associated with these strands are formulated and discussed in the next chapter (Chapter Two). This chapter, however, provides a review of existing literature on the multiple topics which bear on the
research. The organization of the subsections in this chapter follows the literature specifically associated with each of the three strands defined above.

2.2 The Location of Office Space

2.2.1 The Significance of Office Location Research

There are two fundamental geographic levels on which the location of office space can be analyzed: the intermetropolitan scale (between cities) and the intrametropolitan scale (within cities). On the intermetropolitan level, comparisons are made between cities, states, or regions with respect to the location of office space in such a way that cities are fundamentally treated as points which are not differentiated with respect to their internal structure. The intrametropolitan level, in contrast, is characterized by a much finer spatial resolution which enables, even requires, the analysis of office complex location in the context of the differing urban landscapes for each given city. Such a scale permits researchers to relate office complexes to other elements of urban spatial structure such as, for example, residential areas.

Although the intermetropolitan analysis of office location constitutes an equally important task, again, the focus of the present research is on a set of problems
requiring that analysis be conducted at the intrametropolitan scale. Accordingly, the following discussion will be limited to the issues of office location on the intrametropolitan level.

Reviews of literature on intermetropolitan office location can be found elsewhere (e.g., Armstrong, 1979; Bateman, 1985; Sui and Wheeler, 1993).

Plainly stated, the primary purposes of location analysis is to explain why a particular activity is located where it is located, i.e., to identify and understand factors and forces which determine the position of an activity in a geographical space (Webber, 1984). In the same vein, the study of office location is concerned with the understanding of the regularities in the spatial distribution of office space. Knowledge of these regularities, in turn, can be used for predictive purposes and, of course, for planning applications. Two factors greatly contribute to the importance of locational issues in the case of office complexes. Firstly, office buildings appear as seemingly “footloose”, i.e., not functionally tied to a specific type of place, compared to traditional industrial facilities (Gottmann, 1979). Secondly, the dispersion and deconcentration of office complexes has resulted in quite complex spatial patterns and distributions.
which are far from homogenous (Pivo, 1989). Given the potential to be located almost anywhere, office space clearly, nevertheless, exhibits tendencies for concentration in particular sectors of cities. Alternately, office location also clearly reflects patterns of avoidance of some particular types of places or some sectors of cities. The recent controversy surrounding the creation of "empowerment zones", which are predicated on the introduction of tax relief measures and job training programs as incentives to firms willing to locate in depressed neighborhoods (e.g., Boyle, 1995; McFarlane, 1995), is but one example of the practical recognition of this uneven economic landscape. So, with respect to offices complexes, the paradox between potential and reality calls for an explanation, one avenue of which lies in the realm of location analysis.

2.2.2 Theoretical Perspectives on Office Location

Approaches used in the study of office location can be roughly assigned into three types. The first approach represents an extension of neoclassical economic philosophy into the field of urban locational analysis. This approach is based on the analysis of production functions, or at least the specifics of the production process of office firms. From this perspective, it is assumed that selections of locations by office firms reflect a conscious effort to
maximize profits, either by cost minimization or revenue maximization (Erickson, 1986).

Much of the research in this tradition is based on the premise that inter-firm contact patterns have prime importance in determining office location (Goddard and Pye, 1975; Tauchen and Witte, 1984). There are also more sophisticated models, however, which incorporate not only the "contact" factors but a broad array of other factors which have potential importance for office location. These factors include fiscal conditions, lease rates, the presence of potential competitors and customers at each location, wage rates, any given industry mix by locale, and the social environment (Erickson and Wasylenco, 1980). Still, despite such adjustments, the fundamentals of this perspective remain soundly based in economic efficiency. The construction of production functions for office firms nonetheless poses significant problems due to difficulties in formalizing the production process, and in identification of satisfactory surrogate variables. Further, more pragmatically, there are clear limitations on available information.

The essence of the second type of research approach, namely the behavioral approach, concentrates on the investigation of the relative importance of various
locational factors through the use of surveys aimed at the decision-makers involved, e.g., executives and managers (Fuchs, 1991; Matthew, 1993a). A serious drawback of this approach is that locational preferences expressed by decision-makers reflect perceived (subjective), rather than actual (objective) conditions. The behavioral approach can be faulted then for identifying what should be (or what appears to be), rather then what is.

The third approach, which might be called geographic (or geographical), differs from the previous two approaches in that it emphasizes aggregate analysis rather than disaggregate (individualistic) analysis (Smith and Selwood, 1983; Nelson, 1986; Pivo, 1993). Unlike the neoclassical and behavioral approaches, the spatial approach is concerned with the analysis of large-scale trends and identification and analysis of the "typical" patterns which are associated with fundamental economic and social processes at greater scales of both time and space. Accordingly, patterns and trends in office location are investigated and explained at the aggregate level.

With respect to the thematic content of the research, as opposed to research philosophies, there are three separate, yet related, aspects of the office location analysis. By definition, "location" implies reference to
other objects (or, at least, to some system of coordinates). Office location, then, is conventionally described by reference to the city center (e.g., CBD vs suburbs, suburbanization and decentralization), to the elements of the urban spatial structure (e.g., residential areas, transportation network), and to other office buildings (e.g., clustering, office morphology).

2.2.3 Empirical Findings in the Existing Office Location Literature

The need for frequent “face-to-face” contacts between employees of different office firms is generally credited for the initial clustering of offices in Central Business Districts (Haig, 1926; Hoover and Vernon, 1962). Concurrent with the introduction of advanced telecommunication technologies, the need for personal contacts has decreased. This has allowed office firms to decentralize in recent decades without any loss in efficiency (Nelson, 1986; Kutay, 1986; Leitner, 1989). In this sense, the decentralization of office space can be seen as a part of the overall process of job suburbanization. That process is often referred to as a “jobs following people” movement, and is generally attributed to the large-scale suburbanization of the population, which shifted the critical mass of population towards the metropolitan periphery (Hughes, 1986; Hughes and Sternlieb, 1988a; Mills and McDonald, 1992).
The suburbanization of office-work is a well documented trend in the United States as well as in other Western countries (Cervero, 1986; Daniels, 1982 and 1985; Gad, 1985; Ley, 1985). In the United States, the share of metropolitan office space located within the CBDs, dropped from 95% in the mid-1950s to 46% by the mid-1980s (Fulton, 1986).

The causes of this suburbanization of office space can be conceptualized in terms of both "push" and "pull" factors. Table 2.1 and Table 2.2 briefly summarize the major disadvantages (push factors) of CBD and the principal attractions of suburban locations (pull factors) for office firms as recognized by previous research.

In terms of morphology, free-standing office buildings tend to form isolated groups, commonly known in the literature as "clusters." Clustering is well documented in studies by Muller (1981), Erickson (1983), Hartshorn and Muller (1986), Peiser (1987), and Pivo (1990). Most typical of the trend are small, low density clusters. Only a few large clusters contain a substantial share of the total metropolitan stock in typical cities (Pivo, 1990). Daniels (1974) proposed four types of clusters: (1) office parks; (2) large suburban centers; (3) small centers; and (4) scattered offices. In a more elaborate scheme, Pivo (1990) identified four basic patterns of office morphology:
### Table 2.1 Disadvantages of Central Business Districts

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<td>Jones and Hall, 1972</td>
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<td>Daniels, 1974</td>
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<td>Nelson, 1986</td>
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<td></td>
<td>Warf, 1993</td>
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<tr>
<td>Traffic and parking problems</td>
<td>Jones and Hall, 1972</td>
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<td></td>
<td>Daniels, 1974</td>
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<tr>
<td>Shortage of clerical labor</td>
<td>Jones and Hall, 1972</td>
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<td></td>
<td>Nelson, 1986</td>
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<td></td>
<td>Warf, 1993</td>
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<tr>
<td>No room for expansion</td>
<td>Pritchard, 1975</td>
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<td>Obsolescence of offices</td>
<td>Daniels, 1974</td>
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Table 2.2 Advantages of Suburbs

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<th>Feature</th>
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<td>Free parking</td>
<td>Jones and Hall, 1972</td>
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<td>Low land Values and rents</td>
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<td>Access to markets (customers)</td>
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(1) "Scatteration"—visually random spread of low-density office development (Blumenfeld, 1986; Fishman, 1987); (2) "Clustering"—the formation of suburban business centers (Erickson, 1983); (3) "Growth corridors"—which are defined as linear, stretched development along freeways (Baerwald, 1978; Hughes and Sternlieb, 1986); and (4) Mixed morphology—a combination of scatteration, clustering, and linear growth. Essentially, however, the typologies used by Daniels (1974) and Pivo (1990) both effectively convey the dualism in the spatial patterns of office growth, namely overall decentralization together with formation of a limited number of large agglomerations.

Archer and Smith (1994) found that traditional explanations for clustering, such as increasing economies of scale (Erickson and Wasylenko, 1980; Peiser, 1987), competition in demand for access, and demand for face-to-face contacts, do not adequately explain the phenomenon of clustering. This is an important distinction between more current research and earlier interpretations. Archer and Smith (1994), following Muller (1981), suggest an alternative explanation, simply that clustering occurs largely due to the demand for a successful or prestigious image. "Incidentally," prestigious office locations tend to coincide with prestigious residential neighborhoods, hence
the link to the office workforce. Archer and Smith (1994) also emphasized importance of a "respectable" business image for office firms.

In the office location literature, the distinction between an office firm and an office building is often blurred. Although it is possible to use the two interchangeably in many situations, this is not always accurate. According to a neoclassical economics approach, the location of an office firm depends on particular requirements manifest as the hypothesized independent variables incorporated in its representative production function. Such a formulation, being logical internally, nevertheless seems to be at odds with reality. My criticism of this approach concerns the implicit assumption of free (unrestrained) locational choice. This assumption, which effectively endows office firms with virtually unconstrained mobility in space, would not appear to be valid under close scrutiny. Firstly, most firms lease office space in preference to owning their own (Daniels, 1975; Clapp, 1993). It is also most typical for a building to have more than one tenant. Secondly, realistically, there is a limited supply of office space, both in terms of available locations and currently unoccupied (i.e., ready to be leased out) space at these locations. If cost requirements of the lessees of
office space are also considered, cost-effective "choices" are narrowed considerably. Thirdly, office firms do not have direct control over the office real estate development business, which is ultimately responsible for decisions about location and the absolute size of office complexes. Given the diversity and unpredictability of prospective tenants, developers seldom select a construction location specifically targeted for a particular firm. Instead, in most cases they must generalize locational requirements for a range of the service industries, and then, based on this information, create general-purpose office space (Archer and Smith, 1994). This is significant in that it means that the characteristics of a particular firm and its production process are largely irrelevant to the decisions related to office building location selection and construction. Assuming, with some justification, that this is the case, then locational externalities should be matched not with individual firms but with office buildings.

Table 2.2 presents a summary of factors representing major locational attractions associated with urban externalities. The table reveals a consensus on the significance of labor orientation, i.e., access to appropriate labor pools, in the location of office buildings. The attraction of office complexes to certain
residential areas with actual and/or potential supplies of workers is not simply a theoretical supposition (Manners, 1974; Kutay, 1986) but rather, it is a significant factor which has received confirmation through sound empirical studies.

Ihlanfeldt and Raper (1990), working within the neoclassical economics modeling framework, detected a positive relationship between the proximity to workers employed in managerial occupations and workers employed in service industries with respect to the number and distribution of office firms in Atlanta. Simultaneously, negative effects were detected for proximity to the clerical workforce, to low-income neighborhoods, and to land used for industrial purposes.

Matthew (1993) and Fuchs (1991) employ behavioral approaches in their research. Matthew (1993) found that office managers in Toronto sought suburban locations which, first and foremost, had both "good" highway access and low operating costs. However, in addition to these factors, their research found that such new locations tended to be selected which also provided good client access and offered reduced commuting, in terms of time, for executives and staff.
Fuchs (1991) found that factors that influence real estate developers and users of office space are actually quite similar. Suburban office managers in the Washington D.C. area all gave high rankings to highways access, proximity to executive housing and employee housing. Similarly, developers, when selecting a site, report concern with the vitality of the local office space market, again access to highways, and the size of the local labor pool.

Finally, Nelson (1986), utilizing a geographic approach focused on the analysis of large-scale processes, compared demographic and socioeconomic profiles of several laborsheds in the San Francisco area and discovered that the presence of an educated female workforce (clerical labor pool) consistently attracted office firms.

The location of office complexes, and all concurrent changes, have many important consequences for urban workers. One of these consequences is associated with the intrametropolitan commuting. Active economic and physical growth, persistent trends towards suburbanization, and the apparent selective concentration of office space have all significantly altered the geography of the “destinations” which constitute the typical urban commute. The sections that follow present a brief survey on these issues related to urban commuting patterns.
2.3 Intrametropolitan Commuting Patterns

2.3.1 Significance of Commuting

The concept of a daily commute to work, or what is commonly called the "journey-to-work", is central to theoretical and empirical research in urban studies. There are three fundamental conditions in urban life which form the basis for the major issues associated with commuting. The first condition has to do with the separation of home and workplace. As a general rule, people must travel from home to work, where they congregate for the purpose of collective production activities. The separation of home and workplace, in relative terms, is a historically new phenomenon, dating back only to the beginning of the Industrial Revolution (Vance, 1966). Cities have been growing ever since, with an increasing portion of the working population adopting a "commuter" lifestyle. Although state-of-the-art information technologies (computer, telephone, fax) allow some people to work at home, the reality is that such workers are estimated to account for only three percent of the total U.S. workforce in 1990 (U.S. Bureau of the Census, 1995).

The second condition has to do with the segmentation, or stratification, of the contemporary urban workforce. Workers differ in terms of occupation, by the type of
industry of employment, by educational status, and of course by the wages they command. Occupation, education, and income are often merged into some comprehensive concept of "social status." Although this concept originated within the Status Attainment school in sociology, it has often since been borrowed and endowed with different meanings by researchers in many disciplines (Grusky, 1994). The utility of this term is in the simplification it offers. At the aggregate level, income, education, and occupation tend to exhibit very high covariation, which warrants, to some extent, the interchangeable use of the three. In that respect, "social status" provides an easy way to refer to nothing more complex than a certain combination of income, education, and occupation. In addition to social status, another set of important differentiating factors concern gender and race/ethnicity characteristics of workers (Scott and Storper, 1986).

The third condition is a reflection of the fact that human settlements, large urban areas in particular, possess a certain order in the spatial arrangement of their internal elements (Bourne, 1982). While the distribution of the residences of a segmented workforce, and of workplaces of differentiated industries, may not necessarily conform
perfectly to a specific pattern, the distributions are nevertheless not random or chaotic.

The combined effects of these three conditions result in a situation where commuting is ubiquitous yet heterogenous. In other words, this is a situation where some journey-to-work is required for the representative (in a statistical sense) worker, and the length of commute consistently varies for a cross-section of urban workers.

In light of the above, the fundamental purpose of commuting research should be clear. Such research seeks to provide theoretical explanations as to the nature of differences in commuting patterns found among different segments of the workforce, and to advance empirical knowledge about commuting. Needless to say, these goals, according to the dialectics of the knowledge acquisition process, are inseparable and mutually reinforcing.

2.3.2 Theoretical Perspectives on Commuting

All approaches in commuting studies share common ground by recognizing, implicitly if not otherwise, what is termed above as the "three conditions." From there, however, the approaches diverge, interpreting commuting quite differently, contingent on dissimilar paradigmatic and theoretical contexts. Three general approaches, most common in studies of urban commuting, can be identified. They are:
(1) neoclassical urban economics; (2) labor economics; and what might be called (3) a spatial or geographical perspective (i.e., having to do with the research traditions in the discipline of Geography).

Within neoclassical urban economics, commuting patterns are viewed as stemming from the pursuit of some theoretical equilibrium in the housing/land market managed in effect by Adam Smith's "invisible hand." Households, in the effort to maximize utility, compete for urban land/housing. Eventually, the spatial arrangement of residences results in a set of regular patterns. Accordingly, for neoclassical urban economists, the patterns of urban spatial structure reflect the market equilibrium which is achieved by the self-serving and "rational" actions of individuals and/or households. In the classical Alonso-Muth-Mills model (Alonso, 1964; Muth, 1969; Mills, 1972), workplaces are located exclusively in the center of the city (an assumption of urban monocentricity which is no longer valid but which does not disrupt the basic theoretical underpinning of the approach). The decision of a household to locate away from the city center is remarkable in that it allows for the acquisition of better, more spacious housing because land is cheaper in the metropolitan periphery vis-a-vis the city center. On the other hand, financial and temporal costs of
commuting are directly related to the distance from the city center. However, with increasing income, gains in housing quantity and quality (e.g., more living space, a better neighborhood environment) outweigh the losses associated with these longer commutes. Hence a positive relationship between income (social status) and the length of commute is implicit in models of this type. The same argument was subsequently extended to cities with decentralized employment (Bender and Hwang, 1985). In the latter case, rather than the absolute distance to the center of the city, the distance, or time, required to travel to the workplace is utilized.

The Alonso-Muth-Mills model was designed with the assumption of male-headed, single-worker households as givens. Of course, in recent decades the share of households with working women (frequently working spouses or single parents) has risen sharply, and the assumption of one-worker two-parent households has, to a great extent, lost its validity. However, the introduction into the model of a second income earner raises certain structural and theoretical problems with these models. Women, on average, receive lower wages than men and consequently, according to the theory, must have shorter commutes. This means that optimum household location for the primary (traditionally,
the role is associated with male head of the households) and secondary wage earners differs. The problem is usually resolved by approximating a joint determination of household location (Singell and Lillydahl, 1986).

Another approach, also based fundamentally on market equilibrium principles, has developed within the labor economics school (e.g., Rees and Schultz, 1970; Madden, 1977a). According to this approach, the direction of causality in the recognized positive relationship between income and the length of commute is reversed: workers are compensated for longer commutes with higher wages. The location of residence is assumed to be fixed (i.e., exogenous), rather, the location of places of employment is allowed to vary. In order to attract workers from distant locations, employers, in theory, must offer higher wages. Consequently, the wage gradient rises with distance away from any given workplace. Respectively, this perspective holds that lower paid workers, including women, are not "willing" to have long commutes because they are not adequately compensated for the journey-to-work in the labor market.

As is often the case in development of abstract theory, these two opposing approaches are, to some degree, synthesized and reconciled in simultaneous workplace and
residential location models (e.g., Siegel, 1975; Madden, 1981). These models are based on the assumption that neither workplace nor residence is fixed, and that households constantly make adjustments in both. However, with respect to the hypothetical relationships between income (social status) and commuting, as well as those for gender and commuting, ultimately the theoretical predictions of simultaneous models are traditional: that is, the high-income workers tend to have longer commutes, while female workers tend to have shorter commutes.

Theories based on interpretations of the market equilibrium principle provide explanations for commuting differences with respect to income and gender, but do not successfully incorporate other important dimensions of the segmented workforce such as race/ethnicity and/or the economic sector of employment. This deficiency, however, does not apply to empirical research, since with respect to model construction, neoclassical economics, labor economics, and simultaneous models typically account for great detail and diversity in the workforce and household structure.

In contrast with these market equilibrium approaches, the geographic (or "spatial structure") approach is based on the assumption that utility maximization for individuals or households is profoundly constrained by the existing urban
spatial structure, i.e., distribution of employment centers and residential housing. In short, both space and time are determining factors. Indeed, due to actual conditions, workers are only able to "select" employment positions which are available only at particular locations at any specific time. In other words, demand for (as well as supply of) labor is always conditioned in space and in time. The selection of housing, although intuitively characterized by a much wider range of choices, is nevertheless also conditioned by economic (i.e., availability and affordability) and social (e.g., neighborhood status) factors. In these respects, commuting patterns may be viewed as reflecting a distribution of employment centers relative to the distribution of housing for a segmented and stratified workforce at a specific time. Accordingly, knowledge about the spatial patterns which can be observed in the distribution of the workforce residences (e.g., location of upper-, middle-, and low-income housing), and in the distribution of different employment centers (e.g., office complexes and factories) can reasonably serve as a foundation for inferences regarding intrametropolitan commuting.

The geographic approach utilizes such continuums as centralization/decentralization, clustering/dispersion,
attraction/repulsion, and compatibility/incompatibility to describe observed and predicted spatial patterns (Wolforth, 1956; Wabe, 1967; Gordon et al., 1989a). For example, it is often argued that longer commutes for workers of high social status can be attributed to the high level of centralization of white-collar employment (Wheeler, 1968); or that shorter commutes for workers of lower social status is related to the location of inexpensive housing next to industrial zones (Scott, 1988).

2.3.3 Empirical Findings in Commuting Literature

Table 2.3 presents a summary of findings from selected, but seminal, research on intrametropolitan commuting. The reported findings should be interpreted with great care since they were obtained within different methodological contexts. This means that all of these studies exhibit particular combinations of analytical tools, feature varying units of analysis, reflect different model specifications, and have different sample characteristics with respect to both time and place. However, the purpose of this compilation is to compare the results in the "final analysis." That is to identify relationships, established in earlier research, between the length of commute and various labor force characteristics as such findings relate to this research. With respect to income, the most widely used
### Table 2.3 Summary of Empirical Findings in the Commuting Literature

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</table>
economic variable, a careful review of the literature reflects an interesting and somewhat ambiguous relationship. Both positive (e.g., Madden, 1981; McLafferty and Preston, 1991) and negative (e.g., Hanson and Johnston, 1985; Singell and Lillydahl, 1986) relationships were encountered in the literature. A positive relationship is consistent with the predictions of the neoclassical and urban economics models. However, "unexpected" negative relationship, it would seem, require additional explanations. Gordon et al. (1989b) suggest that shorter commutes for high-income workers can be explained by the fact that this category of workers is released from an income constraint with respect to the selection of housing. Therefore these workers can afford to live close to their workplaces. According to a different line of reasoning put forward by the same authors (Gordon et al., 1989a), rising incomes stimulate economizing on the journey-to-work length. Such economizing, in turn, becomes possible as urban structures are transformed from monocentric into polycentric (multinucleated) forms. Although the reasoning and findings presented in Gordon et al. (1989) are made at the intermetropolitan level, this argument can be extended to the intrametropolitan level as well. By linking the relationship between income and commuting length to the changing urban forms of American
cities, this work in fact exposed the dynamic nature of the relationship. In other words, the association between higher incomes and longer commutes was valid for the earlier period of the U.S. urban history when monocentric-type cities dominated. However, recent trends in employment decentralization and the consequent multinucleation of the evolving urban spatial structure of contemporary U.S. cities brought about a new pattern. Higher income (or higher social status) can now be associated with shorter commutes.

Education, as a determinant of commuting length, is not widely used in analysis, perhaps because of its generally high statistical and theoretical correlation (covariance) with income. Nevertheless in the few cases when it is considered, again both positive (Johnston-Anumonwo, 1988; Tkocz and Kristensen, 1994) and negative (Madden, 1977a; Izraeli and McCarthy, 1985) relationships are documented. In short, this relationship appears to be closely tied to the conditions found in particular studies.

On the other hand, the relationships between commuting length and factors related to gender and race appear to be unambiguous. Females are always found to face shorter commutes (Blumen, 1994). Minorities (in most studies meaning African Americans), on the other hand, consistently have
longer commutes than any other group (e.g., White, 1986; Madden, 1981).

Studies of occupational differences in commuting typically employ detailed multinomial schemes (8-12 occupational categories ranked by status) which almost necessarily produces rich but overly specific results. For the purpose of generalization, it is best to consider a simple dichotomy of white-collar (managers and professionals) and blue-collar (laborers) workers, or possibly a trichotomy (with the addition of clerical workers as another group). It can be argued that clerical workers constitute a separate category, sometimes called "pink-collar" workers (England, 1993). Clerical jobs typically offer low, to at best average, wages which are comparable to those for low- and semi-skilled industrial workers. However, clerical work occurs in office-type settings, does not require manual labor, and the associated work schedules are generally more flexible.

When a dichotomous classification is used, the relationship between occupational status and the length of commute is often found to be positive, meaning that white-collar workers have longer commutes. Explanations for this positive relationship are usually derived from analyses of distributions of employment by type and by residence.
patterns. Cubukgill and Miller (1982) cite the typical availability of low income housing near blue-collar employment centers (factories, warehouses) and a generally higher degree of dispersion for blue-collar employment and residence as factors behind shorter commutes for workers in that occupational category. Wheeler (1967) attributed the long distances to work for white-collar workers to a heavy concentration of higher status jobs in the CBD, while housing for such workers tends to be dispersed.

Variations in commuting patterns due to differences in the sector of employment have been, surprisingly perhaps, largely neglected in the published research. There is no ready explanation for this other than the overall tendency to emphasize occupational structure at the expense of the industrial mix. However, despite this neglect, the sector of employment appears to be an important, if overlooked, factor. This is particularly true if one considers the cross-sectional differences in types and locations of workplaces.

2.4 Office Complexes and Land Values

The two major theoretical approaches to urban land and housing value research might be characterized as "macro" and "micro" approaches. A "macro" approach is based on the classical Alonso-Muth-Mills theory of urban land values
It postulates the existence of a price gradient for land values and housing values which decline from the Central Business District—the place where all jobs are assumed to be located. This theory views the distance to the CBD as a "force" which structures intrametropolitan land and housing values. Therefore, according to this approach, land and housing values appear as functions of location, or functions of access to the workplace (Segal, 1977).

The "micro" approach, which is applicable particularly to housing value, has its roots in traditional microeconomic price theory (Lancaster, 1971). According to this approach, "housing value" represents a bundle of services and products, rather than a single service or product. These services are typically grouped in such categories as the structural characteristics of the building (size, age, presence and number of various facilities), neighborhood amenities (perceived and real benefits associated with living in a particular neighborhood), and intrametropolitan location (again, actually the distance to the CBD) (Waddell et al., 1993). It is assumed that a homeowner purchases a bundle of these characteristics, which, theoretically, can be priced separately. Accordingly, the implicit prices for these services can be estimated by regression of sales.
prices on an array of these components. Such method, taken collectively, might be classified as studies employing hedonic regression (Nelson, 1978; Linneman, 1980; Dale-Johnson, 1982).

The suburbanization of population and employment in the U.S. during the last three decades as well as other important developments in the urban spatial structure have necessitated revisions in the approaches discussed above. These revisions, first and foremost, concern the new role of the CBD and the real distribution of employment throughout the urban space. The emergence of suburban business centers in American cities, in effect, invalidates the assumption that all, or most, jobs are concentrated in the CBD (Greene, 1980; Erickson, 1986; Garreau, 1991). With respect to the theory, however, the substitution of multiple centers for a single center requires only a small conceptual adjustment. Accordingly, declining housing value gradients are believed to exist around multiple centers, just as they would for the CBD (Bender and Huang, 1985).

A number of studies have tested this hypothesis and have found it to be true. It has been established that business centers exert positive effects on housing values in such cities as Chicago (Bender and Hwang, 1985; McDonald and McMillen, 1990), Baltimore (Dubin and Sung, 1987), Los
Angeles (Heikkila et al., 1989; Richardson, et al., 1990), and Dallas (Waddell et al., 1993). As a corollary to the rise of the suburban centers, it was discovered that the influence of the CBD on the intrametropolitan price gradient weakens over time (Richardson, et al., 1990).

However, the association of suburban business centers, which typically represent a mix of office, retail, and entertainment activities, with the location of the majority of metropolitan jobs somewhat underestimates the scale of the employment decentralization. Besides these centers, which are undoubtedly important in every major American city, hundreds of free-standing office buildings have also emerged. These office complexes, and associated office jobs (as well as other types of service and retail jobs), are dispersed throughout the suburbs (Pivo, 1988a, 1990). The effects of these dispersed office complexes on housing values have yet to be systematically investigated. To date, only one study is available (Thibodeau, 1990). Thibodeau (1990) analyzed the effects of a single office building in Dallas, TX on property values in surrounding neighborhoods. In this research, he found an overall positive influence of an office complex on property values. Along with traditional explanations for positive externalities associated with the accessibility to the work place, Thibodeau (1990) also
suggested that the anticipation of future development near existing office complexes may further contribute to explanations regarding increases in housing values.

2.5 Summary

This chapter has presented a review of the research literature associated with the issues related to location of office space, intrametropolitan commuting, and connection between office complexes and land values. This literature draws upon a variety of theoretical perspectives and empirical formulations which all inform the current work. In some cases, conflicts in findings should reasonably be credited to different purposes and scales of research. On the other hand, it is clear from this review of related literature, which the chapter represents, that there are gaps in work which concentrate upon the role of the workforce in the suburbanization of office space and upon the consequences of this office space suburbanization as it relates to the intrametropolitan labor markets via commuting patterns and via urban land values. In some cases, there is general agreement on the relationships in question. In others, significant and meaningful discrepancies were identified.

The next chapter, building upon the theoretical perspectives and empirical findings reported in this review,
presents original research questions and formal hypotheses of this dissertation.
CHAPTER THREE: RESEARCH QUESTIONS AND FORMAL MODELS

3.1 Relationships between the Location of Office Space and Workforce Characteristics

3.1.1 Research Questions

One of the three research problems addressed in this dissertation concerns the nature and, most importantly, the manifestations of the relationships between the resident workforce and the location of office complexes. This portion of the project is designed to study the problem through the geographical analysis of hypothesized regularities in the dynamic distribution of labor and workplaces (i.e., office complexes). The fundamental research question, simply put, is, "What kind of workers typically live next to office complexes?" Stated another way, "Are office complexes selective in their location with respect to the local workforce?" Once the answers for different points in time are obtained, the important issues of temporal dynamics and the directionality of these relationships between the workforce and office location will also be brought into the analysis.

The rationale behind this basic question, as well as its applications, is not immediately obvious without some understanding of recent developments in the economy and spatial structure of American cities. The following section
provides background information on some of the issues which are most pertinent to the research question stated above.

3.1.2 The Growth of the Service Economy and the Concurrent Proliferation of Office Space

At the heart of the economic restructuring process, which has been going on in the U.S. and other industrialized countries since after WWII, lies the transformation from a manufacturing-dominated economy to a service-dominated economy (Daniels, 1991). In the broadest context, the service sector can be defined as activities not directly involved in traditional material production processes. Thus defined, service activities include two major groups. First, there are intermediate services related to pre-production (e.g., design, market research), post-production (e.g., advertisement, sales), and administrative activities (e.g., planning, management). Second, there are final demand services such as banking and finance, legal services, and various personal services. The increased role of services in the economy of the U.S. and other industrialized countries is a consequence of several concurrent changes, among which the most important are technological progress, corporate reorganization, and the globalization of the economy.

The primary purpose of these service activities, with the obvious exception of personal services, is to collect, process, analyze, and distribute information. Collectively,
these information-related services are referred to as business and professional services. Although diverse with respect to the particular tasks that they carry out, all business and professional services bear close resemblance with respect to both the occupational composition of the workforce and also their requirements for office space.

In terms of the organizational setting, business and professional service activities are carried out either by specialized independent firms (e.g., legal firms, consulting firms) or by internal divisions of large corporations. The latter situation is especially common with respect to intermediate services as defined above. Although services provided internally are often similar to the ones provided externally, "service industries" conventionally refer only to independent businesses. However, it is important to recognize that from a functional perspective, the organizational distinction between the two types of services is largely unimportant. Therefore, in this research the term "business and professional services" (hereafter, simply services or service industries) is modified to include not only autonomous service enterprises, but also dependent (internal) service divisions associated with manufacturing, transportation, and other industries.
In terms of the physical workplaces, services are housed in office complexes which are specifically built for this purpose. Over the years, office buildings have become an integral part of the contemporary service-dominated economy and have turned into essential features of the urban landscape. Office complexes and service industries, then, represent an inseparable duality. The presence of service industries at a particular place is possible only when there is office space available at that location. Alternately, the existence of an office building entails the presence of service industries (unless, of course, the building is vacant). For a number of reasons, this duality justifies the substitution, and interchangeable use of these terms, especially when the spatial dimension is involved. Accordingly, although this research is concerned ultimately with service industries, it is expressed mostly in terms of office buildings and office space as manifestations of the presence of these industries in any urban landscape.

There are three essential aspects of this rapidly growing service sector that are of particular importance: (1) the increase over time in the number of people employed in services (in absolute terms and relative to the other sectors);
(2) the simultaneous increase in the number of office complexes (and total amount of office space) which host service firms; and

(3) temporal changes in the location patterns of office complexes for any given urban system.

The mushrooming of office complexes throughout virtually all metropolitan areas represents a radical change in urban morphology for American cities. This change has already had significance impacts on the U.S. urban cultural, physical, and socioeconomic landscapes and presumably will continue to do so. Accordingly, an investigation of the issues related to the location of office complexes is deemed essential for any understanding of contemporary metropolitan development in the United States or, for that matter, development of urban systems in other nations undergoing sectoral economic transformation.

3.1.3 The "Footloose" Quality of Office Complexes and the Role of Labor in Office Space Location

The importance of actual location with respect to office complexes stems from the following features now characterizing the structural and spatial development of office complexes:

(1) "footloose" quality;

(2) suburbanization and decentralization;

(3) spatial unevenness and clustering.
Thus, it should be recognized that during the last three or four decades, changes have occurred not only in the structure of the workforce, but also in the "geography" (as in "what and where") of the service employment centers.

Footlooseness refers to the situation when proximity to markets and resources does not a play a decisive role in the location of labor-intensive businesses. Labor-intensive businesses can be defined as those for which costs of labor far exceed production costs of materials, equipment, and all associated transportation costs. By definition then, such firms are highly dependent on supplies of (i.e., access to) labor. Accordingly, any given firm hypothetically seeks to optimize its location with respect to the location of the potential or prospective labor pool. A classic example of a footloose industry is the garment industry which has largely fled the United States in response to the cheap labor in East and Southeast Asia, the Caribbean, and Latin America (Dickerson, 1995).

Still, service industries should not be characterized as being totally independent in spatial terms from the market for their services. On the contrary, for many service businesses, especially when face-to-face communication is required (e.g., legal services), proximity to customers is essential. The issue can be partially resolved by
considering the geographical scale of footlooseness. It appears that proximity of some service industries to their markets, as a location factor, is articulated most clearly at intermetropolitan and regional scales, while it is much less important (although, there are exceptions) at the intrametropolitan scale. In other words, for most services, proximity to markets primarily influences selection between potential (or targeted) metropolitan markets (whenever proximity is required), but such considerations have a lesser effect on the selection of locations within a given metropolitan area. Since the focus of this research is the intrametropolitan development of office complexes (with its relation to urban labor markets), henceforth locational independence of service industries from customers will be viewed in the context of the internal geography of cities. Subsequent work may review these relationships at regional or national scales, but this research, as mentioned in Chapter One, will focus on a single metropolitan area—Houston, TX.

With respect to labor, clearly the relative wage rate is not the only consideration. Obviously, the quality of labor is also important. This is especially true for service industries which rely heavily on educated workers with professional and/or modern information technologies skills.
For a typical office-stationed service firm, the costs of labor now comprise up to 80-90% of the total operating budget (Kutay, 1986). Most service businesses actually require limited capital investment. Working premises (office space) are typically not owned but leased. Rent expenses typically represent a fairly small portion of the budget (Clapp, 1993). The equipment that is owned (most importantly, furniture, computers and peripherals) is easily transportable, and represents a minor investment vis-a-vis labor costs.

Given these characteristics, service industries can be conceived as footloose in the sense that they can select between a variety of locations within the city. Naturally, service industries select particular locations only if office buildings with available space exist at these locations. Office space (buildings), then, is provided (leased out) by the real estate development firms which are not directly accountable to the service industries. However, the changing locational preferences of service industries are obviously known to successful developers, who logically and normally try to understand existing demands for office space, while also anticipating future growth. Moreover, since the major portion of all office stock is leased, service industries are not "tied" to a particular building
for a long or indefinite term. Service firms, therefore, are free to pursue better locations with relative ease, thus exerting additional pressure on the real estate development firms to meet the locational requirements of the service industry. This factor emphasizes the important role of the service industries in the eventual determination of sites for new buildings.

Previous research has shown that, on one hand, service industries which are housed in office complexes are extremely labor-intensive. On the other hand, the increasing proliferation of office complexes over time has resulted in a complicated spatial pattern. It is therefore logical to hypothesize that the actual location of office complexes is somehow related to local supplies of labor.

From a geographical perspective, this relationship can be abstracted in the following way. Labor is "supplied" from workers' residences which are found at a variety of locations. Since workers generally must congregate at some production center (an office building in this case), they must engage in day-to-day trips to work. The length, duration, and the costs of the trips that workers can, and are willing to, accept as one aspect of potential employment have their physical and feasibility limitations. The spatial growth of metropolitan areas, popularly known as urban
sprawl, has led to a situation where not all possible intrametropolitan commutes are acceptable. A feedback relationship must exist as absolute demand for office labor stimulates competition among employers. In this situation, employers who offer shorter commutes to work gain, at least theoretically, an edge in the competition.

Shorter commutes to work can be achieved by bringing the workplace closer to the residences of the potential labor pool. In this respect, then, the suburbanization of office complexes might be conceived as a reasonable strategy to achieve that particular goal.

There is a general agreement in academic and popular literature that office industries target labor pools in location strategies which minimize, or least shorten, the length of commute. The sources of relevant information can be classified into three categories according to the origins and types of evidence. The first category is characterized by works of a theoretical nature and also by scholarship in which authors render their own perception of intrametropolitan office development (e.g., Manners, 1974; Kutay, 1985). The other two categories are more empirically based. However, within the latter two categories, there is an important difference between the two. The second category of research work, which is based on a subjective approach,
utilizes information obtained by interviewing office
developers and office managers (e.g., Fuchs, 1991; Matthew,
1993a). The third category of research, which is based on
the objective approach, utilizes actual location-specific
data on office space and the labor force (e.g., Tauchen and
Witte, 1983; Clapp et al., 1992). Regardless of research
approach, most empirical findings support the hypothesis,
discussed earlier; that is “offices follow people.” However,
supporting evidence is scarce, sketchy, anecdotal, and often
contradictory in other aspects.

Overall, it can be said that adequate research based on
an objective analysis of the problem has not yet been done.
Therefore, it is the purpose of this research to test the
hypothesis that there is a close relationship between the
labor force and the location of office complexes. In this
case, the hypothesis will be tested through the use of a
rigorous statistical analysis of observable (objective)
phenomena. Hopefully, findings will contribute to the
growing body of knowledge regarding contemporary
metropolitan socioeconomic structure and the changing urban
landscape. Further, results of the study will provide
practical information of use to urban planners and the real
estate community.
It was noted earlier that by and large, all of the different types of service industries are generally drawing workers from the same occupational pools of labor. This is possible because the skills which office jobs require are by and large easily transferable between different types of service industries. However, this does not imply that all office jobs are equal. In fact, the office workforce for any given firm is fairly well structured, with three distinct groups. The three groups in a typical office workforce are: (1) executives and top management; (2) professionals; and (3) administrative support staff. The shares of each of these groups within different service industries may vary; however, the structure of the workforce remains largely the same across all service industries.

Since the office workforce is in fact structurally heterogeneous and also to a great degree spatially segregated along similar lines in terms of residential location, the question then becomes which of these groups are actually "targeted" by the office industry? That is, which of the groups represents some critical mass of "gravity" that "attracts" office complexes? Of course, in practical terms, if any one of the groups does in fact attract office development, this would in turn mean that this particular group is an advantageous position with respect to the
benefits associated with residing in close proximity to office complexes. The following section proposes a way to formalize, and subsequently test the hypothesized relationships between the location of office space (workplace) and the location of the workforce (home).

3.1.4 A Model of Socioeconomic Determinants of Office Location

Although one of the goals of this research is to evaluate office locations relative to the residential patterns exhibited by the three types of office workers, on the operational level the distinct characteristics of the workforce such as education, income, occupation, sector of employment, and essential demographic indicators should be recognized in such a model. Variation in these characteristics may serve as proxies for these three types of workers. In theory, a particular set of such characteristics should correspond to a particular type of workers. However, boundaries between the types are rather fuzzy. Recognizing that "type" of office workers is an abstract concept, it is not directly observable. Workforce characteristics are the concrete and observable attributes of the workforce. Information on these characteristics is widely used and readily available from many sources.

In order to investigate relationships between office location and resident workforce, a model is proposed in
which amount of the leasable office space is hypothesized to be a function of a set of workforce characteristics. Some sources suggest that office complexes tend to locate in upper and middle class neighborhoods which supply the bulk of the white-collar office employment (Garreau, 1991; Harper, 1991). It is believed that this phenomenon is indicative of the fact that office/service industries exhibit a location strategy which targets residential areas with a workforce which has particular characteristics. If all of the above is accurate (which is, of course, subject to verification), then, theoretically, the better the workforce quality (from the office industry perspective) in an area, the more office space will be found in that area. It is therefore hypothesized that the characteristics which service industries pursue are associated with the "office professional" group within the overall workforce.

Following are six formal hypotheses, which presume specific verifiable relationships between particular workforce characteristics and office space.

Hypothesis #1: The amount of office space in a given area is positively related to aggregate measures of income, education, and number of managerial and professional workers.
Hypothesis #2: The amount of office space in a given area is negatively related to the number of clerical/technical workers.

Hypothesis #3: The amount of office space in a given area is positively related to the number of workers employed in business and professional services.

Hypothesis #4: The amount of office space in a given area is negatively related to the number of workers employed in manufacturing.

Hypothesis #5: The amount of office space in a given area is negatively related to the number of females in the workforce.

Hypothesis #6: The amount of office space in a given area is negatively related with the number of African Americans residents.

The functional relationships, discussed above, between office space and workforce characteristics, wherein a change in one such characteristic (now taken as an independent variable or predictor) causes (in a mathematical sense) a change in the other (dependent or predicted variable). Given the nature of the hypothesized relationships listed above, analysis using multiple regression is appropriate. Regression analysis is probably the most widely used technique in all the social sciences, including geography.
It should be stressed, however, that issues of scale and measurement are critical in the context of this research problem and so deserve some special attention. Firstly, "workforce" as a term is an aggregate characteristic applicable to substantively (people working in a particular industry) and/or spatially (workers living in a particular neighborhood) defined groups. Therefore, spatially aggregated units can be appropriately used in the analysis. Conventionally, the intrametropolitan spatial structure of the workforce in the U.S. is approximated by a grid of census tracts. The typical size of a census tract is small enough to provide "good" resolution and yet large enough for meaningful aggregation (Holmes and James, 1996). Accordingly, the census tract was adopted as the elementary (i.e., indivisible), but not necessarily the ultimate, spatial unit in this research.

Specifically, throughout this research, the term "office complex" refers to a building used for offices which is a real and observable physical element of the urban landscape. As such, it has a particular point-precise location. However, in the context of this research, undertaken at the census tract level, the exact location of office buildings within any given census tract is unimportant. Office space, i.e., the amount of area which
can be used to accommodate office workers, is an attribute of the office complex. This attribute is not only common to all office complexes, but is also qualitatively homogenous. In that respect, office space can be analytically "detached" from office buildings and manipulated independently of office buildings as a characteristic (feature) of an areal unit (census tract, in this case). Therefore, the office space of all the buildings located within a given census tract, can be aggregated into a single value. This value, then, is the total office space, measured in square feet, per census tract for any given year. In this way, for each census tract a "match" can be established between a set of workforce characteristics and the absolute amount of office space, with the latter hypothesized as being dependent upon the former.

In conventional specifications of such a model, values for both the independent and dependent variables for a particular census tract incorporated into the regression equation are going to be exactly equal to the values recorded for that particular census tract. With respect to the spatially referenced socioeconomic data, such an approach is justified in two cases. Firstly, when both the independent and dependent variables are functional attributes of the same "carrier", i.e., when the unit of
analysis is not an areal unit, but in fact a spatially defined group of people. Second, when the units of analysis are comprised of spatially closed systems such as countries or labor markets (Anselin, 1988b). Such a specification can legitimately be called functional, because the dependent variable is hypothesized to be a direct outcome or product of the independent variables. For example, the modeling of income returns to education (income as a function of education) is often done with spatially aggregated data (Clark and Avery, 1976). Both income and education are characteristics of people, and so a group of people can be conceived as "carriers" of these characteristics. What is important is that in this case, the functional relationship is entirely internalized, since all of these characteristics (dependent and independent variables) are recorded for the same group of people.

However, the functionality in the above example should not be extrapolated to apply to this study of office space and workforce characteristics. There are two reasons for this. Firstly, the amount of office space is not an attribute of the workforce, rather it is an attribute of a spatial unit (census tract). Secondly, and perhaps most importantly, each census tract is a small, arbitrarily defined unit which does not delineate urban space into
genuinely meaningful zones with respect to the office buildings. In response to these problems, there are three specifications which can be used as alternatives to the functional specification approach. Interestingly, each of these specifications represents a different theoretical perspective with respect to the relationships between workforce characteristics and volume of office space at any specific location.

Consider the “location decision perspective” which corresponds to a situation which emerges when a developer, informed about service industry workforce preferences, needs to determine a site (census tract) for a new office building. Naturally, the workforce for this new building is going to be drawn from surrounding areas and by no means exclusively from the reference census tract. So, the characteristics of the workforce from a set of tracts must be considered, rather than considering only the workforce characteristics for the census tract in which the office will be located. Such a set of contiguous census tracts (i.e., the surrounding area) represents a micro laborshed centered on a particular census tract. This means that under this specification, the amount of office space in each census tract must be matched with the workforce characteristics not only of the same tract, but rather
matched to a larger area consisting of several tracts. Since the importance of the workforce characteristics in any individual census tract in the estimation of the overall laborshed characteristics are naturally expected to decreases with distance (workers are less likely to commute long distances), observations for individual tracts should be weighted by distance from the reference census tract.

This is not a universally applicable approach, however, as relationships between office space and workforce characteristics can also be viewed from a different, "resident workforce" perspective. This second perspective requires the conceptualization of the office space as a resource which workers utilize. From this perspective, the more office space which is accessible (i.e., located nearby) to workers' residences, the more advantaged these workers are in terms of potential job opportunities. On the other hand, differences in accessible office space among different groups of workers would be indicative of the uneven distribution of office space with respect to the particular "type" of workers discussed previously (i.e., workforce characteristics). Such an approach, basically, poses a new, yet related, question within the context of the same problem. For the workforce of a census tract, accessible office space, naturally, is not limited to the office space
located within the same tract, but should also take into consideration nearby office stock in other census tracts. Therefore, under this specification, for any given census tract, the characteristics of the resident workforce must be matched with the office space accessible to that same workforce. Using a similar procedure as that described for the previous approach, accessible office space is estimated by discounting office space from remote census tracts by distance to these tracts through the use of the distance decay functions. This assumes that the odds of a worker finding employment in the offices in any given tract decreases with distance from the worker’s home census tract.

Following are several features of the “functional” perspective (one-to-one correspondence between tract-based workforce characteristics and office space) which illuminate the disadvantages of that approach and point to the necessity of using some alternative specifications. Firstly, office complexes cannot be, and in fact are not, located in every census tract. So, there is a chance that quite a few census tracts with “favorable” characteristics for office space will be dropped from an analysis since they are lacking office space. In reality, however, office buildings could be present in adjacent or nearby tracts, and they could draw labor from tracts without any office space.
Secondly, the workforce characteristics of a particular tract may not be representative of overall conditions in the area. From a developer’s prospective, such local "fluctuation" is insignificant; however, the use of the functional (one-to-one correspondence) specification forces a match between the observed office space and the characteristics of a potentially irrelevant workforce.

Although the first two alternative approaches to some extent eliminate the problems listed above, they also are not completely free of bias. For example, using the "workforce" approach, a locally "atypical" census tract (in terms of workforce characteristics) will be matched with the accessible (potential) office space; the latter, however, is related (i.e., hypothesized to be related) to "typical" census tracts. A similar problem is also present within the second approach. These problems can be resolved with the framework of a different, third approach, which can be most easily thought of as a combination of the first two.

The basic methodological difference in this research compared to previous research work in this area is the use of what may be called "pseudo continuous" variables on both sides of the equation. These pseudo continuous variable are obtained by the transformation of the original variables. The essence of this transformation is in generating values...
for each tract which are actually reconstitutions of the values of all dependent and independent variables taking into account the assumption that some distance decay function systematically operates on both. As was introduced earlier, for any given census tract there is corresponding aggregate amount of accessible office space (which may be conceived as an "office resource") and corresponding values for workforce characteristics of a laborshed centered on that tract. Both accessible office space and laborshed workforce characteristics can be viewed as, and in fact are, continuous surfaces representing the modeled spatial distributions of these phenomena. Therefore, the problem of the spatial relationships between the workforce (i.e., workforce characteristics) and office space should be treated as a determination of the degree of association or interaction between the two surfaces; not simply a process of matching single census tract dependent variables to single census tract independent variables as is commonly the case in this type of research.

3.2 The Relationships between the Length of Commute and Workforce Characteristics

3.2.1 Research Questions

Since the 1970s, the economic and spatial structures of American cities have changed dramatically. Hypothetically, commuting patterns to a great extent reflect the existing
distribution of employment centers and the existing
distribution of residential housing stock. If that is so,
then observed commuting patterns can be used as an
instrument to study urban spatial structure. Indeed, data on
commuting time from the U.S. Census can be viewed as direct
manifestations of the restructuring process.

With respect to commuting patterns, there are two
research questions which need to be answered:

(1) How are fundamental socioeconomic characteristics
of the workforce related to the length of commute?

And secondly,

(2) How have the relationships between workforce
characteristics and the length of commute changed over
time?

These questions emerge from the geographical (spatial)
theoretical approach proposed earlier in Chapter Two and are
specifically designed to address issues related to
contemporary changes in the urban economy and urban spatial
structure. There is sufficient evidence to expect the
emergence of new relationships between workforce
characteristics and length of commute (new commuting
patterns) in response to the changing spatial structure of
American cities. However, the exact nature of these
relationships is not yet clear. The following section
provides an account of prime factors in a study of these new trends in commuting.

3.2.2 The Emergence of New Trends in Commuting

New trends in commuting are believed to be associated with the sweeping changes occurring in the urban economies of U.S. cities. These changes have transformed the urban labor force and reconstituted spatial distribution of workplaces and homes. These changes are characteristic of most U.S. cities over the past two decades. In order to better appreciate these new trends, it is useful to contrast them with traditional patterns. In fact, the differences seem significant enough to justify a differentiation between what might be called the "new" and the "old" urban mode. Schematically, the urban mode synthesizes conditions of the urban spatial structure and urban economy.

The old urban mode applies to the characteristics of the U.S. cities during the time period from roughly 1900 to 1960. During this period, office workers constituted but a small portion of the workforce. Spatially, office buildings were confined to the CBD. Manufacturing dominated all other sectors, with factories and warehouses found in the central city and, somewhat later, in industrial zones at the metropolitan periphery. Industrial workers resided in nearby housing, whether in older inner-city neighborhoods or in
newer settlements, built for this specific purpose, near peripheral industrial zones. As white-collar employment grew, managerial (which includes owners) and professional workers began to suburbanize on a large scale. Particularly significant for this research, demand for clerical office personnel was largely met by women from the inner-city neighborhoods.

From these spatial distributions stemmed three particular commuting patterns detailed below:

(1) Social status (income, education, occupation) had a positive effect on the length of commute. Higher incomes were, and continue to be, associated with managerial and professional occupations. These occupations, in turn, increasingly required a college education. Managerial and professional jobs were, and still are, most typically found within the office employment sector. Since suburban residents were characterized by higher incomes, most of suburban workers had to engage in a daily commute to CBD-located white-collar office jobs. Due to the great geographical separation (both in terms of straight-line distances and travel time) between suburban neighborhoods and the CBD, the length of the commute for suburbia-resident highly-paid college-educated white-collar office workers was relatively high. This time/distance separation was
considerable, especially in comparison with the blue-collar workers in less prestigious (e.g., equipment operator, laborer) occupations. These latter occupations were typically characterized by lower incomes and lower educational requirements. For this group of workers, the location of blue-collar neighborhoods in close proximity to employment centers resulted in shorter daily commutes.

(2) Employment in the business services sector had positive effects on the length of commute, while employment in manufacturing had negative effects. Although white- and blue-collar jobs are present in every economic sector, there were (and continue to be) significant differences among sectors in terms of occupational composition. White-collar occupations comprise a large share of jobs in business and professional services, while blue-collar occupations dominate in goods-producing industries, particularly in manufacturing. Differences in occupational composition are, in turn, responsible for income and educational disparities between the sectors. Given the resulting correlation between measures of social status and employment sector, the latter appears to be consistently related to the length of commute, particularly when business and professional services are contrasted with manufacturing.
(3) Residence in the minority-dominated neighborhoods has a positive effect on the length of commute. These effects were attributed to a high degree of residential segregation for minorities and to a general lack of employment opportunities in the vicinity of more segregated minority neighborhoods.

Economic restructuring was manifested in the relative decline of manufacturing paralleled by the boom in the various service-type jobs. Specifically, the tremendous growth and suburbanization of office employment has lead to significant changes in the urban spatial structure. The conditions brought about by restructuring can largely be considered to represent a "new" urban mode.

The new mode started to develop during the 1970s and continues to evolve to the present. In contrast with the old mode, office employment makes up a large, and frequently the largest, share of the workforce. Simultaneously, the share of blue-collar workers in the labor force is decreasing. However, at the same time the share of clerical workers increases, largely, but not exclusively, due to higher female workforce participation rates.

Concurrent with the transformation in the labor force were the transformations in the physical work place. Office complexes grew in number and spread out. Although office
complexes can be located throughout any metropolitan area, they tend to be concentrated in middle- and upper-class suburbs. Suburban office complexes serve as magnets for other businesses, such as restaurants, hotels, and various retail and service enterprises (e.g., courier services, copy shops, dry cleaning). This results in a spatially clustered demand for jobs of all types in certain locations. Despite the fact that suburbanization now includes a wider range of income groups, the predominant pattern of outward sectoral growth practically results in the continuing polarization of social space (Adams, 1991). The new mode brought about four new relationships between particular workforce characteristics and length of commute. These are described below:

1. Social status now has a negative effect on the length of commute. The trend for the location of office complexes in middle- and upper-class suburban neighborhoods can be conceptually equated with a "relocation" and subsequent "dispersion" of prior CBD jobs to suburbia. Relatively short intra-suburban commutes increasingly replaced traditional downtown-bound commutes for many white-collar workers (Pisarski, 1987). Suburban office complexes now function as local "growth poles" attracting and stimulating office and non-office employment. In accordance
with the growth of white-collar managerial and professional jobs, office centers also now represent a considerable demand for less skilled/lower paid jobs. Not only are there greater opportunities for clerical positions and other office-support function occupations, but there are other opportunities as well, including many sales and service jobs at the many ancillary retail establishments which grow up around office complexes. This demand for labor is typically met by the residents of blue-collar and lower-income housing areas. Given that low-income housing is realistically "located" rather far away from suburban office centers, it follows that workers with lower incomes (which also entails less educational attainment and less prestigious occupations) now have to commute longer distances (and times) than was the case when the patterns of the "old" mode were dominant.

(2) Employment in business and professional service industries exhibits a negative effect on the length of commute. This means that workers employed in this sector have a relative "commuting advantage" over workers in other sectors. Business and professional services have emerged as almost totally office-based industries with a large, and perhaps the most influential, share of their workforce represented by managers and professionals. In this respect,
predictions about commuting patterns for managers and professionals can be extrapolated from occupationally-based differentiation to sectoral differentiation.

(3) Residence in minority-dominated neighborhoods has a positive effect on the length of commute. Although the progress of de facto residential desegregation and suburbanization of minorities in most American cities may reduce racial commuting inequality over time, it nevertheless most clearly persists at the present time. This is genuinely credited to the continuing absence of workplaces close to minority-dominated communities (Kasarda, 1985, 1988).

(4) A high percent of females in the workforce has negative effect on the length of commute. Participation of women in the workforce has increased considerably over the past several decades. It also has been established in the individual-level studies that women tend to have shorter commutes than men. This phenomenon is explained by women’s preference for shorter work trips on one hand, and by the location strategies of clerical-intensive businesses which are specifically targeting female labor pools on the other. Therefore, it is expected that at the aggregate level, a higher percentage of women in the workforce would contribute to shorter commuting length.
3.2.3 A Model of Socioeconomic Commuting Determinants

The new trends in commuting, described in detail in the previous section, appear as theoretically predicted outcomes in the face of the changes in urban spatial structure and urban economy in contemporary cities in the U.S. It is essential, however, to test these predictions empirically. Propositions regarding relationships between the length of commute and workforce characteristics can be tested with the use of a formal statistical model. A functional link can be established between the two phenomena in such a way that workforce characteristics appear as determinants of the length of commute. This model, then, quantitatively describes the situation in which increases or decreases in the parameters identified for workforce characteristics are consistently reproduced in the length of commute. Multivariate regression technique provides statistical analytical tool adequate to the goals of such analysis.

The research assumptions described above will now be reformulated into more rigorously stated hypotheses which are subject to evaluation depending on the outcome of statistical tests. Five hypotheses, which emerge from a careful review of literature and my own opinions, will be tested using 1980 and 1990 U.S. Censuses data on Harris County, TX, while using census tracts as units of analysis.
Hypothesis #1: The length of commute is negatively related with measures of income, education, the percentage of managerial/professional workers, and the percentage of employed in business and professional services.

Hypothesis #2: The length of commute is positively related with the percentage of clerical/technical workers.

Hypothesis #3: The length of commute is negatively related with the percentage of employed in manufacturing.

Hypothesis #4: The length of commute is negatively related with the percentage of females participating in workforce.

Hypothesis #5: The length of commute is positively related with the percentage of African Americans in the resident population.

3.3 The Relationships between Housing Values and Office Space

The first two sections of this chapter focused on a discussion of research questions and the formulation of hypothesis pertinent to a greater understanding of the relationship between office space and the intrametropolitan workforce. In both sections, office space is treated as the place of work, that is the "destination" in the journey-to-work trip. However, office buildings also exist as physical elements of the urban landscapes. Office space represents one of many possible forms of urban land use. Massive
suburbanization and decentralization of office buildings in the last several decades have significantly altered urban landscapes and modified urban land use patterns. Of course, the implications of these changes are numerous, many of them are related to the issues of urban planning and to urban real estate market. However, at the root of many of these transformations is the market mechanism which determines land and housing values. This final section outlines the research questions and formulates hypotheses pertaining to the effects which office buildings exert upon the intrametropolitan housing and land values.

3.3.1 Research Questions

The fundamental research question which needs to be answered here is related to the effect of the presence of office buildings on land and housing values. In short, does office space have systematic influence over land and housing values? If this is so, then are these influences positive or negative?

With respect to the potential effects of office buildings on housing/land values, there are three different mechanisms hypothesized to be at work. Each of these mechanisms of value formation operate on different dimensions of office complexes. Office complexes can be
viewed as employment centers, as a particular land use, and as a real estate investment.

Since employment in office-stationed jobs constitutes a significant share of overall urban employment, living in proximity to office space can be viewed as a benefit for most urban residents. Therefore, it might be expected that, due to commuting convenience, an extra premium is being placed on land and housing located in the vicinity of office complexes.

Besides commuting benefits, office land use, unlike industrial land use, is believed to have positive externalities. Inversely, a negative externality for industrial land use means that factories and warehouses are generally considered unpleasant "neighbors" for residential housing (Segal, 1974). Accordingly, housing and land values are generally lower in areas with proximate industrial land use. Office complexes, on the other hand, are hypothesized to have positive externalities. Living close to office space is typically perceived as a desirable amenity, or at the least, not damaging to either neighborhood image or property values. Such positive externalities, in turn, are hypothesized to translate into an additional premium placed on land and housing values in areas where office complexes can be found. Therefore, the presence of significant amounts
of office space in any given census tract is likely to exert upward influence on land and housing values.

The third source of premiums placed on the value of housing and land located in the vicinity of office complexes is associated with the operation of the speculative land market (Feagin, 1982). Once an office complex is built, there is typically a good chance that more development will take place around it. This expectation of future development, i.e., future profits, is thought to practically translate, in turn, into higher land and housing prices (Thibodeau, 1990).

Therefore, theoretically, there seem to exist at least three mechanisms which could be responsible for higher land and housing values in neighborhoods located in proximity to office complexes. However, this theoretical preposition also requires an empirical test.

### 3.3.2 A Model of Office Space Effects on Housing Values

To test the effects of office space on housing/land values, a model is proposed wherein changes in proximate office space are hypothesized to be a predictor for changes in the housing values. Since land values are closely related to housing values (Muth and Goodman, 1989), it is acceptable to use the latter as a proxy for the former. Henceforth, the two concepts are used interchangeably.
The modeling of housing values is typically carried out with the use of the so-called hedonic regression technique (see Chapter 2). In such a model, the price of an individual house is seen as contingent on a number of internal and external characteristics, including the size of the building, its age, neighborhood quality, and proximity to various urban nodes. In the absence of the disaggregate data for housing stock and prices, a model can be constructed using aggregate data (median value of owner occupied housing for census tracts) on housing values which can be derived from the U.S. Census of Population and Housing.

The purpose of the hedonic regression model is to estimate implicit prices of various components of services and amenities which together make up the value of housing. However, the purpose of the model used in this research is slightly different. It is to investigate the direct effect of office space on housing values within any given area. At any given point in time, an actual housing value is expected to depend largely on structural characteristics of the building and on neighborhood characteristics. Therefore, proximity to office space in itself, compared to other factors, should be assumed to contribute a relatively small portion of “explanation” to actual housing values. However, influence of office space on property values might be more
pronounced when changes over time are considered. Accordingly, a model is formulated in which change in the absolute amount of proximate office space appears as a predictor for changes in the median value of owner-occupied housing. The preference for a dynamic model (change over time) over a static model relationship at a given moment in time) is also justified by the consideration that these influences on the market value of property only appear after some period of time, i.e., with a lag. In short, the market is hypothesized to make adjustments, but not immediately. It takes time for the mechanisms of workplace accessibility, positive externality, and expectations of future development to start functioning. Therefore, it is expected that changes in proximate office space and housing values proceed in the same direction.

The formal hypothesis which will be tested in Chapter Six is that for any given census tract in Houston, TX, changes in proximate office space over time (1970, 1980, and 1980) have positive effects on changes in the housing values.

3.4 Summary

In this Chapter, the qualitative issues associated with the interaction between the workforce and office space (sections 3.1 and 3.2) and between office and housing values
(section 3.3) are introduced. Later in the discussion, in Chapter Five, the methodology by which these issues will be quantitatively evaluated will be described. Before this, however, the study area of this research—the city of Houston, TX and the associated Harris County—are introduced so that the subsequent analyses can be placed in their appropriate historical, geographical, and socioeconomic contexts.
4.1 Introduction

As stated in Chapter One, the study area for this research is Harris County, TX, which incorporates the city of Houston and most of the city’s suburbs. The purpose of this chapter is to provide basic geographical, historical, and economic information about the city and the county.

Harris County occupies 1,729 square miles in the southeastern part of the state of Texas (Figure 4.1). In terms of physical geography, Harris County lies within the Gulf Coastal Plain physiographic region (Birdsall and Florin, 1992). Although technically the county does not border on the Gulf of Mexico, the southeastern section of the county faces the Galveston Bay, one of the major harbors along the Texas portion of the Gulf of Mexico.

The city of Houston occupies the central part of Harris County (Figure 4.2). Houston exhibits political and administrative dominance over the entire county and, in fact, on portions of several adjacent counties as well. The administrative dominance is due to Houston’s extraterritorial jurisdiction (ETJ) which extends five miles from the city’s corporate limits and allows annexation of new areas by simple ordinance (Thomas and Murray, 1991). Because of the ETJ policy, instituted in 1963 (Palmer and
Figure 4.1 Location of Harris County Relative to the U.S. and the State of Texas
Place names associated with numbers are given in Table 4.1

Figure 4.2 Administrative Divisions of Harris County
Rush, 1976), Houston’s growth has not experienced any serious obstacles of a political nature. As a consequence, the city’s official size increased from 83.7 square miles in 1948 to 556.4 square miles in 1990.

In addition to Houston, there are several other “cities” in the Harris County. Some of them, for example, Bunker Hill, Bellair, and West University Place, encircled by Houston (Figure 4.2 and Table 4.1). In reality, however, Houston and these smaller independent entities comprise a seamless urban landscape (Palmer and Rush, 1976; Feagin, 1988), thus making a strong case for the selection of the county and not merely the city of Houston as the appropriate geographical universe (in a statistical sense) for this research.

In the span of approximately a century and a half, the population of Harris County grew from 4.7 thousand in 1850 to 2.8 million in 1990 (Table 4.2). Since their founding, the city and the county exhibited strong growth dynamics. Of course, this growth is related to dynamic regional and urban economies which will be discussed shortly. As of the latest national census, Harris is the third most populous county in the United States (after Los Angeles County, CA and Cook County, IL). The population of Houston proper in 1990 was
Table 4.1 Names and Population of Incorporated Places in Harris County, 1990

<table>
<thead>
<tr>
<th>On Map</th>
<th>Place Name</th>
<th>Population in Harris County</th>
<th>Population outside Harris County*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aldine</td>
<td>11,133</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Barrett</td>
<td>3,052</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Baytown</td>
<td>61,126</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bellaire</td>
<td>13,842</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Bunker Hill Village</td>
<td>3,391</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Channelview</td>
<td>25,564</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Cloverleaf</td>
<td>18,230</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crosby</td>
<td>1,811</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Deer Park</td>
<td>27,652</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>El Lago</td>
<td>3,289</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Friendswood</td>
<td>7,835</td>
<td>14,979</td>
</tr>
<tr>
<td>12</td>
<td>Galena Park</td>
<td>10,033</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Hedwig Village</td>
<td>2,616</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Highlands</td>
<td>6,632</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Hillshire Village</td>
<td>665</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Humble</td>
<td>12,080</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Hunters Creek Village</td>
<td>3,954</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Jacinto City</td>
<td>9,343</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Jersey Village</td>
<td>4,826</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Katy</td>
<td>6,453</td>
<td>1,552</td>
</tr>
<tr>
<td>21</td>
<td>Kingwood</td>
<td>37,350</td>
<td>47</td>
</tr>
<tr>
<td>22</td>
<td>La Porte</td>
<td>27,910</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>League City</td>
<td>133</td>
<td>30,026</td>
</tr>
<tr>
<td>24</td>
<td>Mission Bend</td>
<td>10,750</td>
<td>14,195</td>
</tr>
<tr>
<td>25</td>
<td>Missouri City</td>
<td>3,957</td>
<td>32,219</td>
</tr>
<tr>
<td>26</td>
<td>Morgans Point</td>
<td>341</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Nassau Bay</td>
<td>4,320</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Pasadena</td>
<td>119,363</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Pearland</td>
<td>1,463</td>
<td>17,234</td>
</tr>
<tr>
<td>30</td>
<td>Piney Point Village</td>
<td>3,197</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Seabrook</td>
<td>6,685</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Sheldon</td>
<td>1,653</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Shoreacres</td>
<td>1,316</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>South Houston</td>
<td>14,207</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Southside Place</td>
<td>1,392</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Spring</td>
<td>33,111</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Spring Valley</td>
<td>3,392</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Stafford</td>
<td>307</td>
<td>8,090</td>
</tr>
<tr>
<td>39</td>
<td>Taylor Lake Village</td>
<td>3,394</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Tomball</td>
<td>6,370</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Waller</td>
<td>170</td>
<td>1,323</td>
</tr>
<tr>
<td>42</td>
<td>Webster</td>
<td>4,678</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>West University Place</td>
<td>12,920</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Houston</td>
<td>1,603,524</td>
<td>27,029</td>
</tr>
<tr>
<td></td>
<td>Unincorporated</td>
<td>682,809</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Harris County</td>
<td>2,818,199</td>
<td></td>
</tr>
</tbody>
</table>

* This column reports the population residing outside of Harris County for incorporated places which corporate limits cross county boundaries.
Table 4.2 Population Growth in the city of Houston and Harris County, TX, 1850-1990

<table>
<thead>
<tr>
<th>Year</th>
<th>Harris County</th>
<th>City of Houston</th>
</tr>
</thead>
<tbody>
<tr>
<td>1850</td>
<td>4,668</td>
<td>2,396</td>
</tr>
<tr>
<td>1860</td>
<td>9,070</td>
<td>4,845</td>
</tr>
<tr>
<td>1870</td>
<td>17,375</td>
<td>9,382</td>
</tr>
<tr>
<td>1880</td>
<td>27,985</td>
<td>16,513</td>
</tr>
<tr>
<td>1890</td>
<td>37,249</td>
<td>27,557</td>
</tr>
<tr>
<td>1900</td>
<td>63,786</td>
<td>44,639</td>
</tr>
<tr>
<td>1910</td>
<td>115,693</td>
<td>78,800</td>
</tr>
<tr>
<td>1920</td>
<td>186,667</td>
<td>138,276</td>
</tr>
<tr>
<td>1930</td>
<td>359,328</td>
<td>292,352</td>
</tr>
<tr>
<td>1940</td>
<td>528,961</td>
<td>384,514</td>
</tr>
<tr>
<td>1950</td>
<td>806,701</td>
<td>596,163</td>
</tr>
<tr>
<td>1960</td>
<td>1,243,158</td>
<td>938,219</td>
</tr>
<tr>
<td>1970</td>
<td>1,741,912</td>
<td>1,232,407</td>
</tr>
<tr>
<td>1980</td>
<td>2,409,547</td>
<td>1,595,138</td>
</tr>
<tr>
<td>1990</td>
<td>2,818,199</td>
<td>1,630,553</td>
</tr>
</tbody>
</table>

1.6 million which currently ranks fourth among the American cities (after New York, Los Angeles, and Chicago).

4.2 A Brief History of Houston

Houston's formal history commenced in 1836, when brothers Gus and John Allen bought 6,600 acres of land located at the confluence of the Buffalo and White Oaks Bayous and began marketing these marshy acres to commercial capitalists and ordinary settlers as a site destined to become "the great commercial emporium of Texas" and the seat of the government of the new Texas Republic (McComb, 1981).

Although Houston was the capital of Texas for only three years (1836 to 1839), the Allen brothers correctly predicted the city's future economic fortunes. During the remainder of the 19th century, the city grew rapidly and indeed became a major commercial and transportation center for the emerging southern Texas agricultural economy. Cotton, sugar cane, grain, and lumber were the principal items of trading, processing, warehousing, and shipping. The latter was done mostly via numerous rail roads which not only connected Houston to the rural hinterlands upon which it was dependent, but also to distant markets on both coasts via transcontinental routes.

Throughout the 19th century however, Houston was in direct and fierce competition for regional dominance with
Galveston, located some 50 miles southeast of Houston on Galveston Island. By the end of the 19\textsuperscript{th} century, Galveston had developed into a major port and a trade center. The viability of Galveston is explained, to a great extend, by the city's more favorable climate. Due to the ocean breeze, Galveston had a more amenable climate than in-land swampy Houston. Fortunately, at least for Houston, this rivalry ended in September of 1900, when the entire city of Galveston was literally leveled by a devastating hurricane and associated flooding (Writer's Program, 1942).

The discovery of rich oil deposits east of Houston in 1905 marks the beginning of the transformation of Houston from a regional agricultural center into a national- and world-class center for the petroleum industry. At this early stage, the presence of pre-existing transportation and commercial facilities (e.g., rail depots, warehouses), as well as business services (e.g., banking, law firms) in Houston played a major role in attracting oil business to the city (Shelton et al., 1989). Just a few year later, in 1914, Houston's position as an oil center was reinforced with the opening of the Houston Ship Channel, which linked the city to the Gulf of Mexico and ultimately to the world economy (Fleming, 1989).
Although the mining industry in Houston is popularly associated with oil and gas, the extraction of other minerals, such as sulphur, salt, and lime, has always been important in this area. In fact, mining for sulphur and other non-fuel minerals started in the late 1880s, actually predating drilling for oil and gas. To some extent, the presence of these other mining industries in Houston served as an additional factor in attracting oil business operations to the city (Feagin, 1988).

In the 1910s and 1920s, in response to the demand of the rapidly expanding automobile industry for motor fuel and lubricants, numerous oil refineries and petrochemical facilities were built in the Houston area. This created a solid manufacturing base for the city (Hill and Feagin, 1987). It should be recognized, however, that manufacturing, although an important sector, did not dominate the Houston economy. The city had an occupationally balanced workforce, with a large administrative and professional workforce, a large manufacturing workforce, and a large commercial workforce (Shelton et al., 1989).

During the 1930s, many new oilfields were discovered in eastern Texas. These discoveries helped the city maintain admirable economic and demographic growth even through the worst years of the Great Depression (McComb, 1981).
Construction of new petrochemical facilities, as well the expansion of the related infrastructure, continued. By the end of the decade, the Gulf Coast (Texas and Louisiana) had emerged as the dominant southern oil refining region, accounting for a full third of the U.S. refining capacity (Feagin, 1988).

Federal expenditures played a great role in the development and expansion of Houston's petrochemical industry as government purchases of such strategic commodities as fuel, lubricants, and synthetic rubber skyrocketed during WWII (Feagin, 1988). Also during the war years, two major oil pipelines were built connecting Houston with the East Coast. Ironically, for a city which has become something of an icon of the free-market economy, Houston has received, throughout the twentieth century, substantial support from the federal government. In addition to subsidies and transfers of capital typical of all large U.S. cities, in the case of Houston, further support for the city came in the form of contracts for commodities and direct investments in industrial and transportation infrastructure (Feagin, 1984a).

After the war, the growing national economy, and the massive shift to personal automobiles in particular, provided robust opportunities for growth. Demand for energy
and petrochemical products such as gasoline, rubber, asphalt, fertilizers, and plastics skyrocketed. This demand contributed to the expansion of Houston’s chemical and oil industries as well as to the further development of related transportation and business service industries in the postwar era.

In the 1960s and 1970s, major oil companies began to locate and re-locate their rapidly growing business and research divisions in Houston (Feagin, 1988). Following the oil “majors” came hundreds of small ancillary geological, engineering, accounting, law, and other service firms. The agglomeration effects associated with these major firms significantly increased the white-collar workforce in the Houston area.

In particular, the growth of the white-collar workforce bears significantly on this research. Besides the concentration in Houston of oil-related business during this period, another significant event was the creation of the NASA space complex which employed thousands of white-collar workers (McComb, 1981).

By the mid-1970s, Houston had evolved into a business and technology center for global oil and gas markets, providing products and services for oil and gas exploration from the North Sea to Malaysia (Feagin, 1985a). Because of
these cultivated international connections, Houston’s economy experienced a boom during the 1973-1975 “energy crisis.” As a result of that boom, Houston’s economy became less diversified and, consequently, more vulnerable to fluctuations in the oil market (Feagin, 1988). Following yet another boom in the late 1970s came a drastic drop in the price of oil in the early 1980s. This retrenchment, in turn, had diverse negative affects for the city manifested in increased unemployment, business failures, and mortgage foreclosures (Feagin and Beauregard, 1990).

After a brief and slight recovery which lasted just a few years, the city went into a severe economic recession during the mid-1980s. Again, this decline was associated with low prices for oil and gas. Many oil-related companies went out of business and the unemployment rate further increased. However, as oil prices began to recover in the late 1980s, so did the Houston economy (Rice, 1991).

Due to the dominant role of the oil business in the city’s economy, Houston has kept, and even expanded, its functions as a major transportation node. The port of Houston is the number one in imports among all U.S. ports, and ranks second in total cargo tonnage (The World Almanac, 1995). The major import categories are oil, steel, and transportation equipment. The major export categories at the
present time are heavy machinery, petrochemical products, and grain.

The developments in the Houston economy over the last few decades are well reflected in the changing occupational and sectoral structures of the workforce for Harris County, TX, presented in Table 4.3. In terms of sectoral employment, the most radical changes occurred within manufacturing and services—tracking this pattern in virtually all major U.S. cities for the same period. Over the last 30 years, the share of workers employed in manufacturing dropped from almost a quarter of the workforce to just under 14 percent. These manufacturing “losses” were gains, however, for the service industry which grew from 22.7 percent in 1960 to 32.4 percent in 1990. Also noteworthy is the steady growth of the employment share for finance, insurance, and real estate (conventional acronym FIRE). The FIRE industries, in fact, all belong to a broadly defined service or quaternary sector. Employment in other sectors, although reflecting some temporal fluctuations, has remained relatively stable over time.

The same counter movement of manufacturing and services is reflected in the dynamics of the occupational structure. The percentage of workers employed in professional and technical as well as managerial occupations increased over
Table 4.3 Sectoral and Occupational Structures of the Workforce in Harris County, TX

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Workforce</td>
<td>422,030</td>
<td>711,749</td>
<td>1,224,828</td>
<td>1,381,829</td>
</tr>
<tr>
<td>Employment by Sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(percent of the total)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Industries</td>
<td>4.12</td>
<td>3.64</td>
<td>5.23</td>
<td>4.48</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>24.13</td>
<td>20.10</td>
<td>18.09</td>
<td>13.52</td>
</tr>
<tr>
<td>Construction</td>
<td>8.27</td>
<td>8.90</td>
<td>10.25</td>
<td>8.26</td>
</tr>
<tr>
<td>TCPU</td>
<td>10.21</td>
<td>7.97</td>
<td>8.38</td>
<td>8.11</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>6.64</td>
<td>6.28</td>
<td>6.33</td>
<td>6.20</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>17.55</td>
<td>16.56</td>
<td>15.13</td>
<td>16.77</td>
</tr>
<tr>
<td>FIRE</td>
<td>5.66</td>
<td>5.89</td>
<td>6.73</td>
<td>7.39</td>
</tr>
<tr>
<td>Services</td>
<td>22.68</td>
<td>27.20</td>
<td>27.23</td>
<td>32.44</td>
</tr>
<tr>
<td>Public Administration</td>
<td>0.73</td>
<td>3.46</td>
<td>2.61</td>
<td>2.85</td>
</tr>
<tr>
<td>Employment by Occupation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(percent of the total)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional and Technical</td>
<td>13.45</td>
<td>16.94</td>
<td>16.64</td>
<td>19.43</td>
</tr>
<tr>
<td>Managerial</td>
<td>10.72</td>
<td>8.91</td>
<td>12.40</td>
<td>14.07</td>
</tr>
<tr>
<td>Clerical</td>
<td>17.14</td>
<td>19.62</td>
<td>19.25</td>
<td>16.70</td>
</tr>
<tr>
<td>Sales</td>
<td>8.40</td>
<td>8.75</td>
<td>11.41</td>
<td>13.16</td>
</tr>
<tr>
<td>Skilled Industrial</td>
<td>14.86</td>
<td>14.63</td>
<td>14.95</td>
<td>11.47</td>
</tr>
<tr>
<td>Unskilled Industrial</td>
<td>21.76</td>
<td>18.61</td>
<td>15.24</td>
<td>12.39</td>
</tr>
<tr>
<td>Service</td>
<td>13.67</td>
<td>12.55</td>
<td>10.10</td>
<td>12.78</td>
</tr>
</tbody>
</table>

time, from a combined 24.2% in 1960 to 33.5% in 1990. Inversely, the percentage of workers in industrial (both skilled and unskilled) occupations dropped dramatically over the same period from 51.5% to 23.9%. To avoid confusion perpetuated by the U.S. Bureau of the Census, it should be noted that the category "service occupations" in Table 4.3 only partially overlaps with "service industries." "Service occupations" primarily include protective and personal service occupations, such as police, firefighters, cleaners, and the like, while the category of "service industries" is essentially comprised of business and professional services.

A description of Houston and Harris County will not be complete without a brief up-to-date demographic and socioeconomic sketch. Some of the most important characteristics are presented in Table 4.4. This table also incorporates the U.S. national averages which are useful for comparative and contrastive purposes. In terms of ethnic and racial compositions, Houston and Harris County have considerably higher percentage of African Americans and Hispanics in total population than the U.S. taken as a whole. Both African Americans and Hispanics are relatively more concentrated in the city than the county. Figure 4.3 illustrates that areas with highly-segregated African-American neighborhoods are situated to the north-east and to

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Table 4.4 Demographic and Socioeconomic Characteristics for the City of Houston and Harris County in Comparison with the U.S. Averages

<table>
<thead>
<tr>
<th></th>
<th>City of Houston</th>
<th>Harris County</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent in the Population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blacks</td>
<td>28.1</td>
<td>19.2</td>
<td>12.1</td>
</tr>
<tr>
<td>Hispanics</td>
<td>27.6</td>
<td>22.9</td>
<td>9.0</td>
</tr>
<tr>
<td>Ages under 18</td>
<td>26.7</td>
<td>28.5</td>
<td>25.6</td>
</tr>
<tr>
<td>Ages 18-65</td>
<td>65.1</td>
<td>64.4</td>
<td>61.8</td>
</tr>
<tr>
<td>Ages over 65</td>
<td>8.2</td>
<td>7.1</td>
<td>12.6</td>
</tr>
<tr>
<td>Median Household Income</td>
<td>$26,261</td>
<td>$30,970</td>
<td>$30,056</td>
</tr>
<tr>
<td>Percent of Residents over 25 Years Old with College Education</td>
<td>25.1</td>
<td>25.4</td>
<td>20.3</td>
</tr>
<tr>
<td>Percent of Families with Income below Poverty Level</td>
<td>17.2</td>
<td>12.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Housing Units Built after 1970</td>
<td>48.1</td>
<td>58.0</td>
<td>42.5</td>
</tr>
<tr>
<td>Unemployment Rate</td>
<td>6.1</td>
<td>5.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Source: County and City Data Book: 1994.
Figure 4.3 Distribution of African-American Population in Harris County, 1990
the south from the center of the city. Neighborhoods with high concentrations of Hispanic population, according to Figure 4.4, are located mostly in the eastern and northern parts of the city.

The demographic and economic data reported in Table 4.4 reveal an interesting situation. The percentage of the population of working age (18 to 65) in Harris County (and Houston alone) and the percentage of college-educated residents are greater than the national averages. The unemployment rate in both entities is lower than for the entire U.S.

Still, Houston faces the plethora of social and economic problems faced by all major U.S. cities at the present time. Despite the generally positive economic and demographic indicators noted above, the median household income in Houston is lower than the national median (although somewhat higher for the county as a whole). At the same time, the percentage of families with incomes below the poverty level is significantly higher than the U.S. average, especially for the city proper. This fact is clearly supported by the map presented on Figure 4.5: wealthy neighborhoods form an archetypal ring of “suburban prosperity” around the lower income neighborhoods of the central city. An important addition to this pattern,
Figure 4.4 Distribution of Hispanic Population in Harris County, 1990
Figure 4.5 Median Household Income in Harris County, 1990
however, is the presence of high-income neighborhoods in the area immediately to the west of the CBD.

4.3 The Spatial Structure of Houston

Circa 1910, with a population of fewer than 80,000 residents, much of the city was within a mile from the small downtown, which had only a few shops and office buildings. North of the downtown area, extensive railroad yards and repair facilities, so important to the city's early growth, were concentrated. The construction of oil refineries in the 1920s occurred along the ship channel, east of the downtown, and stimulated the eastern and southeastern direction of the city's growth. Specifically, blue-collar residential housing was built near the refineries and rail yards. In the same period, housing for white-collar workers started to appear to the west side of the downtown district, in neighborhoods well removed from the refineries to the east and rail yards in the north (e.g., the current West University neighborhood). Shelton et al. (1989) suggested that the present vernacular division of Houston into the blue-collar East and white-collar West has its origin in this early period. The 1990 census data to a considerable extent support that vernacular division of Houston. According to the maps presented on Figures 4.6 and 4.7, college-educated population (proxy for white-collar workforce) clearly
Figure 4.6 Distribution of College-Educated Population in Harris County, 1990
Figure 4.7 Distribution of Workers Employed in Manufacturing, 1990
predominates in the western section of the county, while workers employed in manufacturing (proxy for blue-collar workforce) are concentrated in the east.

Throughout most of its history, Houston's physical growth correlates highly with economic and management changes in the oil and gas industry. As mentioned above, the construction of oil refineries in the 1920s spurred development in the eastern sector. New petrochemical facilities, built during WWII, provided an additional impulse to the eastern and southeastern directions of growth. As mentioned earlier, the location of corporate headquarters and oil-related service businesses in Houston started on a massive scale in the 1970s. This trend resulted in the intensification of non-industrial development in the western, and especially the southwestern, sections of the city.

The development of the interstate highway system, which started in the 1950s, provided Houston with major freeways running north-south and west-east from the city center (Figure 4.8). These highways provided the transport framework which would prove to be vital to the outward expansion of the city. As in a typical American city, the modern road network in Houston appears as a combination of radial and circumferential highways (Hughes and Sternlieb,
Figure 4.8 Major Roads in Harris County
1988). Interstate highways 10 and 45 are the major spokes of this gigantic "wheel" (Figure 4.8). A circular freeway (Loop I-610) was constructed around the older, central part of the city. Beltway 8 and Farm-to-Market road 1960 (not completely closed yet) are the two other circumferential roads positioned approximately 13 and 18 miles respectively from the CBD. Apart from Intestates 10 and 45, State Highways 225 and 288 and U.S. Highways 59 and 290, are the most significant of the radial roads in Houston transportation system.

Since the 1960s, large-scale development on the one hand and decentralization on the other have been characteristic for Houston's internal growth. The development of Houston often proceeded in what might be described as an unsystematic, "leap-frog" fashion, which created pockets of commercial and residential concentration, while leaving large tracts of land undeveloped between such concentrations (Mieszkowski and Smith, 1991).

The system of circumferential and radial freeways in Houston, as well as in other American cities, plays a major role in channeling and organizing suburban development. Large suburban centers and individual office buildings tend be located along the freeways. The intersections of radial and circular roads are particularly attractive to non-
resident development because of the strategic location in the transportation network (Hartshorn and Muller, 1986).

Despite the high degree of recent decentralization characteristic of urban development in Houston, numerous centers of office and retail activities have developed. This multi-centered, or "polynucleated", pattern of urban development is reasonably attributed to the presence of the massive freeway network, the lack of restrictions on development (absence of formal zoning regulations), and the availability of private investment capital for large-scale construction projects (Feagin, 1988; Garreau, 1991).

These centers (or "nucleations") vary in size, from small clusters of three or four office buildings to gigantic, "downtown-like formations" (with five or more million square feet of leasable office space) but yet within suburban settings. This pattern of growth has been popularized by J. Garreau, who coined the term "edge cities." According to Garreau (1991), "edge cities" in Houston are not only representative of the national trend in urban development, but some of them, for example Galleria and Greenway Plaza, also appear as some of the largest suburban centers in the U.S. The location of Houston's "edge cities" and major business activity centers (Figure 4.9) reflects a distinctive westerly bias. As discussed in
Figure 4.9: Edge Cities and Secondary Business Centers in Houston
Chapter Three, one of the hypothesis of this research is that this locational bias of contemporary office development is a direct reflection of the labor-targeting strategies of service industries.

Since this research deals with the transformations associated with the growth and suburbanization of office space, a descriptive chapter on Houston can also not be complete without a brief history of office development in the city and county. The first multi-story office buildings, located downtown, appeared in Houston towards the end of the 19th century. Initially, they were built for leading cotton trading firms (McComb, 1981). Following the oil boom in the early 1900s, which saw ever more construction, the buildings owned and used by oil corporations came to dominate the city's downtown (Feagin, 1988). As oil and petrochemical industries grew, they required progressively more office space. As a reflection of this demand for office space, the construction of office buildings in the downtown continued at a varying pace, concurrent with booms and busts in the industry, through the first half of the 20th century (Table 4.5).

An important note about Table 4.5 is that the reported data are for leasable office space only. Office buildings owned and occupied exclusively by a single tenant
Table 4.5 Historical Growth of Leasable Office Space in Houston

<table>
<thead>
<tr>
<th>Year</th>
<th>Million Square Ft. by the Date</th>
<th>Percent Increase over Previous Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>1910</td>
<td>0.77</td>
<td>394</td>
</tr>
<tr>
<td>1920</td>
<td>1.09</td>
<td>142</td>
</tr>
<tr>
<td>1930</td>
<td>3.91</td>
<td>357</td>
</tr>
<tr>
<td>1940</td>
<td>4.43</td>
<td>113</td>
</tr>
<tr>
<td>1950</td>
<td>5.00</td>
<td>112</td>
</tr>
<tr>
<td>1960</td>
<td>8.25</td>
<td>165</td>
</tr>
<tr>
<td>1970</td>
<td>18.73</td>
<td>227</td>
</tr>
<tr>
<td>1980</td>
<td>69.62</td>
<td>377</td>
</tr>
<tr>
<td>1990</td>
<td>139.5</td>
<td>200</td>
</tr>
</tbody>
</table>

(typically, headquarters of large corporations) are not reported in Black’s Guide because that type of office space is not available for lease. Consequently, office space of such buildings is not included in the calculations. However, prior research (Rice Center, 1984; Feagin, 1988) has estimated that in Houston leasable office space makes up 85% of the total office space (this is also true for overall U.S. office stock). Using this ratio, the data for leasable office buildings were adjusted to reflect total office space and then matched against the published annual totals (Feagin, 1988). Thus calculated, total office space differed from the published estimates by no more one or two percent for any given time period.

The traditional dominance of Houston’s downtown as the preferred site for office buildings continued through the end of the 1950s. Beginning in the 1960s, population and industrial growth were matched by a considerable expansion of office space. Most importantly, beginning in the late 1960s and early 1970s, progressively more office complexes were being constructed beyond the limits of the CBD, i.e., in suburban locations. Figures 4.10 through 4.13 illustrate the trend in the location of offices complexes in Houston over the last four decades. A review of these maps, which are based on the information derived from the Black’s Guide,
Each star denotes an individual office building

Figure 4.10 Office Buildings Built before 1960
Figure 4.11 Office Buildings Built from 1960 to 1969

Each star denotes an individual office building.
Each star denotes an individual office building.
Each star denotes an individual office building.

Figure 4.13 Office Buildings Built from 1980 to 1990.
not only reflects the rapid growth of office complexes, but also testifies to the remarkable western orientation of office space suburbanization in the city and county over time. In 1990, 68% of all the leasable office space in Harris County was located in the western section of the county (53% in the southwest quadrant alone). Only eight percent of total leasable office space constructed by 1990 was located in the eastern section of the county. Downtown Houston, which still claims 24% percent of the total leasable office space in the county (compare with 92% in 1960), remains an important office district. However, this continuity is overshadowed by the sheer magnitude of the growth of suburban office complexes in the past several decades.

Finally, the issue of Houston’s uniqueness must be addressed. Two factors greatly contribute to the popular image of Houston as an atypical city. The first factor is associated with the role played by oil and gas and petrochemical industries in the city’s economy. The second factor is associated with the lack of planning, in particular, with notorious absence of formal zoning regulations in Houston. A careful examination of both factors suggests that the uniqueness of Houston is exaggerated.
With respect to the first factor, although the share of employment in Houston in oil, oil-related, and petrochemical industry is indeed high—around 60 percent (Rice, 1991)—the oil business is only marginally involved in local politics (Kaplan, 1983). Moreover, "petrodollars" did not constitute a major source of financing for real estate, including office space, development in Houston. Rather capital required for large-scale development projects was channeled by banks and investment firms from a variety of sources, including foreign funds (Feagin, 1985b).

Regarding the second factor, it is true that Houston has very limited public planning. However, in Houston, planning is a prerogative of private sector (Kaplan, 1983). For example, deed restrictions (protective covenants, i.e., limitations on land use imposed on the buyer of real estate by the seller, usually a developer), which are very common in Houston, serve as effective substitution for, if not an equivalent of, zoning laws (Mieszkowski and Smith, 1990). Further, the patterns of land use in "unzoned" Houston appear to be not significantly different from that of the zoned cities (Palmer and Rush, 1976; Feagin, 1984b).

In short, Houston well represents patterns and trends of urban growth in the late twentieth century (Fisher, 1989). Ironically, the uniqueness of Houston might lie in a
different sphere. According to urban sociologist Joe Feagin, the best authority on this city in academia, Houston is the least studied of major U.S. cities (Feagin, 1985a).

4.4 Summary

In summary, the changes in office building location for Houston and Harris County clearly reflect the dynamic spatial reorientation of this new dominant sector of the city’s and county’s economy. While there are some unique features of Houston’s economy, most importantly the very strong linkages to oil and gas and to petrochemical industries, this process of employment suburbanization and emergence of “edge cities” is quite typical of modern American cities. Despite local manifestations, the trends in office space location reflected in Figures 4.5 through 4.8 are typical (Pivo, 1990; Garreau, 1991). Houston, then, is an excellent case study for the analysis of the relationships which are at the center of the current research.

In the following chapter, the data and the methods of statistical analysis which will be used to explore these relationships are introduced.
CHAPTER FIVE: DATA AND METHODS OF ANALYSIS

5.1 Sources of Data

Given the research questions and the formal hypotheses outlined in Chapter Three, the data which are required for this research fall into three categories:

(1) socioeconomic data at the census tract level derived from the 1970, 1980, and 1990 U.S. Censuses of Population and Housing;

(2) office building data from Black's Guide to the Office/Industrial Space Market for the Houston Market (Black’s Guide, 1993);

(3) cartographic data (digital boundary files) from the U.S. Bureau of the Census.

The role of the first two categories of data is quite clear: the census provides the aggregate socioeconomic characteristics of the resident population by census tract for Houston Primary Metropolitan Statistical Area (PMSA), i.e., Harris County, TX. The information on office buildings, including physical location, total square footage of leasable office space, and year of construction, for the Houston area is derived from the Black's Guide to the Office/Industrial Space Market for the Houston Market (Black’s Guide, 1993). These two sources provide the substantive data which is used for statistical analysis. The
cartographic information (i.e., digital boundary files), on the contrary, does not really enter this analysis as explicitly as the socioeconomic and office data. At the least, the characteristics and utility of the cartographic data are different. The reason why cartographic, or geo-referencing, information is considered "data" in this study is related to the fact that in this research, geo-referencing information is not used merely to produce maps, but rather, to account, and control for, the implicit spatial structure of the socioeconomic and office buildings data. Further, the reconfiguration, whenever appropriate, of the units of analysis is based on this information. Cartographic information is utilized, then, in two ways. Firstly, as an auxiliary, but vital, component of the statistical models. And secondly, in a more traditional mapping application simply to present spatial distributions of variables and results. A detailed discussion of the issues pertaining to the use of geo-referencing information can be found later in this section of the dissertation.

The following section provides pertinent information on the sources of, and manipulations on, the data incorporated in the study. Figure 5.1 presents a schematic chart which depicts the different stages and paths of data processing and analysis which are required by this research.
Figure 5.1 Collection, Compilation, and Analysis of Data for the Study of Office Suburbanization in Houston, TX
5.1.1 The Compilation of Variables from the U.S. Census

Technically, the exact ways of obtaining data from the U.S. Census of Population and Housing for the three time periods (1970, 1980, and 1990) are somewhat different. This reflects progressive systematic improvements in census data availability over time. For the 1990 census, Summary Tape File 3A (STF-3A) is available on CD-ROM in PC-readable DBF format at all U.S. census repositories (U.S. Bureau of the Census, 1992). All the relevant 1990 census information (socioeconomic variables) was downloaded from this CD-ROM and stored in Paradox Data Base Management System (DBMS) for further processing (Borland International, 1996). Data from the 1970 and 1980 censuses were compiled from the STF-3A tape files (U.S. Bureau of Census, 1972 and 1982). The extracted data from the 1970 and 1980 STF-3A tape files were subsequently converted to PC-readable format to make it compatible with the 1990 data.

5.1.2 Office Space Data

Information on individual office buildings within the Houston area comes from the Black's Office/Industrial Guide 1993. Pivo (1989) pioneered the use of Black's Guide data in academic research. This guide, the commercial sale of which is directed primarily at realtors and companies seeking leases, provides detailed information on every single
leasable office building for a particular metropolitan area. *Black's Guides* are published annually and available for most large cities in the United States. The information contained in *Black's Guide* includes, among other, the street address, the year of construction, the number of floors, the name and contact information of the leasing agency, and the total leasable area (square feet) for every office building in and around the city. The hard copy version of the *Black's Guide 93* for Houston market (*Black's Guide, 1993*) was purchased from the publisher, and relevant information on just over 1,200 buildings was then entered into a QuattroPro electronic spreadsheet (Corel Corporation, 1996) for subsequent computer-aided data management and analysis. Data management for this project was carried out using Paradox DBMS, while statistical analysis was done largely using the SpaceStat statistical package (Anselin, 1995). A simple FORTRAN program was written by the author for the calculation of the "potentials" discussed in Chapter Six.

Processing of the office space data requires two principal stages. At the first stage, an address matching procedure was performed using ARC/INFO GIS (Environmental Systems, 1996). This procedure, uses the street addresses of each building (e.g., 1020 Main Street) to establish the geographic coordinates for individual office buildings. The
digital address files, required for the address matching procedure, were constructed from the TIGER/LINE file which are discussed in the subsequent section. At the second stage of data processing, once the geographic coordinates for office buildings was established, information on the square footage of individual office buildings was aggregated by census tracts.

5.1.3 Cartographic Data

Digital boundary maps for census tracts in Houston PMSA for 1980 and 1990, as well as the associated street line maps, were constructed from TIGER/LINE files using ARC/INFO GIS. TIGER/LINE files are created and distributed by the U.S. (U.S. Bureau of the Census, 1992). Digital census tract boundary files were subsequently used to create the maps used in this research. Census tracts for 1970 were recreated from the 1980 coverage using the 1970-1980 census tracts comparability table provided by the U.S. Bureau of the Census. In 1980, census tract boundaries for Harris County were substantially revised, as many older (1970) census tracts were subdivided into smaller tracts. The tract comparability tables, included in the census publications, provide the composition of 1970 census tracts in terms of 1980 tracts. This allows the establishment of correspondence between the fairly different systems of census tracts used.
for 1970 and 1980. This standardization is necessary for analysis of changes in the socioeconomic variables for each tract over time.

Information on topological relations between the census tracts was extracted from each of the three (1970, 1980, and 1990) ARC/INFO coverages (i.e., geographical and data files) in the form of the table which lists pairs of adjacent (sharing a border) tracts (i.e., an Arc Attribute File in ARC/INFO coverage). This information was subsequently used to create and assemble the binary adjacency matrix. This matrix is required for the spatial regression analysis which is central to this research.

5.1.4 The Definition of Variables Employed in the Research

All of the variables described in this section apply to the census tracts of Houston PMSA. These census tracts are the basic units of analysis. It is important to realize that in all cases, the variables reflect aggregate commuting, socioeconomic, demographic, and housing characteristics of the workforce resident within each census tract. The only exception to this is the total amount of office space aggregated by census tract. Wherever appropriate, relative (percentage) values, rather than absolute values are used in order to adjust for differences in the size of the absolute population and the workforce found across the census tracts.
For clarity, Table 5.1 provides brief definitions of the original variables used in this research. All variables are applicable to census tracts in Houston, TX. Following, is a detailed discussion of each of the variables.

(1). Mean Commuting Time (MCOMT). This variable represents an average commuting time from home to work (one direction only) for all workers residing in a census tract, but by convention excludes non-commuting workers. Because the census does not report this variable directly, it was calculated by dividing the total reported commuting time by the number of commuting workers for each census tract. Commuting data is not available in the 1970 census; it first appeared in the 1980 census. This variable is the dependent variable for the "commuting patterns" model.

(2) and (3). Income 1 (MHINC) and Income 2 (INCOM). Two different measures of income are used in this research. The first variable—median household income—is a direct measure of the typical income of the households living within any given census tract. The second variable—the number of households in the high-income category—is used instead of the median household income wherever aggregation, averaging, or calculation of potentials have to be carried out. Income characteristics of a census tract are measured using the proportion of households with incomes in approximately top
Table 5.1 Definitions of the Census Tract-Level Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Code</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Commuting Time</td>
<td>MCOMT</td>
<td>Aggregate commuting time divided by the number of commuters</td>
</tr>
<tr>
<td>Income 1</td>
<td>MHINC</td>
<td>Median Household Income</td>
</tr>
<tr>
<td>Income 2</td>
<td>INCOM</td>
<td>Households in the high-income category (over $60,000 for 1990; over $35,000 for 1980; and over $15,000 in 1970)</td>
</tr>
<tr>
<td>Education</td>
<td>BGDEG</td>
<td>Residents over 25 years old with college and higher degrees</td>
</tr>
<tr>
<td>Managers and Professionals</td>
<td>MANAG</td>
<td>Workers employed in managerial and professional occupations</td>
</tr>
<tr>
<td>Clericals and Technicians</td>
<td>ADMSU</td>
<td>Workers employed in administrative support and technical occupations</td>
</tr>
<tr>
<td>Business and Professional Services</td>
<td>SERVI</td>
<td>Workers employed in business and professional services</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>MANUF</td>
<td>Workers employed in manufacturing</td>
</tr>
<tr>
<td>Female Workforce</td>
<td>FEMEM</td>
<td>Females in the workforce</td>
</tr>
<tr>
<td>Minority Population</td>
<td>MINOR</td>
<td>African-American residents</td>
</tr>
<tr>
<td>Office Space</td>
<td>OFSPA</td>
<td>Square feet of leasable office space</td>
</tr>
<tr>
<td>Size-Adjusted Housing Value</td>
<td>MHVAL</td>
<td>Median housing value divided by average rooms per housing unit</td>
</tr>
</tbody>
</table>
20 percent of the income distribution for Harris County as a whole. Income ranges reported in the censuses vary from decade to decade for a variety of reasons, including inflation and economic growth. For each census year, the range closest to 20 percent was selected. The fact that selected thresholds almost double every ten years ($15,000 in 1970; $35,000 for 1980; and $60,000 for 1990) reflects the increasing prosperity over time as well as the inflation.

(4). Education (BGDEG). This variable measures the educational level of any given tract's labor force. Most "white-collar" jobs require at least a college education. Traditionally, the completion of a high-school degree was considered an important educational benchmark. However, the proliferation of post-secondary educational opportunities and the subsequent rise in the proportion of college graduates has diminished the relative value of a high-school diploma. Therefore, given the research context, the number of college graduates in the workforce appears as a preferred measure of educational level.

(5). Managers and Professionals (MANAG). This variable measures the concentration, within any given census tract, of workers employed in managerial and professional occupations. These two categories of workers are most
closely associated with the upper tier of office jobs, and of course with higher incomes.

(6). Clericals and Technicians (ADMSU). This variable measures the concentration, within any given census tract, of workers employed in administrative support and technical occupations. These two categories are also closely associated with office employment. However, workers in administrative support (i.e., clerical) occupations and technicians should be considered belonging to a second, lower-paid tier of office workers.

(7). Business and Professional Services (SERVI). This variable measures the concentration, within any given census tract, of workers employed in business and professional services, including finance, insurance, and real estate. These industries are most closely associated with office-type workplaces.

(8). Manufacturing (MANUF). This variable provides the concentration, within any given census tract, of workers employed in manufacturing. With a few exceptions, manufacturing is generally not associated with office-type workplaces.

(9). Female Workforce (FEMEM). This variable reflects the gender composition of the workforce within any given census tract. Previous research reported in the literature
suggests that gender is an important factor in commuting patterns and office location (Nelson, 1986; Hanson and Pratt, 1992; Blumen, 1994).

(10). Minority Workforce (MINOR). This variable reflects the racial composition of the population within any given census tract. There is evidence in the literature that race is an important factor in commuting patterns and office location (Madden, 1981; McLafferty and Preston, 1991).

(11). Office Space (OFSPA). This variable measures, for any given census tract, the amount (in square feet) of leasable office space. This is the dependent variable for the "office location" model.

(12). Size-Adjusted Housing Value (MHVAL). This variable provides, for any given census tract, the median value of owner-occupied housing (valued by room). This variable is the dependent variable for the "effects of office complexes" model.

5.2 Methods of Analysis

5.2.1 The Specification of the Spatial Regression Models Employed in This Research

It is increasingly accepted among geographers, sociologists, and economists conducting quantitative research that conventional Ordinary Least Squares (OLS) estimation frequently produces biased results when the data used to generate the model represent spatially distributed
sets, i.e., points, lines, or polygons. In most cases, objects (i.e., observations—in this case, census tracts) that are located in close proximity to each other tend to have similar values for the variables describing the attributes of these objects. This phenomenon, known as positive spatial autocorrelation, may dramatically affect the estimation of coefficients (and their respective significance levels) when using the standard OLS method of estimation (Cliff and Ord, 1973; Griffith, 1987; Odland, 1988).

Recently, new, more rigorous, methods for dealing with spatial autocorrelation in regression have been developed (Anselin, 1988b, 1992). It is appropriate to use these new methods for the estimation of the regression models in this research because the census tracts, which are the basic units of analysis in this research, do in fact represent a spatially distributed set.

The purpose of any linear regression technique is to determine the relationships between a dependent variable and a set of independent variables. In mathematical notation, the regression equation is expressed as:

$$Y = X\beta + \epsilon$$

where $Y$ is a vector of observations on the dependent variable, $X$ is an $m$ by $n$ matrix of uncorrelated (i.e., free
of multicollinearity) observations on the independent variables (where \( m \) is the number of variables and \( n \) is the number of observations), \( \beta \) is a vector of regression coefficients, and \( e \) is the random error term.

The estimates for \( \beta \) are obtained by minimizing the sum of squared prediction errors (\( Y \) actual minus \( Y \) predicted). Certain assumptions about the distribution of error terms must be met in order for the Ordinary Least Squares method to produce unbiased and efficient estimates. These assumptions require that the random error terms (1) be distributed normally, (2) have a constant (homoscedastic) variance, and (3) be uncorrelated.

There are a variety of techniques available for testing against non-normality and heteroscedasticity (e.g., Belsley et al., 1980). This research utilizes the method suggested by Kiefer and Salmon as test for normality in the error terms (Kiefer and Salmon, 1983). This is an asymptotic test, with the test statistic following a chi-square distribution with two degrees of freedom. Breusch-Pagan (Breusch and Pagan, 1979) and Koenker-Bassett (Koenker and Bassett, 1982) tests are used to test against heteroscedasticity in the regression residuals. The Koenker-Bassett test is robust, i.e., it can be used when the distribution of the error terms is not normal. Both tests are asymptotic, and the test...
statistics follow a chi-square distribution with $P$ degrees of freedom (where $P$ is the number of variables in the heteroscedastic specification).

Realistically, for most spatially distributed data, even if the first two requirements (normality and homoscedasticity) are satisfied, the third assumption is regularly violated because of inherent spatial autocorrelation. Therefore, if spatial autocorrelation is detected, a different specification must be used to avoid problems associated with spatial autocorrelation. Perhaps the most popular test statistic for spatial autocorrelation is Moran's I. Formally, Moran's I defined as

$$I = \frac{\sum_i \sum_j w_{ij}(x_i - \mu)(x_j - \mu)}{\sum_i (x_i - \mu)^2}$$

where $w_{ij}$ is the element of in the row-standardized matrix of spatial weights, $x_i$ and $x_j$ are observations for locations $i$ and $j$, and $\mu$ is the mean. A positive and significant value for $I$ indicates positive autocorrelation, while a negative and significant value is indicative of negative spatial autocorrelation.

Fundamentally, there are two alternative specifications for the spatial regression: the Spatial Lag (SL) model and the Spatial Error (SE) model (Anselin, 1992). Both specifications employ Maximum Likelihood estimation method.
The SL regression specification is denoted as

\[ Y = \rho \hat{W} Y + X \beta + \varepsilon \]

where \( \hat{W} Y \) is a spatially lagged dependent variable and \( \rho \) is the spatial autoregressive coefficient. In this case, spatial autocorrelation pertains to the dependent variable.

The other form of spatial regression, that is the SE specification, shifts the modeling focus to the spatial autocorrelation in the error term itself:

\[ \varepsilon = \lambda \hat{W} \varepsilon + \xi \]
\[ Y = X \beta + \varepsilon \]

where \( \lambda \) is the autoregressive coefficient and \( \xi \) is normal error term (Dorean, 1981; Anselin, 1988b, 1992).

Therefore, an autoregressive process can be modeled appropriately through either the SL approach or through the SE approach. Two different Robust Lagrange Multiplier (LM) tests can help select the most appropriate specification for spatial regression analysis for any given set of data (Anselin, 1988a). Both LM tests are asymptotic (i.e., work best with large samples). They approximate a chi-square distribution with one degree of freedom (Anselin 1988a, 1992).

However, the use of the Maximum Likelihood estimation in either SL or SE regression specifications nevertheless require that the assumptions of homoscedasticity and
normality in the distribution of the error term be met. This is realistically problematic from the standpoint of real-world data, which frequently produces regression results with non-normal and heteroscedastic errors. Indeed, these assumption are quite restrictive. Previously, when researches using conventional OLS regression were faced with non-normality and heteroscedasticity in the residuals, they were forced to either abandon regression techniques altogether or, alternately, report statistically illegitimate results. Things change, and now there are new methods available. While still not widespread in geographic research, there are new techniques which can produce unbiased and efficient regression estimates even in the presence of non-normal and heteroscedastic residuals. Collectively, such methods of estimation are called "robust" estimation methods. The great advantage of the robust methods is that they are insensitive to the form of the error distribution.

Within the family of spatial regressions, one such robust method is the "bootstrap" estimation. The technique was originally proposed by Freedman and Peters (1984) and further modified by Anselin (1988). The bootstrap method uses the randomness in simulated data sets (created by
The bootstrapping procedure involves several stages. For the first stage, estimates for $\rho$ and $\beta$ are obtained from

$$y = \rho Wy + X_{ins}\beta + \varepsilon$$

where $X_{ins}$ is a matrix of instrumental variables (defined as spatially-lagged independent variables). In the second stage, the vector of error terms $e$ is then estimated as

$$e = y - \rho Wy - X\beta$$

where estimates of $\rho$ and $\beta$ are taken from the first stage. On the third stage, a series of vectors of pseudo observations $y_r$ are generated according to

$$y_r = \rho Wy + X_{ins}\beta + e_r$$

where $e_r$ is randomly drawn error from vector $e$. This, in effect, is equivalent to the generation of new observations for the dependent variable. If this procedure is repeated, for example, one hundred times, it then results in the generation of one hundred "new" data sets with varying observations on the dependent variable, but still with the same observations for the independent variables.

In the forth stage, a series of values for $\rho$ and $\beta$ are estimated from

$$y_r = \rho Wy + X\beta + \varepsilon$$
The procedure must be repeated some large (at least, several hundreds) number of times to generate an empirical distribution for \( \rho \) and \( \beta \). The bootstrap estimate is then calculated as a mean of the empirical frequency distribution. Although the bootstrap technique has not yet received wide recognition, in situations where heteroscedasticity and non-normality in the error terms are present, the bootstrap estimation provides a viable alternative to Maximum Likelihood estimation (Anselin, 1988b, 1992). Presumably, given the spatial nature of cross-sectional data analyzed by geographers and researchers from other social science disciplines such as economics, sociology, and demography, the technique will grow in popularity (Efron and Tibshirani, 1993; Mooney and Duval, 1993).

In short, the selection of an appropriate estimation method and model specification depend on a particular combination of the following constraints: presence or absence in the regression residuals of normality, constant variance, and spatial autocorrelation (which can assume two different forms—spatial lag and spatial error). Table 5.2 lists all possible combinations of these four factors and provides an estimation method and a model specification most
Table 5.2 Criteria for Selection of Regression Estimation Methods and Model Specifications

<table>
<thead>
<tr>
<th>Normality Test</th>
<th>Constant Variance Test</th>
<th>Spatial Autocorrelation Tests</th>
<th>Lagrange Multiplier Spatial Error Test</th>
<th>Lagrange Multiplier Spatial Lag Test</th>
<th>Recommended Estimation Method and Model Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>OLS</td>
<td></td>
</tr>
<tr>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>FAIL</td>
<td>SL ML</td>
<td></td>
</tr>
<tr>
<td>PASS</td>
<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
<td>SE ML</td>
<td></td>
</tr>
<tr>
<td>PASS</td>
<td>PASS</td>
<td>FAIL</td>
<td>FAIL</td>
<td>SL ML or SE ML</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>ROBUST OLS</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
<td>ROBUST OLS</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
<td>HE ML</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>PASS</td>
<td>FAIL</td>
<td>FAIL</td>
<td>SL BOOTSTRAP</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
<td>FAIL</td>
<td>SL BOOTSTRAP</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>SL BOOTSTRAP</td>
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</tr>
<tr>
<td>PASS</td>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>SL BOOTSTRAP</td>
<td></td>
</tr>
<tr>
<td>PASS</td>
<td>FAIL</td>
<td>FAIL</td>
<td>PASS</td>
<td>HL ML</td>
<td></td>
</tr>
<tr>
<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
<td>HE ML or ROBUST OLS</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>FAIL</td>
<td>PASS</td>
<td>FAIL</td>
<td>SL BOOTSTRAP</td>
<td></td>
</tr>
<tr>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>PASS</td>
<td>HE ML</td>
<td></td>
</tr>
</tbody>
</table>

OLS - Ordinary Least Squares Estimation
ML - Maximum Likelihood Estimation
SL - Spatial Lag Model
SE - Spatial Error Model
HE - Heteroscedastic Error Model

Source: Constructed by Author from Anselin (1992).
appropriate (according to Anselin, 1992) in a particular situation.

5.2.2 Matrices of Spatial Weights

It is important to recognize that spatial autocorrelation can be assessed in many ways. The use of a spatial semi-covariogram is one of the most useful techniques as it helps to identify particular forms of autocorrelation (Clarke, 1990). Directing the discussion to the current research, the diagrams provided in Figures 5.2 and 5.3 depict covariation between neighboring census tracts with respect to the mean commuting time which is one of the dependent variables in the research. "Neighbors" can be defined in two ways: (1) based on the distance between centroids of the census tracts; and (2) based on the degree of adjacency between any two census tracts. In the first case, semi-covariance for one mile (the horizontal scale) is calculated using only tracts which are separated by not less than one mile; for two miles, using only tracts which are separated by not less than two miles, and so on. In the second method (adjacency approach), a continuous measure of distance is replaced by a discrete (considering only integer values) measure of adjacency. Simply put, if any given pair of tracts, identified as A and B, share a common border (touching sides) they are assigned an adjacency value of
Figure 5.2 Distance-Based Semi-Covariogram for Mean Commuting Time

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Figure 5.3 Adjacency-Based Semi-Covariogram for Mean Commuting Time
one; if tract C borders tract B (adjacency value of one) but
does not border tract A, then tracts A and C are both
assigned an adjacency value of two, and so forth. Semi­
covariation, rather than full covariation, must used to
avoid unnecessary double counting (covariation between A and
B is identical to covariation between B and A). In this
research, the calculation of semi-covariograms were made
using a FORTRAN computer program written by the author
specifically for the purposes of this research.

Curves in Figures 5.2 and 5.3 are characteristic of a
typical spatial autocorrelation pattern. Practically, small
values of spatial separation (using distance and/or
adjacency approach), indicate that spatial autocorrelation
is high, and its magnitude consistently decreases with an
increase in the spatial separation. The two approaches,
however, have different strengths and shortcomings.
Distance-based semi-covariance is more easily interpretable
and intuitively appealing. As can be seen from the diagram
in Figure 5.2, spatial autocorrelation almost completely
disappears beyond a threshold of 15 miles.

However, despite this appeal, it should be noted that
the distance-based method approach is also more restrictive.
Realistically, U.S. census tracts are established based on
the population criteria, and as such they are far from being
equal with respect to absolute physical area. For example, less populated tracts at the periphery of the Harris County are much larger than the densely-populated tracts located in the central parts of the city. Accordingly, centroids of large tracts are separated by greater absolute distances. This means that these tracts might not always be included in the calculation of semi-covariance for low values of distance threshold. This problem is avoided, however, when the adjacency-based (essentially, an expanded nearest-neighbor method) approach is used.

The analysis of semi-covariograms is important because it can help in selection of appropriate matrix of spatial weights. This matrix is of size $n$ by $n$, where $n$ is the number of spatial elements, in this case, the census tracts of Houston. Each cell in this matrix contains a measure of spatial proximity between any two elements and is used to "weight" data which describes attributes of the elements when spatial regression or other statistical techniques are used.

This matrix of spatial weights is used in all methods of formal spatial analysis, from standard measures of spatial autocorrelation, such as Moran's I and Geary's C (Cliff and Ord, 1973), to complex spatial regression models (Anselin, 1988b). Accordingly, and significantly, the
results of spatial analysis to a large extent depend on the form of the matrix of spatial weights (Arbia, 1986). Since detecting and accounting for spatial autocorrelation is one of the most important tasks of spatial analysis, a matrix of spatial weights should be appropriately constructed so as to reveal as fully as possible the spatial autocorrelation in the data set.

According to the diagrams in Figures 5.2 and 5.3, the highest semi-covariance (a proxy for autocorrelation) is achieved under the most stringent criteria. This result was confirmed in a series computational experiments. When a measure of spatial autocorrelation (Moran’s I) was calculated iteratively by employing varying forms of the matrix of spatial weights, the results indicated that the “best” adjacency-based matrix should utilize a threshold of one, when only bordering tracts are considered.

However, in a situation when spatial units, in this case census tracts have different sizes, the stipulated distance-based threshold should be low enough to allow inclusion of at least one pair with the largest tract. In order to meet this requirement, a higher distance threshold must be applied. However, the application of higher (i.e., less stringent) distance threshold, in turn, results in an inefficient matrix of spatial weights. For this reason,
after a comparison of results derived when using both of the methods discussed above, preference was given to the use of adjacency-based matrix.

Thus, the matrix of spatial weights that was selected for subsequent use in this analysis has the form of adjacency-based binary contiguity; that is, bordering tracts were assigned the value of one; all other pairs were assigned a value of zero. Elements of the matrix were then standardized by row so that summation over a row gives unity. In some situations, a modified version of the binary contiguity matrix might be employed. This modified matrix, which can be called a weighted contiguity matrix takes into account actual length of the boundaries. In other words, if non-zero elements of a single row in a row-standardized binary contiguity matrix all have the same value, then in the weighted contiguity matrix, non-zero elements receive different weights. In effects, this means that the longer the shared boundary, the higher the resulting value in the matrix.

From the standpoint of regression modeling, it is not the spatial autocorrelation in the dependent variable per se that is important, rather it is the spatial autocorrelation among the residuals (or error terms) which is of greatest concern. Although the residuals can be spatially
uncorrelated when the dependent variable is itself
autocorrelated, the reverse situation is highly unlikely, if
not impossible. Therefore, based on the analysis of the
autocorrelative properties of one of the dependent
variables, the selection of the spatial weights matrix for
regression modeling is justified.
6.1 Introduction

In this chapter, the results of three sets of regression models are reported: the "office location" model, the "commuting determinants" model, and the "housing values" model. As discussed earlier, these models represent the three distinct strands of the research outlined in Chapter Three. The three sets of models are closely related from both the substantive and the data perspectives. Thus, workforce characteristics are used as independent variables in both the office space location and in the commuting determinants models; while office space is used as a dependent variable in the office location model, and also as an independent variable in the housing values model. It's important to realize, however, that depending on the particular model, the variables are appropriately transformed.

6.2 Estimation of the Model of Office Location

The specification of the regression model incorporates the total amount of "new" accessible office space in each laborshed for each of the three time periods (1970, 1980, and 1990) as the dependent variable. "New" office space is defined as office space constructed within a decade culminating in a decennial census. For example, the 1970
census workforce data are matched against the office space constructed in the period 1960-1969. Maps presented on Figures 6.1, 6.2, and 6.3 show the spatial distribution of the actual amount of new leasable office space aggregated by census tracts.

The model used to predict the amount of leasable office space is as follows:

\[
\ln(\text{Office Space}) = b_0 + b_1 \ln(\text{INCOM}) + b_2 \ln(\text{ADMSU}) \\
+ b_3 \ln(\text{BGDEG}) + b_4 \ln(\text{MANAG}) + b_5 \ln(\text{FEMEM}) \\
+ b_6 \ln(\text{MANUF}) + b_7 \ln(\text{SERVI}) + b_8 \ln(\text{MINOR})
\]

where \( b_0 \) is a constant, \( b_1 \) through \( b_8 \) are estimated parameters, and:

- \( \text{INCOM} \) is the number of households with high incomes;
- \( \text{ADMSU} \) is the number of administrative support workers and technicians in the workforce;
- \( \text{BGDEG} \) is the number of persons with college degrees;
- \( \text{MANAG} \) is the number of workers in managerial and professional occupations;
- \( \text{FEMEM} \) is the number of females in the workforce;
- \( \text{MANUF} \) is the number of employed in manufacturing;
- \( \text{SERVI} \) is the number of employed in business and professional services;
- \( \text{MINOR} \) is the number of resident African Americans.
Figure 6.1 Office Space Built in Harris County from 1960 to 1969, by 1990 Census Tract
Figure 6.2 Office Space Built in Harris County from 1970 to 1979, by 1990 Census Tract
Figure 6.3 Office Space Built in Harris County from 1980 to 1990, by 1990 Census Tract
It is critical, however, to realize that the variables used in this model differ in an important way from the conventional regression inputs. Significantly, the values for the dependent and the independent variables are not the actual values for each observation on census tracts, rather they are transformed into what is known in the literature as “potentials” (Duncan et al., 1961; Land and Deane, 1992). With respect to the dependent variable (office space), for any given census tract, the “potential” for that tract is defined as the amount of office space in that same tract plus the values of weighted amounts of office space (with diminishing weight assigned with increasing distance) in the surrounding tracts. For any given census tract, this office space potential represents a measure of exposure of that tract to office space, or, alternatively, a measure of access to office space. Again, this is an improvement over traditional approaches which match dependent and independent variables for each single tract in that the new method recognizes that the boundaries of census tracts are not barriers to worker access.

With respect to the workforce characteristics, the “potential” for any given census tract is estimated as the number of specific type of workers in that same tract plus the distance-discounted number of workers in surrounding
tracts. For any given census tract, potential for professional/managerial workers, for example, represent the magnitude of the managerial workforce which is comprised of professional/managerial workers residing in proximity to that census tract.

"Potentials" represent the local overlapping laborsheds, which can be conceptualized as local labor markets ("accessability zones", for lack of a better term, with respect to office space). These local labor markets characterize employment in the area centered around each census tract. Respectively, the interaction between the office space and workforce characteristics is analyzed at the level of the constructed laborsheds. The exact size of the laborshed, that is its areal extent, cannot be easily identified. Clearly, close places provide greater possibilities for the provision of labor for any set of office buildings, but the full extent of the labor threshold is ultimately variable. Due to this uncertainty with respect the size of the laborsheds, two a priori specifications were developed:

(1) laborsheds constructed with the negative power exponential distance-decay function ("entropy"); and

(2) laborsheds constructed with the quadratic inverse distance-decay function ("gravity").
The significant and substantive difference between these two distance-decay functions is that the discount factor (represented by the value of the denominator) in the exponential function, which is defined as

\[ p_i \cdot X_i \cdot \sum_{j=1}^{n} \frac{X_j}{\exp{d_{ij}}} \]

is much more restrictive than the discount factor in the function defined as

\[ p_i \cdot X_i \cdot \sum_{j=1}^{n} \frac{X_j}{d_{ij}} \]

which is the inverse distance function.

As a result of this difference in the denominator which alters the final calculations, laborsheds constructed with the entropy function tend to be smaller. Given the same distance, the negative power exponential function produces much larger discount factor (compare, for example, \(2.718^{10}=22,026\) with a mere \(10^2=100\), where 10 is the distance, measured in miles, between the central points of census tracts). In other words, potentials estimated using the gravity function contain the workforce and office space characteristics of a larger area.

The range and variance of values for the transformed variables (potentials) is high for both leasable office space and workforce characteristics. Given this great range, it is appropriate, and indeed standard, to use a logarithmic transformation of the dependent variable. This
transformation simply compacts the range of values and typically eliminates non-linearity (Chatterjee and Price, 1977). Thus, natural logarithm was taken of both dependent and independent variables which enter the equation.

For the first stage of analysis, simple OLS regressions with tests for spatial autocorrelation were run for all the six models (three time periods by two specifications—the gravity function and the entropy function—for potentials). At this stage of analysis, a serious multicollinearity problem was encountered. The presence of strongly intercorrelated variables on the right-hand side of the equation violates one of the fundamental assumptions of all regression techniques (Belsley et al., 1980). It appeared that the “potential” variables became strongly correlated among themselves, when compared to the original variables. It was expected that the conversion of the variables to potentials would decrease the variance in the data sets; however, the acuteness of the multicollinearity problem was not anticipated. Due to a strong multicollinearity in the data sets, it was impossible to proceed in the analysis, as was planned, with the multivariate regression technique. It is extremely painful to have to abandon such a powerful method of analysis as multivariate regression; however, the
principles of methodological scrupulousness and academic integrity must reign unconditionally.

In these circumstances, when the nature of the data set is such that it is impossible and inappropriate to use the multivariate regression technique, the only viable solution seemed to be the use of the bivariate regression. In the context of the bivariate regression the analysis has to be limited, in effect, to a set of pair-wise comparisons of the variables.

The transformed (potential) variables are characterized with a great degree of spatial smoothness or continuity. When measured for census tracts, the socioeconomic variables represent discrete distributions. There could be, and indeed often exist, sharp differences between neighboring census tracts. In the transformed variables, these differences are smoothed to such an extent that the transformed variables might be conceived as continuous distributions. Since these transformed variables are based on spatially-distributed units (census tracts), it might be appropriate to refer to these variables as surfaces, that is three-dimensional (having x, y, and z, coordinates, where z measures some socioeconomic characteristic, for example population). Therefore functionally, this set of bivariate regressions actually represent the relationships between the “surface”
corresponding to the distribution of the office space and the surfaces corresponding to the spatial distributions of different types of the workforce.

For each individual bivariate regression, the goodness-of-fit statistic, therefore, will measure the closeness of association between each pair of surfaces; while the parameter estimate will measure the magnitude of influence of the predictor surface on the predicted surface. Since the models were designed to test the hypotheses about the sensitivity of office space to workforce characteristics, the predicted surface will reflect variations in the office space; while the surfaces representing different workforce characteristics will be used as predictors. Standardized regression coefficients may be used to compare the relative effects of different variables across models.

Preliminary runs of bivariate OLS regressions indicated (based on the Robust Lagrange Multiplier spatial lag and spatial error tests) the presence of spatial autocorrelation in the residuals. To control for these effects, Spatial Lag Maximum Likelihood regression specifications were substituted for the OLS specification. Weighted contiguity spatial weights were employed in the estimation.

Table 6.1 presents results of the Spatial Lag estimation for potentials constructed using a negative power
Table 6.1 Results of the Maximum Likelihood Estimation of the Spatial Lag Bivariate Regressions for the Office Location Model

<table>
<thead>
<tr>
<th>Period</th>
<th>Function Type</th>
<th>Parameter Estimates and Pseudo R-squares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gravity</td>
<td>Entropy</td>
</tr>
<tr>
<td></td>
<td>BGDEG</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.871)</td>
</tr>
<tr>
<td></td>
<td>MANAG</td>
<td>0.206</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.888)</td>
</tr>
<tr>
<td></td>
<td>INCOM</td>
<td>0.154</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.856)</td>
</tr>
<tr>
<td></td>
<td>SERVI</td>
<td>0.186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.876)</td>
</tr>
<tr>
<td></td>
<td>ADMSU</td>
<td>0.158</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.854)</td>
</tr>
<tr>
<td></td>
<td>FEMEM</td>
<td>0.150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.835)</td>
</tr>
<tr>
<td></td>
<td>MANUF</td>
<td>0.114</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.726)</td>
</tr>
<tr>
<td></td>
<td>MINOR</td>
<td>0.072</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.647)</td>
</tr>
</tbody>
</table>

Source: Calculated by author.
exponential (columns labeled "Entropy" in Table 6.1) and a quadratic inverse (columns labeled "Gravity" in Table 6.1) distance-decay functions. It is important to realize that the reported coefficients are from different regression models, but are reported as one table for clarity and convenience. Each model for each time period consisted of a dependent variable (office space), an independent variable (one of the workforce characteristics), and an auxiliary variable (spatially lagged dependent variable which is used to account for spatial autocorrelation).

Each cell in the Table 6.1 contains a parameter estimate for the respective variable. The coefficients are reported in standardized form. All the parameter estimates were highly significant. Below each coefficient given in parenthesis is the goodness-of-fit statistic for the model—squared correlation between the observed and the predicted values for the dependent variable. This measure (pseudo R-square) is used instead of traditional R-square, which does not exist for the Maximum Likelihood estimation. Since the spatially lagged dependent variable is used merely as a control for spatial autocorrelation, the coefficients for that variables pose little interest, and, therefore, they are not reported in Table 6.1.
Results reported in Table 6.1 require a special approach in their interpretation. In order to compare the variables with each other and over time, squared correlation coefficients and standardized parameter estimates were ranked (separately) according to their magnitudes. Ranking allows to differentiate between the model estimates which are otherwise quite similar. Altogether, there are six sets of models: three time periods (reported as 1970, 1980, and 1990--the years of the decennial censuses) by two functional specifications for the distance-decay (gravity and entropy) function. Each set consists of eight bivariate regression models. The ranking, therefore, refers to the sorting of the variables in descending order of magnitude within each set.

Tables 6.2 and 6.3 present rankings for, respectively, the goodness-of-fit of the models (squared correlation between predicted and observed variables) and for the standardized coefficients. The pseudo R-square is interpreted as a measure of the closeness of association between the office space and different categories of workers. In turn, the standardized parameter estimates are interpreted as a measure of responsiveness of office space to different categories of workers. Ranking provides a simple, yet useful method of comparing the variables with respect to these two measures.
Table 6.2 Ranks of the Pseudo R-squares from Table 6.1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BGDEG</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>MANAG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>INCOM</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>SERVI</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>ADMIN</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>FEMEM</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>MANUF</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>MINOR</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: Calculated by author.
Table 6.3 Ranks of the Parameter Estimates from Table 6.1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BGDEG</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>MANAG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>INCOM</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>SERVI</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>ADMSU</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>FEMEM</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>MANUF</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>MINOR</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: Calculated by author.
As evident from Table 6.1, the "gravity" models produced a consistently better fit vis-a-vis the "entropy" models. This result, however, to some degree was anticipated since the quadratic inverse distance-decay function introduces a higher degree of smoothing, thus significantly decreasing the variability in the data.

According to the ranks reported in Table 6.2, the variables exhibit quite interesting patterns of behavior. Regardless of the time period and the specification, potential for manufacturing workforce (MANUF) and potential for African-American residents (MINOR) exhibit the least association with the potential for office space. In other words, the association between the spatial distribution of workers employed in manufacturing (MANUF) and minority population (MINOR) on the one hand, and spatial distribution of office complexes on the other hand, is extremely week, both in relative (ranks) and absolute (pseudo R-square) terms.

However, the results for the three different time periods and for the two different specifications for the other six variables do not exhibit the consistency found for the minority population (MINOR) and for manufacturing workforce (MANUF). According to Table 6.2, the pseudo R-square ranks for models with potential for residents with
college education (BGDEG) and for models with potential for managers/professionals (MANAG) are consistently higher for the "gravity" specification. Similarly, the ranks for the models with potential for high-income households (INCOM) are also higher for the "gravity" specification.

The remaining three variables—potentials for workers employed in business and professional services (SERVI), for workers employed in administrative support occupations (ADMSU), and for female workers (FEMEM)—behave in an opposite manner. For these variables, models with the "entropy" specification yielded higher ranks, except for the 1970 time period for the first variable. Quite interestingly, a significant change is recorded for the potential for female workers (FEMEM) in 1990 model: the rank for this variable jumped from the fifth ("gravity" specification) to the first ("entropy" specification).

A suggested interpretation of these results is as follows. High-income households, managers/professionals, as well as college-educated residents are distributed spatially in such a manner that these variables appear to be better predictors, in relative terms, for office space on the larger scale (wider spatial extent of the laborsheds) than on the smaller scale (narrower spatial extent of the laborsheds). The inverse appears to be true with respect to
the workers employed in business and professional services, clerical workers, and female workers. In other words, these categories of workers appear to reside quite close to the office space, as if forming pockets of local concentration of much more limited spatial extent.

At the large scale (gravity specification), the best predictors (based on the squared correlation between the observed and the predicted values) for office complexes are the presence within the laborshed of high levels of (1) managerial/professional workforce (MANAG), and (2) college-educated workforce (BGDEG). At the small scale (entropy specification), the best predictors for office complexes are workers employed in business and professional services (SERVI), clerical workforce (ADMSU), and female workforce (FEMEM, the latter, only for the 1990 time period). Again, the least powerful predictors for office space, regardless of specification, are manufacturing workforce (MANUF) and African-American residents (MINOR).

Except for the varying importance of the female workforce (FEMEM) over time and across specifications of the laborsheds, other variables exhibit a remarkable stability in ranks over time. However that particular exception appears to be of great importance and significance. At the small scale, the presence of a significant female workforce
in 1990 was the best predictor for office space constructed in the period 1980-1989. There are two possible explanations for this result. One explanation is based on the causation flowing from female workforce to office space: office complexes are being built in locations with abundant supplies of female workers. The other explanation is based on the causation flowing in the opposite direction: the emergence of office complexes has boosted female workforce participation in the neighborhoods proximate to these new office complexes. However, the two explanations need not be construed as mutually exclusive since both processes can be at work simultaneously taking the form of a cumulative causation (Pred, 1966).

While the goodness-of-fit (correlation coefficient between the observed and the predicted values in the model) measures the degree of association between office space and workforce characteristics, the slope estimate (regression coefficient) measures the degree of responsiveness in the dependent variable (office space potential) conditioned on the changes in the dependent variable (workforce potential). Following is the discussion of the ranks of the regression coefficients (Table 6.3).

With respect to the specification of the potentials, there is little variation in the ranks over time and across
functions for any given variable. That means that relative (i.e., based on ranks) responsiveness of office space is not sensitive to the size of the laborsheds. The only exception to that patterns is an unexpectedly low rank for college-educated workforce (BGDEG) in the 1990 model with the entropy specification.

According to the results presented in Table 6.3, office space in Houston appears to be most responsive to the size of the managerial/professional workforce (MANAG), the business services workforce (SERVI), and a college-educated workforce (BGDEG, with the above mentioned exception). The variables to which office space is least responsive are manufacturing workforce (MANUF) and African-American population (MINOR).

Finally, high-income households (INCOM), clerical workforce (ADMSU), and female workforce (FEMEM) appear to have moderate, in relative terms, effects on the location of office space in the study area. Quite interestingly, the income characteristic (INCOM—the number of households in the high income category) did not figure prominently in the models both with respect to the measure of association and the measure of responsiveness (i.e., influence). Perhaps, this result can be interpreted to mean that office space is quite sensitive to land values. Since land is more expensive
in wealthy neighborhoods, high land values in some parts of suburbia can serve as a barrier for office space development.

Based on the results obtained through the regression analysis (and subsequent rankings) of the office space and workforce data for Houston, TX, for 1970, 1980 and 1990, with respect to the models of office location, the following conclusions may be drawn:

1. A quite close association is discovered between the spatial distribution of office complexes and the spatial distributions of different categories of the office-related workforce in Houston, TX. This association, however, varies across scales. Assuming a smaller laborshed, a closer association with office space is registered for workers employed in business services, administrative support workers, and female workers (only for the 1990 data). Assuming a larger laborshed, a closer association with office space is registered for managers/professionals and college-educated workers.

2. The spatial distribution of office space in Houston, TX, is discovered to be most responsive to the spatial distributions of managerial/professional workers, workers employed in business services, and college-educated workers.
3. The spatial distribution of office space in Houston, TX, appears to be unrelated to the spatial distribution of minority (African-American) population and to the spatial distribution of workers employed in manufacturing.

6.3 Estimation of the Model of Commuting Determinants

The specification of this regression model incorporates the mean commuting time as the dependent variable (MCOMT). Maps presented on Figures 6.4 and 6.5 illustrate the spatial variation among the census tract in Harris County with respect to the mean commuting time.

The model used to predict the mean commuting time for census tracts in Houston for 1980 and 1990 was initially specified as follows:

\[
MCOMT = b_0 + b_1 \cdot (INCOM) + b_2 \cdot (ADMSU) + b_3 \cdot (BGDEG) + b_4 \cdot (MANAG) + b_5 \cdot (FEMEM) + b_6 \cdot (MANUF) + b_7 \cdot (SERVI) + b_8 \cdot (MINOR) + b_9 \cdot (D6-18) + b_{10} \cdot (D16+) + b_{11} \cdot (NE) + b_{12} \cdot (SE) + b_{13} \cdot (NW)
\]

where \( b_0 \) is a constant, \( b_1 \) through \( b_{13} \) are estimated parameters and where:

- \( INCOM \) is the median household income;
- \( ADMSU \) is the percentage of administrative support workers and technicians in the workforce;
- \( BGDEG \) is the percentage of persons with college degrees;
- \( MANAG \) is the percentage of workers in managerial and professional occupations;
Figure 6.4 Mean Commuting Time in Harris County, 1980
Figure 6.5 Mean Commuting Time in Harris County, 1990
FEMEM is the female workforce participation rate, in percent;
MANUF is the percentage of employed in manufacturing;
SERVI is the percentage of employed in business and professional services;
MINOR is the percentage of African Americans in the population;
D6-18 is a dummy variable for census tracts separated from the CBD by more than 6 but less than 18 miles;
D18+ is a dummy variables for census tracts separated from the CBD by more than 18 miles;
NE is a dummy variable for census tracts located in the North-Eastern section of Harris County;
SE is a dummy variable for census tracts located in the South-Eastern section of Harris County;
NW is a dummy variable for census tracts located in the North-Western section of Harris County.

"Geographical" dummy variables are used to account for possible and plausible systematic variation in the modeled relationships across space. The stipulated dummy variables separate Harris county into four sectors and three zones (Figure 6.6). The zonal dummy variables are used to capture variation associated with location with respect to the distance from downtown Houston. Although in Houston
Figure 6.6 Sectoral and Zonal Divisions in Houston
population and employment are generally decentralized, the structural monocentricity of the urban area has not disappeared altogether, even considering the decreased role of the CBD as an employment center (Mieszkowski and Smith, 1991). On the other hand, in practical terms, outward urban growth contributes to declining densities, and can create conditions which lengthen commutes. Therefore, it is expected that commuting time will be systematically longer for census tracts located far away from the center, when all other factors are held constant. Since a households’s location (i.e., location of the commuting “origin”) in the central part of the city, by itself, may provide some economizing on commutes, the dummy for the central part of the city (within 6 miles of the downtown) is used as a control and therefore it is omitted from the model. Coefficients for the included dummy variables (location in the intermediate zone and location in the outer zone), then, should be interpreted as differences between parameter estimates for either of these variables and the estimates for the omitted dummy variable (Hardy, 1993).

In addition to the zonal variation observed in Houston, there are significant differences between the geographical sectors of the city in terms of the prevailing types of neighborhoods and the types of available employment (Feagin,
1988). The most distinct and different sectors are the Southwest and Southeast of Harris County. The Southwestern sector contains great concentrations of office complexes. Many of Houston's upper- and middle-class neighborhoods are located in this sector, or, at least, in the two Western sectors. In contrast to the Southwest, the Southeastern quadrant of the county can be described as a predominantly blue-collar, industrial area, both in terms of employment and residences.

Since it is hypothesized, that white collar workers, due to proximity to office employment, have shorter commutes, the Southwestern sector was selected as the reference (i.e., omitted) dummy variable. As shown on Figure 6.1, the sectoral divisions do not coincide perfectly with the four geographical quadrants. That is because the sectors were assigned based on the conventional enumeration method of the census tracts: each tract has a five-digit code number, the first digit being 2, 3, 4, or 5. Tracts with the same first digit comprise an area approximating one of the four quadrants. Using this Census Bureau classification, each tract was assigned to one of the four geographical sectors.

Preliminary runs of the regressions indicated that the models produced unsatisfactory results with respect to
multicollinearity in the independent variables and non-normality in the distribution of the regression residuals. Two measures were taken to correct these problems. First, it was established by the means of a simple correlation coefficients and analysis of the variance inflation factors (Belsley et al., 1980) that there were three variables largely responsible for multicollinearity. These variables were the percentage of college-educated residents, the percentage of managers and professionals in the workforce, and the percentage of workers employed in business services.

Of course, the high correlations among these three variables are not coincidental; rather, they accurately represent the reality of the contemporary labor markets in which professional and managerial jobs, requiring college education, are concentrated in the service sector. To a great extent, these three variables represent a single "dimension" in the multidimensional space of workforce characteristics. Therefore, it is not practical, for methodological reasons, to keep all the three variables as regressors in the same model. It was established through experimental regression trials, that the omission of the variable representing the percentage of workers in managerial and professional occupations and the variable for the percentage of workers employed in the service industries
resulted in the smaller reduction in the explained variance compared to the omission of other possible combination of variables. Thus, of these three variables, the percentage of college-educated residents was included in the final model. Formally, the re-specified model appears in the following form:

\[
MCOMT = b_0 + b_1 \times (\text{INCOM}) + b_2 \times (\text{ADMSU}) + b_3 \times (\text{BGDEG}) + b_4 \times (\text{FEMEM}) + b_5 \times (\text{MANUF}) + b_6 \times (\text{MINOR}) + b_7 \times (\text{D6-18}) + b_8 \times (\text{D18+}) + b_9 \times (\text{NE}) + b_{10} \times (\text{SE}) + b_{11} \times (\text{NW})
\]

With respect to the problems associated with non-linearity in the distribution of residuals, it was discovered that non-linearity was caused by a few outliers with either extremely high or extremely low values on the dependent variable. A decision was made to use the restricted ("trimmed") data set in the final estimation. It should be noted that the parameter estimates obtained for the restricted data set did not differ from the parameter estimates obtained for the complete data set. However, the error terms (residuals) for the model with restricted data set were distributed normally. Since the elimination of the outliers did not affect any of the modeled relationships, while simultaneously correcting the problem of non-normality in the residuals, it appears that this procedure was applied appropriately. Further, the scale of the elimination of the
outliers is indeed minimal: only nine observations were removed from the 1980 data set and just ten observation from the 1990 data (initial data sets included 508 and 568 observation for respectively 1980 and 1990).

Table 6.4 presents results of the conventional Ordinary Least Squares (OLS) regression model for 1980 and 1990 census data. There is no data reported in the 1970 census on commuting time, therefore the analysis must be limited to just the two time periods.

Both models achieved a satisfactory goodness-of-fit. The adjusted $R^2$ was 0.43 for the 1980 model and 0.45 for the 1990 model. Statistics for the Kiefer-Salmon test on normality of errors were not significant, indicating that the residuals in both models were, in fact, distributed normally. However, results of the Breusch-Pagan test on heteroscedasticity of errors indicated that for the both models the assumption of constant (equal) variance in the residuals was violated. The causes of heteroscedasticity may be related to the nature of the data used for modeling as well as to the "spatial effects" arising from the fact that the data come from a spatially distributed population (Anselin, 1988b, 1992).

Various transformations, including logarithmic and exponential, were applied to the data set with the goal of
Table 6.4 Results of the OLS Estimation for the Commuting Determinants Model

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>23.0752*</td>
<td>24.3259*</td>
</tr>
<tr>
<td>INCOM</td>
<td>0.0002*</td>
<td>3.22E-05***</td>
</tr>
<tr>
<td>ADMSU</td>
<td>0.0810***</td>
<td>0.0833**</td>
</tr>
<tr>
<td>BGDEG</td>
<td>-0.0769*</td>
<td>-0.0784*</td>
</tr>
<tr>
<td>FEMEM</td>
<td>-0.0640**</td>
<td>-0.0429**</td>
</tr>
<tr>
<td>MANUF</td>
<td>-0.0894**</td>
<td>-0.0915**</td>
</tr>
<tr>
<td>MINOR</td>
<td>0.0894*</td>
<td>0.0516*</td>
</tr>
<tr>
<td>D6-18</td>
<td>2.7083*</td>
<td>2.6236*</td>
</tr>
<tr>
<td>D18+</td>
<td>5.5852*</td>
<td>5.7366*</td>
</tr>
<tr>
<td>NE</td>
<td>0.9000</td>
<td>0.0820</td>
</tr>
<tr>
<td>SE</td>
<td>-0.7602</td>
<td>-0.5330</td>
</tr>
<tr>
<td>NW</td>
<td>1.9794**</td>
<td>1.4196**</td>
</tr>
<tr>
<td># of Observations</td>
<td>499</td>
<td>558</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.4275</td>
<td>0.4478</td>
</tr>
<tr>
<td>Kiefer-Salmon Normality</td>
<td>0.5178</td>
<td>3.2780</td>
</tr>
<tr>
<td>Breusch-Pagan</td>
<td>91.3274*</td>
<td>68.4512*</td>
</tr>
<tr>
<td>Moran's I Test</td>
<td>0.4895*</td>
<td>0.4924*</td>
</tr>
<tr>
<td>Robust LM (error) Test</td>
<td>0.6055</td>
<td>3.2075***</td>
</tr>
<tr>
<td>Robust LM (lag) Test</td>
<td>37.8763*</td>
<td>48.2292*</td>
</tr>
</tbody>
</table>

* p=99.99
** p=99.00
*** p=90.00

Source: Calculated by author.
eliminating unequal variance in the regression residuals. However, no satisfactory solution to this problem was found.

As mentioned earlier, heteroscedasticity often occurs in spatial data sets. The use of the spatial regression specifications with Maximum Likelihood (ML) estimation method instead of conventional OLS may eliminate the problem of unequal variance (Anselin, 1988b, 1992). Finally, if ML spatial regression fails to produce homoscedastic residuals, robust estimation methods, such as the bootstrap method, insensitive to the violation of the standard OLS and ML assumptions, can be employed.

As expected, a high degree of spatial autocorrelation in the regression residuals in both 1980 and 1990 models was detected. Moran's I statistics were high and significant. As evident from the comparison of Robust Lagrange Multiplier (LM) test for spatial error and Robust LM test for spatial lag, the preferable specification of the spatial regression model was the spatial lag model. This conclusion is based on the fact that the statistic for the Robust LM test for spatial error was small and insignificant. The interpretation of this result is that the spatial error model is not effective in the elimination of the spatial autocorrelation in the regression residuals. At the same time, high and significant statistic for the Robust LM lag
test indicates that the spatial lag specification can be effective and appropriate technique of modeling the spatial autoregressive process in the residuals. Accordingly, the spatial lag regression specification was selected for the next step of model building in this sequence.

Although, in the light of the preceding several paragraphs, it appears that the OLS models serve only an auxiliary role (as a first step in the selection of the most appropriate specification), it is nevertheless instructive to briefly analyze the results. Overall, the two models produced remarkably similar results, thereby considerably undermining the advocated thesis of rapid restructuring in commuting patterns. Perhaps, a span of just ten years between the two data sets is not long enough for genuine changes in commuting patterns to develop. Since OLS estimates are not reliable in the presence of spatial autocorrelation and heteroscedasticity in the regression residuals, it is perhaps not technically correct to assign great significance to the OLS estimates in the discussion. However, it should be noted that most parameter estimate (i.e., regression coefficients) in the OLS models loaded with the previously hypothesized signs.

The final specification of the commuting model takes on the following form:
\[ \text{MCOMT} = b_0 + b_1 * (W_{\text{MCOMT}}) + b_2 * (\text{INCOM}) + b_3 * (\text{ADMSU}) + \\
   b_4 * (\text{BGDEG}) + b_5 * (\text{FEMEM}) + b_6 * (\text{MANUF}) + b_7 * (\text{MINOR}) + b_8 * (D6-18) + \\
   b_9 * (D18+) + b_{10} * (\text{NE}) + b_{11} * (\text{SE}) + b_{12} * (\text{NW}) \]

where \( W_{\text{MCOMT}} \) is a spatially lagged dependent variable, and the other variables remain with the same definitions provided earlier in the chapter.

Table 6.5 presents results of the Maximum Likelihood (ML) estimation of the spatial lag (SL) regression model for the 1980 and 1990 data sets. Different spatial weights were tried in the computation of the spatial lag. It was discovered that for the 1980 data set, the weighted contiguity matrix of spatial weights was the most efficient. However, for the 1990 data set, the binary contiguity matrix of spatial weights was discovered to be the most efficient. Efficiency in this case is defined as the ability of the spatial weights to reflect the spatial autocorrelation in the residuals.

As is typically expected, the parameter estimates generated using the SL specification are characterized by both lower magnitude and lower significance compared to OLS results. This is a reflection of the "cleansing" action of the SL model, and it in fact underscores the importance of accounting for spatial autocorrelation in the regression analysis. Both the 1980 and the 1990 models achieved quite
### Table 6.5 Results of the Maximum Likelihood Estimation of the Spatial Lag Specification for the Commuting Determinants Model

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>7.6427*</td>
<td>8.2285*</td>
</tr>
<tr>
<td>W_COMT</td>
<td>0.6548*</td>
<td>0.6990*</td>
</tr>
<tr>
<td>INCOM</td>
<td>9.07E-05**</td>
<td>1.01E-05</td>
</tr>
<tr>
<td>ADMSU</td>
<td>0.0095</td>
<td>-0.0075</td>
</tr>
<tr>
<td>BGDEG</td>
<td>-0.0525**</td>
<td>-0.0409*</td>
</tr>
<tr>
<td>FEMEM</td>
<td>-0.0081</td>
<td>-0.0123</td>
</tr>
<tr>
<td>MANUF</td>
<td>-0.0487***</td>
<td>-0.0212</td>
</tr>
<tr>
<td>MINOR</td>
<td>0.0424*</td>
<td>0.0259*</td>
</tr>
<tr>
<td>D6-18</td>
<td>1.0041***</td>
<td>0.9556*</td>
</tr>
<tr>
<td>D18+</td>
<td>2.1744*</td>
<td>2.4420*</td>
</tr>
<tr>
<td>NE</td>
<td>-0.1379</td>
<td>-0.8190***</td>
</tr>
<tr>
<td>SE</td>
<td>-0.5751</td>
<td>-0.7107***</td>
</tr>
<tr>
<td>NW</td>
<td>0.2241</td>
<td>-0.0567</td>
</tr>
<tr>
<td># of Observations</td>
<td>499</td>
<td>558</td>
</tr>
<tr>
<td>Squared Correlation</td>
<td>0.4761</td>
<td>0.4878</td>
</tr>
<tr>
<td>Spatial Breusch-Pagan Heteroscedasticity Test</td>
<td>83.9971*</td>
<td>56.5923*</td>
</tr>
<tr>
<td>LM (error) Test</td>
<td>1.0728</td>
<td>3.2918***</td>
</tr>
</tbody>
</table>

* p=99.99
** p=99.00
*** p=90.00

Source: Calculated by author.
reasonable goodness-of-fit. Squared correlation between observed and predicted values (used as a surrogate for traditional R-square, which again is not available under the Maximum Likelihood method of estimation) is 0.476 for 1980 and 0.488 for 1990. Spatial error dependence in residuals is eliminated almost completely in the SL models, as indicated by the low and insignificant LM Error statistics reported in Table 6.5.

However, residuals from these two spatial lag models are characterized with unequal variance (Spatial Breusch-Pagan Test in Table 6.5), which renders the parameter estimates inefficient. In this situation, when heteroscedasticity is present, the bootstrap estimation provides a viable alternative to the Maximum Likelihood estimation (Leger et al., 1992; Anselin, 1992). Technical details on the bootstrap method can be found in Chapter Five.

Accordingly, the two models of mean commuting time were re-estimated using the bootstrap method. Results of the bootstrap estimation are presented in Table 6.6. The results from both 1980 and 1990 models can be seen as comparable, while still different in some interesting ways. Moreover, some of these differences match a hypothesized scenario of urban transition. It is not very likely that these
Table 6.6 Results of the Bootstrap Estimation of the Spatial Lag Regression Specification for the Commuting Determinants Model

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>1990</th>
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</thead>
<tbody>
<tr>
<td>Constant</td>
<td>4.5519*</td>
<td>5.1312**</td>
</tr>
<tr>
<td>W_COMT</td>
<td>0.7882***</td>
<td>0.8318*</td>
</tr>
<tr>
<td>INCOM</td>
<td>7.37E-05***</td>
<td>0.66E-05</td>
</tr>
<tr>
<td>ADMSU</td>
<td>-0.0016</td>
<td>-0.0226</td>
</tr>
<tr>
<td>BGDEG</td>
<td>-0.0463**</td>
<td>-0.0334**</td>
</tr>
<tr>
<td>FEMEM</td>
<td>0.0009</td>
<td>-0.0069</td>
</tr>
<tr>
<td>MANUF</td>
<td>-0.0417***</td>
<td>-0.0105</td>
</tr>
<tr>
<td>MINOR</td>
<td>0.0328*</td>
<td>0.0206*</td>
</tr>
<tr>
<td>D6-18</td>
<td>0.6846***</td>
<td>0.6513***</td>
</tr>
<tr>
<td>D18+</td>
<td>1.5480**</td>
<td>1.8210*</td>
</tr>
<tr>
<td>NE</td>
<td>-0.3506</td>
<td>-0.9549**</td>
</tr>
<tr>
<td>SE</td>
<td>-0.5139</td>
<td>-0.7223***</td>
</tr>
<tr>
<td>NW</td>
<td>-0.0777</td>
<td>-0.3002</td>
</tr>
<tr>
<td># of Observations</td>
<td>499</td>
<td>558</td>
</tr>
<tr>
<td>Squared Correlation</td>
<td>0.4702</td>
<td>0.4711</td>
</tr>
</tbody>
</table>

* p=99.99
** p=99.00
*** p=90.00

Source: Calculated by author.
differences stem from the slightly different sample sizes (508 census tracts in 1980 vs. 568 tracts in 1990), which are due to the redefinition of census tracts in Houston by the U.S. Bureau of the Census between these years. Therefore, these differences, which will be discussed shortly, should be viewed as related to structural causes and not as mere artifacts of the model building process.

The spatially lagged dependent variable (W_MCOMT) loaded positively and further was highly significant for both the 1980 and 1990 models. This result means that nearby census tract tend to have similar values for mean commuting time. This result in itself is very important since it attests to certain cohesion and orderliness in the spatial structure of urban labor markets. The fact that workers living in proximate neighborhoods do in fact have similar commuting patterns reveals the existence of elusive laborsheds or labor catchment areas. Further, the high estimates for this variable support to some extent the use of potentials in the office space location model as well. Of course, the nature of these laborsheds is probabilistic; there are no physical boundaries analogous to ridges in natural watersheds that would preclude the free movement of people. However, this result clearly indicates that there are structural forces at work which effectively partition
metropolitan space into identifiable areas with respect to the location of both the labor force and the workplaces.

The income measure (INCOM) loaded positively for both time periods; however, the parameter estimate in the 1990 model is insignificant. Although negative relationships for both periods were expected, these results conform to conventional beliefs about the positive relationship between the length of commute and income. Moreover, the insignificance of median household income in the 1990 model as a predictor for median commuting time can be interpreted as an indication of the temporal change. According to the obtained results, the relationship between income and commuting time did not become negative as was expected; however, it is also not positive.

With respect to the magnitude of these and other coefficients in the commuting determinants model, it should be noted that such small values are nevertheless quite meaningful. Mean commuting time, as a variable, is very conservative in the sense that it is characterized with restricted variation across space and time. Therefore, a rather small absolute (in minutes) impact of the independent variables is expected. However, these small values of parameter estimates reveal unobvious relationships between the structure of the local workforce and the average degree
of the home-work separation. Further, the use of aggregate characteristics, expressed in percentages, reduces variance for the set of independent variables, thus ensuring that slope estimates are relatively small in absolute terms.

As was hypothesized, the percentage of workers with a college education (BGDEG) was related negatively to mean commuting time. This means that, for any given census tract, the more educated the local workforce, the shorter the average commuting length for that tract. This result appears to be a reflection of the suburbanization of office complexes. The growth of offices complexes in suburban locations has brought the workplaces of college-educated workers closer to their residences. This closeness is measured in terms of the commuting time. Therefore, the fact that office complexes in their location strategies targeted college-educated workforce, which was confirmed in the office location model, in turn manifests itself in the shorter commutes for the college-educated workers.

To the extent that these two measures can be separated, income and education reveal the dialectical nature of contemporary urban restructuring: as employment centers have been moving into white-collar neighborhoods, with education being the main attractor, high levels of income in certain places served, in the form of the correspondingly high land
values or land use restrictions, as a deterrent for employment suburbanization.

The percentage of workers employed in administrative support and clerical occupations (ADMSU) loaded negatively for both time periods, although the parameter estimates were not significant. This result means that the percentage of clerical workers, in the presence of other explanatory variables, does not appear to be a good predictor for the mean commuting time. A possible explanation for the failure of this variable may be related to the fact that clerical workforce for the service industries may be drawn from a wide geographical and income array of neighborhoods. Traditionally, clerical needs of the office industries were met by women from low income households. Geographically, these types of households are associated with central-city neighborhoods. However, the increased female workforce participation in the last several decades has led to a situation where women from middle- and high-income households began to be actively employed in the administrative support occupations. In fact, it is contended in the literature that the expanding service industries sought to tap the labor pools of the middle-class suburban women (Nelson, 1986; England, 1993). Therefore, residences of the administrative support workers appear not to be
limited geographically to just the central city, they now include suburbs as well. Hence the inability of this variable (ADMSU) to explain the different commuting times among the census tracts in Houston.

The variable representing the percentage of workers employed in manufacturing industries (MANUF) also loaded, as was expected, negatively in both models, although the parameter estimate for 1990 is not significant. This result indicates, somewhat similarly to the case of the variable for median household income (INCOM), that the commuting advantages for manufacturing workers, under the pressures of increasing "servicization" of the economy, maybe disappearing. In 1980, a larger share of manufacturing workers in a tract's workforce led to a shorter commute. However, during the 1980s, the manufacturing base shrunk, thereby forcing the residents of traditionally manufacture-oriented neighborhoods to take jobs in other, most probably service, industries. Incidentally, these service jobs are located away from major industrial zones. Accordingly, this trend has resulted in a situation where the percentage of workers employed in manufacturing is systematically related to the mean commuting time.

The variable representing female workforce participation rate (FEMEM) loaded positively for 1980 data
and negatively for 1990 data. However, neither estimate is statistically significant. Since females tend dominate the clerical workforce, a possible explanation of the obtained result has much in common with the explanation given for the percentage of administrative support workers.

Confirming the theoretical supposition, the variable for the racial composition of the workforce (percentage of African Americans in the population—MINOR) loaded positively and significantly for the both periods, thus indicating the persistence of commuting disadvantage associated with residence in a minority neighborhood over time. This result reiterates the geographical basis of the minority unemployment problem. The rapid growth of suburban jobs, concentrated mostly in and around suburban business centers, has created a spatial disparity between the location of minority neighborhoods and the location of the metropolitan workplaces.

The use of the spatial regression and bootstrap estimation had an interesting impact on the slope estimates for the zonal dummy variables. First of all, there is an impressive reduction in the magnitude of these coefficients.

According to the OLS model, using the 1990 data, census tracts located on the outer periphery of the county (beyond the 18-mile radius zone centered on the CBD, variable D18+)
were characterized by an increase in commuting time of 5.7 minutes. However, when the autocorrelation effects are accounted for, this value drops to 2.4 minutes in the Maximum Likelihood estimation, and to 1.8 minutes in the bootstrap estimation. Furthermore, for the 1990 tracts located within the inner concentric ring defined by the six-mile and the 18-mile circles (variable D6-18), the standard OLS model predicts an increase in commuting time of 2.6 minutes over the central city tracts (located within six miles of the Houston CBD). However, in the spatial lag (Maximum Likelihood) model, this value decreased to 1.0, and further to 0.7 in the bootstrap estimation.

These results have important methodological implications. It appears that the application of appropriate regression specification reduces conventionally perceived effects of distance from the city center on commuting times.

Somewhat surprisingly, sectoral dummies did not account for any systematic variation in the mean commuting time for census tracts in Houston. Parameter estimates for all three sectoral dummy variables are insignificant for the 1980 data in the bootstrap spatial lag model. For the 1990 data, the dummy variables for the Southeastern sector (SE) and for the Northeastern sector are significant. Both variables loaded negatively, indicating decreases of 1.0 and 0.7 minutes
associated with location in, respectively, the Northeastern and Southeastern sectors of the city. Most likely, this result can be attributed to the aggregate effects of blue-collar industrial neighborhoods in the Eastern sector and to the proliferation of residential and office space development in the Clear Lake/NASA Space center area.

Based on the results of this set of regression models, the following conclusions regarding the relationships between workforce characteristics and the length of commute, can be made:

1. Partial support is found for Hypothesis #1 (formulated in section two of Chapter Two). Specifically, a predicted negative relationship is established between the commuting time and the percentage of college-educated workers. However, the relationship between commuting time and the median household income is positive for the 1980 data, while no definite relationship is discovered for 1990 data. Due to statistical limitations on the model building, the relationships between the mean commuting time on the one hand, and the percentage of managerial/professional workers and the percentage of workers employed in business services on the other hand, were not tested.

2. No support is found for Hypothesis #2 and #4. Specifically, no definite relationships was discovered
between the median commuting time and (A) the percentage of administrative support and clerical workers, and (B) female workforce participation rate.

3. Partial support is found for Hypothesis #3. Specifically, a negative relationship was established between the mean commuting time and the percentage of workforce employed in manufacturing using 1980 census data. However, no definite relationship was established using 1990 data.

4. Full support is found for Hypothesis #5. A positive relationship is established between the median commuting time and the percentage of African Americans in the population.

5. The behavior of some variables over time confirms to the hypothesized scenario of urban spatial restructuring, as implied by such results as the disappearance of (A) the positive effects of median household income and (B) the negative effects of the employment in manufacturing on the mean commuting time in the model using 1990 data as compared to the 1980 model.

6.4 Estimation of the Model of Office Space Effects on Housing Values

The model for housing values introduces the change (in constant dollars) in the median value of owner-occupied housing for census tracts (defined in their 1990 boundaries)
as the dependent variable. The independent variables are the change in the office space potential for census tracts and a set of locational dummy variables similar to those used in the preceding section. Formally, the OLS model is defined as follows:

Change in Housing Value = b₀ + b₁*ln(OFSPA) + b₂*(D6-18) + b₃*(D18+) + b₄*(NE) + b₅*(NW) + b₆*(SE)

where OFSPA is defined as the change for office space potential and the other variables remain as defined earlier in the chapter.

The independent variable measures the change in the amount of local office space. This variable, again calculated as a potential, represents not only the actual office space located in a given census tract, but also takes into account office space in surrounding tracts. As was the case previously, two different specifications of the distance-decay function were used in the calculation of potentials: the more restrictive negative power exponential ("entropy" model) and the less restrictive inverse quadratic ("gravity" model). Office space potentials were initially estimated for each of the three census years (1970, 1980, and 1990), and then the differences between the years were calculated. These differences represent changes in the accessible office space for a given census tract over a
specific period of time. It is hypothesized that housing values for each census tract, within and around which office complexes emerged, experienced increases over previous years.

In order to control for the difference in the absolute sizes of homes— one of the most important value determinants— the dependent variable was standardized by size. The median value of owner-occupied housing in the census tract was divided by the average number of rooms per home in the census tract. Therefore, the dependent variable can be interpreted as a change in the average value of an average room in owner-occupied housing.

The units of analysis are the 1990 census tracts. Housing values data for 1990 were simply taken from the 1990 census. However, for 1970 and 1980, housing values (for census tracts in their 1990 boundaries) were recreated using a spatial overlay procedure available in ARC/INFO GIS. The change over time is calculated for the three periods: 1970 to 1990, 1980 to 1990, and 1970 to 1980. Maps presented on Figures 6.7, 6.8, and 6.9 illustrate the spatial variation in the housing values in Harris County for the three time periods.

In the absence of a direct measure of the age of housing stock, the two zonal dummy variables (D6-18 and
Figure 6.7 Median Room Value in Harris County, 1970
Figure 6.8 Median Room Value in Harris County, 1980
Figure 6.9 Median Room Value in Harris County, 1990
D18+) were used as proxies. It is assumed, therefore, that newer housing stock, that is geographically more distant from the Houston's CBD, will carry an additional premium with respect to median value.

Results of the OLS estimation are presented in Tables 6.7 and 6.8. As evident from test statistics reported in Tables 6.7 and 6.8, residuals from OLS models are characterized by both non-normality and heteroscedasticity. This finding renders OLS models inappropriate. Moreover, diagnostics for spatial autocorrelation in the residuals indicate the presence of strong autocorrelation effects. These effects, however, can be effectively accounted for in the Spatial Lag (SL) regression. Given the problems with non-normality and heteroscedasticity, it is most appropriate, again, to use the bootstrap estimation (Anselin, 1992).

Results of bootstrap estimation for the SL regression models are presented in Tables 6.9 and 6.10. As evident from an analysis of both sets of tables, the bootstrap estimation produced vastly different results, both in terms of parameter estimates and standard errors (i.e., significance levels). This underscores the importance of using an appropriate model specification for non-normal and heteroscedastic data.
Table 6.7 Results of the OLS Estimation for the Housing Values Model (Entropy Distance-Decay Function)

<table>
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</thead>
<tbody>
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<td>Constant</td>
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<td>7571.38**</td>
<td>7374.53***</td>
</tr>
<tr>
<td>Office Space Potential</td>
<td>-27.85</td>
<td>994.79*</td>
<td>1059.56*</td>
</tr>
<tr>
<td>D6-18</td>
<td>771.9*</td>
<td>-2747.99**</td>
<td>-1559.74***</td>
</tr>
<tr>
<td>D18+</td>
<td>1868.09*</td>
<td>-291.05</td>
<td>2484.09***</td>
</tr>
<tr>
<td>NE</td>
<td>-1129.51*</td>
<td>-9434.68*</td>
<td>-10102.5*</td>
</tr>
<tr>
<td>NW</td>
<td>-551.18</td>
<td>-9090.29*</td>
<td>-9476.77*</td>
</tr>
<tr>
<td>SE</td>
<td>-1128.31</td>
<td>-8301.42*</td>
<td>-9018.19*</td>
</tr>
<tr>
<td># of obs.</td>
<td>568</td>
<td>568</td>
<td>568</td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.163</td>
<td>0.292</td>
<td>0.300</td>
</tr>
<tr>
<td>Kiefer-Salmon Normality Test</td>
<td>513.00*</td>
<td>14375.69*</td>
<td>10061.57*</td>
</tr>
<tr>
<td>Koenker-Bassett Heteroscedasticity Test</td>
<td>73.40*</td>
<td>42.26*</td>
<td>52.77*</td>
</tr>
<tr>
<td>Robust LM Error Test</td>
<td>0.627</td>
<td>0.118</td>
<td>0.004</td>
</tr>
<tr>
<td>Robust LM Lag Test</td>
<td>5.54***</td>
<td>10.292**</td>
<td>10.173**</td>
</tr>
</tbody>
</table>

* p=99.99  
** p=99.00  
*** p=90.00

Source: Calculated by Author.
### Table 6.8 Results of the OLS Estimation for the Housing Values Model (Gravity Distance-Decay Function)

<table>
<thead>
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<th></th>
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<tbody>
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<td>Constant</td>
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<td>58400.53*</td>
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<tr>
<td>Office Space</td>
<td>-462.368*</td>
<td>5124.12*</td>
<td>5091.91*</td>
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<tr>
<td>Potential</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>D6-18</td>
<td>408.81***</td>
<td>-884.53</td>
<td>798.342</td>
</tr>
<tr>
<td>D18+</td>
<td>965.88**</td>
<td>5096.4*</td>
<td>8660.63*</td>
</tr>
<tr>
<td>NE</td>
<td>-1973.44*</td>
<td>-2810.99***</td>
<td>-3495.31***</td>
</tr>
<tr>
<td>NW</td>
<td>-1010.15</td>
<td>-5990.87*</td>
<td>-6130.37*</td>
</tr>
<tr>
<td>SE</td>
<td>-1959.35</td>
<td>-1682.91</td>
<td>-2464.37***</td>
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<tr>
<td># of obs.</td>
<td>568</td>
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<tr>
<td>Adj. R²</td>
<td>0.189</td>
<td>0.365</td>
<td>0.363</td>
</tr>
<tr>
<td>Kiefer-Salmon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normality Test</td>
<td>677.67*</td>
<td>11453.42*</td>
<td>7486.41*</td>
</tr>
<tr>
<td>Koenker-Bassett</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Heteroscedasticity Test</td>
<td>73.21*</td>
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<tr>
<td>Robust LM Error</td>
<td></td>
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</tr>
<tr>
<td>Test</td>
<td>0.021</td>
<td>0.014</td>
<td>0.001</td>
</tr>
<tr>
<td>Robust LM Lag Test</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2.47</td>
<td>10.900*</td>
<td>11.332*</td>
</tr>
</tbody>
</table>

* p=99.99
** p=99.00
*** p=90.00

Source: Calculated by Author.
Table 6.9 Results of the Bootstrap Estimation of the Spatial Lag Specification for the Housing Values Model (Entropy Distance-Decay Function)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Lag</td>
<td>0.725*</td>
<td>0.714*</td>
<td>0.698*</td>
</tr>
<tr>
<td>Constant</td>
<td>728.73</td>
<td>1748.68</td>
<td>1761.63</td>
</tr>
<tr>
<td>Office Space Potential</td>
<td>-18.02</td>
<td>332.76***</td>
<td>367.97***</td>
</tr>
<tr>
<td>D6-18</td>
<td>164.92</td>
<td>-783.16</td>
<td>-476.325</td>
</tr>
<tr>
<td>D18+</td>
<td>456.18</td>
<td>29.75</td>
<td>903.05</td>
</tr>
<tr>
<td>NE</td>
<td>-349.98</td>
<td>-2805.48</td>
<td>-3140.95</td>
</tr>
<tr>
<td>NW</td>
<td>-182.11</td>
<td>-2852.69*</td>
<td>-3111.26***</td>
</tr>
<tr>
<td>SE</td>
<td>-396.43</td>
<td>-2496.23</td>
<td>-2878.66</td>
</tr>
<tr>
<td># of obs.</td>
<td>568</td>
<td>568</td>
<td>568</td>
</tr>
<tr>
<td>Sq. Corr.</td>
<td>0.177</td>
<td>0.317</td>
<td>0.324</td>
</tr>
</tbody>
</table>

* p=99.99  
** p=99.00  
*** p=90.00

Source: Calculated by Author.
Table 6.10 Results of the Bootstrap Estimation of the Spatial Lag Specification for the Housing Values Model (Gravity Distance-Decay Function)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Lag</td>
<td>0.663**</td>
<td>0.757*</td>
<td>0.742***</td>
</tr>
<tr>
<td>Constant</td>
<td>4208.34***</td>
<td>-18106.7***</td>
<td>-18704.8***</td>
</tr>
<tr>
<td>Office Space Potential</td>
<td>-235.53</td>
<td>1550.12***</td>
<td>1558.65***</td>
</tr>
<tr>
<td>D6-18</td>
<td>38.43</td>
<td>-103.64</td>
<td>301.13</td>
</tr>
<tr>
<td>D18+</td>
<td>148.17</td>
<td>1696.85</td>
<td>2685.69</td>
</tr>
<tr>
<td>NE</td>
<td>-818.67***</td>
<td>-393.65</td>
<td>-700.77</td>
</tr>
<tr>
<td>NW</td>
<td>-432.41</td>
<td>-1574.81</td>
<td>-1729.28</td>
</tr>
<tr>
<td>SE</td>
<td>-862.98***</td>
<td>-136.54</td>
<td>-499.889</td>
</tr>
<tr>
<td># of obs.</td>
<td>568</td>
<td>568</td>
<td>568</td>
</tr>
<tr>
<td>Sq. Corr.</td>
<td>0.197</td>
<td>0.386</td>
<td>0.384</td>
</tr>
</tbody>
</table>

* p=99.99
** p=99.00
*** p=90.00

Source: Calculated by Author.
Regardless of the function used in the computation of office space potential, the model for the 1970-1980 change stands apart from the models for the 1980-1990 and for the 1970-1980 change. The model for the 1970-1980 change has a much weaker explanatory power than the other models. Further, the principal explanatory variable—the change in office space potential—produced insignificant parameter estimates in the 1970-1980 change model. This "non-result" is quite interesting if somewhat confusing. Essentially, the absence of any relationship in the model means that in the 1970s, housing values did not co-vary with available office space. The failure of the office space potential to predict changes in the housing values during the 1970s might be related to the fact that at early stages of office space suburbanization benefits associated with living in proximity to office complexes were not yet realized. In other words, the mechanisms of property value formation associated with office complexes needed time to develop.

The situation, however, changed dramatically in the 1980s. Models for the 1980-1990 change are characterized with reasonably good fits. The squared correlations between the observed and the predicted values are 0.32 for the entropy specification and 0.39 for the gravity specification. Parameter estimates for the change in office
space potential are positive and significant for both specifications. That means that during the 1980s, increases in accessible office space did indeed lead to the corresponding increases in housing values. This result fits perfectly with the theoretical prediction: as office complexes gained prominence, their role in structuring urban space via positive influences on land and housing values increased. The same models for the 1970-1990 change produced results similar to the results for the 1980-1990 model. However, the satisfactory performance of the cumulative two-decades change model can be attributed almost entirely to the processes which operated in the 1980s.

As was expected, the spatially lagged dependent variables produced positive and significant coefficients. These coefficients reflect a degree of similarity between adjacent neighborhoods with respect to some variables. In this case, it is the change in average room value. That means that there is a great deal of homogeneity in housing values within areas stretching over several neighborhoods.

Finally, none of the geographical dummy variables in the models for 1980-1990 and 1970-1990 resulted in significant estimates. This does not mean, however, that newer housing stock, which is proxied by the distance rings (D6-18 and D18+), is not contributing to the increases in
the property values. The obtained results might be interpreted as an indication of the fact that office complexes often emerge in neighborhoods with new housing stock. In turn, new office complexes can and do attract residential development (Garreau, 1992; Hartshorn and Muller, 1992).

Based on the results of regression modeling, it can be concluded that the fairly strong positive relationship between the changes in housing values and changes in the accessible office space does in fact exist. This relationship, however, is not stable over time. For Harris County, TX this relationship is registered for the 1980-1990 and for the 1970-1990 period, but not for the 1970-1980 period.

6.5 Summary

Some of the many results reported in this chapter were anticipated, others were not. While the substantive issues will receive the greater attention in the concluding chapter which follows, it is also important to recognize that the process of iterative model building which is reported in this chapter has some very significant methodological implications. The use of OLS, surely most common in geographic and other social science research of this type, does not appear appropriate for the models of the current
research. Because of the problems associated with multicollinearity, spatial autocorrelation, and heteroscedasticity, new, yet unconventional, functional forms and estimation methods were employed. The obtained results, therefore, are statistically legitimate and accurate with respect to anticipated relationships.

The following chapter will discuss some of the most important and interesting findings of the research.
CHAPTER SEVEN: CONCLUSIONS

There are a number of interesting and important results which this research generated. Results from the three sets of models, which address different aspects of the project, are first reported independently and then synthesized. Finally, the broader implications of the research and related finding are discussed.

7.1 A Summary of Findings

With respect to the model of office location, results of statistical modeling revealed a sound and significant locational connection between office space and the office-related workforce. The distribution of office complexes in Houston appears to be closely associated with the distribution of college-educated workers, managers and professionals, workers employed in business services, administrative support workers, and female workers. On the other hand, no spatial (locational) association was established between office complexes and manufacturing employment. Similarly, no relationship was found between the location of office complexes and minority population.

Although the positive relationship between office complexes on the one side, and (A) the clerical workforce and (B) the female workforce on the other side was not expected, this result, nevertheless, can be reasonably
explained. Apparently, suburban office complexes stimulate employment among the residents of nearby-located neighborhoods, particularly among female members of the workforce. This means that the degree of spatial segregation, with respect to the location of the residences of the office workforce (professionals vis-a-vis clericals) is not necessarily high. In other words, office industries appear to be able to draw both types of workers from the same geographical pools of labor.

In short, there seems to be sufficient evidence to support the hypothesis that decentralizing office industries are targeting (or drawn to) residential areas with high proportions of white-collar office workers, while simultaneously avoiding industrial and minority neighborhoods.

The model of commuting determinants and the model of office location are intricately connected. Both models were developed to investigate, although through different means, the fundamental relationships between the spatial distribution of homes (places where people live) and the spatial distribution of employment (places where people work). Therefore, both models were expected to produce comparable results, which indeed they did. In particular, the model of commuting determinants established that those
census tracts characterized by higher concentrations of college-educated residents were also characterized with systematically shorter average commuting times. The inverse relationship (i.e., longer average commuting times) was also established with respect to minority populations.

Clearly, shorter commutes for college-educated workers, as well as longer commutes for African-Americans in Houston stem from the fact that office complexes, which also bring in many non-office jobs, "follow" (in terms of location strategy) the white-collar office workforce and, in turn, avoid low-income, minority neighborhoods. Further, the fact that no statistically definitive relationship was established between mean commuting time for any given census tract on the one hand, and the percentage of administrative support workers and the female workforce participation rate on the other hand, acquires new meaning. This is particularly the case in light of an interpretation of the results of the office location model. As shown earlier, suburbanized office complexes created local pockets of inflated female employment in clerical occupations. For these workers, commuting time is shorter. However, at the same time, a fair proportion of the required clerical workforce is still supplied from the central city and other parts of Harris County not affected by the suburbanization...
of office space. For these workers, commuting time is longer. Therefore, the failure of regression analysis to discern an unequivocal relationship most likely is a reflection of the existence of these two dissimilar but simultaneous patterns in the distribution of offices and the distribution of female clerical employment.

The third model incorporated in the research, which was designed to investigate influences of office complexes on housing values (and thereby on land values as well) in Houston over the 20-year period (from 1970 to 1990), may seem to be independent from the first two models. Yet, the model of housing values addresses the same fundamental type of locational problem implicit in the presumed associations between employment and population. According to the results of this statistical analysis, the changes in housing values for Houston's census tracts during the period 1980-1990 and 1970-1990 were co-directional (i.e., positive relationships exist) with changes in accessible office space. In other words, the suburbanization of office complexes helped boost housing and land values in the neighborhoods to which they moved. The significant implications of this result will be discussed below.

In order to obtain a broader perspective on urban change in the last three or so decades, the results of the
three models discussed above are synthesized into what might be termed "a scenario of urban restructuring." Following are key stages of this scenario:

1. The spectacular growth of the service sector spurs demand for office employment and, concurrently, for office space.

2. To meet this demand, new office complexes are built in selected intrametropolitan locations, mostly in the residential areas which house white-collar workers.

3. As a result of the location bias of office suburbanization, white-collar office workers commute shorter distances, while for other categories of workers the home-work separation increases.

4. As advantages of living in proximity to office complexes are realized, neighborhoods with significant office space receive a premium on the market value of housing and land.

With respect to the spatial arrangement of employment and housing, it is fairly easy to see that the unfolding of this scenario leads to an increasing polarization of urban space. Further, a continuation of the trend might lead to dangerous imbalances in urban spatial structure. Employment centers (office complexes) are being built in white-collar middle- and upper-class neighborhoods, in the western part
of Harris County. This makes it fairly difficult, both in terms of cost and availability of transportation, for the residents from other parts of the county (in terms of geography) and from less wealthy neighborhoods (in terms of class), which often coincide, to access the expanding employment opportunities represented by suburban jobs.

Moreover, the coupling of employment centers with higher housing values exacerbates the job-housing mismatch. Over time, housing values in the neighborhoods into which office complexes, and accordingly jobs in office and supporting industries, move are pushed upward by the positive externalities exerted by office space. The result is the increasing polarization of urban space which leads to dangerous imbalances in the urban spatial structure.

Social-spatial polarization now emerges not only in the sphere of residential housing, but also in the sphere of workplace location. In short, the benefits associated with decentralization of employment have disproportionately accrued to the well-off neighborhoods as vividly testified by office complex concentrations in western Houston.

There are already signs of the unmet demand for lower paid jobs in suburban office centers. This result can be interpreted as to be a direct outcome of the "jobs-housing mismatch" problem, that is the problem of unavailability of
a range of housing opportunities in close proximity to suburban employment centers. For many prospective workers, these suburban jobs are simply located too far from their residences to represent realistic opportunities.

7.2 Implications of the Research

The results of this research have several important implications for urban geography, urban planning, and social policies.

With respect to the contributions to the academic sub-discipline of urban geography, this research provides some insights which will advance, it is hoped, our understanding of the contemporary morphology of U.S. cities. Although the empirical portion of the research was conducted only for Houston, TX, conclusions regarding the connections between the location of jobs and the location of workers' homes may very well be extended, with due caution, to other metropolitan areas. Of course every city is unique, but nevertheless, there are typical trends in urban restructuring, and the suburbanization of office complexes and the related patterns of workforce location appear to be a great example of such a trend.

In addition to addressing substantive issues, this research also addresses complex but important methodological problems related to the modeling of spatial interactions and
the treatment of discrete and continuous space. It appears that the advocated approach—the use of potentials in modeling—is a useful method which can be applied to a wide range of geographical problems. Nevertheless, this methodology requires further conceptualization and development. This dissertation, then, offers new techniques but also the hope that these approaches will receive critical attention which will foster debate in these areas.

The results of this study also have important implications with respect to urban planning. The dual dispersion of employment and population have significantly altered demand for several types of transportation systems. Perhaps the most important outcome of decentralization is the fact that, due to low population and employment densities, public transportation is no longer effective and efficient. Yet, a complete reliance on personal automobile for intra-urban commute is not feasible, both because of traffic congestion and because automobiles are too costly to be used for long commutes by lower-paid workers (particularly, in the long run). There is no ready solution to this problem, but, perhaps, non-traditional approaches may serve as a remedy. One example of such an approach is the introduction of privately managed van-pooling, which is, in effect, an intermediate form between a personal
automobile and a large capacity bus (Cervero, 1989). Certainly, the provision of an effective and efficient transportation system which will connect lower-income housing with burgeoning suburban job markets poses an extremely difficult, if not insurmountable, task for urban planners.

However, dealing solely with efforts to transform the transportation system fundamentally addresses the outcome and not the cause of the problem, which is a clear and distinct imbalance where suburban housing market around employment centers is inflated, in part because of the presence of office space. The practical ways of achieving a balanced housing structure, or, at least of decreasing the imbalance, will certainly differ across cities. However, given the current trends in population and employment decentralization, this problem most likely will exacerbate over time, and therefore must necessarily be addressed in the near future by urban planners and municipal governments.

With respect to social policies, the results of this research make it clear that urban unemployment is not entirely a structural (i.e., related to the lack of marketable skills) problem, but also a geographical problem associated with particular intricacies for any given place and time of the spatial arrangement of jobs and housing.
within metropolitan areas. Therefore, aspatial (i.e., not taking spatial issues into consideration) social policies designed to improve the economic well being of urban residents will not be successful because of the fundamental constraints imposed by the urban spatial structure.

Given the close association between the spatial distribution of employment and the spatial distribution of workforce in general, and given the clear preference of office industries for white-collar suburbs in particular, it appears that policies of employment stimulation in depressed sections of metropolitan areas, such as “empowerment zone” programs, also will not be successful. The reason for that is that these policies are designed, in effect, to counteract the developing market trends in office location. Therefore, policies which do recognize these market trends in location of intra-urban economic activity will have some greater potential for success.

Finally, a few words about directions in which further research may proceed. With respect to the temporal scope, the U.S. Census of the year 2000 is near. The forthcoming census will provide extremely important current information regarding trends in urban transformation. With respect to the geographical scope, it is hoped that office complexes will increasingly receive more attention among geographers.
Accordingly, there will be need for similar studies for different metropolitan areas in the U.S. and perhaps for cities around the world where similar transformations are taking place.
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VITA

Dmitry Mesyanzhinov was born in 1966 in Moscow, Russia. After successfully graduating from Moscow High School #46 in 1984 he was drafted in the military where he served for two years. In 1987 Mr. Mesyanzhinov began his 5-year studies at the Lomonosov Moscow State University Faculty of Geography, and in 1992 he received a degree of Master of Arts in Geography. In 1992 Mr. Mesyanzhinov was admitted to a doctoral program at the Louisiana State University Department of Geography and Anthropology and was awarded a Tuition Exemption Award by the L.S.U. Graduate School. During his studies at L.M.S.U. and L.S.U., Mr. Mesyanzhinov received extensive training in human geography, geographic information systems, and statistical analysis. His major research interests include economic, social, and urban geography, regional development, statistical methods of data analysis, and geographic information systems. Since the Fall of 1992, Mr. Mesyanzhinov has been working as a Graduate Research Assistant at the LSU Center for Energy Studies. During his tenure at the Center for Energy Studies, Mr. Mesyanzhinov has participated in a number of research projects dealing with economic analysis, coauthored several publications, and earned excellent reviews from his supervisors. In September 1996, Mr. Mesyanzhinov was offered
a Research Associate position at the Center for Energy Studies which he accepted and currently occupies. He will receive his degree of Doctor of Philosophy in December 1997.
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Major Field: Geography

Title of Dissertation: Suburbanization of Office Space: A Case Study of Houston, Texas

Approved:

[Signatures]

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination: November 5, 1997