IMPACTS OF URBAN CONTAINMENT POLICIES
ON URBAN GROWTH AND STRUCTURE

DISSERTATION

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ABSTRACT

Numerous communities have adopted some form of urban containment policies (UCPs), such as greenbelt, urban growth boundaries (UGBs), and urban service areas (USAs), as methods to prevent urban sprawl and protect open space. Although there is controversy over the negative and positive impacts of UCPs, little is known on their impacts on population and employment growth, and on the overall urban spatial structure. The purpose of this research is to (1) understand the system of UCPs, (2) empirically analyze their impacts on population and employment growth, and built-up areas in combination with housing values, and (3) examine their impacts on the location of industrial activities as well as population. Two approaches are considered to empirically analyze the impacts of UCPs on urban growth and urban spatial structure. In the first approach, a simultaneous equation model is used with, as endogenous variables, the changes in total population, total employment and sectoral employment, housing values, and land area at the municipal/city level. In the second approach, population and employment density gradients, estimated with both monocentric and polycentric models at the metropolitan level, are used to examine the impacts of different UCPs on urban spatial structure. The research finds that both the stringent containment policies (SCPs), including greenbelts and UGBs, and the less stringent containment policies (LSCP),
including USAs, have significant impacts on changes in population, employment, housing values, and land areas. When both direct and indirect effects are taken into account, the SCPs have a positive effect on changes in population, employment, housing values, and land area twice larger than the LSCPs, suggesting that SCPs more successfully accommodate new growth within the growth boundaries, and that housing values increase with the tightness of UCPs. In terms of the urban spatial structure, statewide SCPs encourage metropolitan areas to move to a polycentric development pattern, locally-enforced SCPs support a monocentric pattern, and USAs produce sprawled development patterns.

Keywords: urban containment policies; greenbelts; urban growth boundaries; urban service areas; population and employment growth; urban spatial structure
Dedicated to my parents, my sister, my daughter and son, and my wife,
Kyungsoon Wang
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CHAPTER 1

INTRODUCTION

The boundaries of American urban areas have expanded much faster than their population (Cox, 2000) in recent decades. This geographic expansion, known as “urban sprawl\(^1\)”, has been criticized in connection to the problem of “first suburbs\(^2\)” in the Midwest. Critics of sprawl point to a number of problems, including excessive encroachment on agricultural land, a loss of amenity from open space, increased traffic congestion, higher air pollution, decay of downtown areas, and reduction of social interactions (Balchin, Isaac, & Chen, 2000; Brueckner, 2000; Cox, 2000; Ewing, 1994; Bank of America, 1995). Moreover, it is commonly believed that low-density metropolitan areas are inherently inefficient relative to more compact cities, incurring higher costs of infrastructure development and public services operations.

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\(^1\) There is no universal definition of urban sprawl, but it is commonly defined as the excessive spatial growth of cities, with low density and non-contiguous development (Galster et al., 2001; Brueckner, 2000; Ewing, 1994).

\(^2\) The First Suburbs can be defined as post-WWII suburbs, that were built near central cities between 1945 and 1960. These suburbs have begun to experience deterioration, problematic sewer and water systems, disinvestments, and the flight of residents with above-average income (Seaver, Morris, & Rapson (1998); Kleismit (2003)).
In order to promote sustainable development and environmental protection, states and local governments have adopted policies designed to deal with urban sprawl, including the establishment of physical containment policies, such as Greenbelts\(^3\), Urban Growth Boundaries\(^4\) (UGBs), and Urban Service Areas\(^5\) (USAs), the imposition of development fees, encouragement of urban development towards “infill”\(^6\), and restrictions on residential capacity. Numerous communities, including cities and counties, have adopted some form of urban containment policy (UCP) as a method to restrict suburban development or protect open space, and UCPs are increasingly seen as the growth control tool of choice by local governments (O’Toole, 2003; Staley et al., 1999). For example, seven states, including Oregon, Washington, Tennessee, Maryland, New Jersey, Maine, and Hawaii, have mandated UCPs at the local level (Kolakowski et al., 2000). Also, more than 200 cities are identified with UCPs in other states, including California, Florida, Michigan, Minnesota, Colorado, Kentucky, Ohio, Pennsylvania, Nebraska, South Dakota, Missouri, and Wisconsin.

Physical UCPs, in contrast to other tools, may significantly affect urban areas, including the growth and location of population and economic activities, because they

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\(^3\) Since the purpose of greenbelts is the permanent protection of open space or natural resources, it is known that greenbelts are the tightest containment policy (Pendall et al., 2002).

\(^4\) Staley et al. (1999) define an urban growth boundary (UGB) as a line drawn around a municipality, with areas beyond the line not permitted to have new development or discouraged to do so. Brueckner (2000) also defines UGB as a zoning tool, the imposition of which involves drawing a circle surrounding a city and prohibiting development outside this circle.

\(^5\) An Urban Service Area is the least restrictive containment policy, because it is easy to modify. In fact, the focus is on reducing the cost of infrastructure rather than limiting geographical expansion (Pendall et al., 2002).

\(^6\) The creative recycling of vacant or underutilized lands within UCP boundaries.
directly limit the physical size of communities. Richardson, Gordon, Jun, & Kim (1993) examine the economic impacts of growth controls on jobs and economic output in Pasadena, California, using a regional input-output model. They conclude that the largest economic losses come from denied nonresidential construction, with particular impact on the lowest-skilled occupational groups. Levine (1999) estimates that fully one-third of rental housing built in California during the 1980s was displaced from controlled to uncontrolled communities as developers moved to other jurisdictions to reduce development costs and time. On the other hand, Landis, Deng, and Reilly (2002) point out that UGBs seem to successfully redistribute development from fringe areas toward more central locations.

There is much controversy over the negative and positive impacts of UCPs. It has been shown that imposing UCPs has contributed to the desired population density and preservation of farmland, accommodating most new residents within the boundary and lowering the cost of new growth for local governments. Nelson et al. (2004) show that UCPs, including ‘urban growth boundary’, ‘service extension limits’, or ‘greenbelt’, contribute to central-city revitalization, using a multiple regression model with the number of residential units constructed as the dependent variable. Wassmer (2006) analyzes the impacts of UCPs on the size of urban areas, using regression analysis with square miles of urban areas as the dependent variable. He finds that the presence of UCPs reduces the size of urban area. On the other hand, the negative effects of UCPs are alleged to include increases in housing values, lower-density residential rings outside the boundary, increase in traffic congestion, and other externalities (Pendall, Martin, & Fulton, 2002; Staley, 1999; Weitz & Moore, 1998). These different views on UCPs and
urban sprawl are related to different focuses. Utility maximization by new homebuyers favors sprawl, but local governmental issues, such as providing public services and infrastructure and protecting farmland, favor enforcement of UCPs.

Previous research related to the impacts of UCPs, including greenbelts, UGBs, and USAs, has focused on housing markets or specific areas. While some research has analyzed the economic and spatial impacts of growth controls, little is known regarding the impacts of containment policies on urban population and economic growth and on the urban spatial structure. In addition, the differences in the tightness of UCPs have not been taken into account in empirical analyses.

The purpose of this research is to (1) understand the system of UCPs, specifically greenbelts, urban growth boundaries, and urban service areas, (2) empirically analyze their impacts on population and employment growth, and built-up areas in combination with housing values, and (3) examine the impacts of the enforcement of UCPs on the location of industrial activities as well as population. The results should be helpful to assess whether the enforcement of UCPs is having desirable results for the future of a metropolitan area, or just generating negative externalities, such as congestion and rising housing prices, and how different containment policies affect urban areas.

The remainder of this dissertation is organized as follows. Chapter 2 consists of a literature review. The theoretical framework and methodology are presented in Chapter 3. Data sources and processing are described in Chapter 4. The estimation of simultaneous equation models of population, employment, land areas, and housing values at the municipal level are discussed in Chapter 5. Similar analyses for population and
employment density gradients at the metropolitan level are presented in Chapter 6. Chapter 7 concludes this dissertation and outlines areas for future research.
CHAPTER 2

LITERATURE REVIEW

This chapter reviews three literature streams: (1) urban sprawl; (2) the nature of urban containment policies (UCPs); and (3) impacts of UCPs. Urban sprawl has been the original reason for which communities have adopted some form of containment policies (Landis et al., 2002). While there is controversy on the positive and negative aspects of urban sprawl, most planners believe that urban sprawl should be curbed by public policies or planning tools, so as to achieve a sustainable community. To prevent urban sprawl, enforcing UCPs, such as greenbelts, urban growth boundaries, and urban service areas, has become a popular method because of ease of implementation. This literature review examines why urban sprawl is problematic, how UCPs do differ, and research on the impacts of UCPs.

2.1 URBAN SPRAWL

No definition of urban sprawl has been universally accepted yet. However, several researchers have tried to clarify this phenomenon. For example, Brueckner (2000) defines urban sprawl as the excessive spatial growth of cities. In an urban sprawl pattern, both residential and nonresidential developments occur in a noncontiguous way outward
from the central city. Nonresidential development includes shopping centers, retail outlets along major transportation corridors, industrial and office parks, and scattered industrial and office buildings. Single-family detached housing is a prototype of urban sprawl. These developments are usually taking place through consumption of agricultural and other fragile lands beyond the existing urban areas (Burchell et al., 1998). However, Weitz and Moore (1998) point out that characteristics other than contiguity should be taken into account to define urban sprawl, including density, design, and availability of urban services and facilities. Galster et al. (2001) provide a conceptual definition of sprawl based on eight distinct dimensions of land-use patterns: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity. According to this definition, sprawl is a condition where the values of those criteria are low. Ewing (1994) shows that urban sprawl is often characterized by undesirable land-use patterns such as scattered\(^7\), leapfrog\(^8\), strip or ribbon\(^9\), or continuous low-density development. He also suggests that sprawl is a matter of degree, with polycentric or multinucleated development usually regarded as a desirable land-use pattern, because they reduce the costs of commuting and traffic congestion (Haines, 1986, cited by Heim 2001: p 273).

The negative effects of urban sprawl can be summarized as follows.

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7 Fujii & Hartshorn (1995) describe scateration as the wide distribution of functions and activities in many locations. In the context of office development, Pivo (1990) describes scateration as low-density development spread randomly across the suburban fabric and not associated with any particular focal points or activity centers.

8 Heim (2001) defines leapfrogging as “a process where developers may skip over properties to obtain land further out, leaving vacant tracts behind”.

9 Strip or ribbon development refers to linear spread along major transportation corridors. It increases travel distances and automobile use (Heim, 2001).
• First is the increase in travel and congestion. It has been argued that sprawl reduces travel time although it increases trip length, and that travel time is more important than trip length. The jobs/housing balance has been used as a predictor of trip length. For example, in the San Diego region, trip lengths for commuters living in job/housing balanced areas have been found to be two miles less than the regional average and four miles less than areas with an excess of housing over jobs (Ewing, 1994). This implies that excessive residential development (urban sprawl) without consideration of employment center locations leads to longer trip length and produces negative externalities.

• Second is the increase in energy consumption and air pollution. Studies have consistently found that compact development is more energy-efficient than low-density sprawl, and that polycentric development is the preferred alternative in terms of energy efficiency (Balchin et al., 2000; Ewing, 1994).

• Third is the degradation of agricultural and environmental resources. New single-family detached housing consumes agricultural and other environmentally sensitive areas (Bank of America, 1995), leading to a decrease in available land in the long term.

• Finally, there is the isolation of older communities, including central cities and first suburbs built in the 1940s and 1950s. Urban sprawl disrupts social stability and increases economic disparity between older communities and newer suburbs. Moreover, as employment centers have spread out dramatically\(^\text{10}\), they have become problematic for older neighborhoods, because the new jobs are inaccessible to the poor and the working class (Bank of America, 1995).

\(^{10}\) Decentralization is the process of a urban area “spreading out”, holding population constant.
However, some researchers present different views in assessing urban sprawl. In terms of the costs of sprawl, Richardson and Gordon (2000) assert that the qualitative benefits of suburban lifestyles should be considered in addition to the quantitative costs of sprawl, because people have strong preferences for more living space, lower densities, access to good schools, relative safety from crime, access to the countryside and recreational amenities, and a high degree of mobility, even though these qualitative aspects are difficult to quantify\textsuperscript{11}. In addition, Brueckner (2000) argues that the loss of land from lower-density housing consumption can be offset by other benefits, such as improved access to open space and improved mobility due to less traffic congestion in rural areas, making consumers better off.

Thus, new homebuyers, developers, and some economists who emphasize the maximization of individual utility, favor urban sprawl. On the other hand, planners and environmentalists, who support minimizing the costs of providing public services and infrastructure and protecting farmland, favor the prevention of urban sprawl. In the short run, urban sprawl may seem inexpensive for a new homebuyer and politically gainful for a government. However, these homeowners, the government, and the larger society will eventually have to shoulder the costs of sprawl externalities. Moreover, in the long run, sprawl may make the city economically uncompetitive and create social, environmental and political problems (Bank of America, 1995). Future generations will be faced with the problems caused by sprawl, including depletion of available land, degradation of natural resources, increase in traffic congestion, and other negative externalities.

\textsuperscript{11} While researchers have used price information to develop value estimates for the effects of sprawl in the marketplace, this information does not exist for non-market factors such as qualitative social factors. In cost-benefit analysis, the Contingency Valuation Method (CVM) or the Travel Cost Method have been used to elicit information about the value of non-market factors (Hanley and Spash, 1993).
However, as Balchin et al. (2000) point out, even for the current generation, the economies of scale and benefits from access to services\textsuperscript{12} enjoyed by large urban areas may be counterbalanced by a poor-quality environment and a higher cost of living.

As for the causes of urban sprawl, it is well known that several U.S. policies have promoted sprawl, including the federal tax treatment of mortgage interest and property taxes (Persky & Kurban, 2003), zoning codes that favor low densities, comparatively low gasoline taxes, highway construction, large-lot residential zoning, local tax inducements to industrial firms, etc. This would suggest that urban sprawl is a product of misguided policies. However, there are also policies that promote central cities, including downtown redevelopment subsidies, convention centers subsidies, and heavily subsidized transit systems, which counteract the sprawl-promoting policies. Hence, the other view is that urban sprawl is the result of residents’ preferences rather than the result of misguided policies (Richardson & Gordon, 2000). In addition, a large amount of money has been spent on revitalization programs without much success in preventing urban sprawl (Nelson et al., 2004). This further supports the notion that urban sprawl is the result of revealed preferences. Thus, urban containment policies that directly limit geographical growth rather than guide residents’ or developers’ behavior are the efficient way to prevent urban sprawl.

\textsuperscript{12} The benefits of large-city size for consumers lie in a greater choice and range of goods and services created by the demands of a large urban population (Balchin et al., 2000).
2.2 NATURE OF URBAN CONTAINMENT POLICIES

Table 2.1 presents a comparison of different containment policies. Staley et al. (1999) define an urban growth boundary (UGB) as a line drawn around a municipality, with areas beyond the boundary not allowed or discouraged to have new developments. Brueckner (2000) also defines a UGB as a zoning tool, with urban uses inside the boundary and rural uses, such as farmland, forest, and low density residential, outside the boundary (Pendall et al., 2002).

As seen from Figure 2.1, an Urban Service Area (USA) is similar to a UGB in that it draws a line around an urban area, within which new developments are encouraged and public services are provided. However, USAs usually allow new developments beyond the boundary, but without provision of infrastructure, and are flexible in terms of boundary changes. Pendall et al. (2002) characterize USAs as a “pull policy”, in contrast to “push policies”, such as UGBs and Greenbelts, and point out that USAs focus more on financial issues than on limiting geographical growth. Local governments with USAs try to minimize the costs of public services by limiting the service boundary. Therefore, USAs are more a “market-based” system, while UGBs are closer to a “command and control” development system.

Pendall et al. (2002) describe greenbelts as the “tightest” containment strategy, because greenbelts are primarily used for the permanent protection of open space and natural resources. Change in boundaries is uncommon, even under high development pressures. Greenbelts form a band of protected natural and fragile lands. South Korea and England have a long history of using greenbelts, but only a few cases can be identified in
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Purpose</th>
<th>Tightness</th>
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<td>Greenbelt</td>
<td>New developments are not allowed within the belt area</td>
<td>The permanent protection of open space or natural resources</td>
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<tr>
<td>UGB</td>
<td>New developments are discouraged beyond the boundary with some exceptions</td>
<td>Protecting agricultural land and open space, and curbing urban sprawl</td>
</tr>
<tr>
<td>USA</td>
<td>New developments are allowed beyond the boundary without provision of services</td>
<td>Minimizing the costs of public services with a service boundary</td>
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Table 2.1 Comparisons of different urban containment policies

Figure 2.1 The shape of urban containment policies
U.S. cities. Unlike greenbelts, UGBs are often re-evaluated periodically and then changed if necessary.

USAs denote a line beyond which a city will not install or upgrade infrastructure or offer services, and are also periodically reviewed by local governments. In fact, urban development is not prohibited beyond USAs, but developers are burdened with the costs of development, including infrastructure and services.

### 2.2.1 Urban Growth Boundaries (UGB)

#### 2.2.1.1 Oregon

The Oregon UGB is strong and can be characterized as a top-down policy, because the state establishes its goals and guidelines and reviews local government plans to assess whether they meet state goals. As shown in Figure 2.2, UGBs are spread out across the state because it is mandatory for each of Oregon’s 240 cities\(^{13}\) to adopt UGBs. The Land Conservation and Development Commission (LCDC), created by the 1973 Senate Bill 100, adopted Goal 14 (Urbanization), together with other statewide planning goals in December 1974. Since then, Goal 14 has been amended five times\(^ {14}\).

The 1975 Goal 14 is to provide for “an orderly and efficient transition from rural to urban land use, and UGBs shall be established to identify and separate urbanizable

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\(^{13}\) Unusually, the UGB outside the city of Turner, Oregon, had been removed in 1982 because the city did not comply with a mandate to provide homeowners with a wastewater system. In 1999, the city did put in a sewer/wastewater system. However, the city of Turner did not ask for the old UGBs back because the city had enough buildable land.

\(^{14}\) Goal 14 had been amended in September 1980 for the first time. However, this amendment was not put into effect, because of a court decision. Several amendments have been adopted in 1988, 1994, 2000, and 2005 (Oregon Department of Land Conservation and Development, “Goal Adoption and Amendment Dates”, [http://www.oregon.gov/LCD/goals.shtml](http://www.oregon.gov/LCD/goals.shtml)).
land\textsuperscript{15} from rural land”. After each city delineates its UGB\textsuperscript{16}, the state's LCDC reviews it to make sure that it is consistent with Goal 14, which provides several factors for establishing and changing UGBs: (1) land beyond the UGB will remain rural and urban services will not be extended; (2) most of the land outside UGBs will continue to be used for farming and forestry; (3) local governments should consider incentives to encourage developments that support a compact, livable community. Proposals for changing UGBs can be reviewed periodically, and the conversion of land from rural use to urban use within UGBs must be based on the following four factors: (1) orderly, economic provision of public facilities and services; (2) availability of sufficient land for the various uses to insure choices in the market place; (3) LCDC goals or the acknowledged comprehensive plan (effective since 1988); and (4) encouragement of development within urban areas before conversion of urbanizable areas. These factors imply that even land converted to urban uses within a UGB must be monitored for consistency with the goal of the UGB, which is considered as a strict tool for containment, on par with Greenbelts. Conceptually, UGBs should be larger than city limits. Areas lying between the UGB and the city limit are the urbanizable lands that would accommodate the 20-year projected population increase. However, in reality, although most cities have UGBs that include the whole city corporations, the UGBs of some cities, such as Union, Dundee, and Antelope, are smaller than city limits. Based on GIS calculations, 18.6% of the cities

\textsuperscript{15} Urbanizable land is defined as land within the UGBs that is available over time for the conversion to urban uses.

\textsuperscript{16} Unlike other parts of Oregon, the UGB around the Portland area is a regional boundary rather than a city-level boundary. It is administered by the Metropolitan Service District, generally known as Metro, rather than individual cities. Metro is a regional government directed by an elected council that is responsible for establishing and amending the UGB around the Portland area, which consists of 25 cities and 3 counties (Multnomah, Clackamas, and Washington).
in Oregon have UGBs smaller than their city limits. In some cases17, a portion of the city is not included in the UGB to preserve farmland, open spaces, or forestry. In principle, since lands that are to be brought into the city limits and developed at urban densities should also be brought into the UGB, these small UGBs ensure that the city remains small or is unable to grow.

Figure 2.2 UGBs in the state of Oregon

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17 The cases where a portion of a city is not included in a UGB, include Astoria, Depoe Bay, Garibaldi, Gearhart, Gold Hill, Junction City, Pendleton, and Seaside.
2.2.1.2 Washington

The Washington UGBs, called Urban Growth Areas (UGA), are less strong than those in Oregon, because they are not required from all cities, and local governments have the flexibility to prepare their own growth management plans (Nelson & Dawkins, 2004). The concept of UGA is similar to that of the Oregon UGB, in that its purposes are to preserve farmland and open spaces and to direct population growth into urban areas. The Growth Management Act (GMA, Chapter 36.70A RCW)\(^\text{18}\), adopted by the Legislature in 1990 in response to Washington’s rapid growth, threats from urban sprawl, and destruction of the environment, requires state and local governments to manage growth. Certain counties\(^\text{19}\) that fully plan under the GMA are required to adopt county-wide planning policies and to establish UGAs.

Thus, UGAs are designated by a county in coordination with the towns and cities located within the county. Counties also assign projected population growth to UGAs, which need to accommodate a 20-year growth. County projections are provided by the state Office of Financial Management. Therefore, counties, not cities or towns, have final authority in determining where the municipal UGA boundaries are located.

The UGA is one of the main methods in the GMA. It designates areas where urban growth is expected and urban services are provided. When the GMA was adopted, the statute included a formula for the counties and cities inside those counties required to

\(^{18}\) The GMA mandates that the fastest growing counties and their cities make a comprehensive plan that forecasts future growth and impact for a 20-year period.

\(^{19}\) Of the twenty counties that either were required to fully plan under the GMA or have chosen to do so, some counties such as Chelan, Clallam, Clark, Grant, Island, Jefferson, King, Kitsap, Lewis, Mason, Pierce, San Juan, Skagit, Snohomish, Spokane, Thurston, and Whatcom, are mandated to draw UGAs. Also, six counties, including Clark, King, Kitsap, Pierce, Snohomish, and Thurston, have special requirements that demand periodical in-depth review at five-year intervals.
meet the GMA. The counties and cities would only need to plan for critical and fragile areas based on the population rate of growth. As a result, most cities and counties in Washington are required to adopt UGAs as part of their comprehensive planning process. However, in contrast to Oregon cities, other jurisdictions with smaller population and slower growth, are not required to adopt comprehensive plans or to draw UGA boundaries. For example, Thurston County is a fully planning county, and the county has drawn UGAs around all of the cities within its boundary. Even in slow-growing counties, some cities voluntarily adopt their own UGAs or some form of UGBs. Othello, in Adams County, adopted a UGA in 2004, even though the GMA did not require it. Oroville, in Okanogan County, established a UGA in 1993 for planning purposes, although it was not a GMA requirement. Ocean Shores, in Grays Harbor County, has a Utility Service Area boundary that extends beyond the city limits. In some cases, these Utility Service Area boundaries become the basis for the final UGAs. For example, Marysville’s interim UGA has been designated in 1991 and finalized in 1995, based on the previous Utility Service Area that had been maintained from 1980 to 1991.

Washington State law requires that all municipalities must be included within UGA boundaries as shown in Figure 2.3. UGAs can be larger than a city jurisdictional territory and are intended to define the area within which the city will potentially expand over a 20-year planning horizon. The following shows a brief history of the UGA process in Washington, as described in ‘RCW 36.70A.110’.

The cities in counties that had been required or chose to plan under the GMA, proposed the location of a UGA within one year from July 1, 1990. The county would try to reach an agreement with each city located within its boundary, on the location of
UGAs. If there is a disagreement, the county must justify in writing why UGAs are designated as they are. A city can object to the designation of its UGA. Disputes between jurisdictions or involving property owners and other citizens may be appealed to a Growth Management Hearing Board before going to a court of law. Three regional Growth Management Hearing Boards resolve such disputes. Before October 1, 1993, each county that had been initially required to plan under the GMA, adopted development regulations, including interim UGAs. The UGAs are adopted when comprehensive plans that include the designation of UGAs are adopted. The Act requires the counties to evaluate the growth boundaries every 10 years.

Different counties take different approaches. Since counties are given the authority to establish UGAs, there are some cases where more than one city is contained within the same UGA. For example, the Southwest Urban Growth Areas include nine cities: Bothell, Brier, Edmonds, Everett, Lynnwood, Mill Creek, Mountlake Terrace, Mukilteo, and Woodway. Having nine cities within the same UGA has resulted in some issues related to planning responsibilities and annexation. So, those nine cities have been working with the County to divide the UGA into smaller units and assign portions to each city. This would result in a well-defined UGA for each city. These subdivisions of the larger UGA are called "Municipal Urban Growth Areas" or "MUGA", and most cities have adopted their own MUGAs. Cities are expected to take an active role in planning (in cooperation with the County) for the future urban development of their respective

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20 For example, the City of Spokane and Spokane County still have unresolved issues from the creation of the UGAs in 2001, that have been and still are being mediated by the regional Eastern Growth Management Hearings Board.
MUGA areas. Cities may annex all lands within their assigned MUGA area, but cannot cross the line into the MUGA of a neighboring city. MUGA boundaries can be adjusted with the mutual consent of the County and the affected cities.

Thus, the UGA in Washington is similar to the UGB in Oregon in that both were initiated by the state. However, the approach to the Washington UGA varies, depending on the implementation policies of each county and city. Some communities are more actively involved in this policy and others are not, despite being fast-growing communities. There are several communities that are not required to have UGAs, but some cities in slowly-growing counties have their own UGAs.

Figure 2.3 UGBs in the state of Washington
2.2.1.3 California

Although adoption of UGBs is not required in California, many communities have adopted UGBs as a planning tool to protect natural resources and curb urban sprawl. The state of California has mandated each county to have a Local Agency Formation Commission (LAFCO)\(^{21}\), and each LAFCO has sole responsibility for establishing a Sphere of Influence (SOI) for a city within the county. The Cortes-Knox-Hertzberg Local Government Reorganization Act of 2000 (California Law) defines a Sphere of Influence (SOI) as a plan for the probable physical boundaries and service area of a local agency, as determined by the Commission. Urban development is to be encouraged within SOIs. The lands lying within the SOI are areas that the city may someday propose to incorporate. In fully developed areas, the SOI may be the same as city limits. In cities with unincorporated county lands, an SOI is established by the LAFCO to allow for some growth within city limits. According to a 1977 opinion of the California Attorney General, the SOI should serve as a planning tool to curb urban sprawl, provide planned development patterns, and preserve prime agricultural lands and open spaces (Miner et al., 1997).

In determining the SOI of each city, LAFCOs must prepare a written statement on the present and planned land uses in the area, the present and probable needs for public facilities and services in the area, the present capacity of public facilities and adequacy of public services, which the agency provides or is authorized to provide, and the existence

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\(^{21}\) LAFCO is an independent state agency. The commission membership is usually comprised of 7 members, based on the following distribution: 2 members representing the County Board of Supervisors, 2 members representing the cities, 2 members representing special districts, and 1 at-large public member (Contra Costa County LAFCO).
of any social or economic communities of interest in the area, if the commission
determines that they are relevant to the agency (2001 LAFCO SERVICE REVIEW
GUIDELINES). A LAFCO is required to adopt the SOI, and review and update it, as
necessary, but no less than once every 5 years. However, in many cases, amending an
SOI requires a Municipal Service Review, which is a comprehensive study designed to
better inform the LAFCO, local agencies, and the community about the provision of
municipal services.

An SOI in California is similar to an Urban Growth Boundary (UGB) for the
following characteristics: (1) they are physical boundaries within which annexation and
provision of public services are permitted; (2) they are periodically reviewed to
investigate whether boundaries expansion is needed (every 5 years for SOIs, and 10 to 20
years for UGBs); (3) their purposes include preventing urban sprawl and preserving
farmland and open spaces. The SOI is to define the maximum area around a city which
can be annexed to it. Many of the California SOIs are very large, and include areas that
should remain as agricultural land. One of the important purposes of SOIs is to avoid
conflicts among cities and agencies as they continue to grow and expand their boundaries
outward. In other words, SOIs were created in part to avoid future conflicts and legal
actions among cities and agencies that may compete for the same lands. For these
reasons, in order to protect natural resources and prevent sprawled development more
effectively, more than 65 cities have UGBs distinct from SOIs. Figure 2.4 shows the
distribution of those cities with UGBs. The UGBs are part of a city’s planning efforts to
define the area within the SOI which is most likely to be annexed first. Thus, UGBs may
be within or outside city limits, but must be within SOI, as long as they are adopted by
cities\textsuperscript{22}. UGBs appear within a jurisdiction’s General Plan Land Use Element and serve as the outer boundary for a city’s probable future growth area.

\begin{center}
\textbf{Figure 2.4 UGBs in the state of California}
\end{center}

\textsuperscript{22} Contra Costa County adopted an Urban Limit Line (ULL) in 1990. ULLs adopted by counties are usually too large to control the growth of each city. In half of the cities in Contra Costa County, ULLs extend across SOIs.
2.2.1.4 Lancaster County, Pennsylvania

Lancaster County, Pennsylvania, adopted a Growth Management Element in 1993, under which Urban Growth Areas (UGA) and Village Growth Areas (VGA) were established. The purposes of these “Designated Growth Areas” (UGA and VGA) are to preserve farmland and natural resources and revitalize existing urban areas.

UGAs cover Lancaster City, its boroughs, and the developed areas of townships within the county. They include developable land to accommodate future growth over a 25-year period. Public services, such as sewer and water supply, must be provided for new developments within UGAs. The 2030 Growth Management Element Update indicates that the targeted average density of residential development in UGAs is 7.5 dwellings per residential acre.

A VGA includes an existing “traditional village core” and areas surrounding the developed parts of townships, as well as developable land over a 25-year period. Developments within VGAs are expected to maintain the characteristics of the villages. A full range of public services must be provided when new development takes place, and the targeted residential density in a VGA is 2.5 units per acre.

New UGAs and VGAs have been adopted since 1993. Initially, 2 UGAs and 2 VGAs were established in Lancaster County. The 1997 Growth Management Element included another 7 UGAs and 12 VGAs. Since 1997, by adding 4 UGAs and 12 VGAs, Lancaster County has now 13 UGAs and 26 VGAs. Moreover, 31 townships and 19

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24 Previously, the targeted residential density in a UGA was 5.5 dwellings per acre.
municipalities are currently engaged in establishing UGAs and VGAs. Figure 2.5 shows the distribution of those communities with UGBs.

The Pennsylvania Municipalities Planning Code (MPC) Act of 1968 (P.L.805, No.247) encourages communities to develop “multi-municipal plans”. As of 2003, there were 11 such plans in Lancaster County. This type of collaborations across communities is essential for land-use planning, because it helps control for spillover effects across communities. In addition, municipalities have implemented other ordinances and plans to make UGAs and VGAs effective. For example, 28 communities have updated their Zoning Ordinances or Sewage Facilities Plans.
2.2.1.5 Other UGB Cases

Tennessee has adopted a state-wide program for UGBs, which, as defined in Tennessee Code 6-58, do not restrict growth beyond the boundary, but rather restrict annexation by municipalities. The growth plans of most of the communities that include UGBs were approved in the late 1990s and early 2000s.

Lexington, Kentucky, established a UGB, called Urban Service Area25, in 1958. The American Planning Association (APA) recognized Lexington as having established the first growth boundary in the U.S. This boundary has been maintained, with some adjustment, and currently comprises about 30 percent of the area of Fayette County. When the UGB was created, Lexington was the only municipality in Fayette County. In 1974, the governments of Fayette County and Lexington merged to form the Lexington-Fayette Urban County Government (LFUCG). The LFUCG Planning Commission, with all members appointed by the mayor, reviews subdivision plats for the Urban and Rural Service Area, and the Urban County Council decides all zoning changes. In 1999, a minimum lot size of 40 acres was established for the Rural Service Area, where more than 95 percent of the land is agricultural.

2.2.2 Urban Service Areas (USA)

2.2.2.1 The Metropolitan Urban Service Area of Minneapolis – St. Paul

The Metropolitan Urban Service Area (MUSA) of Minneapolis – St. Paul, Minnesota restricts the provision of urban services and facilities, such as public sewers,

25 Although Lexington’s UGB is called Urban Service Area, its characteristics are close to the concept of UGBs, in that development beyond the boundary is restricted to much lower densities and linked to a minimum lot size (40 acres).
public water supply, and major highways (Metropolitan Council, 2006). The MUSA has been established and managed by the Metropolitan Council of the twin-cities metropolitan area since 1975. The 1967 state legislature established the Metropolitan Council to cope with urban problems, such as the increasing costs of urban services, the decline of central cities, and the dispersed development pattern in the seven counties (Anoka, Carver, Scott, Dakota, Hennepin, Ramsey and Washington), where the twin-cities metropolitan area is located.

There are 189 cities and towns within the MUSA. Figure 2.6 presents the extent of MUSAs in the Minneapolis-St. Paul metropolitan area. Under the Metropolitan Land Planning Act (state law), the Council has the ability to expand the MUSA, to be consistent with regional plans and policies. Each municipality must meet six criteria to expand its MUSA, considering the impacts on the regional wastewater system and the compliance with other regional policies. A first category of criteria includes a minimum population density (three units per developable acre since 2000), the available capacity of regional and local wastewater systems, and the water runoff and infiltration reduction plans at the metropolitan level. The other category of criteria includes the fulfillment of previous Council actions and negotiations regarding the city’s comprehensive plan, the consistency of the Comprehensive Plan Amendments with the Council’s 2030 forecasts for households and employment, and strategies for storm water management and natural resource protection (Metropolitan Council, 2005).

The MUSA is similar to a UGB for the following reasons. First, the MUSA sets geographical boundaries on urban growth. Second, the MUSA was established to encourage “orderly, economic, and contiguous growth”, by having development in areas
where public services and facilities already exist. However, the major purpose of the MUSA is to fully use the existing infrastructures to minimize taxpayers’ burden (Metropolitan, 2006). Thus, the initial motivation for the MUSA is “financial” rather than “geographical”, as in the case of a UGB.

Pendall et al. (2002) indicate that USAs have more flexibility and are relatively easier to expand than UGBs, because USAs focus on continuous growth rather than on constraints. The 2030 Regional Development Framework (Metropolitan Council, 2004) emphasizes the accommodation of growth in a flexible manner.

Figure 2.6 USAs in the Minneapolis-St. Paul Metropolitan Area
2.2.2 Other USA cases

USAs are identified in some cities or counties in other states: city of Fayetteville in North Carolina; Orange, Sarasota, Citrus, Seminole counties in Florida; and Loudon county in Virginia. Also, the state of Maryland has some form of UGB which is close to the USA concept, because the state of Maryland does not mandate or enforce UGBs, leaving land-use and planning decisions to local governments. Maryland has defined targeted growth areas, called Priority Funding Areas (PFAs), and requires that all state funding for growth-related needs, such as highways, water and sewer systems, and economic development assistance, be spent only in those designated areas. Local officials and developers may decide to locate a big subdivision outside designated PFAs, but they will not receive any state funding to meet the infrastructure needs of the development.

2.2.3 Greenbelts

Greenbelts have been identified in three U.S. cities: Boulder (Colorado), and Lodi and San Luis Obispo (California). The case of Boulder is described here, because Boulder has a long experience with greenbelts and an almost complete concentric form of greenbelts, while Lodi and San Luis Obispo have only partial greenbelts.

The Greenbelt of Boulder was born out of two protection programs, the Open Space Program and the Mountain Parks Program, which were combined in 2001 as one program, and the lands obtained from this program are called open space lands. The citizens of Boulder initially voted for taxes to purchase mountain lands in 1963, and a “10-year tax initiative” was passed in 1995 to purchase more land to form “Mountain Parks”.

28
The Open Space Program was established to protect and maintain open spaces. In 1967, a measure adding “0.40 cents sales tax on each dollar” was passed by voters to purchase and manage open spaces. The Open Space Board of Trustees was created by City Council in 1973, and a charter amendment was adopted to protect open space lands more permanently in 1986. Additional sales taxes of 0.33 cents and 0.15 cents on each dollar were passed by voters in 1989 and 2003.

The purposes of open spaces protection by greenbelts are preserving natural lands, water resources, and agricultural lands, and preventing urban sprawl. As a result, approximately 43,000 acres of open spaces are preserved around the city of Boulder.

Figure 2.7 Greenbelts in the City of Boulder, Colorado
2.3 IMPACTS OF URBAN CONTAINMENT POLICIES

2.3.1 Positive Impacts

Empirical research has confirmed that many of the goals of urban containment policies (UCPs) have been achieved in urban containment communities (Carlson & Dierwechter, 2007; Wassmer, 2006; Nelson et al., 2004); these goals include:

- First, preserving open space and farmland (Staley, 1999), which cannot compete on land value terms with urban land (Pendall et al., 2002). UCPs are also believed to prevent urban sprawl, to preserve agricultural land, and to encourage higher-density development (Pendall et al., 2002; Ding et al., 1999).

- Second, minimizing the use of land, generally by reducing lot sizes and increasing residential densities in order to use land more efficiently. This can help achieve cost-efficient construction and reduce infrastructure costs and public operation costs, by encouraging urban revitalization, infill, and compact development (Staley, 1999; Pendall et al., 2002).

- Third, clearly separating urban and rural uses, to ensure the orderly transition from rural to urban land use.

- Finally, promoting a sense of unified community and reducing the social disruption due to urban sprawl. High-density and compact developments, as promoted by the New Urbanism movement, help people communicate with their neighbors more frequently.

The empirical results of Carlson and Dierwechter (2007) indicate that UGBs accommodate new housing developments within the boundary. They use a kernel density
calculation on residential building permit data from 1991 to 2002 for Pierce county, Washington, and show that building activities substantially increase within UGBs. Wassmer (2006) analyzes the impacts of UCPs on the size of urban areas in California cities, using regression analysis, with the square miles of urban areas as the dependent variable. He finds that UCPs reduce the size of an urban area, reducing the use of land and promoting compact developments. Nelson et al. (2004) show that UCPs, including ‘urban growth boundary’, ‘service extension limits’, or ‘greenbelt’, contribute to central-city revitalization. They use a multiple regression model with the number of constructed residential units as the dependent variable over 144 metropolitan areas, and find these policies positively affect development in central cities.

2.3.2 Negative Impacts

Although UCPs have become very popular growth control tools for urban planners and local governments, several negative characteristics of these policies have emerged.

First, UCPs can have negative welfare impacts on land and housing markets, by raising housing prices within the boundary and reducing land values outside the boundary (O’Toole, 2003; Richardson & Gordon, 2000). Staley (1999) points out that UCPs require a comprehensive knowledge of real-estate markets to avoid increases in housing prices. Brueckner (1995) presents two models related to increases in housing prices. One is the amenity-creation model, whereby population decreases due to the limit on its
spatial growth, and the amenity created by the smaller population raises housing prices as well as other real-estate prices. The other model is the supply-restriction model, whereby restrictions in the supply of developable land increase land prices under the principle of equilibrium between land supply and demand. Phillips and Goodstein (2000), analyzing the relationship between housing price and demand side variables and supply side constraints, find that the effect of UGBs on housing prices is relatively small in magnitude. Landis et al. (2002) also argue that growth control programs are not principally responsible for California’s high housing prices and rents. Similarly, Levine (1999) finds that urban limit lines in California do not appear to have significantly reduced new housing construction.

Second, UCPs may encourage a non-optimal pattern of development, such as leap-frogging, which results in higher commuting and travel costs (Richardson & Gordon, 2000). Levine (1999) estimates that fully one-third of the rental housing constructed in California during the 1980s was displaced from controlled to non-controlled communities. Developers move to other jurisdictions, where UCPs are not in force, to reduce development costs and time. Peiser (1989) states that, without growth controls, the land value of infill sites, which result from discontinuous development or urban sprawl, increases faster than the land values at the urban fringe. If density is a function of land values, then these infill sites will be developed at a higher density than would otherwise be the case. According to Peiser, land-use controls, restricting discontinuous development, may lead to lower, rather than higher, overall urban

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26 A higher population reduces rent via the disamenity effect (Brueckner, 1990).
density. His analysis suggests that urban growth controls are counterproductive. However, Breslaw (1990) argues that Peiser’s assertion implies that public policies to control urban development may be misguided and cities should let the land market seek its natural level of densities. Although the invisible hand works well in many markets, this is not the case for land use, because of the externalities involved.

Third, residential development at the edge of cities has resulted in a low-density residential ring outside UCP boundaries, and urban development inside the boundary has not occurred at the desired urban densities (Weitz & Moore, 1998).

Fourth, delineation of the boundary is very difficult, because not all agricultural land is prime, and many sites outside the boundary may have few alternative uses except housing. UCPs have created new winners and losers in the agricultural realm. New winners are wealthier households who own noncommercial farms as a hobby and are subsidized by lower land values outside the growth boundary. The losers are lower- and middle-income families who may suffer from rising land values inside the growth boundary (Levine, 1999; O’Toole, 2003; Staley, 1999).

Fifth, the scarcity of available land within the boundary may be a threat to open and recreational spaces, as they can be converted into urban uses (Richardson & Gordon, 2000).

27 This conclusion is based on the following three propositions. First, land-use density is positively related to land value. Second, land values at infill sites are higher than they would have been had surrounding development not taken place. Finally, the overall density, based on the resulting price mix of non-controlled land use, is higher than would exist based on the price mix of controlled land use.

28 In Portland, Oregon, the urban growth boundary was established in 1979, and vacant land within the boundary has decreased by almost 20% between 1980 and 1997 (Staley et al., 1999).
Sixth, UCPs do not allow for the spacious yards that most Americans want to own in suburban areas (O’Toole, 2003). In fact, the preference for larger housing lots is one of the main factors that produce sprawl.

Finally, UCPs may restrict the location choices of new industries. In fast-growing areas undergoing significant economic changes (e.g., moving from traditional manufacturing to high-technology), it is not easy to determine the optimal size of the growth boundary and its expansions. As the region evolves, the tastes of local residents change, and local planning policies must have the flexibility to accommodate the needs and demands of new residents as well as existing residents (Staley, 1999). The negative impacts of UCPs, such as increases in housing prices and deficit of residential units and available land, may also negatively affect the regional economy by restricting the location of new industries and their employees, who would move in from other regions. Workers commuting from outside the boundary add to traffic congestion and to the demands on the transportation infrastructure. Richardson et al. (1993) examine the economic impacts of growth control on jobs and output in Pasadena, California, using a regional input-output model. They conclude that the largest economic losses come from denied nonresidential construction, particularly for the lowest-skilled occupational groups.

In relation to the negative effects of UCPs, Bruekner (2000a) points out that the imposition of stringent policies can yield undesirable results. Based on simulation results,

---

29 In the case of Boulder County, Colorado, “Boulder County’s commercial development may depend on neighboring communities pursuing more relaxed growth-control policies, allowing affordable housing to develop within commuting distance of jobs in the county. Ironically, Boulder County’s “success” may well depend on the willingness of other counties to house Boulder County workers and regional commitments to upgrade infrastructure to accommodate increased traffic volumes from low- and moderate-income commuters” (Staley, 1999).
Brueckner (2001) concludes that UCPs raise housing prices and cut housing consumption, and restrict the spatial sizes of cities while maintaining the incomes of absentee landowners. In addition, if growth boundaries are converted into static lines in the land, the city is likely to face the density/housing price tradeoff already evident in Portland, Oregon, and Boulder, Colorado. Ironically, if growth boundaries are successful, they will force development to occur at higher densities on relatively high-cost land near or within existing urban areas. Households will pay more for homes with fewer amenities. Thus, higher-density urban living is achieved by producing lower-quality housing and amenities (Staley, 1999).

2.4 SUMMARY

Urban sprawl results from individual behaviors, in particular preferences for more space and “flight from blight”, with the support of some policies, such as the federal tax treatment of mortgage interests and property taxes, low gasoline taxes, large lot residential zoning, etc. Since land uses are not efficiently allocated by the invisible hand, public policies are necessary to prevent urban sprawl. One popular growth management tool is an urban containment policy (UCP), increasingly adopted by local and state governments. The possible impacts of UCPs have been analyzed by several researchers. Table 2.2 summarizes the impacts of UCPs. Most previous research is related to the impacts on housing markets and infrastructure costs. Little is known regarding the impacts of UCPs on economic and population growth, and the spatial distribution of population and economic activities. In particular, it is not known whether UCPs promote population and economic growth or discourage it, and whether they encourage
concentration or dispersion of population and economic activities. Although there are some studies on these issues (Gerber & Phillips, 2004; Richardson et al., 1993), they are restricted to specific areas. Moreover, the differential impacts of different policies (greenbelts, UGBs, and USAs) have not been assessed. It is important to distinguish among these policies, because they vary substantially in their tightness. Nelson and Dawkins (2004) broadly characterize UCPs as “weak-restricted”, “strong-restricted”, “weak-accommodating”, and “strong-accommodating”. However, they do not analyze the impacts of specific policies, and use data restricted to metropolitan areas, counties and large cities with more than 20,000 people. Since local governments are increasingly choosing containment policies, specifically UGBs and USAs, as their growth control tools (Staley et al., 1999), it is important to analyze these effects at the municipal level as well as at the metropolitan level.

<table>
<thead>
<tr>
<th>Positive Impacts</th>
<th>Negative Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preservation of open space and farmland</td>
<td>• Increase in housing price</td>
</tr>
<tr>
<td>• Minimization of the use of land</td>
<td>• Leap-frogging development</td>
</tr>
<tr>
<td>• Cost-efficient construction and reduction of infrastructure costs</td>
<td>• Not achieving the desired higher density within the boundary</td>
</tr>
<tr>
<td>• Separation of urban and rural uses</td>
<td>• Threats on open and recreations spaces within the boundary</td>
</tr>
<tr>
<td>• Orderly transition of land from rural to urban uses</td>
<td>• Not able to provide residents with preferred housing spaces</td>
</tr>
<tr>
<td>• Promotion of a sense of unified community</td>
<td>• Increase of traffic and congestion</td>
</tr>
<tr>
<td></td>
<td>• Restrictions in the location of new industries</td>
</tr>
</tbody>
</table>

Table 2.2 Positive and Negative Impacts of Urban Containment Policies
CHAPTER 3

MODELING METHODOLOGY

3.1 THEORETICAL FRAMEWORK

3.1.1 Land and Housing Prices under Stringent Containment Policies (Greenbelts & UGBs)

When choosing where to live, people consider several factors, such as workplace, housing costs, natural amenities, social amenities, and other variables (e.g. land-use controls and taxes), in other words, the costs and benefits associated with several alternatives. If a high weight is set on housing costs, and if the other variables are not significant, then land consumers lose benefits when stringent containment policies, such as greenbelts and urban growth boundaries (UGBs), are enforced. Anas (1999) explains the supply and demand of land markets under urban containment policies (UCPs) for the Portland metropolitan area and New York State. This is illustrated in Figure 3.1, where the horizontal axis represents the amount of land available for development, and the vertical axis land values. The curves S and D are the land supply and demand curves, respectively. Without enforcement of UGBs, equilibrium occurs at point i. $\Delta aci$ represents the consumer’s surplus, and $\Delta cdi$ is the producer’s (landowner) surplus.
However, once UGBs are enforced, the available land is fixed at $\overline{q}$ and the supply is represented by the vertical curve $S'$. Since the available land is restricted, its price increases from $c$ to $b$. As a result, the loss to land consumers located inside UGBs is measured by ‘$bcef$’ and the loss to those outside the UGBs is $\Delta efi$. Similarly, the gains for landowners inside the UGBs due to the higher price are measured by the area ‘$bcef$’, which represents the transfer of benefits from consumers to landowners. The competition for the limited amount of land bids up its price, so that sellers gain and buyers lose. On the other hand, landowners located outside the UGBs lose the opportunity to sell the land, and $\Delta fgi$ represents their loss.
The supply curve can be interpreted as the Marginal Private Cost curve (MPC), and the Marginal Social Cost curve (MSC) is the sum of the Marginal Private Cost and the externalities. If a UGB is properly designed, the hatched area, $\Delta ehi$, can then be interpreted as the external costs occurring when too much land is developed through sprawl. With enforcement of UGBs, this area becomes a gain for society by curbing sprawl and preserving outer open spaces.

As long as UGBs are designed below the competitive equilibrium, only existing landowners inside the boundary gain. Amenities, generated by preserving outer areas, can somewhat offset the losses of land consumers and landowners outside UGBs, depending upon how much they are willing to pay for amenities. Assuming that housing price is proportionate to land price, and that housing price weighs heavily for consumers, the enforcement of UGBs could discourage the influx of population into the contained areas. Thus, when UGBs are enforced, population growth could be sensitive to housing prices and vice versa. Nevertheless, if population grows more in UGB cities than in uncontained cities, this means that UGBs successfully accommodate new growth within the growth boundaries.

### 3.1.2 Land and Housing Price under Less Stringent Containment Policies (USAs)

There is no restriction on the spatial growth in urban service areas (USAs), in contrast to greenbelts and UGBs, because developers can construct residential units outside USAs if they are willing to pay for the infrastructure costs. The infrastructure subsidies are usually provided inside USAs to promote developments in these areas and
these subsidies reduce development costs. As a result, the demand for land development increases inside USAs and decreases beyond USAs. This is illustrated in Figure 3.2.

Inside the service boundary, the consumer’s surplus changes from ‘adb’ to ‘egf’. Both a gain (eahf) and a loss (gdbh) are associated with this change. The net benefit (‘eahf’-‘gdbh’) is positive because the gain is bigger. The losses are the forgone benefits from having a lower price and the gain is derived from having more land developed despite a higher price. Outside the service boundary, land consumers are losers. This is the reverse of what happens to the consumers inside the boundary. The land consumer’s surplus changes from e’g’f’ to a’d’b’. There is a loss associated with the reduction in the amount of land available at equilibrium. The loss is represented by e’a’h’f’. Although there is a gain (g’d’b’h’) because the equilibrium price is lower, the gains are smaller and
the land consumers are net losers. The landowners outside USAs are also losers because of the reduced demand for their land. However, the landowners inside USAs enjoy a gain measured by ‘gdbf’.

3.1.3 Land Rent for Firms under Urban containment Policies

In general, as illustrated in Figure 3.3, the bid rent curve of firms decreases from the CBD to point \(s^*\), where it intersects with the agricultural land rent \(R_A\). \(s^*\) represents the limit of the urban area. Once UCPs are enforced and the growth limit is reduced to \(\bar{s}\), the bid rent curve moves inward and becomes steeper (1→2). Under enforcement of UCPs, land rent will rise due to limited land supply, thus increasing costs for firms. As a result, their profits will fall, and the bid rent curve will move further inward (2→3).

Mills and Hamilton (1989) define two categories of industries to explain their locations: cost-oriented (production and transport) and amenity-oriented industries. Cost-oriented industries include textiles, where lower wages are important because it is a labor-intensive industry. Transport-cost oriented industries include steel, where the input and the output are heavy and bulky. As the importance of transportation costs decline due to the development of transportation systems and infrastructure, and the innovations derived from information technologies, firms tend to consider other factors, leading to footloose industries with an amenity orientation. If UCPs lead to housing price increases and a lack of residential housing units and available land, they may negatively affect labor-intensive industries and space-intensive industries, such as manufacturing.

Therefore, the extent to which these factors affect the spatial location of industries depends on the nature of the industries. For example, routine back office functions, such
as paperwork processing, can be located in any places where the land is cheap and labor wages are low. Lower land rent and labor costs are important factors for the production and distribution of goods (i.e. manufacturing). On the other hand, face-to-face contacts with customers are important for retail firms.

The above discussion strongly suggests that population growth, economic growth, and land values (housing values) are jointly determined, therefore calling for some form of simultaneous equation modeling.

Figure 3.3 Bid Rent Curves of Firms under Urban containment Policies
3.2 IMPACTS ON POPULATION, EMPLOYMENT, HOUSING VALUES, AND LAND AREAS

Two approaches are considered to empirically analyze the impacts of UCPs on population, employment, land development, and housing values. In the first approach, the changes in a city’s total population, total employment, housing values, and land area are used as the endogenous variables. These variables help capture how UCPs directly affect population and employment growth, increases in housing values, and changes in the developed urban land area. In the second approach, sectoral employment variables (instead of total employment) are used as endogenous variables, together with changes in population, housing values, and land areas. Since each industry has different locational characteristics, using sectoral employment may provide differential results and implications.

3.2.1 Changes in Population, Employment, Housing Values, and Land Areas

The relationship between population and employment has been examined using simultaneous equation models. Steinnes (1977) uses simultaneous equations to examine the causality between population and employment, using the shares of residents and employees in the center city out of the whole SMSA and finds that (1) manufacturing and services follow people, and (2) people follow retail. Following Steinnes, several studies have attempted to examine the relationship between population and various employment sectors. Carlino and Mills (1987) use a simultaneous equation model to analyze the effects of economy, demography, climate, and government policies on population and employment.
growth, using population and employment densities. Boarnet (1994a) uses changes in population and employment as the endogenous variables, and concludes that the population change in a municipality affects the employment changes in the surrounding labor markets. However, past research has not considered the effects of housing values on population and employment. Also, population and employment affect housing values because they are important demand factors in the housing market. In addition, Alperovich (1983) suggests that land area can be used as an endogenous variable, because it depends on population and employment growth. In particular, land areas are determined by the interaction between land and housing producers and consumers, when land and housing markets are regulated by specific policies. This implies that housing values and land areas should also be considered as endogenous variables.

Since population, employment, housing values, and land areas are jointly determined, the following simultaneous-equation model is proposed, with:

\[
\Delta \text{POP}_i = f_p(\text{POP}_{it-1}, \Delta \text{EMP}_i, \Delta \text{HOUV}_i, \Delta \text{LAND}_i, \text{NA}_i, \text{SA}_i, \text{INC}_i, \text{SCP}_i, \text{LSCP}_i) \quad (3.1)
\]

\[
\Delta \text{EMP}_i = f_e(\text{EMP}_{it-1}, \Delta \text{POP}_i, \Delta \text{HOUV}_i, \Delta \text{LAND}_i, \text{NA}_i, \text{SA}_i, \text{INC}_i, \text{SCP}_i, \text{LSCP}_i) \quad (3.2)
\]

\[
\Delta \text{HOUV}_i = f_h(\text{HOUV}_{it-1}, \Delta \text{POP}_i, \Delta \text{EMP}_i, \Delta \text{LAND}_i, \text{INC}_i, \text{NA}_i, \text{SA}_i, \text{SCP}_i, \text{LSCP}_i) \quad (3.3)
\]

\[
\Delta \text{LAND}_i = f_l(\text{LAND}_{it-1}, \Delta \text{POP}_i, \Delta \text{EMP}_i, \Delta \text{HOUV}_i, \text{INC}_i, \text{NA}_i, \text{SA}_i, \text{SCP}_i, \text{LSCP}_i) \quad (3.4)
\]

\[(i = 1, \ldots, n, \ t = 1, \ldots, m)\]

where \(i\) refers to a city, \(t\) to the current period (2000), and \(t - 1\) to the previous period (1990). \(\Delta \text{POP}, \Delta \text{EMP}, \Delta \text{HOUV}, \text{and} \Delta \text{LAND}\) are the endogenous variables, representing changes in population, employment, median housing values, and land areas between 1990 and 2000, respectively. The \textbf{NA} (Natural amenities) vector represents amenity factors.
The **SA** (Social amenities) vector includes air quality, educational achievement, crime rate, and transportation access. **INC** refers to median household income. **SCP** and **LSCP** are dummy variables, where **SCP=1** denotes stringent containment policy (greenbelts and UGBs) cities, and **LSCP=1** less stringent containment policy (USAs) cities. Since the number (4) of observations for greenbelts is too small, both greenbelts and UGB cities are categorized as SCP cities.

### 3.2.2 Changes in Sectoral Employment

Cooke (1978) extends Steinnes’ model by including more employment equations and tests relationships between employment sectors, using measures of population and employment density gradients. He finds that retail and manufacturing follow people. Thurston and Yezer (1994) use the density gradients of population and industrial sectors as the endogenous variables, and find that the population density gradient positively affects the gradient of the retail and other service sectors.

The previous model is expanded to analyze the impacts of UCPs on each industrial sector, with:
\[ \Delta POP_i = f_P (\Delta POP_{it-1}, \Delta HOUV_i, \Delta LAND_i, \Delta MANUF_i, \Delta RETAIL_i, \Delta SERVICE_i, NA_i, SA_i, INC_i, SCP_i, LSCP_i) \] (3.5)

\[ \Delta HOUV_i = f_H (\Delta POP_i, \Delta LAND_i, \Delta MANUF_i, \Delta RETAIL_i, \Delta SERVICE_i, NA_i, SA_i, INC_i, SCP_i, LSCP_i) \] (3.6)

\[ \Delta LAND_i = f_L (\Delta POP_i, \Delta HOUV_i, \Delta MANUF_i, \Delta RETAIL_i, \Delta SERVICE_i, NA_i, SA_i, INC_i, SCP_i, LSCP_i) \] (3.7)

\[ \Delta MANUF_i = f_M (\Delta POP_i, \Delta HOUV_i, \Delta LAND_i, \Delta RETAIL_i, \Delta SERVICE_i, NA_i, SA_i, INC_i, SCP_i, LSCP_i) \] (3.8)

\[ \Delta RETAIL_i = f_R (\Delta POP_i, \Delta HOUV_i, \Delta LAND_i, \Delta MANUF_i, \Delta SERVICE_i, NA_i, SA_i, INC_i, SCP_i, LSCP_i) \] (3.9)

\[ \Delta SERVICE_i = f_S (\Delta POP_i, \Delta HOUV_i, \Delta LAND_i, \Delta MANUF_i, \Delta RETAIL_i, NA_i, SA_i, INC_i, SCP_i, LSCP_i) \] (3.10)

\[ (i = 1, \ldots, n, \ t = 1, \ldots, m) \]

where MANUF, RETAIL, and SERVICE represent the Manufacturing, Retail, and Service sectors, respectively.

### 3.3 IMPACTS ON URBAN SPATIAL STRUCTURE

Once UCPs are enforced, they affect housing and land markets and economic behaviors. These effects may generate a specific urban spatial structure. For example, UCPs may reinforce a monocentric urban pattern or encourage a polycentric one. UCPs are known to encourage compact developments and promote concentrations of population and employment in central cities. However, these effects have not been measured at a metropolitan level. In addition, those effects might vary, depending on the tightness of the UCPs.
Employment and population density gradients will be measured and analyzed to examine the impacts of different UCPs on urban spatial structure in U.S. metropolitan areas. Density gradients measure the extent of concentrations. For instance, a steeper population density gradient means that the population is more concentrated in the existing center.

### 3.3.1 Density Gradients

#### 3.3.1.1 Economic Models of Density Gradients

The traditional assumption of a density function is that population or employment density declines with distance from the center. The economic models for measuring density gradients have evolved since Muth (1969) and Mills (1972) provided the justification of the negative exponential functions:

\[
D(x) = D_0 e^{-\gamma x}
\]  

(3.11)

where \(D(x)\) is the density at distance \(x\) from the CBD, \(D_0\) the density of the CBD, and \(\gamma\) the density gradient that reflects the degree of suburbanization. The larger the gradient, the lower the level of suburbanization. The gradient in the exponential density function is constant.

On the other hand, in a cubic spline density function, the relationship between density and distance is modeled with piecewise and continuous polynomials. The \(X\) axis is divided into several segments, and those points linking segments are called knots. If there are four knots denoted by \(X_0, X_1, X_2,\) and \(X_3\), \(X_0\) and \(X_3\) are the minimum and maximum values of the \(X\) axis, respectively. The regression model is as follows.
\[ \text{DEN}(X_i) = [a_i + b_i(X_i - X_o) + c_i(X_i - X_o)^2 + d_i(X_i - X_o)^3]D_1 + [a_2 + b_2(X_i - X_1) + c_2(X_i - X_1)^2 + d_2(X_i - X_1)^3]D_2 + [a_3 + b_3(X_i - X_2) + c_3(X_i - X_2)^2 + d_3(X_i - X_2)^3]D_3 \]  

(3.12)

where \( D_i \) is a dummy variable defined for interval \( i \). This model can be simplified by defining new dummy variables \( D^*_i \). The simplified model of a cubic spline density function for \( k + 1 \) segments is as follows:

\[ \text{DEN}(X_i) = a_i + b_i(X_i - X_o) + c_i(X_i - X_o)^2 + d_i(X_i - X_o)^3 + \sum_{i=1}^{k}(d_{i+1} - d_i)(X_i - X_1)^3 D^*_i + u_i \]  

(3.13)

where

\[ D^*_i = \begin{cases} 1 & \text{if } X_i \geq X_i \\ 0 & \text{otherwise} \end{cases} \]

Thus, the cubic spline function is a multiple regression model, where the parameters \( a_i, b_i, c_i, d_i \), and \( (d_{i+1} - d_i) \) are estimated (Anderson, 1985; Muniz et al., 2003). The optimal number of segments can be determined by several methods. Anderson (1985) and Muniz et al. (2003) used the minimum standard error of regression, Zheng (1991) used the statistical significance of the coefficients estimated. In addition, the \( R^2 \) or a combination method can be also used to determine the optimal number of segments.

However, the strategy of including multiple distance terms creates a bias problem, because regressions including multiple variables denoting distances to employment centers might have the problem of multicollinearity. McMillen and McDonald (1997) used a nonparametric estimation procedure\(^3\), locally weighted regression (LWR), to

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\(^3\)Nonparametric estimation allows the functional form of the regression function to be flexible. Parametric estimation, by contrast, makes assumptions about the functional form of the regression function (e.g. linear in the independent variables) and the estimate is of those parameters that are free (http://economics.about.com/cs/economicsglossary/g/nonparametric_e.htm).
reduce the misspecification bias of multicollinearity. A nonparametric estimation procedure, locally weighted regression, has been applied to several urban areas since Cleveland and Devlin (1988) proposed it as a spatial modeling method. McMillen (1996) demonstrates the spatial variations in land values in Chicago, using a nonparametric estimator. McMillen and McDonald (1997) use a nonparametric estimation procedure to estimate employment density in suburban Chicago. Craig and Ng (2001) also use a nonparametric procedure to identify employment sub-centers using quantile smoothing splines for Houston. The common idea of all these nonparametric procedures is to find local rises in the density function by comparing the density gradient of the fitted employment density functions with what would be expected without an employment sub-center.

Fotheringham et al. (1998) suggest that geographically-weighted regression (GWR) and the expansion method can be used to measure density gradients by examining the spatial variability of regression results over space. GWR allows local parameters to be estimated so that

$$Y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)X_i + u_i,$$

where $Y_i$ represents $\ln(DEN_i) - \ln(D_0)$, $(u_i, v_i)$ denotes the coordinates of the center point of the $i$th spatial unit, and $\beta_k(u_i, v_i)$ is a realization of the continuous function $\beta_k(u, v)$ at point $i$. Specifically, $\beta_1(u_i, v_i)$ refers to ‘a negative density gradient’. This method uses a subset of the points in the data set that are close to $i$. The $\beta_k(u_i, v_i)$s are estimated for $i$ and for the next $i$, a new subset of ‘nearby’ points is used, and so on.
Thus, GWR produces localized parameter estimates which can exhibit a high degree of variability over space.

In terms of the polycentric development pattern, if the locations of the employment centers are identified, the employment and population density gradients of all the centers can be estimated by the following non-linear model:

\[
DEN_m = \sum_{n=1}^{N} A_n e^{-\gamma_n X_{m,n}}
\]  

(3.15)

where \(DEN_m\) is the density at TAZ m, \(X_{m,n}\) represents the distance from TAZ m to center n, and \(\gamma_n\) represents the density gradient of center n. This model assumes that every center has an influence and requires nonlinear estimation (Anas & Small, 1998).

3.3.1.2 Measuring Density Gradients for the Impacts of UCPs

GWR, non-linear model, nonparametric methods, and the cubic spline function can measure density gradients more realistically than the monocentric exponential model, because they can measure density gradients from each sub-center. A non-linear model is used to verify where urban growth has taken place, using data from four selected contained metropolitan areas (Eugene-Springfield, OR, Minneapolis-St. Paul, MN, Lancaster, PA, and Lincoln, NE). However, the traditional monocentric exponential model is used with main dataset in this research because the density gradients derived from the monocentric model may explain the influence of the central city on other areas within the metropolitan area. In this research, the relationship between the central city and other areas within the metropolitan area is the central focus, because UCPs are usually enforced in central cities. In addition, since the estimated density gradients are
used as the endogenous variables to measure how different UCPs affect density gradients, a single density gradient per metropolitan area is desirable when used in regression models. Alperovich (1983) uses population density gradients of metropolitan areas as the dependent variable in multiple regression models to examine their determinants. This approach is discussed next.

Traffic Analysis Zones (TAZs), as defined in the Census Transportation Planning Package (CTPP), are the spatial units used to measure the density gradients of a set of U.S. metropolitan areas. The following exponential equations are formulated to measure population and employment density gradients:

Population: \[ DPOP_m = DPOP_0 e^{-\gamma_P X_m} e^{\mu_{P_m}}, \quad m = 1, 2, 3, \ldots, M \]  
Employment: \[ DEMP_m = DEMP_0 e^{-\gamma_E X_m} e^{\mu_{E_m}}, \quad m = 1, 2, 3, \ldots, M \]

where \( M \) is the total number of TAZs in a metropolitan area, \( X_m \) the distance from each TAZ to the CBD, \( DPOP_m \) and \( DEMP_m \) the population and employment densities in TAZ \( m \), \( DPOP_0 \) and \( DEMP_0 \) the population and employment densities in the CBD, \( \gamma_P \) and \( \gamma_E \) the population and employment density gradients, and \( e^{\mu_m} \) a multiplicative error term associated with TAZ \( m \). A larger density gradient represents a more compact spatial structure for the metropolitan area. In contrast, a smaller density gradient characterizes a more dispersed spatial structure.

3.3.2 Impacts of UCPs on Density Gradients

Cooke (1978), and Thurston and Yezer (1994) use population and employment density gradients in their economic models to examine the causality of population and
employment. Their focus is on the interrelationships between population and employment, rather than on specific policies that affect population and employment. Alperovich (1983) investigates the main factors that influence the population density gradients of Israeli cities, using a multiple regression model. Transportation costs, income, city age, and the tightness of the land market (land area per resident) are the exogenous variables, and the population density gradient the endogenous variable. However, Alperovich fails to consider the urban policies that may affect population density gradients.

This research incorporates the interrelationships between population and employment density gradients and other determinants, including urban containment policies, using a simultaneous equation modeling approach.

The negative exponential model approach assumes that the decrease of density from the CBD results from utility maximization of residents and profit maximization of firms. O’Sullivan (2003) argues that a residential location is determined by the trade-off between land costs and commuting costs. In this connection, when household income rises, the following two possibilities may be considered: (1) an increase in opportunity costs of commuting because time is more valuable, and (2) an increase in housing consumption because housing is a normal good. Therefore, it is not clear how the increase of income affects decentralization of cities. However, if the income elasticity of demand for housing space is larger than the income elasticity of commuting costs, wealthier people will live in suburban areas with larger houses (Alperovich, 1983). As a result, as income increases, people tend to move further out for more housing space, because their bids for housing shift from the center to outer areas. In other words, they
feel that the increase in transportation costs to get to their workplaces is smaller than the increase in the benefits of living in larger houses. They are willing to pay more for transportation costs if they can enjoy a larger house. However, the absolute size of a metropolitan area must be considered, because this trade-off is only true when transportation costs are relatively small. In small metropolitan areas, the transportation costs of people living in suburban areas are small because traffic congestion is not severe. On the other hand, in larger metropolitan areas, transportation costs are higher due to long commuting time, traffic congestion, and sometimes congestion fees. When transportation costs are very high, people consider moving to the central city. The behavior leading to suburbanization is also restricted when urban containment policies are enforced. This is the reason why urban policies must be incorporated into the analysis. The estimated population and employment density gradients are modeled as follows.

\[
PDG_i = p(EDG_i, POPD_{0i}, INC_i, HOUS_i, TRANS_i, SIZE_i, EXP_i, UCP_{ij})
\]  
(3.18)

\[
EDG_i = e(PDG_i, EMPD_{0i}, INC_i, HOUS_i, TRANS_i, SIZE_i, EXP_i, UCP_{ij})
\]  
(3.19)

where PDG_i and EDG_i represent the population and employment density gradients of metropolitan areas, POPD_{0i} and EMPD_{0i} the population and employment densities in the CBD, INC a vector of income characteristics, HOUS a vector of housing characteristics (values, tenure, vacancy rate), TRANS a vector of transportation characteristics (modes and commuting times), SIZE a vector of size (area and population), EXP a vector of financial characteristics (federal funding and tax expenditures), and UCP a vector of dummy variables representing stringent (UGBs) and
less stringent (USAs) containment policies. Stringent containment policies\textsuperscript{31} are divided into state-mandated UGBs and locally-enforced UGBs. This distinction is important because, in metropolitan areas with statewide UGBs, urban growth may concentrate on several cities where UGBs are enforced, promoting polycentric patterns, as illustrated in Figure 3.4. However, under locally-enforced UGBs, urban growth is concentrated only in central cities, and spillover effects may be dispersed if specific containment policies are not enforced in surrounding counties or cities. One example of locally-enforced UGBs is illustrated in Figure 3.5. Similarly, USAs (less stringent containment policies) may have spillover effects on surrounding cities because there is no restriction on those cities beyond the USAs, as illustrated in Figure 3.6.

\textsuperscript{31} The Boulder, Colorado, greenbelt is excluded from this analysis because this city is within the influence of the Denver metropolitan area rather than a central city. Therefore, stringent containment policies include only urban growth boundaries.
Figure 3.4 Statewide UGBs (Eugene-Springfield, OR)
Figure 3.5 Locally-enforced UGBs (Lexington, KY)
Figure 3.6 Less stringent containment policies (USAs, Minneapolis, MN)
CHAPTER 4

DATA SOURCES AND PROCESSING

This chapter describes the geographical units of the analysis, the data sources, and their processing. The empirical analysis includes analyses of (1) the impacts of UCPs on urban growth, and (2) the impacts of UCPs on urban spatial structure. Municipal-level data are used for the first analysis, and metropolitan-level data are used for the second one. The primary data sources for population, employment, housing values, and land areas are the Census Transportation Planning Package (CTPP) and the U.S. Bureau of the Census (American FactFinder).

4.1 GEOGRAPHICAL UNITS

4.1.1 Identification of Cities with Urban Containment Policies

statewide urban containment policies. Thus, based on published literature and web information, a list was made of 920 possible sample cities that have adopted UCPs in 22 states. An email survey was implemented in the Summer 2005 to contact planners in those sample cities, to check whether they really have some form of urban containment policies (greenbelts, UGBs, and USAs). A review of comprehensive planning documents was conducted for the non-response cases. One advantage of an email survey, as compared to other methods, is that planners have more time to prepare answers and responses from emails are relatively easier to compile than mail surveys. During the survey, some errors in previous studies have been uncovered. For example, Nelson et al. (2004)’s study identify Dayton, OH as a contained area. However, it turns out that the “future growth areas”, mentioned in some planning documents prepared by the Miami Valley Regional Planning Commission (MVRPC) of the Dayton metropolitan area, are not legally binding. Also, Gerber & Phillips (2004) identify 85 UGB cities in California, although only 65 cities have been identified in this survey. One reason is that several cities in Gerber & Phillips’ UGB list have only SOIs, because many planners have identified SOIs as UGBs. A second reason, although unusual, is that some cities may have canceled their UGBs. For example, the city of Delano canceled in 2005 the UGB that had been approved in the 2000 General Plan, because it was shown that a UGB was not a proper predictor of the demand for urban growth in this community.

Based on the email survey results and other public agencies planning documents, 795 municipalities in 18 states have been selected, including all jurisdictions in Oregon, all jurisdictions in 17 counties in Washington, and some cities in California, Colorado, Kentucky, Michigan, Nebraska, Pennsylvania, and Tennessee for UGBs, some cities in
Arizona, Maryland, Minnesota, Missouri, New Jersey, North Carolina, North Dakota, Florida, South Dakota, Virginia, and Wisconsin for USAs, and Boulder in Colorado and some cities in California for greenbelts. Figure 4.1 shows that these states span the whole U.S.

However, not all these 795 cities could be considered as contained for the purpose of this research. First, the growth boundaries adopted by some counties are usually too large to control the growth of each city. For example, Contra Costa County has adopted an Urban Limit Line (ULL) in 1990. In half of the cities in Contra Costa, ULLs extend across the Spheres of Influence (SOIs). For these reasons, most cities in this county were excluded from the sample of UGB cities. Second, those cities that adopted UCPs after 1996, were excluded from the sample, because the focus is on UCP impacts over the 1990-2000 period. Finally, employment data at the municipal level is available only for those cities with more than 2,500. Therefore, some cities with less than 2,500 in 1990 or
2000 were excluded. As a result, 309 municipalities are used as UCP cities in the analysis.

4.1.2 Spatial Units for the Analysis of Urban Growth

The analysis of urban growth focuses on how UCPs affect population and employment growth, housing values, and built-up area. The nationwide municipal-level data is used in this analysis.

In the final dataset, 309 municipalities are UCP communities (221 for SCP and 88 for LSCP). As benchmark sample, all other cities of the nation that have more than 2,500 people in 1990 and 2000 and have not adopted UCPs are included in the dataset. They are 5,373 such incorporated places. Hawaii and Alaska are excluded from the dataset due to their geographic characteristics.

4.1.3 Spatial Units for the Analysis of Urban Spatial Structure

The impacts of UCPs on the urban spatial structure are analyzed by examining population and employment density gradients in both contained areas and uncontained areas. The density gradients of U.S. metropolitan areas are used as the endogenous variables. Therefore, the primary spatial unit of this analysis is a metropolitan area. In order to estimate the density gradients of a metropolitan area, population and employment data at the Traffic Analysis Zones (TAZs) level are used.

Statistical Areas (MSA) out of 279 Metropolitan Areas (MAs\textsuperscript{32}) were selected as the sample based on the following reasons.

First, Consolidated Metropolitan Statistical Areas (CMSAs) are deleted from the sample because they are too big to capture the influence of one C.B.D. CMSAs sometimes extend across more than one state. For example, the CMSA of ‘New-York – Northern New Jersey – Long Island’ consist of 29 counties across four states. On the other hand, MSAs are metropolitan areas (MAs) surrounded by non-metropolitan areas. Since MSAs do not closely interact with other MAs, the impacts of UCPs for a central city can be measured effectively within its MSA.

Second, some MSAs, where either population and employment or geographical data on TAZs in both 1990 and 2000 were not available, were removed from the sample. For example, 2000 TAZ data for Columbus (OH) MA and all MAs in Oregon, except for Eugene-Springfield MA, are not available, although the corresponding 1990 data are available.

The sample of the 135 MSAs is compared with the other non-selected MAs in Table 4.1. This table indicates that the sample had a smaller population growth rate from 1990 to 2000 than the other MAs. The mean population growth rate of the sample MSAs was 11.18%, while the mean population growth rate of the other non-selected MAs was 16.00%, a statistically significant difference. However, the sample is not significantly different from the other non-selected MAs in terms of total population in 1990 and 2000.

\textsuperscript{32} MA is defined by the U.S. Census Bureau as an area that “contains either a place with a minimum population of 50,000 or a Census Bureau-defined urbanized area and a total MA population of at least 100,000 (75,000 in New England)”.

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and the change in population over 1990-2000. This suggests that the sample reasonably represents all U.S. metropolitan areas.

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
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</tr>
</thead>
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<td></td>
<td></td>
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<tr>
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<td>Population Change</td>
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<td></td>
<td>Satterthwaite/Unequal</td>
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<td>Sample MSAs</td>
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<td>Non-selected MAs</td>
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<td>Population Growth Rate</td>
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<td></td>
<td>Satterthwaite/Unequal</td>
</tr>
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<td>Sample MSAs</td>
<td>135</td>
<td>11.18%</td>
<td></td>
</tr>
<tr>
<td>Non-selected MAs</td>
<td>144</td>
<td>16.00%</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1 Comparisons of the sample MSAs with the other non-selected MAs
4.2 VARIABLES FOR URBAN GROWTH ANALYSIS

4.2.1 Endogenous Variables

Four endogenous variables are used in simultaneous equation models, including changes of population, employment, median value of specified owner-occupied housing units\(^{33}\), and land areas from 1990 to 2000. Most data used in this research are downloaded from several websites. Population, median values of specified owner-occupied housing units, and land areas are downloaded from the American FactFinder website of the U.S. Bureau of the Census (http://factfinder.census.gov). Employment data are obtained from the Census Transportation Planning Package (CTPP\(^{34}\)). The reason for which CTPP data are used, rather than the Economic Censuses, is that the CTPP provides decennial data in 1990 and 2000, consistent with the population and housing data from the Census (Economic Census data are available for 2002, 1997, 1992, etc., with five-year intervals).

The change of employment is disaggregated by major industry categories: Manufacturing, Retail, and Services. The original CTPP industry data include 18 sectors in 1990, based on SIC codes, and 14 sectors in 2000, based on NAICS codes. The SIC codes are matched with the NAICS codes. However, because the CTPP does not provide

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\(^{33}\) The Bureau of Census defines specified owner-occupied housing units as “owner-occupied family houses on less than 10 acres without a business or medical office on the property”. Therefore, these units exclude “mobile homes, houses with a business or medical office, houses on 10 or more acres, and housing units in multi-unit buildings”.

\(^{34}\) The CTPP is a database derived from the Population Census to support transportation planning activities. This database has information on places of work and on the flows of workers between home and work. In this study, most of the data drawn from the CTPP are at the place and TAZ level (incorporated areas).
information on lower-digit industries, it is difficult to exactly match SIC with NAICS codes. Therefore, both 1990 and 2000 data were adjusted, based on the bridge between SIC and NAICS provided by the Economic Censuses. The service sector includes finance, insurance, and real estate; professional, scientific, management, administrative, and waste management services; educational, health and social services; arts, entertainment, recreation, accommodation and food services; transportation and warehousing, and utilities; and information.

4.2.2 Exogenous Variables

The exogenous variables include natural amenities, social amenities, lagged variables for population, employment, housing values, land areas, and income and UCP dummy variables.

Natural amenities are among the most important factors attracting population. The amenity scale\textsuperscript{35}, calculated by McGranahan (1999), is used to represent natural amenities. Since the original data characterized counties, county data are applied to their incorporated areas, under the assumption of intra-county homogeneity. McGranahan measures the amenity scale by summing the standardized values of six measures, including “Warm winter (average January temperature)”, “Winter sun (average January days of sun)”, “Temperate summer (low winter-summer temperature gap)”, “Summer humidity (low average July humidity)”, “Topographic variation (topography scale)”, and “Water area (water area as proportion of total county area)”.

\textsuperscript{35} This data is downloadable from the website of Natural Resources Conservation Service (http://www.nrcs.usda.gov/technical/NRI).
Social amenities include air quality, educational achievement, crime rate, and access to highways. The average value of the Air Quality Index (AQI) from 1996 through 2000 is used to measure air quality. The AQI is calculated by the Environmental Protection Agency (EPA), based on the five major air pollutants regulated by the Clean Air Act: ground-level ozone, particulates, carbon monoxide, sulfur dioxide, and nitrogen dioxide. Air quality is measured by the number of days when the AQI is good divided by the number of days when AQI data is available. County-level data are applied to the cities within the county.

The educational achievement is measured by the education attainment reported in 1990 and 2000 by the Census. The data is downloadable from the American FactFinder (http://factfinder.census.gov). The change from 1990 to 2000 in the ratio of people with a bachelor’s degree or higher to the total population is used.

The 2000 FBI index of violent and property crime per capita is used to measure the crime rate in each city. Violent crimes include murder and non-negligent manslaughter, forcible rape, robbery, and aggravated assault, property crimes include burglary, larceny theft, motor vehicle theft, and arson.

The access to highways is measured by a dummy variable equal to one in cities criss-crossed by interstate highways. In order to identify the existence of interstate highways, coverages of interstate highways and city boundaries are overlayed in ArcGIS. Initially, this variable was measured by the distance from the city boundary to the nearest interstate highway. However, this distance variable turned out to be statistically insignificant.
The 1990 population, employment, median housing value, and land area are used as lagged variables.

The 1990 and 2000 median household incomes at the municipal level are downloaded from ‘1990 Summary Tape File 3 (STF 3) - Sample data’ and ‘Census 2000 Summary File 3 (SF 3) - Sample Data’, respectively.

Finally, two UCP dummy variables are used to characterize Stringent Containment Policies (SCP) and Less Stringent Containment Policies (LSCP).

In order to create the final dataset, population and housing values from the U.S. Bureau of the Census are combined with employment data from the Census Transportation Planning Package (CTPP), using place codes, and the MS Access program.

4.3 VARIABLES FOR URBAN SPATIAL STRUCTURE ANALYSIS

Most data for the variables of the urban spatial structure analysis are obtained at the metropolitan level. However, some variables are measured at the central city level, in order to examine the influence of central cities on metropolitan areas.

4.3.1 Endogenous Variables (Density Gradients)

4.3.1.1 Urban Geographic Data of TAZs

The basic spatial unit for estimating density gradients is the Traffic Analysis Zone (TAZ), as used in the Census Transportation Planning Package (CTPP). The geographic coverage (shape file) and attribute data file of TAZs for 1990 have been downloaded from the Bureau of Transportation Statistics website (http://www.transtats.bts.gov).
However, the 2000 geographic coverages (shape file) are not available from this website, but the attribute data are. Two other sources provide the geographic coverage files for the 2000 TAZs: the U.S. Bureau of the Census and the Environmental Systems Research Institute (ESRI). Although the maps from these two sources look similar, one should be cautious in using the geographic data from the Census, because the matching codes are not consistent between geographic and attribute data. The appropriate TAZ coverages should be downloaded from the ESRI website (http://arcdata.esri.com/data/tiger2000/tiger_download.cfm).

4.3.1.2 Density Gradients of Population and Employment

Population and employment density gradients for 1990 and 2000 are estimated using the negative exponential model and TAZ data for each metropolitan area. The sectoral employment density gradients for manufacturing, retail, and services are estimated with the same method. The population and employment densities (DPOP₀ and DEMP₀) of the CBD are also derived with these models.

The density gradients in the central cities are also estimated and compared with those for the whole metropolitan areas. The TAZ layer of a metropolitan area is intersected with the boundary of the central city, to create a central city TAZ coverage. Figure 4.2 presents the geographical boundaries of TAZs, UCPs, and central city within a metropolitan area. UCPs are larger than the central city boundary, and TAZs are the smallest spatial units.
4.3.2 Exogenous Variables

4.3.2.1 Population and Housing Variables

As a metropolitan area (MA) is fully suburbanized and the population density of its central city is relatively low, the density gradient for the MA is likely to be small, indicating a population dispersed across the MA.

Increasing housing values induce people to move further out, as long as the demand for high density residential developments in the central city does not increase. Due to the preferences of homeowners for larger spaces, a larger proportion of homeowners, as compared to renters, is closely related to suburbanization. Also, a higher vacancy rate for housing units corresponds to more suburbanization with smaller density.
gradients. In connection with the housing vacancy rates, the age (median built year) of housing units is used to represent the extent of deterioration in the central city.

The 2000 data for population, population density (central city), median housing values, housing tenure (ratio of homeowners to renters), housing vacancy, and the median built year, are downloaded from the American FactFinder (http://factfinder.census.gov).

4.3.2.2 Transportation and Infrastructure

There is no doubt that improvements in transportation systems, in particular highways, has contributed to urban sprawl. In addition, low gas prices and relatively cheap transportation have promoted the use of cars rather than transit systems, making urban areas more spread out. Also, the improvement of informational technology (IT) enables workers to reduce travel to work by allowing them to work at home. This telecommuting option makes it possible for people to select their home anywhere, regardless of distance to workplace, promoting sprawled developments (U.S. Congress, 1995). In order to measure those factors, the means of transportation to work, commuting times by transportation modes, and the share of telecommuters are obtained from the 2000 CTPP (http://www.transtats.bts.gov).

Federal spending and tax expenditures are known to promote urban sprawl by reducing development costs in outer areas (Persky & Kurban, 2003). Total expenditures per capita of federal funds and grants (1996), general expenditure by city governments (1996-1997), and general expenditure for highways by city governments (1996-1997) are obtained from the Geospatial & Statistical Data Center housed in the University of Virginia Library (http://fisher.lib.virginia.edu).
4.3.2.3 Income, Size of MAs, and UCPs

There are two models regarding the effects of income on suburbanization: “natural evolution” and “flight from blight”. According to the “natural evolution model”, an increase in household income increases housing consumption because housing is a normal good. If the income elasticity of housing demand is larger than income elasticity of commuting costs, people move to suburban locations with larger houses. The “flight from blight” model assumes that households, as their income increases, move to the suburbs in response to the fiscal and social problems associated with the central city. Income per capita and median household incomes for White, Black, Asian, and Hispanics are collected from American FactFinder.

Alperovich (1983) suggests that the density gradient is a negative function of the size of an urban area, because large urban areas extend further out than small metropolitan areas. Large metropolitan areas can accommodate more sub-centers, resulting in the dispersion of population employment. The area of each TAZ from the 2000 CTPP is calculated using ArcGIS and summed up to represent the total area of each metropolitan area.

Finally, the UCP dummy set includes three dummy variables: statewide UGBs (SUGB), locally-enforced UGBs (LUGB), and USAs (USA), where SUGB=1 denotes a metropolitan area where a statewide UGB has been enforced, LUGB=1 a metropolitan area where a UGB had been adopted by its central city, and USA=1 a metropolitan area where its central city has adopted a USA.
CHAPTER 5

IMPACTS OF URBAN CONTAINMENT POLICIES ON
POPULATION, EMPLOYMENT, HOUSING VALUES,
AND LAND AREAS

This chapter discusses the impacts of urban containment policies (UCPs) on urban growth. Two approaches are considered to empirically analyze the impacts of UCPs on population, employment, housing values, and land areas, using simultaneous equation models. In the first approach, the changes in a city’s total population, total employment, housing values, and land area are used as the endogenous variables. In the second one, sectoral employment variables, instead of total employment, are used as endogenous variables, together with changes in population, housing values, and land areas.

5.1 OVERVIEW

The enforcement of urban containment policies directly or indirectly affects housing markets, population, employment, and land areas, depending upon their tightness. Table 5.1 presents the mean values of related variables for each of the
Table 5.1 Mean values of major variables and comparison tests between contained and uncontained cities

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>T-TEST (t Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SCP</td>
<td>LSCP</td>
</tr>
<tr>
<td>Housing Value - 2000 ($)</td>
<td>178,988</td>
<td>156,036</td>
</tr>
<tr>
<td>Growth Rate of Housing Values, 1990-2000</td>
<td>0.88</td>
<td>0.59</td>
</tr>
<tr>
<td>Population – 2000 (#)</td>
<td>38,279</td>
<td>52,726</td>
</tr>
<tr>
<td>Population Density - 2000 (#/sq.mile)</td>
<td>2,679</td>
<td>2,173</td>
</tr>
<tr>
<td>Growth Rate of Population, 1990-2000</td>
<td>0.34</td>
<td>0.24</td>
</tr>
<tr>
<td>Growth Rate of Employment, 1990-2000</td>
<td>0.33</td>
<td>0.50</td>
</tr>
<tr>
<td>Growth Rate of Land Area, 1990-2000</td>
<td>0.24</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Note: * significant at the 1% level, ** significant at the 5% level, and *** significant at the 10% level.

As expected, SCP cities have the highest mean median housing value in 2000 ($178,988). LSCP cities have the second highest one ($156,036), and UC cities have the smallest one ($120,560). These differences are significant at the 1% level between UC

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and SCP/LSCP cities, and at the 5% level between SCP and LSCP cities. SCP cities have the highest mean growth rate for housing values from 1990 to 2000 (0.88). The mean growth rates of housing values in LSCP cities and UC cities are 0.59 and 0.49, respectively, and the difference is significant at the 1% level. These tests imply that housing values and their growth increase with the tightness of UCPs.

Unexpectedly, population growth and employment growth are higher in SCP/LSCP cities than in UC cities. Population growth is highest in SCP cities (0.34), followed by LSCP cities (0.24), and UC cities (0.14), respectively. The mean population and land area in SCP/LSCP cities are bigger than in UC cities, which indicates that larger cities have adopted urban containment policies. SCP cities have the highest population density (2,679 people per square mile), while LSCP cities have the lowest one. LSCP cities have the largest mean total land area (29.68 square miles).

Mean employment growth is highest in LSCP cities (0.50), followed by SCP cities (0.33) and UC cities (0.23), which may imply that scale economies in contained cities attract more employment than UC cities, and the employment growth rate increases with decreasing strictness in containment policies.

SCP cities have expanded their land areas by 24% on average between 1990 and 2000, while UC cities have expanded by 17% and LSCP cities by 4%. SCP cities must accommodate their growth within the growth boundaries, and therefore are likely to aggressively expand their corporate boundaries. On the other hand, spillover effects can take place beyond the service areas of LSCP cities, without requiring the expansion of their incorporated areas, because new developments are allowed beyond urban service
areas without provision of public services. The differences in the mean values of most variables between contained and uncontained cities are statistically significant.

In summary, the mean growth rates in Table 5.1 support the assumption that the growth of population, employment, housing values, and land areas are differentially affected by the tightness of containment policies.

5.2 CHANGES IN POPULATION, EMPLOYMENT, HOUSING VALUES, AND LAND AREAS

The simultaneous equation models for the changes in population, employment, housing values, and land areas are estimated while taking the logarithm of the endogenous variables and all the exogenous variables (except the dummy variables). In such models, the coefficients represent elasticities (Wassmer, 2006). The structural equation system is estimated using the three-stage least squares (3SLS) procedure. Some variables that were not statistically significant were dropped. Table 5.2 presents the results for the final models, where the variables meaning the changes between the two time periods are represented by ratios [i.e. \( \ln(Y_t/Y_{t-1}) = (\ln Y_t - \ln Y_{t-1}) \)].

In order to assess whether the structural equations can be identified, given the knowledge of the coefficient of the reduced-form equations, both the order and the rank conditions are tested. The order condition, which is a necessary condition for identification, is satisfied when the number \( K_j^+ \) of excluded exogenous variables in equation \( j \) is equal to or greater than the number \( M_j \) of included endogenous variables.
<table>
<thead>
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<th>Endogenous Variables</th>
<th>Intercept</th>
<th>Change_Population</th>
<th>Change_Employment</th>
<th>Change_Housing value</th>
<th>Change_Land area</th>
</tr>
</thead>
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<tr>
<td>Intercept</td>
<td>-1.276350* (-6.92)</td>
<td>3.723368* (6.42)</td>
<td>2.050272* (8.74)</td>
<td>1.240080* (8.97)</td>
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<td>Population(1990)</td>
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<td>-</td>
<td>-</td>
<td></td>
</tr>
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<td>Employment(1990)</td>
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<tr>
<td>Housing value(1990)</td>
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<td>-0.176080* (-16.13)</td>
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<tr>
<td>Land area(1990)</td>
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<td>-</td>
<td>-0.016950* (-5.54)</td>
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<td>Change_Population</td>
<td>0.287289* (10.08)</td>
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<td>0.090578** (2.31)</td>
<td>-0.297340* (-9.76)</td>
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<tr>
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<td>1.270386* (6.29)</td>
<td>-</td>
<td>0.456471* (8.52)</td>
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</tr>
<tr>
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<td>0.381392* (3.37)</td>
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<td>Topographic variation</td>
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<td>0.002451* (3.86)</td>
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</tr>
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<td>Natural Amenity</td>
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<td>-</td>
<td>0.007268 (0.67)</td>
<td>-</td>
<td></td>
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<tr>
<td>Air quality</td>
<td>-0.042110* (-3.06)</td>
<td>0.082038 (1.44)</td>
<td>-</td>
<td>-</td>
<td></td>
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<td>0.030655** (1.99)</td>
<td>0.104645* (13.73)</td>
<td>-</td>
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<td>Violent crime</td>
<td>-0.008190 (-1.48)</td>
<td>0.024241 (1.51)</td>
<td>-0.021180* (-7.05)</td>
<td>0.010016** (2.48)</td>
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<td>Property crime</td>
<td>-0.007890 (-0.72)</td>
<td>0.040607 (1.18)</td>
<td>0.011564*** (1.91)</td>
<td>0.022443* (3.03)</td>
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<td>Highway access</td>
<td>-0.008300 (-0.65)</td>
<td>0.037892 (1.02)</td>
<td>-0.011490 (-1.62)</td>
<td>0.018291*** (1.95)</td>
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<td>Commuting time</td>
<td>0.175893* (5.04)</td>
<td>-0.518710* (-5.01)</td>
<td>0.024680 (0.94)</td>
<td>-0.190400* (-7.55)</td>
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</tr>
<tr>
<td>Transit</td>
<td>-0.020750* (-3.77)</td>
<td>0.039368*** (1.78)</td>
<td>0.007192 (1.45)</td>
<td>-</td>
<td></td>
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<tr>
<td>Change_Income</td>
<td>0.680563* (6.25)</td>
<td>-1.921080* (-5.73)</td>
<td>0.822331* (12.53)</td>
<td>-0.596620* (-6.93)</td>
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<tr>
<td>Dummy SCP</td>
<td>0.170296* (6.20)</td>
<td>-0.497710* (-6.16)</td>
<td>0.190937* (11.96)</td>
<td>-0.164880* (-7.55)</td>
<td></td>
</tr>
<tr>
<td>Dummy LSCP</td>
<td>0.067752*** (1.71)</td>
<td>-0.219140*** (-1.85)</td>
<td>0.092312* (4.22)</td>
<td>-0.098650* (-3.69)</td>
<td></td>
</tr>
</tbody>
</table>

System Weighted R² 0.3035

Note: * significant at the 1% level, ** significant at the 5% level, and *** significant at the 10% level.

Table 5.2 Structural equations for population, employment, housing values, and land areas
Table 5.3 Identification of simultaneous equations

<table>
<thead>
<tr>
<th></th>
<th>Change_ Population</th>
<th>Change_ Employment</th>
<th>Change_ Housing value</th>
<th>Change_ Land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^*_j$</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>$M_j$</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Rank($A^*_j$)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

in equation $j$ minus 1. The rank condition\(^{36}\), which is a sufficient condition for identification, is satisfied when the rank ($A^*_j$) of the sub-matrices made by structural equation coefficients is equal to the number ($M_j$) of included endogenous variables in equation $j$. The results in Table 5.3 show that the structural equations are over-identified in terms of the order condition, and that the rank condition is satisfied.

### 5.2.1 Interrelationship between population, employment, housing values, and land areas

Figure 5.1, derived from Table 5.2, displays the statistically significant relationships between the four endogenous variables.

An increase in population positively affects changes in employment and land areas. This result makes intuitive sense, because employment increases due to the

\(^{36}\) Given the transpose of the coefficient matrix ($A$), when a “0” is found in row $j$ of $A$, the rest of that column is written down, and a new matrix ($A^*_j$) is created. Thus, the number of columns in $A^*_j$ is the same as the number of zeros in row $j$ of $A$. If rank ($A^*_j$) = $M_j$, the number of included endogenous variables in equation $j$, equation $j$ is identified. The rank ($A^*_j$) is calculated using the MATLAB software.
increase in demand for services required by the population, further resulting in the expansion of built-up areas. Thus, an increasing population attracts employment, and population also follows employment. This is consistent with literature results. An increasing land area points to growth in the supply of land for residential development, thus positively affecting population growth.

Changes in land area and employment negatively affect each other, implying that land annexation is directed to the influx of population rather than to employment growth. Increases in land area and housing values positively affect each other. Because a producer increases output to raise profits when prices are high, an increase in housing values encourages developers to construct more housing units, resulting in the expansion of built-up areas.

An increase in housing values discourages the influx of population. However, unexpectedly, the effect of population on housing values is not statistically significant. On the other hand, changes in housing values and employment positively affect each other, suggesting that fast growing industries, such as services37, are less sensitive to high land values. The reduced forms of the simultaneous equations are presented in Table 5.4. The coefficients of the structural equations measure only the direct effects of the exogenous variables on the endogenous variables, without capturing the indirect effects embodied in the other equations. The reduced-form coefficients incorporate both the direct and indirect effects of the exogenous variables (Weber & Dudney, 2003; Carlino & Mills, 1987).

37 The share of employment in the service sector is more than 50%, but is less than 20% in manufacturing in 2000 (U.S. Bureau of Census).
The coefficients of the lagged exogenous variables add a meaningful insight into the traditional debate regarding the causality of population and employment. The size of the population contributes to employment growth while the size of employment negatively affects population growth, suggesting that employment follows people. The elasticity of the change in employment with respect to population is 0.1663, whereas the elasticity of the change in population with respect to employment is -0.0705.
<table>
<thead>
<tr>
<th>Exogenous Variables</th>
<th>Change Population</th>
<th>Change Employment</th>
<th>Change Housing value</th>
<th>Change Land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-2.5277</td>
<td>-0.7134</td>
<td>2.2094</td>
<td>-0.2860</td>
</tr>
<tr>
<td>Population(1990)</td>
<td>0.0654</td>
<td>0.1663</td>
<td>0.0178</td>
<td>0.0297</td>
</tr>
<tr>
<td>Employment(1990)</td>
<td>-0.0705</td>
<td>-0.2514</td>
<td>-0.0172</td>
<td>-0.0097</td>
</tr>
<tr>
<td>Housing value(1990)</td>
<td>0.0670</td>
<td>-0.0172</td>
<td>-0.1898</td>
<td>-0.0087</td>
</tr>
<tr>
<td>Land area(1990)</td>
<td>0.0101</td>
<td>0.0962</td>
<td>-0.0070</td>
<td>-0.0377</td>
</tr>
<tr>
<td>Topographic variation</td>
<td>-0.0015</td>
<td>-0.0139</td>
<td>0.0010</td>
<td>0.0055</td>
</tr>
<tr>
<td>Natural amenity</td>
<td>-0.0028</td>
<td>0.0007</td>
<td>0.0078</td>
<td>0.0004</td>
</tr>
<tr>
<td>Air quality</td>
<td>-0.1264</td>
<td>-0.1301</td>
<td>-0.0397</td>
<td>-0.1167</td>
</tr>
<tr>
<td>Educational attainment</td>
<td>-0.0410</td>
<td>0.0786</td>
<td>0.1105</td>
<td>-0.0176</td>
</tr>
<tr>
<td>Violent crime</td>
<td>-0.0036</td>
<td>-0.0168</td>
<td>-0.0218</td>
<td>0.0012</td>
</tr>
<tr>
<td>Property crime</td>
<td>0.0161</td>
<td>0.0547</td>
<td>0.0284</td>
<td>0.0366</td>
</tr>
<tr>
<td>Highway access</td>
<td>0.0182</td>
<td>0.0463</td>
<td>-0.0005</td>
<td>0.0240</td>
</tr>
<tr>
<td>Commuting time</td>
<td>0.2303</td>
<td>0.1935</td>
<td>0.0155</td>
<td>0.0093</td>
</tr>
<tr>
<td>Transit</td>
<td>-0.0674</td>
<td>-0.0720</td>
<td>-0.0124</td>
<td>-0.0575</td>
</tr>
<tr>
<td>Income</td>
<td>0.7267</td>
<td>0.7238</td>
<td>0.9490</td>
<td>0.4110</td>
</tr>
<tr>
<td>Dummy SCP</td>
<td>0.1580</td>
<td>0.1298</td>
<td>0.2055</td>
<td>0.0620</td>
</tr>
<tr>
<td>Dummy LSCP</td>
<td>0.0281</td>
<td>0.0688</td>
<td>0.0740</td>
<td>-0.0548</td>
</tr>
</tbody>
</table>

Table 5.4 Reduced-form equations\textsuperscript{38} for population, employment, housing values, and land areas

\textsuperscript{38} In order to determine the significance of the reduced form equations, the t-statistics for the reduced form coefficients should be calculated. However, although the reduced form coefficients are estimated by many software packages, none of the popular econometric software provides t-statistics for reduced form coefficients.
5.2.2 Effects of Natural and Social Amenities

Table 5.2 indicates that the natural amenity variable is not statistically significant in all equations. McGranahan (1999) mentions that natural amenities are good predictors of population growth in rural counties, although the impact on employment is not clear. Thus, a possible reason why the effects of natural amenities are not significant may be that the dataset focuses on relatively large municipalities (more than 2,500 people) rather than rural areas.

Among the social amenity variables, educational attainment positively affects employment and housing values growth, but negatively affects population growth, possibly because more educated people have fewer children. Large families usually have poorer schooling records (Eijck & Graaf, 1995). Both violent and property crime rates have different effects on housing values, but have positive effects on the increase in land area. Violent crime rates have a negative effect on housing values, but property crime rates have the reverse effects. Harries (2006) argues that property crimes rise with higher population density, by providing thieves more private property targets. This is one of the “push factors” that have people move further out, resulting in the expansion of land area. However, further research is necessary regarding the effects of crimes on housing values.

Highway access appears to positively impact the expansion of land area, by facilitating access from fringe areas to city center. This is consistent with literature results. In addition, many shopping malls, industrial parks, and office parks are located around highway interchanges. Commuting time is significant in most equations, except for housing values. In particular, population growth is positively affected by long commuting time, because most growing cities are located in suburban areas, with many
workers still commuting to the central city. On the other hand, long commuting times negatively affect employment growth and land area, implying that less commuting time contributes to employment growth and promotes the expansion of built-up area. Using a transit system to work has a positive effect on employment growth and a negative one on population growth. Transit systems are well developed in most central cities and inner ring suburbs, in contrast to suburban and exurban areas. Those central urban areas have experienced decreases in population.

An increase in median household income has a significant effect in all equations. For example, population and housing values are positively affected by increase in household income. Intuitively, an income increase contributes to the tax base of municipalities, followed by service improvements, which attract people and raise housing values. In addition, as income increases, people spend more money on housing because a house is a normal good. This also contributes to the rise of housing values. On the other hand, an increase in household income has a negative effect on employment and change in land area. The negative impact on employment is partly due to an imbalance between jobs and housing, implying that people with high incomes tend to live in residential-intensive municipalities, rather than in mixed-use or employment-intensive ones. Change in income has a negative effect on change in land area. The literature argues that an increase in income contributes to urban sprawl, expanding the urbanized areas of a metropolitan area. Households choose municipalities, based on their preferences for a combination of lower taxes and local public goods. This is known as the “Tiebout Hypothesis”. Fulton et al. (2001) argue that metropolitan areas that have more fragmented local governments tend to have more sprawl. However, at the municipal
level, an increase in income does not always increase the land area, because residents, specifically in the higher income class, do not want their jurisdiction to be expanded. For example, Gerber & Phillips (2004) find that UGBs, amended by voters, are seldom changed, as compared to the ones amended by city councils.

5.2.3 Effects of Urban Containment Policies

The results in Table 5.2 indicate that both the SCP and LSCP dummy variables have a significant impact on changes in population, employment, housing values, and land area.

Under SCP, new developments are not allowed beyond growth boundaries. On the other hand, new developments are allowed beyond LSCP boundaries, and therefore, relatively more land is available under LSCP than under SCP.

In line with the difference in tightness of SCP and LSCP, the coefficients of the SCP dummy variable for the changes in population, employment, housing values, and land area are almost twice higher than those of the LSCP dummy variables, although the signs are the same for both dummy variables. For example, the coefficients of SCP and LSCP for the change in population are 0.170 and 0.068, respectively. This suggests that SCP more successfully accommodates new growth within the growth boundaries than LSCP. The reduced-form coefficients in Table 5.4 also confirm that SCP has a positive effect on population growth seven times higher than LSCP. This undermines the amenity-creation model, wherein population decreases due to the spatial limitation of SCP.

Both the structural equations and the reduced-forms coefficients indicate that both SCP and LSCP have a significant positive effect on change in housing values. The
reduced-form coefficient of SCP is almost three times larger than LSCP’s, confirming that housing values increase with the tightness of containment policies. Since the supply of available land is tightly limited under SCP, the corresponding increase in housing values is higher than with LSCP.

The signs of the structural employment equations coefficients of SCP and LSCP are negative. SCP has a negative effect on employment growth more than twice as large as LSCP, implying that tighter containment policies lead to lesser employment growth. However, when both the direct and indirect effects are taken account, the reduced-form coefficients indicate that both SCP and LSCP positively affect employment growth. SCP still has a positive effect on employment growth twice as large as LSCP. The effects of urban containment policies on employment growth are further examined using sectoral employment data in the next section.

Although both SCP and LSCP have negative structural equations coefficients for the change in land area, the reduced form coefficients show that only LSCP negatively impacts the increase in land area, suggesting that there was less annexation of fringe areas in LSCP cities between 1990 and 2000. While it may appear that LSCP minimizes the expansion of cities, this does not guarantee that LSCP prevents urban sprawl, because new developments may take place beyond the boundaries of the metropolitan area. On the other hand, the reduced-form coefficient of SCP in the land area change equation is positive. A growing population under SCP may force the expansion of these cities by incorporating fringe areas. Since new developments are not allowed outside SCP boundaries, these developments are likely to occur between SCP boundaries and city boundaries, by expanding incorporated areas. However, this does not mean that the
supply of land under SCP is sufficient. For example, Table 5.4 indicates that the ratio (2.548) of the coefficients of SCP for the change in population (0.158) to the change in land area (0.062) is much higher than the corresponding ratio for LSCP (-0.5128 = 0.0281/-0.0548). This suggests that the supply of land under SCP is insufficient, as compared to the supply under LSCP, thus supporting the supply-restriction model, wherein housing values increase due to the limited supply of land under SCP.

In order to look in more detail at the characteristics of contained cities, two distinct datasets were extracted from the whole sample: one with SCP cities only, and another with LSCP cities only. The simultaneous equations were estimated separately with each of these datasets. Table 5.5 presents some structural equations coefficients that differ from those obtained earlier with the whole dataset. Overall, the results for SCP cities only or LSCP cities only are similar to those obtained with the whole dataset, except for housing values. When the whole dataset is used, the change in population does not significantly affect the change in housing values (Table 5.2), rejecting the earlier hypothesis that housing values increase due to the increase of amenities, derived from the decrease of population under the enforcement of SCPs. However, the results obtained with data for SCP cities only, indicate that increasing population negatively affect the change in housing values, supporting the hypothesis at least in SCP cities. In addition, air quality is a good predictor for the change in housing values, and natural amenities and the use of transit systems have a positive effect on the increase in housing values. These results support the amenity-creation model.
Table 5.5 Structural equations for contained cities only

### 5.3 CHANGES IN SECTORAL EMPLOYMENT

Table 5.6 presents the average employment shares and growth rates for the three selected industrial sectors (manufacturing, retail, services), for SCP, LSCP, and UC cities.

As expected, the shares of sectoral employment vary across SCP, LSCP, and UC cities. The share of manufacturing is lowest in SCP cities (13.11%), possibly because of higher land values, while LSCP cities have the highest share (18.28%). The difference between LSCP and UC cities (16.33%) is not significant. The retail share is highest in SCP cities, possibly because of the positive impact of SCP on population growth. The difference between LSCP and UC cities is not significant. Services are major providers of employment in cities, and the differences in services shares among city categories are not
significant. The growth of the service sector is clearly different between contained and uncontained cities. LSCP cities have the highest growth rate (0.64), while UC cities have the lowest (0.33), and the difference is significant at the 1% level. SCP cities have the next highest growth rate (0.45), which is also significantly different from the growth rate of UC cities (0.33). While the differences in the growth rates of the manufacturing and retail sectors between SCP and LSCP cities are significant, the corresponding growth rates of SCP and UC cities are not significantly different. Overall, the employment growth rates in LSCP cities are highest in all sectors. SCP cities have a significantly (1%) higher growth than UC cities in the service sector.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>T-TEST (t Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SCP</td>
<td>LSCP</td>
</tr>
<tr>
<td>Share of Manufacturing - 2000 (%)</td>
<td>13.11</td>
<td>18.28</td>
</tr>
<tr>
<td>Share of Retail-2000 (%)</td>
<td>26.42</td>
<td>24.14</td>
</tr>
<tr>
<td>Share of Services-2000 (%)</td>
<td>54.17</td>
<td>53.84</td>
</tr>
<tr>
<td>Growth of Manufacturing 2000/1990</td>
<td>0.24</td>
<td>0.66</td>
</tr>
<tr>
<td>Growth of Retail 2000/1990</td>
<td>0.36</td>
<td>0.89</td>
</tr>
<tr>
<td>Growth of Services 2000/1990</td>
<td>0.45</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Note: * significant at the 1% level, ** significant at the 5% level, and *** significant at the 10% level.

Table 5.6 Characteristics of the industrial sectors across contained and uncontained cities
Table 5.7 presents the structural equation coefficients for population, housing values, land areas, and sectoral employments in manufacturing, retail, and services. Table 5.8 presents the measures of the order and rank conditions for identification, which are all satisfied. The reduced forms of the simultaneous equations are presented in Table 5.9.
<table>
<thead>
<tr>
<th>Endogenous Variables</th>
<th>Change_Population</th>
<th>Change_Manufacturing</th>
<th>Change_Retail</th>
<th>Change_Service</th>
<th>Change_Housing Values</th>
<th>Change_Land Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.543290*</td>
<td>3.935020*</td>
<td>0.914348*</td>
<td>0.810974*</td>
<td>2.299860*</td>
<td>0.461968*</td>
</tr>
<tr>
<td>Population(1990)</td>
<td>0.013664*</td>
<td>5.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing(1990)</td>
<td></td>
<td>-0.082460*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail(1990)</td>
<td></td>
<td></td>
<td>-0.0403*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service(1990)</td>
<td></td>
<td></td>
<td></td>
<td>-0.07303*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing value(1990)</td>
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<td></td>
<td></td>
<td></td>
<td>-0.173740*</td>
<td></td>
</tr>
<tr>
<td>Land area(1990)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.01327*</td>
</tr>
<tr>
<td>Change_population</td>
<td>0.058647**</td>
<td>2.38</td>
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<td>-0.09</td>
<td>0.085063</td>
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<td>Change_manufacturing</td>
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<td></td>
<td>0.85</td>
<td>-0.02422</td>
</tr>
<tr>
<td>Change_retail</td>
<td>0.243788*</td>
<td>11.66</td>
<td>-1.14934*</td>
<td>0.083798*</td>
<td>0.005288</td>
<td>-0.17034*</td>
</tr>
<tr>
<td>Change_service</td>
<td>0.102302*</td>
<td>3.16</td>
<td>-0.50635*</td>
<td></td>
<td>0.172685*</td>
<td>-0.12553*</td>
</tr>
<tr>
<td>Change_housing value</td>
<td>-0.225630*</td>
<td>0.631279*</td>
<td>0.348868*</td>
<td>0.749185*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change_land area</td>
<td>1.012891*</td>
<td>7.03</td>
<td>-6.105*</td>
<td>0.477076*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topographic variation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.001126</td>
<td></td>
</tr>
<tr>
<td>Natural amenity</td>
<td>-0.016050</td>
<td>-1.37</td>
<td>-0.11571</td>
<td>0.023137</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air quality</td>
<td>-0.007460**</td>
<td>2.38</td>
<td>0.006788</td>
<td>-0.11571</td>
<td>0.052288</td>
<td></td>
</tr>
<tr>
<td>Educational attainment</td>
<td>-0.007460**</td>
<td>0.004572*</td>
<td>0.030246***</td>
<td>0.107070*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Violent crime</td>
<td>-0.007460**</td>
<td>0.004572*</td>
<td>0.030246***</td>
<td>0.107070*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property crime</td>
<td>-0.007460**</td>
<td>0.004572*</td>
<td>0.030246***</td>
<td>0.107070*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway access</td>
<td>0.005768</td>
<td>0.55</td>
<td>0.12</td>
<td>-0.11571</td>
<td>0.023137</td>
<td></td>
</tr>
<tr>
<td>Commuting time</td>
<td>0.041192*</td>
<td>3.03</td>
<td>-0.533240*</td>
<td>-0.019230*</td>
<td>-0.002349**</td>
<td></td>
</tr>
<tr>
<td>Transit</td>
<td>-0.001800**</td>
<td>-2.25</td>
<td>0.000362</td>
<td>-0.019230*</td>
<td>0.002349**</td>
<td></td>
</tr>
<tr>
<td>Change_income</td>
<td>-0.0099990*</td>
<td>-2.21</td>
<td>-0.0089990*</td>
<td>-0.0507440***</td>
<td>0.271699</td>
<td>0.016364*</td>
</tr>
<tr>
<td>SCP</td>
<td>0.128907*</td>
<td>4.96</td>
<td>-0.40938*</td>
<td>0.479547*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSCP</td>
<td>0.095416**</td>
<td>2.46</td>
<td>-0.36073*</td>
<td>-0.52334*</td>
<td>0.114121*</td>
<td>-0.09151*</td>
</tr>
<tr>
<td>System Weighted R²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.2570</td>
<td></td>
</tr>
</tbody>
</table>

Note: * significant at the 1% level, ** significant at the 5% level, and *** significant at the 10% level.

Table 5.7 Structural equations with sectoral employment variables
### Table 5.8 Identification of simultaneous equations with sectoral variables

<table>
<thead>
<tr>
<th>$K_j^*$</th>
<th>Change Population</th>
<th>Change manufacturing</th>
<th>Change retail</th>
<th>Change service</th>
<th>Change housing value</th>
<th>Change land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>$M_j$</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Rank($A_j^*$)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

### Table 5.9 Reduced-form equations with sectoral employment variables

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.6734</td>
<td>-0.1469</td>
<td>0.0251</td>
<td>0.0971</td>
<td>-0.0797</td>
<td>0.0853</td>
<td>0.1112</td>
<td>-0.0094</td>
<td>0.1172</td>
<td>0.0420</td>
<td>-0.0448</td>
<td>-0.0102</td>
<td>-0.0003</td>
<td>-0.0219</td>
<td>0.2183</td>
<td>0.0355</td>
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<td>1.3320</td>
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<td>-0.0247</td>
<td>-0.0918</td>
<td>-0.0057</td>
<td>0.1357</td>
<td>-0.0115</td>
<td>-0.0777</td>
<td>-0.3039</td>
<td>0.0859</td>
<td>-0.0246</td>
<td>0.0544</td>
<td>0.2197</td>
<td>0.6021</td>
<td>0.0606</td>
<td>0.1644</td>
<td>0.1904</td>
<td>0.2023</td>
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<tr>
<td></td>
<td>-2.7499</td>
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<td>0.0128</td>
<td>-0.0136</td>
<td>-0.0575</td>
<td>0.0843</td>
<td>0.2304</td>
<td>0.0196</td>
<td>0.0764</td>
<td>0.0905</td>
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<td>0.0929</td>
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<td>0.5693</td>
<td>0.8214</td>
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<td>-0.3298</td>
<td>-0.1737</td>
<td>0.0147</td>
<td>-0.3728</td>
<td>-1.0219</td>
<td>-0.2586</td>
<td>-0.0058</td>
<td>-0.0026</td>
<td>0.4390</td>
<td>0.0309</td>
<td>0.5861</td>
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<td>0.8135</td>
<td>0.2753</td>
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<td></td>
<td>2.6107</td>
<td>0.0184</td>
<td>-0.0065</td>
<td>-0.0015</td>
<td>-0.0251</td>
<td>-0.2101</td>
<td>0.0017</td>
<td>-0.0002</td>
<td>0.0240</td>
<td>0.0391</td>
<td>0.1286</td>
<td>-0.0236</td>
<td>0.0209</td>
<td>0.0241</td>
<td>0.0019</td>
<td>-0.0173</td>
<td>0.8158</td>
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<td>0.0784</td>
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<td></td>
<td>-0.0069</td>
<td>-0.2031</td>
<td>0.0528</td>
<td>0.1503</td>
<td>-0.0682</td>
<td>0.0508</td>
<td>0.0644</td>
<td>-0.0055</td>
<td>0.1448</td>
<td>0.1476</td>
<td>-0.0501</td>
<td>-0.0058</td>
<td>0.0214</td>
<td>-0.0615</td>
<td>0.0342</td>
<td>0.0930</td>
<td>1.2347</td>
<td>-0.1352</td>
<td>-0.0944</td>
</tr>
</tbody>
</table>
5.3.1 Interrelationship between sectoral employments, population, housing values, and land areas

The structural equations suggest that population and sectoral employment growth positively affect each other. The reduced form equations also indicate that population and manufacturing positively affect each other. This result is consistent with Steinness (1977) and Thurston & Yezer (1994). As discussed in the previous section, using aggregate employment data suggests that total employment follows population. However, when sectoral employment data are used, services follow population and population follows retail. For example, the lagged population has a positive effect on the change in services, while lagged services have a negative effect on population growth. The elasticity of growth in services with respect to the 1990 population is 0.821 and the elasticity of growth in population with respect to the 1990 retail is 0.097. These results are consistent with those obtained by Steinness (1977). A 10% increase in population in 1990 results in an 8.2% increase in services and a 0.4% increase in manufacturing.

Figure 5.2 presents the structural equations interrelationships. Both retail and services positively affect the increase in housing values. Since the retail and services sectors make up almost 80% of the total employment in most cities (Table 5.6), an increase in retail and services employment results in population growth, with consequent demand for housing and a rise in housing values.
5.3.2 Effects of Natural and Social Amenities

Natural amenities negatively affect the growth of manufacturing, but positively affect the growth of services. It is intuitive to assume that certain types of natural amenities are closely related to service sectors, such as tourism and leisure, while manufacturing is less sensitive to natural amenity.

Commuting time has a positive effect on the growth of population, but a negative one on the growth of manufacturing. The reduced-form coefficients also confirm that a 10% increase in commuting time results in a 1.17% of increase in population and a 0.78% decrease in manufacturing employment. This suggests that commuting time increases in suburban or exurban areas, where population increases, as compared to central city or inner ring suburbs.
5.3.3 Effects of Urban Containment Policies on Sectoral Employments

Table 5.7 indicates that both the SCP and LSCP dummy variables have negative effects on the growth of all sectors, although the effect of LSCP on manufacturing is not significant. However, there are differences between SCP and LSCP. For example, SCP has a negative effect on manufacturing more than four times larger than LSCP. The average population size of LSCP cities is larger than that in SCP or UC cities. The larger the population, the more manufacturing labor available. Furthermore, LSCP cities have less impact on increases in housing and land values, thus benefiting land consumers, specifically renters and “lower or moderate” income level groups, who form the labor force for labor-intensive industries, such as manufacturing. Also, the lesser impact on housing values under LSCP, in contrast to SCP, may help manufacturers locate in these areas. On the other hand, since SCP cities lead to a rise in housing prices and a lack of residential housing and available land, they have negative effects on labor-intensive and space-intensive industries. In particular, with innovations in production processes and information technologies, manufacturing increasingly needs “horizontal” technologies such as assembly-line production, which demands large spaces. Manufacturing that demands such large spaces may suffer from high land costs. For similar reason, SCP cities have more negative effects on the retail sector than LSCP cities. However, the difference is small.

The reduced-form coefficients show how the impacts on sectoral employments differ between SCP and LSCP cities. The coefficient of SCP for the growth of services is 0.813, while the corresponding LSCP coefficient is 0.275. SCP cities have a positive effect on the service sector almost three times larger than LSCP cities, probably because
SCP cities have a higher population growth than LSCP and UC cities. One important characteristics of the service sector is the need for face-to-face contacts with consumers. Therefore, these industries are affected by an increased population growth, which is an important demand factor.

5.4 SUMMARY

The enforcement of urban containment policies directly or indirectly affects population, employment, housing markets, and land areas, depending upon their tightness. As expected, SCP cities have the highest mean growth rate for housing values from 1990 to 2000 (0.88). Mean employment growth is highest in LSCP cities (0.50), followed by SCP cities (0.33) and UC cities (0.23), which may imply that, because of scale economies, contained cities attract more employment than UP cities, and the employment growth rate increases with decreasing tightness in containment policies.

The results of the simultaneous equations estimations indicate that both the SCP and LSCP dummy variables have significant impacts on changes in population, employment, housing values, and land areas. The reduced-forms coefficients of the SCP dummy variable for changes in population, employment, housing values, and land area are almost twice as large as those of the LSCP dummy. This suggests that SCP more successfully accommodate new growth within the growth boundaries than LSCP, rejecting the amenity-creation model wherein population decreases due to the spatial limitation of SCP.
The structural equations coefficients show that SCP has negative effects on employment growth more than two times larger than LSCP, implying that tighter containment policies lead to less employment growth.

Both the structural equations and the reduced-forms coefficients indicate that both SCP and LSCP have a significant positive effect on change in housing values. The reduced-form coefficient of SCP is almost three times larger than that of LSCP, confirming that housing values increase with the tightness of containment policies.

The reduced form coefficients show that LSCP negatively impact the increase of land area, suggesting that there was less annexation of fringe areas in LSCP cities between 1990 and 2000. While it may appear that LSCP minimize the expansion of cities, this does not mean that LSCP prevents urban sprawl, because new developments may take place beyond the boundaries of the metropolitan area.

The structural equations coefficients for the disaggregate models show that both the SCP and LSCP dummy variables have negative effects on the growth of all sectors. However, depending on the sector, there are differences between SCP and LSCP. SCP has a four times larger negative effect on manufacturing, possibly because LSCP have less impact on housing values and the larger populations that make up the labor force of labor-intensive industries. However, SCP cities have a positive effect on the service sector almost three times larger than in LSCP cities, probably because SCP cities have a higher population growth than LSCP and UC cities. One of characteristics of the service sector is the need for face-to-face contacts with consumers. Therefore, these industries are affected by an increase in population, which is an important demand factor.
CHAPTER 6

IMPACTS OF URBAN CONTAINMENT POLICIES
ON URBAN SPATIAL STRUCTURE

The results presented in Chapter 5 indicate that UCPs affect population and employment growth, and housing and land markets. These effects may generate specific urban spatial structures. For example, UCPs may reinforce a monocentric urban pattern or encourage a polycentric one. UCPs are known to encourage compact developments and promote concentrations of population and employment in central cities. However, these effects have not been measured at the metropolitan level. In this chapter, employment and population density gradients, taken as concentrations measures, are estimated for 135 metropolitan areas with the monocentric model, and then these estimated density gradients are used in a simultaneous equation model to assess the impacts of different UCPs on the urban spatial structure of U.S. metropolitan areas. Finally, density gradients are estimated using the polycentric model and analyzed for four selected metropolitan areas.
6.1 OVERVIEW

Central cities have lost large shares of population (20%) and employment (25%) to suburban communities from 1950 to 1990 (Mieszkowki & Mills, 1993). Although there is still controversy over whether there are close interactions between central cities and suburban communities or whether these two areas are independent (Ihlanfeldt, 1995), many efforts and policies have been implemented to prevent the decline of central cities, because their vitality is still important to their metropolitan areas and the regional economy. Among those policies, Nelson et al. (2004) suggest that UCPs have contributed to this vitality. In Chapter 5, containment policies were shown to have positive effects on population and total employment growth. Therefore, it is likely that the population and employment growth of central cities is affected by their containment policies. Because increasing shares of population and employment are located beyond central cities, the next research question is how UCPs affect the structure of metropolitan areas.

Table 6.1 shows how housing characteristics in central cities differ among contained and uncontained areas. As expected, median housing values are higher in contained central (CC) cities than in uncontained central (UC) cities. CC cities have a lower housing vacancy rates than UC cities, implying that the limited supply of land due to UCP enforcement may prevent the existing housing stock from being abandoned and encourage new growth within the growth boundaries. In addition, the average age of housing in central cities with statewide UGBs (UGB_ST) is relatively lower than that of UC cities. This is consistent with Nelson et al. (2004), who suggest that new developments are likely take place in UGB central cities by encouraging infill
<table>
<thead>
<tr>
<th></th>
<th>UGB_ST</th>
<th>UGB_Local</th>
<th>USA</th>
<th>Uncontained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing value (2000,$)</td>
<td>137,240*</td>
<td>113,475***</td>
<td>124,442</td>
<td>91,509</td>
</tr>
<tr>
<td>Vacancy rate (2000,%)</td>
<td>5.74*</td>
<td>5.74*</td>
<td>5.08*</td>
<td>8.55</td>
</tr>
<tr>
<td>Median built year (2000)</td>
<td>29.4**</td>
<td>31.0</td>
<td>33.0</td>
<td>36.5</td>
</tr>
</tbody>
</table>

Note: * significant at the 1% level, ** significant at the 5% level, and *** significant at the 10% level.

Table 6.1 Urban growth and housing characteristics of central cities among different metropolitan areas

devolution and redevelopment. However, there is no significant evidence that the average age of locally-enforced UGB (UGB_Local) or USA central cities are different from those of UC cities. These different housing characteristics under containment policies may affect the spatial structures of suburban areas as well as central cities within metropolitan areas.

In line with the previous arguments, Table 6.2 shows that CC cities have had a population growth more than three times higher than UC cities from 1990 to 2000. However, during the same period, the suburban areas of CC cities have experienced a population growth similar to that of UC cities. For example, the growth rate of suburban areas with statewide UGBs is 20.83%, 21.40% with locally-enforced UGBs, 17.85% with USAs, and 19.46% for UC cities. Since even suburban cities are bounded by growth boundaries under statewide UGBs, it is expected that the growth of these suburban areas is accommodated within the growth boundaries. However, in uncontained suburban areas of UGB_Local and USA metropolitan areas, the suburban growth of 21.40% and 17.85%
beyond the growth boundaries might take place in both incorporated areas and unincorporated areas of suburbs, by promoting the dispersion of growth, because there are no restrictions of development in suburban cities, beyond UGBs_Local and USAs.

For employment growth, central cities with statewide UGBs have a much higher growth rate (26.80%), as compared to UC cities (9.09%), while their suburban areas have a growth rate of 28.56%, relatively lower than for the suburban areas of UC cities (42.00%). However, locally-enforced UGBs and USAs do not seem to prevent the suburbanization of employment, allowing growth rates of 42.29% and 45.05% in suburban areas, respectively. These growth rates are very similar to the average growth rate (42.00%) of suburban areas in UC cities. This suggests that statewide UGBs prevent non-residential sprawl, but locally-enforced UGBs and USAs do not. The following sections examine where growth has taken place.

<table>
<thead>
<tr>
<th>UGB_ST</th>
<th>UGB_Local</th>
<th>USA</th>
<th>Uncontained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population growth (1990-2000,%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central city</td>
<td>25.39</td>
<td>16.14</td>
<td>19.14</td>
</tr>
<tr>
<td>Metropolitan area</td>
<td>22.61</td>
<td>20.04</td>
<td>17.13</td>
</tr>
<tr>
<td>Suburban area</td>
<td>20.83</td>
<td>21.40</td>
<td>17.85</td>
</tr>
<tr>
<td>Employment growth (1990-2000,%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central city</td>
<td>26.80</td>
<td>8.42</td>
<td>16.71</td>
</tr>
<tr>
<td>Metropolitan area</td>
<td>26.68</td>
<td>23.95</td>
<td>21.59</td>
</tr>
<tr>
<td>Suburban area</td>
<td>28.56</td>
<td>42.29</td>
<td>45.05</td>
</tr>
</tbody>
</table>

Table 6.2 Comparison of population and employment growth in different urban areas
6.2 POPULATION AND EMPLOYMENT DENSITY GRADIENTS WITH THE MONOCENTRIC MODEL

6.2.1 Measuring Density Gradients with the Monocentric Model

The population and employment density gradients of 135 metropolitan areas (26 for contained metropolitan areas and 109 for uncontained ones) are estimated using the following negative exponential model, with TAZ-level data (see Appendix A for the estimated density gradients for each metropolitan area):

\[ x e^{D} = D_p e^{-x} \]

where \( x \) is the density at distance \( x \) from the CBD, \( D_p \) the density of the CBD, and \( \gamma \) the density gradient. The centroid of the TAZ that has the highest employment density is used as the location of the CBD. In addition, U.S. street maps were used to verify whether the selected centroid is located within the downtown area.

Table 6.3 shows that the average population density of the CBDs in UGB_ST metropolitan areas has decreased by 4.97% from 1990 to 2000. On the other hand, the CBDs in UGB_Local and USA metropolitan areas have experienced population density decreases of 11.76% and 28.06%, respectively, during the same period. Employment density in the CBDs increased by 13.82% in UGB_ST metropolitan areas, but decreased by 3.75% and 0.47% in UGB_Local and USA metropolitan areas, respectively. In line with the results of Nelson et al. (2004), this suggest that the tightness of containment policies contributes to the revitalization of the CBD. Overall, population density has decreased faster than employment density in the CBDs.

As expected, the employment density gradients are steeper than the population density gradients, implying that residents are located further out from the CBD than
<table>
<thead>
<tr>
<th>Metropolitan areas</th>
<th>UGB_ST</th>
<th>UGB_Local</th>
<th>USA</th>
<th>Uncontained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of observations</td>
<td>8</td>
<td>11</td>
<td>7</td>
<td>109</td>
</tr>
<tr>
<td>Change of CBD Population density</td>
<td>-0.0497</td>
<td>-0.1176</td>
<td>-0.2806</td>
<td>-0.2062</td>
</tr>
<tr>
<td>Change of CBD Employment density</td>
<td>0.1382</td>
<td>-0.0375</td>
<td>-0.0047</td>
<td>-0.0225</td>
</tr>
<tr>
<td>Population density gradient (2000)</td>
<td>0.0770</td>
<td>0.1541</td>
<td>0.1962</td>
<td>0.1619</td>
</tr>
<tr>
<td>Employment density gradient (2000)</td>
<td>0.0995</td>
<td>0.1827</td>
<td>0.2834</td>
<td>0.2238</td>
</tr>
<tr>
<td>R² of Population density function</td>
<td>0.1377</td>
<td>0.2383</td>
<td>0.4015</td>
<td>0.3059</td>
</tr>
<tr>
<td>R² of Employment density function</td>
<td>0.1381</td>
<td>0.2673</td>
<td>0.4606</td>
<td>0.3396</td>
</tr>
</tbody>
</table>

Table 6.3 Average population and employment density measures in contained and uncontained metropolitan areas

economic activities. However, the difference between population and employment density gradients is relatively small in UGB metropolitan areas (e.g. 0.023 for UGB_ST and 0.029 for UGB_Local), while the difference for USA metropolitan areas is 0.087. This means that residential and economic activities are more likely to be co-existing in UGB than in USA metropolitan areas, possibly because of higher land values in UGB metropolitan areas.

Both the population and employment density gradients are lowest in UGB_ST metropolitan areas, because most of the land in central cities and neighboring jurisdictions under UGB_ST are densely developed, implying that UGB_ST metropolitan areas have a polycentric development pattern. This is confirmed by the lowest R² for population and employment density gradients in UGB_ST metropolitan areas. The R² of
both the population and employment density functions are close to 0.14 in UGB_ST metropolitan areas, but are equal to 0.40 and 0.46 in USA metropolitan areas.

### 6.2.2 Effects of Urban Containment Policies on Density Gradients with the Monocentric Model

The following simultaneous equation model is estimated, using the three-stage least squares (3SLS) method, to uncover the determinants of density gradients and the effects of UCPs:

\[
P_{D}(i) = P_{D}(i_0) + \beta_1 \text{EDG}_i + \beta_2 \text{INC}_i + \beta_3 \text{HOUS}_i + \beta_4 \text{TRANS}_i + \beta_5 \text{SIZE}_i + \beta_6 \text{EXP}_i + \beta_7 \text{UCP}_i
\]

(6.2)

\[
E_{D}(i) = E_{D}(i_0) + \beta_1 \text{PDG}_i + \beta_2 \text{INC}_i + \beta_3 \text{HOUS}_i + \beta_4 \text{TRANS}_i + \beta_5 \text{SIZE}_i + \beta_6 \text{EXP}_i + \beta_7 \text{UCP}_i
\]

(6.3)

where \(PDG_i\) and \(EDG_i\) are the population and employment density gradients for 135 metropolitan areas, \(POP_{D(i)}\) and \(EMP_{D(i)}\) the population and employment densities in the CBD, \(INC\) a vector of income characteristics, \(HOUS\) a vector of housing characteristics, \(TRANS\) a vector of transportation characteristics, \(SIZE\) a vector of the size of metropolitan areas, \(EXP\) a vector of financial characteristics, and \(UCP\) a vector of dummy variables representing UGB_ST, UGB_Local, and USA metropolitan areas.

The models are estimated while taking the logarithm of the endogenous variables (population and employment density gradients) and of all the exogenous variables (except for the dummy variables). Table 6.4 presents the estimation results for the final models. Table 6.5 presents the values of the order and rank conditions for identification. The structural equations are over-identified in terms of the order condition, and the rank condition is satisfied. The reduced forms of the simultaneous equations are presented in Table 6.6.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Population density gradient</th>
<th>Employment density gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.687915* (4.39)</td>
<td>6.170385* (5.54)</td>
</tr>
<tr>
<td>Population density gradient</td>
<td>-</td>
<td>0.480787* (7.17)</td>
</tr>
<tr>
<td>Employment density gradient</td>
<td>0.523981* (7.28)</td>
<td>-</td>
</tr>
<tr>
<td>Population density (CBD)</td>
<td>0.471580* (6.45)</td>
<td>-</td>
</tr>
<tr>
<td>Employment density (CBD)</td>
<td>-</td>
<td>0.409848* (8.44)</td>
</tr>
<tr>
<td>Population (1990)</td>
<td>-0.284810* (-5.64)</td>
<td>-0.175260* (-4.89)</td>
</tr>
<tr>
<td>Rural population</td>
<td>0.199193* (4.82)</td>
<td>0.184008* (6.47)</td>
</tr>
<tr>
<td>Housing vacancy</td>
<td>-</td>
<td>-0.145310* (-2.96)</td>
</tr>
<tr>
<td>Homeownership</td>
<td>-0.341330*** (-1.82)</td>
<td>0.523400* (3.21)</td>
</tr>
<tr>
<td>Income (capita)</td>
<td>-</td>
<td>0.333119** (2.45)</td>
</tr>
<tr>
<td>Income (white)</td>
<td>-</td>
<td>-0.725030* (-4.18)</td>
</tr>
<tr>
<td>Built year (housing)</td>
<td>-</td>
<td>-0.091490** (-2.20)</td>
</tr>
<tr>
<td>Commuting (car)</td>
<td>1.355606*** (1.81)</td>
<td>-</td>
</tr>
<tr>
<td>Working at home</td>
<td>0.164256** (2.19)</td>
<td>-</td>
</tr>
<tr>
<td>Commuting time (car)</td>
<td>-0.542180* (-4.27)</td>
<td>-</td>
</tr>
<tr>
<td>Metropolitan size (acre)</td>
<td>0.064528* (2.76)</td>
<td>-</td>
</tr>
<tr>
<td>Government expenditures</td>
<td>0.075035* (2.97)</td>
<td>-</td>
</tr>
<tr>
<td>UGB_ST</td>
<td>-0.198600*** (-1.67)</td>
<td>-0.075360 (-0.72)</td>
</tr>
<tr>
<td>UGB_LOCAL</td>
<td>0.116745** (2.26)</td>
<td>0.000500 (0.01)</td>
</tr>
<tr>
<td>USA</td>
<td>-0.106450 (-0.98)</td>
<td>-0.191100*** (-1.83)</td>
</tr>
</tbody>
</table>

Note: * significant at the 1% level, ** significant at the 5% level, and *** significant at the 10% level.

Table 6.4 Structural equations for population and employment density gradients in 135 metropolitan areas
<table>
<thead>
<tr>
<th>$K_j^*$</th>
<th>Population density gradients</th>
<th>Employment density gradients</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>$M_j$</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rank($A_j^*$)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 6.5 Identification of simultaneous equations

<table>
<thead>
<tr>
<th>Exogenous Variables</th>
<th>Endogenous Variables</th>
<th>Population density Gradients</th>
<th>Employment density gradients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>7.9151</td>
<td>9.9758</td>
<td></td>
</tr>
<tr>
<td>Population density (CBD)</td>
<td>0.6304</td>
<td>0.3031</td>
<td></td>
</tr>
<tr>
<td>Employment density (CBD)</td>
<td>0.2871</td>
<td>0.5479</td>
<td></td>
</tr>
<tr>
<td>Population (1990)</td>
<td>-0.5035</td>
<td>-0.4173</td>
<td></td>
</tr>
<tr>
<td>Rural population</td>
<td>0.3952</td>
<td>0.3740</td>
<td></td>
</tr>
<tr>
<td>Housing vacancy</td>
<td>-0.1018</td>
<td>-0.1943</td>
<td></td>
</tr>
<tr>
<td>Homeownership</td>
<td>-0.0897</td>
<td>0.4803</td>
<td></td>
</tr>
<tr>
<td>Income (capita)</td>
<td>0.2333</td>
<td>0.4453</td>
<td></td>
</tr>
<tr>
<td>Income (white)</td>
<td>-0.5078</td>
<td>-0.9692</td>
<td></td>
</tr>
<tr>
<td>Built year (housing)</td>
<td>-0.0641</td>
<td>-0.1223</td>
<td></td>
</tr>
<tr>
<td>Commuting mode (car)</td>
<td>1.8121</td>
<td>0.8712</td>
<td></td>
</tr>
<tr>
<td>Working at home</td>
<td>0.2196</td>
<td>0.1056</td>
<td></td>
</tr>
<tr>
<td>Commuting time (car)</td>
<td>-0.7248</td>
<td>-0.3485</td>
<td></td>
</tr>
<tr>
<td>Metropolitan size (acre)</td>
<td>0.0863</td>
<td>0.0415</td>
<td></td>
</tr>
<tr>
<td>Government expenditures</td>
<td>0.1003</td>
<td>0.0482</td>
<td></td>
</tr>
<tr>
<td>UGB_ST</td>
<td>-0.3183</td>
<td>-0.2284</td>
<td></td>
</tr>
<tr>
<td>UGB_LOCAL</td>
<td>0.1564</td>
<td>0.0757</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>-0.2762</td>
<td>-0.3239</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.6 Reduced-form equations for population and employment density gradients
6.2.2.1 Determinants of density gradients

The results in Chapter 5 suggest that a change in population is more likely to affect a change in employment than the reverse (the elasticity of change in employment with respect to change in population is 3.09, while that of population with respect to employment is 0.29, Table 5.2). However, as seen in Table 6.4, the population and employment density gradients positively affect each other, and their elasticities are almost same. This implies that the direction of change between population and employment is similar under spatial disaggregation: if population is dispersed, employment is dispersed as well, and vice versa, although the employment density gradient is steeper than that of population.

When the size of the population (1990) is taken into account, the extent of dispersion is different between population and employment. The effect of population size on the population density gradient is larger (-0.285) than on the employment gradient (-0.175), implying that population is more likely dispersed than employment as population increases, resulting in an expansion of the metropolitan area. However, the physical size of the metropolitan areas positively affects the population density gradient (0.064), implying that more people are concentrated in the CBDs of larger metropolitan areas. Alperovich (1983) also argues that small cities tend to have small population density gradients.

As the number of housing units with homeowners increases, the population density gradient tends to decrease (-0.341). As more owner-occupied (rather than rental) housing is developed in outer areas, homeowners are more likely to live far away from the CBD. On the other hand, an increase in owner-occupied housing positively affects the
employment density gradient (0.523), implying that employment does not follow the development of owner-occupied housing in outer areas, resulting in the creation of bedroom communities and an increase in congestion.

The housing vacancy rate and age (median built years) negatively affect the employment density gradient (-0.145 and -0.091), suggesting that housing deterioration encourages employment dispersion. However, these variables have no significant effect on the population density gradient.

Unexpectedly, the income variables are significant for the employment density gradient only. Per-capita income positively affects this gradient, but the median income of the white population does so negatively, implying that an increase in the income of the white population leads to employment dispersion. The income variables for the other racial groups do not appear to be significant.

Muth (1969) used car registration data as indication of transportation costs, and Alperovich (1983) used the percentage of families who own cars. However, their results did differ: the sign of Muth’s transportation costs is negative and that of Alperovich’s positive. Alperovich interpreted this difference as related to differences in car purchasing habits. If the costs of purchasing and operating a car are high, transportation costs are high, resulting in steeper density gradients. In this research, two variables are used: (1) the percentage of commuters who drive cars, and (2) the median travel time for commuting. The results show that the higher use of cars for commuting makes the population density gradient steeper (1.356), but a long commuting time makes it flatter (-0.542). This suggests that people consider owning a car as the true transportation costs, rather than travel time.
The literature argues that an improvement in information technology (IT) makes it possible for people to work at home, and this may contribute to urban sprawl. However, the sign of the variable “working at home” is positive (0.164), suggesting that the more people work at home, the steeper the population density gradient is. The interpretation of this result is not straightforward, but a possible reason for why the sign is not as expected is that those who are working at home in data processing are not those who live in suburban areas and enjoy the rural life. In addition, those who work at home make up a small share of the total employment.

Finally, government expenditures on central cities have a positive effect on the population density gradient (0.075), possibly because they contribute to the revitalization of central cities.

6.2.2.2 Effects of urban containment policies on density gradients

Under statewide UGBs (UGB_ST), urban growth is likely to be concentrated in several cities where UGBs are enforced within a metropolitan area. However, under locally-enforced UGBs (UGB_Local), urban growth may be restricted only for central cities, and spillover effects may take place in surrounding counties or cities where no containment policies are enforced. USAs may have spillover effects in all surrounding areas because there are no restrictions beyond the USAs.

The results in Table 6.4 indicate that the UGB_ST and UGB_Local dummy variables have significant effects on the population density gradients only, and the USA dummy variable has a significant effect on the employment density gradient only. This result is interesting because the results in Chapter 5 show that stringent containment
policies (SCP), including greenbelts and UGBs, have a stronger positive effect on population growth than less stringent containment policies (LSCP), such as USAs, and, on the other hand, LSCP have a less negative effect on employment growth than SCP. In other words, SCP has a negative effect on employment growth more than two times larger than LSCP. This means that there is close connection between the effects of UCPs on urban growth and urban spatial structure.

UGB_ST has a negative effect (10% significance) on the population density gradient (-0.198), not because population is dispersed across the metropolitan area, but because the central city is already densely developed and other suburban communities within the growth boundaries are also densely developed. Although population and employment are concentrated in the CBD and central cities, other suburban subcenters also attract population and employment within UGBs.

UGB_Local has a positive effect (5%) on the population density gradients (0.117), implying that the CBD and central cities are revitalized by population concentrations at the center without dispersion to or concentration in suburban centers.

USA has a negative effect on the employment density gradient (-0.191), implying that employment is dispersed across the metropolitan area. Even when a polycentric pattern is taken into account (see Section 6.3), the average changes in employment density gradients are negative within both central cities and suburbs. The reduced form coefficients in Table 6.6 also confirm that USA has a negative effect on both the population and employment density gradients.
6.3 POPULATION AND EMPLOYMENT DENSITY GRADIENTS WITH THE POLYCENTRIC MODEL

In order to examine where suburban growth takes place beyond UCP boundaries, the population and employment density gradients of all centers are estimated for selected UCP metropolitan areas, using non-linear regression.

Oregon cities and Minneapolis, Minnesota, have often been selected as UGB and USA study areas, because of their long histories of containment policies and data availability. In this section, the Eugene-Springfield, OR metropolitan area is selected as a UGB_ST case study area. Although there are several metropolitan areas in Oregon, including Portland, Corvallis, and Medford-Ashland, 2000 TAZ data are available only for the Eugene-Springfield metropolitan area. The Minneapolis metropolitan area is selected as a USA case study area. Lexington (Kentucky) and Lincoln (Nebraska) are selected as UGB_Local metropolitan areas. Both Lexington and Lincoln have a long standing policy (more than 40 years) of containing their growth within their incorporated limits. Lexington was designated as the first UGB community by the American Planning Association (APA).

6.3.1 Identification of Subcenters

It is reasonable to assume that most metropolitan areas are characterized by a polycentric rather than monocentric pattern. In order to identify peak points of employment, two procedures are used: geographically weighted regression (Fotheringham et al., 1998) and the employment cutoff method (Giuliano & Small, 1991).
As discussed in Chapter 3, Fotheringham et al. (1998) suggest that Geographically-Weighted Regression (GWR) can be used to examine the spatial variability of regression results over space. In contrast to the standard regression model for the exponential density function

\[
\ln(DEN_i) = \ln(D_0) - \gamma X_i + u_i, \quad (6.4)
\]

GWR allows local parameters to be estimated so that

\[
Y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)X_i + u_i, \quad (6.5)
\]

where \(Y_i = \ln(DEN_i) - \ln(D_0)\), \((u_i, v_i)\) denotes the coordinates of the centroid of TAZ \(i\), and \(\beta_1(u_i, v_i)\) is a realization of the continuous function \(\beta_1(u, v)\) at point \(i\). Specifically, \(\beta_1(u_i, v_i)\) refers to ‘a negative density gradient’. This method uses a subset of the points in the data set that are close to \(i\). The \(\beta_1(u_i, v_i)\)s are estimated for \(i\), and, for the next \(i\), a new subset of ‘nearby’ points is used, and this procedure is repeated for all TAZs. Thus, GWR produces localized parameter estimates that can exhibit a high degree of variability over space.

TAZs with regression residuals greater than 0 at the 5% significance level may be chosen as potential centers, thus including TAZs with unusually large employment densities (McMillen, 2001). Since this procedure usually identifies too many centers, the cutoff method is used to narrow this set, with minimum employment density and minimum total employment, as proposed by Giuliano and Small (1991). They used the cutoffs of 10 employees per acre and 10,000 employees in total for the Los Angeles metropolitan area. McMillen and McDonald (1998) used 20 employees per acre and 20,000 employees in total as cutoff points for the Chicago metropolitan area. Thus, a
trial-and-error process is required to determine the cutoff points for each metropolitan area. In this research, different cutoffs have been used for each metropolitan area. In addition, comprehensive planning documents of central cities and counties, and street maps were used as complementary material to determine centers. Figure 6.1 through 6.4 present the distribution of these centers for each metropolitan area.

As expected, all centers are identified within the growth boundaries of the Eugene UGB_ST metropolitan area. In the case of UGB_Local, the Lexington and Lincoln metropolitan areas have one center outside the UGB. Since the Minneapolis metropolitan area has a metro-wide USA, most centers are located within the service boundaries, but 4 centers are identified beyond the USAs.

In addition, the identified centers are tested again, using the density gradients estimated by the non-linear regression models, as described in the next section. This procedure may help verify whether the identified centers are statistically significant or not.
Note: “C” denotes centers within a central city and “S” denotes suburban centers

Figure 6.1 Distribution of centers in the Eugene metropolitan area, OR (UBG_ST)
Note: “C” denotes centers within a central city and “S” denotes suburban centers

Figure 6.2 Distribution of centers in the Lincoln metropolitan area, NE (UGB_Local)
Figure 6.3 Distribution of centers in the Lexington metropolitan area, KY (UGB_Local)
Note: “C” denotes centers within a central city and “S” denotes suburban centers

Figure 6.4 Distribution of centers in the Minneapolis metropolitan area, MN (USA)
6.3.2 Measuring Density Gradients with the Polycentric Model

Given the locations of the identified employment centers, their employment and population density gradients are estimated for each metropolitan area in 1990 and 2000, using the following non-linear model:

\[
Den_m = \sum_{n=1}^{N} A_n e^{-\gamma_n x_{m,n}}
\]  

(6.6)

where \( Den_m \) is the density in TAZ \( m \), \( x_{m,n} \) is the distance from TAZ \( m \) to center \( n \), and \( \gamma_n \) represents the density gradient of center \( n \). This model assumes that every center has an influence, and this influence diminishes at larger distances (Anas and Small, 1998).

The 1990 and 2000 density gradients for each study area are estimated, using the NLIN procedure of the SAS software (see Appendix B).

6.3.3 Effects of Urban Containment Policies on Density Gradients with the Polycentric Model

In most cases, the employment density gradients are larger than the population ones because firms have steeper bid rent curves than households. If the population density gradient is similar to the employment for a given center, this suggests that the population and employment may be co-located. In line with this idea, a mixed-use index is derived by dividing the employment density gradients by the population density gradients at each center. The smaller this mixed-use index is, the more the employment and population are co-located. Table 6.7 presents the average values of this index for each metropolitan area. The UGB_ST metropolitan area has the smallest value (1.33),
while the USA metropolitan area has the largest one (37,811.93\textsuperscript{39}). This implies that population tends to be concentrated at employment centers in UGB\_ST metropolitan areas, promoting polycentric patterns, while the population density gradients in USA metropolitan areas are very small at employment centers, implying that the population is dispersed away from these centers, and the imbalance between jobs and housing increases. Mixed-use indices for UGB\_Local areas have moderate value indices: 10.58 and 12.99 for Lexington and Lincoln, respectively.

Table 6.8 shows how the population and employment density gradients of centers changed between 1990 and 2000. The CBD of Eugene, OR (UGB\_ST) has the highest growth rates of density gradients for both population and employment. In addition, the density gradients increased in most centers. This supports the hypothesis that UGB\_ST metropolitan areas have a polycentric pattern.

<table>
<thead>
<tr>
<th>Metropolitan areas</th>
<th>Number of total centers</th>
<th>Number of subcenters outside growth boundaries</th>
<th>EMP density gradient/POP density gradient (2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UGB_ST Eugene, OR</td>
<td>8</td>
<td>0</td>
<td>1.33</td>
</tr>
<tr>
<td>USA Minneapolis, MN</td>
<td>21</td>
<td>4</td>
<td>37,811.93 (715.32\textsuperscript{*})</td>
</tr>
<tr>
<td>UGB_Local Lexington, KY</td>
<td>6</td>
<td>1</td>
<td>10.58</td>
</tr>
<tr>
<td></td>
<td>Lincoln, NE</td>
<td>7</td>
<td>12.99</td>
</tr>
</tbody>
</table>

\textsuperscript{*}: A revised value after removing outliers.

Table 6.7 Comparisons of mixed-use indices for different case study areas (2000)

\textsuperscript{39} Even after some outliers are removed, the value is still high (715.32).
The employment density gradients of Minneapolis, MN (USA) decreased in most centers, except the CBD, implying that employment has become dispersed. As seen in Figure 6.4, four subcenters (S18, S19, S20, and S21) are identified outside USAs in Minneapolis. The population density gradients increased highly in these centers. However, as seen in Table B.2, because the employment density gradients are not significant for these centers, it can be concluded that these centers outside USAs are the products of population concentrations, without a significant increase in employment opportunities.

The employment density gradients decrease at most centers in UGB_Local metropolitan areas. However, the average population density gradients increase within the CBD and growth boundaries.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBD</td>
<td>Within growth boundaries</td>
</tr>
<tr>
<td>Minneapolis, MN</td>
<td>0.038</td>
<td>-0.125</td>
</tr>
<tr>
<td>Lexington, KY</td>
<td>-0.130</td>
<td>-0.130</td>
</tr>
<tr>
<td>Lincoln, NE</td>
<td>-0.142</td>
<td>-0.028</td>
</tr>
</tbody>
</table>

Table 6.8 Growth rate of employment and population density gradients (1990-2000)
6.4 SUMMARY

In this chapter, employment and population density gradients have been estimated, using the negative exponential model, to examine the impacts of UCPs on urban spatial structure in U.S. metropolitan areas.

Although the population and employment density gradients positively affect each other, population is more likely dispersed than employment as population increases, resulting in an expansion of the metropolitan area. However, the physical size of the metropolitan area, transportation costs, and government expenditures in central cities positively affect the population density gradient, implying that more people are concentrated in the CBD as these values increase. On the other hand, as more owner-occupied housing is developed in outer areas, the population density gradient tends to decrease. However, employment does not follow the development of owner-occupied housing in outer areas, resulting in the creation of bedroom communities and an increase in congestion. The deterioration of cities, measured by the housing vacancy rate and age, and the income of the white population, negatively affects the employment density gradient, suggesting that these variables encourage employment dispersion, while per-capita income positively affects the employment density gradient.

Employment density increased by 13.82% in CBDs of UGB_ST metropolitan areas, while UGB_Local and USA metropolitan areas experienced 3.75% and 0.47% decreases, respectively, from 1990 to 2000. This suggests that the tightness of containment policies contributes to the vitalization of the CBD.

Both the population and employment density gradients are lowest in UGB_ST metropolitan areas, because most land in central cities under UGB_ST are densely
developed. In addition, other neighboring jurisdictions within the metropolitan areas are also densely developed, implying that UGB_ST metropolitan areas have a polycentric development pattern. In order to examine which type of metropolitan area has a polycentric pattern, density gradients for each center are estimated with both monocentric and polycentric models.

Under the monocentric density gradient hypothesis, UGB_ST has a negative effect on the population density gradient because a central city is already densely developed and other suburban communities within the growth boundaries are also densely developed. Although population and employment are concentrated in the CBDs and central cities, other suburban centers also have population and employment concentrations within UGBs.

UGB_Local has a positive effect on the population density gradient, implying that the CBDs and central cities are revitalized by population concentrations. In addition, suburban centers outside the growth boundaries have no statistically significant effects.

USA has a negative effect on the employment density gradient, implying that employment is dispersed across the metropolitan area. Even when a polycentric pattern is taken into account, the average changes in employment density gradients were negative within both central city and suburbs.

Under the polycentric density gradient hypothesis, UGB_ST metropolitan areas have the smallest ratio between the employment density gradient and the population density gradient, while USA metropolitan areas have the largest ratio. This result supports the hypothesis that population tends to be concentrated at employment centers in UGB_ST metropolitan areas, promoting polycentric patterns, while the population
density gradients in USA metropolitan areas are very small at employment centers, indicating that the population is dispersed away from the centers and the imbalance between job and housing increases. In addition, since employment density gradients are not significant at centers outside USAs, it may be concluded that these centers are the results of population concentrations without accompanying employment opportunities.

Employment density gradients decrease at most centers in UGB_Local metropolitan areas. However, the average population density gradients increase within CBD and growth boundaries, implying that UGB_Local metropolitan areas are close to monocentric pattern.

In summary, UGB_ST encourages metropolitan areas to move to a polycentric development pattern, UGB_Local supports a monocentric pattern, and USA produces sprawled development patterns. A polycentric development pattern is known as the most efficient spatial structure in terms of energy savings and environmental issues, such as air pollution, specifically, by reducing commuting and travel time (Haines, 1986). Thus, the results imply that urban growth boundaries specified at the regional level are desirable to shape future metropolitan areas.
CHAPTER 7

CONCLUSIONS

Previous research related to the impacts of urban containment policies (UCPs), specifically greenbelts, urban growth boundaries, and urban service areas, has focused on housing markets or specific areas. While some research has analyzed the economic and spatial impacts of growth controls, little is known regarding the impacts of containment policies on urban population and economic growth and on the urban spatial structure. In addition, the differences in the tightness of UCPs have not been taken into account in empirical analyses. Therefore, the purpose of this research is to (1) understand the system of UCPs, (2) empirically analyze their impacts on population and employment growth, and built-up areas in combination with housing values, and (3) examine the impacts of the enforcement of UCPs on the urban spatial structure, using estimates of population and employment density gradients.

The estimation results for the simultaneous equations of population, employment, housing values, and land areas, indicate that an increase in population positively affects changes in employment and land areas. Intuitively, employment increases due to the
increase in demand for services required by the population, further resulting in the expansion of built-up areas. Thus, an increasing population attracts employment, and population also follows employment. This is consistent with literature results. An increasing land area points to growth in the supply of land for residential development, thus positively affecting population growth. Changes in land area and employment negatively affect each other, implying that land annexation is directed to the influx of population rather than to employment growth. Increases in land area and housing values positively affect each other. Because a producer increases output to raise profits when prices are high, an increase in housing values encourages developers to construct more housing units, resulting in the expansion of built-up areas.

The reduced forms of the simultaneous equations add a meaningful insight into the traditional debate regarding the causality of population and employment. The size of the population contributes to employment growth while the size of employment negatively affects population growth, suggesting that employment follows people. The elasticity of the change in employment with respect to population is 0.1663, whereas the elasticity of the change in population with respect to employment is -0.0705.

The descriptive analysis of urban growth at the municipal level shows that the stringent containment policies (SCP) cities have the highest mean growth rate for housing values from 1990 to 2000 (0.88). Mean employment growth is highest in less stringent containment policies (LSCP) cities (0.50), followed by SCP cities (0.33) and uncontained (UC) cities (0.23), which may imply that, because of scale economies, contained cities attract more employment than UC cities, and the employment growth rate increases with decreasing tightness in containment policies. In addition, this suggests that the
enforcement of UCPs directly or indirectly affects population, employment, housing markets, and land areas, depending upon their tightness.

The estimation results of the simultaneous equations for population, employment, housing values, and land areas indicate that both the SCP and LSCP dummy variables have significant impacts on changes in population, employment, housing values, and land areas. The structural equations coefficients, which show the direct effects of the exogenous variables, indicate that SCP has negative effects on employment growth more than two times larger than LSCP, implying that tighter containment policies lead to less employment growth. The reduced-forms coefficients, which show both the direct and indirect effects of the exogenous variables, indicate that the coefficients of the SCP dummy variable for changes in population, employment, housing values, and land area are almost twice as large as those of the LSCP dummy. This suggests that SCP more successfully accommodate new growth within the growth boundaries than LSCP, rejecting the amenity-creation model wherein population decreases due to the spatial limitation of SCP. LSCP negatively impact the increase of land area, suggesting that there was less annexation of fringe areas in LSCP cities between 1990 and 2000. While it may appear that LSCP minimize the expansion of cities, this does not mean that LSCP prevents urban sprawl, because new developments may take place beyond the urban service boundaries of the metropolitan area. Both the structural and the reduced-forms coefficients indicate that both SCP and LSCP have a significant positive effect on change in housing values. The reduced-form coefficient of SCP is almost three times larger than that of LSCP, confirming that housing values increase with the tightness of containment policies.
Both the SCP and LSCP dummy variables have negative effects on the growth of all sectors. However, depending on the sector, there are differences between SCP and LSCP. SCP has a four times larger negative effect on manufacturing, possibly because LSCP have less impact on housing values and the larger populations that make up the labor force of labor-intensive industries. However, SCP cities have a positive effect on the service sector, almost three times larger than in LSCP cities, probably because SCP cities have a higher population growth than LSCP and UC cities. One characteristic of the service sector is the need for face-to-face contacts with consumers. Therefore, these industries are affected by an increase in population, which is an important demand factor.

The estimation results of the simultaneous equations for population and employment density gradients indicate that population is more likely dispersed than employment as population increases, although the population and employment density gradients positively affect each other, resulting in an expansion of the metropolitan area. However, the increases in the physical size of the metropolitan areas, transportation costs, and government expenditures in central cities encourage more people to be concentrated in the CBD. On the other hand, more owner-occupied housing, developed in outer areas, promotes population dispersion. However, employment does not follow the development of owner-occupied housing in outer areas, resulting in the creation of bedroom communities and an increase in congestion. The deterioration of cities, measured by the housing vacancy rate and age, and the income of the white population encourage employment dispersion, by negatively affecting the employment density gradient, while per-capita income positively affects the employment density gradient.
The analysis of the impacts of urban containment policies on urban spatial structure reveals that employment density increased in the CBDs of UGB_ST metropolitan areas (13.82%), while UGB_Local and USA metropolitan areas experienced 3.75% and 0.47% decreases, respectively, from 1990 to 2000, suggesting that the tightness of containment policies contributes to the revitalization of the CBD.

Under the monocentric density gradient hypothesis, UGB_ST has a negative effect on the population density gradient, because a central city is already densely developed, and other suburban communities within growth boundaries are also densely developed. UGB_Local has a positive effect on the population density gradient, implying that the CBDs and central cities are revitalized by population concentrations. In addition, suburban centers outside the growth boundaries have no statistically significant effects. USA has a negative effect on the employment density gradient, implying that employment is dispersed across the metropolitan area. Even when a polycentric pattern is taken into account, the average changes in employment density gradients are negative within both central city and suburbs.

Under the polycentric density gradient hypothesis, UGB_ST metropolitan areas have the smallest ratio between the employment density gradient and the population density gradient, while USA metropolitan areas have the largest one, supporting the hypothesis that population tends to be concentrated at employment centers in UGB_ST metropolitan areas, promoting polycentric patterns. However, the population density gradients in USA metropolitan areas are very small at employment centers, indicating that the population is dispersed away from the centers and the imbalance between jobs and housing increases. In addition, since employment density gradients are not significant
at centers outside USAs, it may be concluded that these centers are the results of population concentrations without accompanying employment opportunities. Employment density gradients decrease at most centers in UGB_Local metropolitan areas. However, the average population density gradients increase within CBD and growth boundaries, implying that UGB_Local metropolitan areas are close to the monocentric pattern.

In summary, both SCP and LSCP have a significant positive effect on change in housing values. The effects of SCP and LSCP on employments vary depending on the characteristics of sectors. When both direct and indirect effects are taken into account, SCP has a positive effect almost twice larger than LSCP for changes in population, employment, housing values, and land area, suggesting that SCP more successfully accommodate new growth within the growth boundaries than LSCP, rejecting the amenity-creation model wherein population decreases due to the spatial limitation of SCP. In other words, tighter containment policies generate some negative effects, such as an increase in housing values and a decline in space-intensive industries, although they accommodate increased population and service sectors within the growth boundaries. The implication is that if containment policies are enforced at the municipal level, those municipalities where growth in specific industrial sectors, such as manufacturing, is vital, should be cautious in selecting containment policies. Depending on their main industrial sectors, municipalities might consider other complementary planning tools or plans, such as the reservation of land for industrial parks or incentives for existing industrial zones.

However, in terms of the urban spatial structure, UGB_ST encourages metropolitan areas to move to a polycentric development pattern, UGB_Local supports a
monocentric pattern, and USA produces sprawled development patterns. A polycentric development pattern is known as the most efficient spatial structure in terms of energy savings and environmental issues, such as air pollution, specifically, by reducing commuting and travel time. Thus, the results imply that urban growth boundaries specified at the regional level are desirable to shape future metropolitan areas.

This research is unique in that it uses a nationwide municipal-level database, including information of different urban containment policies, for the analysis of urban growth. This unique dataset makes it possible to analyze how the impacts of containment policies differ, depending upon their tightness. In addition, the analysis of density gradients, estimated using the large set of traffic analysis zones for 135 metropolitan areas, is distinct from earlier research where population density gradients were estimated for a limited number of metropolitan areas/central cities, or measured by simply comparing population densities between the CBD and suburban areas.

Future research should incorporate the values of amenities created by urban containment policies, such as preserved open space, parks, and farmland. The valuation of these amenities may help clarify the costs and benefits of urban containment policies as well as urban sprawl, and this might explain why population and some industries expand in cities that have adopted stringent containment policies.

Also, since many municipalities combine such policies as infill development and restriction of development capacity with physical containment policies, the effects of such combinations should be further assessed.

In addition, the distinction between (1) contained cities with UCPs and (2) cities naturally contained by adjacent jurisdictions or topography, should be considered. These
two contained cities are clearly different, in that the former cities have a potential for future growth, because there is developable land beyond city limits or growth boundaries, while the later cities do not. By adding additional dummy variable for these naturally contained areas, the effects of UCPs may be more clearly identified.


APPENDIX A

POPULATION AND EMPLOYMENT DENSITY GRADIENTS

WITH A MONOCENTRIC MODEL
<table>
<thead>
<tr>
<th>Metropolitan area</th>
<th>Population density gradient</th>
<th>t value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany--Schenectady--Troy, NY MSA</td>
<td>0.074</td>
<td>-13.02</td>
<td>0.168</td>
</tr>
<tr>
<td>Albuquerque, NM MSA</td>
<td>0.141</td>
<td>-25.92</td>
<td>0.492</td>
</tr>
<tr>
<td>Allentown--Bethlehem--Easton, PA MSA</td>
<td>0.087</td>
<td>-6.41</td>
<td>0.106</td>
</tr>
<tr>
<td>Amarillo, TX MSA</td>
<td>0.330</td>
<td>-12.16</td>
<td>0.500</td>
</tr>
<tr>
<td>Appleton--Oshkosh--Neenah, WI MSA</td>
<td>0.052</td>
<td>-4.74</td>
<td>0.042</td>
</tr>
<tr>
<td>Athens, GA MSA</td>
<td>0.389</td>
<td>-15.12</td>
<td>0.512</td>
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Table A.1 Population density gradients for U.S. metropolitan areas (2000)
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<th>t value</th>
<th>R²</th>
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(Table A.1 continued)

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(Continued)
(Table A.1 continued)

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<th>R²</th>
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<td>-7.44</td>
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<td>0.040</td>
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<td>Daytona Beach, FL MSA</td>
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<td>Dayton--Springfield, OH MSA</td>
<td>0.103</td>
<td>-14.08</td>
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Table A.2 Employment density gradients for U.S. metropolitan areas (2000)
(Table A.2 continued)

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<th>Metropolitan area</th>
<th>Employment density gradient</th>
<th>t value</th>
<th>R²</th>
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<td>0.303</td>
<td>-17.91</td>
<td>0.375</td>
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<tr>
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<td>0.099</td>
<td>-11.11</td>
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<td>El Paso, TX MSA</td>
<td>0.231</td>
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<td>0.475</td>
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<td>Eugene--Springfield, OR MSA</td>
<td>0.083</td>
<td>-10.43</td>
<td>0.179</td>
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<td>0.296</td>
<td>-13.89</td>
<td>0.312</td>
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<td>Fargo--Moorhead, ND--MN MSA</td>
<td>0.246</td>
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<td>0.108</td>
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<td>Fort Collins--Loveland, CO MSA</td>
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<td>-19.87</td>
<td>0.526</td>
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<td>0.126</td>
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<td>-23.71</td>
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<th>Metropolitan area</th>
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<th>R²</th>
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(Continued)
(Table A.2 continued)

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<th>t value</th>
<th>R^2</th>
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<td>Toledo, OH MSA</td>
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<td>Tucson, AZ MSA</td>
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<td>t value</td>
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(Continued)

Table A.3 Manufacturing density gradients for U.S. metropolitan areas (2000)
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<th>R²</th>
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(Continued)
(Table A.3 continued)

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<td>0.401</td>
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<tr>
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<td>0.266</td>
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<tr>
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<td>-9.34</td>
<td>0.382</td>
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<tr>
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(Continued)
(Table A.3 continued)

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<th>t value</th>
<th>R²</th>
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<td>t value</td>
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<td>-6.68</td>
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Table A.4 Retail density gradient for U.S. metropolitan areas (2000)
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<th>t value</th>
<th>R²</th>
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<th>R²</th>
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(Table A.4 continued)

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<td>t value</td>
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(Continued)
(Table A.5 continued)

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(Table A.5 continued)

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(Continued)
(Table A.5 continued)

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APPENDIX B

POPULATION AND EMPLOYMENT DENSITY GRADIENTS

WITH A POLYCENTRIC MODEL
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Note: Bold-typed characters represent statistically significant density gradients.

Table B.1 Population and employment density gradients for UGB metropolitan areas ($10^2$)
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Note: Bold-typed characters represent statistically significant density gradients.

Table B.2 Population and employment density gradients for USA metropolitan areas (10^2)