THE EFFECTS OF RESIDENTIAL MINIMUM LOT SIZE ZONING ON LAND DEVELOPMENT: THE CASE OF OAKLAND COUNTY, MICHIGAN

By

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ABSTRACT

THE EFFECTS OF RESIDENTIAL MINIMUM LOT SIZE ZONING ON LAND DEVELOPMENT: THE CASE OF OAKLAND COUNTY, MICHIGAN

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Considerable theoretical and empirical debate has addressed the effects of minimum lot size zoning regulations on the development of land. The direction of this relationship certainly has relevance for policy. Previous studies have used econometric techniques to estimate this relationship. This paper uses a land use share multiple regression model in which the dependent variable is the natural logarithm of the ratio of acres developed from 1990-2000 to acres not developed over the same time period. It builds on previous studies by using a weighted average minimum lot size variable rather than a simple dummy variable and by explicitly considering the change in developed land area in the dependent variable. The study area is Oakland County, Michigan, a suburb of Detroit that is experiencing significant suburban development. Results show that there is a quadratic relationship between average minimum lot size and land development. At first, development declines with minimum lot size, but at a diminishing rate. Then, at approximately 5.15 acres (224,330 square feet), development begins to increase with minimum lot size at an increasing rate.

For my family and friends

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Chapter 1 Introduction

Across the United States, land use is becoming more and more decentralized as people move away from cities into suburbs and rural areas in search of their American Dream. The situation is much the same in Oakland County, Michigan, where the land-to-population growth ratio from 1960-1990 was twelve to one (Michigan Land Use Leadership Council 2003). This suburbanization has numerous consequences for society. Every unit of land that is developed for human use simultaneously represents a unit of land the environmental benefits of which are compromised or completely foregone. The opportunity costs of developing land are many and varied—lost farmland, species habitat, and environmental amenities are among the most commonly cited (Benfield, Raimi, and Chen 2001). Other negative effects include central city decay and the rising fiscal costs of providing infrastructure to an ever more decentralized society. This is compounded by the fact that development tends to be permanent and/or irreversible, and that it is unlikely that the land can or will ever be "undeveloped."

What can society do to regulate this phenomenon? Communities looking to combat such sprawl style development are in need of policy options that can control growth. But policies also need to be sensitive to a wide range of interest groups. Developers, planning and zoning officials, and local citizens are among the many interest groups that have a stake in how we choose to control growth.

In the United States, zoning is one, nearly ubiquitous method of land use control. Historically, it has been used as a means of protecting property owners from those nuisances (i.e., negative externalities) that arise when incompatible land uses are located in close proximity to one another. Increasingly, it is also described as a policy tool that is useful for controlling urban growth (Fischel 1990). Minimum lot size restrictions, the workhorse of most residential zoning ordinances, are now often mentioned as a growth control tool. However, both theory and empirical evidence are unclear about the direction of the relationship between lot size restrictions and land use change. Some claim that minimum lot size zoning restrictions actually exacerbate sprawl development (Field 2001). The direction and magnitude of this relationship is an empirical question, and research is needed to address it.

In studying land use change, applied economists have conducted empirical research projects examining those factors that are hypothesized to contribute to the decentralization of society (For example, Irwin, Hsieh, and Libby 2002; and Spalatro and Provencher 2001). These models generally consider how various factors affect land prices (hedonic models) or the quantity of land consumed in development (land use quantity models). Zoning restrictions, when they are incorporated in these models, are usually included as explanatory dummy variables that affect either the price of land or the amount of land that is consumed by developed uses (e.g., Jud 1980; Mark and Goldberg 1986). In regards to zoning, the results of these studies are mixed and inconclusive. There is certainly a need to expand upon this limited body of empirical evidence.

The townships, cities, and villages of Oakland County, Michigan, have traditionally been bedroom communities for people that work in the City of Detroit. Today, however, Oakland County is also one of many rapidly suburbanizing areas in the United States. As the population of Detroit has declined, much of it has relocated to suburban Oakland County (SEMCOG 2004). Land uses vary a great deal within the county, and so do the types and strictness of zoning policies used to control it. Oakland

County therefore represents an excellent study area in which to examine the effects of zoning restrictions on land development.

Given this background, this paper attempts to estimate and interpret the relationship between minimum lot size zoning and land development in Oakland County, Michigan using a land use share multiple regression model. The model presented here is an extension of previous research on the relationship between development and zoning in that it uses the weighted average minimum lot size in each community as an explanatory variable rather than the simple dummy variable that is often used. It also explicitly considers land use change in the dependent variable over a discrete period of time (1990-2000).

The analysis will proceed in the following manner. Chapter 2 begins by discussing the theoretical underpinnings of urban growth and the concept of sprawl development. It then examines the observed pattern of urban growth and development in the United States, Michigan, and Oakland County, and how zoning ordinances regulate land use. Chapter 3 is a literature review that considers previous research on the relationship between zoning and land consumption. In particular, it provides a conceptual model of land use change and a review of several major types of commonly employed empirical models. Chapter 4 describes the model specification used in the present study, while Chapter 5 discusses the data sources. Chapter 6 is a presentation and discussion of the model's results. Finally, Chapter 7 provides some conclusions.

Chapter 2 Problem Background

2.1 Introduction

The previous chapter provided a brief introduction to the land use issue of suburbanization, the relationship between land development and residential zoning restrictions, and the general objectives of this research. This chapter will provide a basic understanding of why suburbanization is occurring, a definition of sprawl, and the basic trends in land consumption in the United States and Michigan. Following this will be a subsection that describes the basics of zoning restrictions. While not exhaustive, by helping to understand the nature of the issue, this background will provide a basis for the remainder of the paper.

2.2 Theories of Suburbanization

Suburbanization is a process in which households (and firms) migrate from the central city to the suburbs (Lopez, Adelaja, and Andrews 1988). Mieszkowski and Mills (1993) discuss the common misconception that suburbanization in the United States is strictly a post World War II phenomenon. They show that suburbanization began prior to World War II in the United States, and that it is an international trend—the populations of most developed countries are now 60 to 80 percent metropolitan.

They describe two theories of the process of suburbanization in the United States. The first is the natural evolution theory. Here, employment opportunities are clustered in the central business districts (CBD) of cities and residential development occurs from the center outward. In the interests of minimizing the costs of commuting, central areas develop first. As land near the CBD is consumed, development moves into the suburbs. High-income people will then move from the city to suburban areas where it is possible to have larger houses and more amenities. This leaves low-income individuals living in the city center, and thus low and high income families have a tendency to become *de facto* geographically segregated. A central assumption of this theory is thus that high-income individuals prefer large single-family properties to small multi-family properties. In other words, there is a high income elasticity of lot size. Transportation, and especially the automobile and the freeway, is also central to this theory because it allows for the possibility of commuting over long distances.

The above is also known as the pull theory of suburbanization. This is because certain aspects of living outside of the city, such as lower crime rates, newer infrastructure, and greater environmental amenities, attract people to live farther away from the city center.

The second theory of suburbanization proposed is based on the fiscal and social problems of cities that may drive affluent residents out of the city center. For example, high taxes, poor public schools, crime, and congestion are all serious inner city problems that may lead high-income individuals to move to the suburbs. This "flight from blight" by the wealthy leads to further deterioration of the city as the tax base is eroded. This is also known as the push theory of suburbanization (the converse of the pull theory) because it is based on factors that make living in the city less attractive. Table 1 lists some important push and pull factors.

Table 1: Push and Pull Factors

Push Factors	Pull Factors
High Crime	Safe Neighborhoods
Poor/Deteriorating Infrastructure	New Infrastructure
Poor Schools	Quality Schools
Declining Property Values	Rising Property Values
Poverty	Large Homes/Properties
Lack of Employment Opportunities	Many Available Jobs
High Taxes	Lower Taxes
Physical Congestion	Open Space

The "flight from blight" theory is a generalization of the well-known Tiebout model (Tiebout 1956). Tiebout wished to deal with the problem of market failure that results from an inability to exclude people from enjoying public goods. This non-excludability allows individuals to enjoy the benefits of public goods without revealing the intensity of their true preferences for them (Fischel 1985). Tiebout hypothesized that dividing public goods into two varieties—local and national—could solve this problem. In a situation with many local governments and a mobile citizenry, citizens will "vote with their feet" and choose to live in the community that provides them with the best overall package of public goods. This creates a market for public services like zoning at the local level. While Tiebout did not apply his theory to land use issues specifically, it is easy to see how it applies. When the wealthy flee from the city, they are simply revealing a preference for a different package of public services that is available in the suburbs.

Mieszkowski and Mills also note that there are many interactions between these two models, and thus it is difficult to make an empirical claim that one or the other is the correct theory. For example, the effects of relative income on the residential location decision are evident in both explanations, as is the tendency of the affluent to move to the suburbs. In reality, a combination of the effects predicted by each theory probably drives suburbanization.

2.3 Suburbanization and Sprawl

When suburbanization reaches the point at which it is deemed excessive, it is often pejoratively termed to be "sprawl." While sprawl has only become a major public policy debate in the last 20 or so years, the term has long been used in the social sciences. In the economics literature, for example, "urban sprawl" was used as early as 1965 (Harvey and Clark). There has always been difficulty, however, in defining exactly what sprawl is.

We know that sprawl is growth that is excessive in nature. What is not clear is the answer to the question: when does development become excessive? Judging when this actually occurs is the crux of the problem. Anthony Downs (1998) provides some general characteristics of urban sprawl. These characteristics include: low-density development, leapfrog development, reliance on private automobiles for transportation, and lack of centralized land use planning. Of these characteristics, leapfrog development may need further description. It is defined as a development pattern in which growth occurs noncontiguously, so as to leave large vacant areas between patches of development.

From an economic perspective, determining the threshold at which growth becomes excessive is a matter of calculating costs and benefits. When individual households make a location choice, they decide by weighing their private benefits against their private costs while ignoring any external costs they may create (Wassmer 2001). Possible private benefits of living in a suburban area include lower costs of land, better schools, lower crime rates, larger homes, increased availability of jobs, and nearer proximity to open spaces. These benefits are the "pull factors" described above. Possible private costs of living in the suburbs include increased time spent commuting and increased distance from urban amenities. A necessary condition for choosing a location is that its private benefits must be greater than its private costs if a household is to choose to reside there. The sufficient condition is that the site finally chosen must have larger net private benefits than any other available location.

Growth also has numerous environmental and fiscal costs associated with it (Benfield, Raimi, and Chen 2001). Environmental costs include increased automotive emissions and energy consumption from longer commutes, loss of prime farmland[1], negative health effects, and the often irreversible loss of environmental amenities. Many of these environmental costs are externalities and thus are not considered by individuals as they make location decisions, even though they are relevant to society as a whole. When the marginal social costs of choosing a certain location become greater than associated marginal social benefits, then growth is excessive from an economic perspective and can be deemed sprawl. Given the difficulties of quantifying external

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[1] Between 1982 and 2001, the United States lost 22.1 million acres of farmland, a decrease of approximately 10 percent (NRCS 2003).

costs and benefits, it is clearly useful to consider the physical manifestations of sprawl described above when attempting to define it.

Benfield, Raimi, and Chen (2001) provide an overview of several studies that investigate the fiscal costs of sprawl. The various studies consistently note that sprawl-style development is more expensive than more compact development. Fiscal costs examined in these studies include school overcrowding, rising infrastructure costs (for water and sewer, roads, and energy), and residential construction costs. The rising cost of infrastructure brought on by sprawl is an intuitive result. Because low-density development entails increased distances between businesses and homes, additional infrastructure is needed to connect it all together.

Fischel (1985) points out that the most obvious cost of sprawl is the time spent commuting to work, as well as in traveling to stores, recreation facilities, and schools. Another important cost is the loss of agglomeration economies. These are the benefits that accrue to firms and households as a result of being located in close physical proximity to each other. Goods and services can be produced and made available in greater quality and quantity when firms and households are clustered together in cities. This is actually one reason that cities exist; agglomeration economies allow us to increase our standard of living. But when a firm chooses to leave the city in favor of suburbia, it only accounts for the internal effect that the loss of these agglomeration economies has on itself. In doing so, it imposes an external cost upon those firms that remain in the central city because those firms experience a decline in benefits from agglomeration economies (Fischel 1995).

2.4 Suburban Growth in the United States

The data in Tables 1 and 2 below comes from the 2001 Natural Resources Inventory (NRI). It is conducted by the Natural Resources Conservation Service (NRCS), a division of the United States Department of Agriculture (USDA). Previously, data was collected every five years starting in 1982, but beginning in 2001 data is now collected yearly for a smaller sample size (NRCS 2003).

Table 2 illustrates major land uses in millions of acres beginning in 1982 and ending in 2001. There is clearly a downward trend in the "Cropland," Pastureland," and "Rangeland" categories. This is not surprising as this has been the trend for most of the United States' history, and is mostly due to increases in agricultural production efficiency and therefore does not threaten the United States' agricultural production base (Vesterby and Krupa 1997). It is the "Developed Land" category that is somewhat troubling. Between 1982 and 2001, developed land increased by 33.5 million acres. This is an area approximately the size of Illinois (NRCS 2003). It represents a 46 percent increase in developed land over a 19-year period. Over the similar time period of 1980 to 2000, the US Census reports that population grew from 226.7 million to 281.4 million people. This is an increase of 24.1 percent. Given these statistics, it is clear that per capita land consumption is increasing.

Table 2: Major Land Use by Year in the United States, in Millions of Acres

	1982	1987	1992	1997	2001
Cropland	420.4	406.2	381.6	376.4	369.6
Pastureland	131.4	127.2	125.4	119.5	116.9
Rangeland	414.5	409.3	405.9	404.9	404.7
Forest Land	402.6	404.4	403.6	404.7	404.9
Other Rural Land	48.3	48.6	49.8	50.3	51.4
Developed Land	72.8	79.0	86.5	97.6	106.3

(NRCS 2003)

A recent study that analyzed the extent of sprawl growth in the United States' urbanized areas (as defined by the Census Bureau) confirms the result that increases in per capita land consumption are a major contributing factor to suburbanization (Kolankiewicz and Beck 2001). This study defined sprawl as "the rural acres lost as an Urbanized Area spreads outward over a period of time" (p. 7). It found that two factors, per capita sprawl and population growth, are the driving forces of sprawl as defined. They define per capita sprawl as an increase in the amount of urban land consumed per resident, and population growth as simply an increase in the number of residents in a geographic area. This is a rather straightforward result: sprawl results from more individuals consuming more land.

Table 3 is a further breakdown of the "Developed Land" category described in Table 2. Here we see that most of the increase in developed land (approximately 92 percent of it) over the period came in the "Large Urban and Built-Up Areas" category. "Large Urban and Built-Up Areas" are defined as those developed areas greater than 10 acres in size. This is clearly the area in which most of the United States' increase in land consumption is occurring.

Table 3: Developed Land by Type and Year, in Millions of Acres

	1982	1987	1992	1997	2001
Large Urban and Built-Up Areas	46.9	52.6	59.6	69.8	77.6
Small Built-Up Areas	4.7	5.1	5.4	6.1	6.7
Rural Transportation Land	21.2	21.3	21.5	21.6	22.0
Total Developed Land	72.8	79.0	86.5	97.5	106.3

(NRCS 2003)

The USDA's Economic Research Service (ERS) also produces data on land use (Vesterby and Krupa 1997).[2] Table 4 below shows the change from 1980 to 1997 of urban and rural residential and nonresidential areas. Here we can see that both urban and rural residential areas have increased significantly over the time period, but that the annual change in rural residential area is nearly 2.5 times greater than that of urban residential area. Much of this difference is due to the fact that large lot sizes are more common in rural areas than in urban areas. Table 4 also shows that urban nonresidential area is growing while rural nonresidential area is declining. Because the ERS is defining "urban" based upon population density, this occurred partially because previously "rural" areas are reclassified as "urban" when their density increases sufficiently.

Table 4: Change in Urban and Rural Residential and Nonresidential Area

	1980			1997			Annual Change	
Area (Million Acres)	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
Residential area	29	56	85	36	73	109	0.42	1.03
Nonresidential	18	2,160	2,178	30	2,124	2,154	0.66	-2.10
Totals	47	2,216	2,263	66	2,197	2,263	1.07	-1.07

(Vesterby and Krupa 1997)

2.5 Suburban Growth in Oakland County, Michigan

The national growth trend described in the previous section is also the prevailing trend in Michigan. Table 5 illustrates the urban expansion that has occurred in Michigan between 1960 and 1997 in thousands of acres. It shows that over the period 1990 to 1997, Michigan experienced an 11 percent increase in urban area (Vesterby and Krupa 1997).

[2] The ERS data includes federal land and the State of Alaska, both of which are omitted from the NRI.

Table 5: Michigan Urban Area (1,000 Acres), 1960-1997

1960	1970	1980	1990	1992	1997
1,017	1,286	1,540	1,705	1,760	1,896

(Vesterby and Krupa 1997)

The study by Kolankiewicz and Beck (2001) discussed above specifically looks at four Michigan urbanized areas: Detroit, Flint, Grand Rapids, and Lansing-East Lansing. Table 6 reproduces their findings for these four areas. The number in parentheses next to each urbanized area represents that area's rank in square miles sprawled (out of the 100 U.S. cities examined). The column labeled "Sprawl Factors Percent Growth" provides population and per capita land consumption growth data on a percentage basis for the period 1970 to 1990. "Overall Sprawl" gives the percent growth in land area and the total increase in square miles of area that occurred over the period. The "sprawl apportionment" column separates the effects of the two sprawl factors—per capita sprawl and population growth—in order to see the relative importance of each for a given city.

Table 6: Sprawl in Michigan's Urbanized Areas, 1970-1990

	Sprawl Factors Percent Growth		Overall Sprawl		Sprawl Apportionment	
Urbanized Area	Population	Per Capita Land Consumption	% Growth in Land Area	Square Mile Growth	Population Growth Factor's Portion	Per Capita Land Use Factor's Portion
Detroit (18)	-6.9%	37.9%	28.4%	247.4	0.0%	100.0%
Flint (71)	-1.2%	72.1%	69.9%	67.4	0.0%	100.0%
Grand Rapids (65)	23.7%	23.4%	52.7%	77.0	50.3%	49.7%
Lansing-East Lansing (95)	15.5%	16.4%	34.5%	25.3	48.7%	51.3%

(Kolankiewicz and Beck 2001)

Of these cities, Detroit and Flint are of relevance to Oakland County because they lie in close geographic proximity to it. Detroit proper is directly to the South in

Wayne County, and much of Oakland County is included in the Detroit urbanized area. Flint proper is located directly to the Northwest of Oakland County in Genesee County.[3] Detroit and Flint are also of particular interest because they fall into a class of cities with negative population growth that still managed to spread outwards. As Table 6 shows, increases in per capita land use were entirely responsible for sprawl growth in both the Detroit and Flint urbanized areas. There were 11 such urbanized areas included in this study.[4] As a group they had an average percentage increase in total urban land of 26 percent. Clearly urban expansion can occur without population growth. This means that if Detroit and Flint proper wish to combat sprawl, they need to focus their policy efforts on its per capita land consumption component. It is also important to note that population growth still exists in many of Detroit's suburban communities, as the following analysis will show.

Data produced by the South Eastern Michigan Council of Governments (SEMCOG 2002) predicts population growth rates for all communities (townships, cities, and villages) within Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne counties.[5] Table 7 presents the population of these seven counties in 1990 and 2000, their 2030 expected population, and the percent growth from 2000-2030. Wayne County, where Detroit is located, is the only county in the group exhibiting an expected negative population growth rate. The other counties all have positive expected

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[3] The terms Detroit proper and Flint proper refer to those cities as they are legally defined. In contrast, the Census Bureau often describes heavily populated areas as "urbanized areas" that are defined by the central city plus the closely settled urban fringe around the city. "Urbanized area" is the definition used in Kolankiewicz and Beck (Kolankiewicz and Beck 2001).
[4] The other nine cities are: Akron, Ohio; Buffalo-Niagara Falls, New York; Cleveland, Ohio; Dayton, Ohio; Milwaukee, Wisconsin; New York City-N.E. New Jersey; Pittsburgh, Pennsylvania; Scranton-Wilkes-Barre, Pennsylvania; and Youngstown-Warren, Ohio.
[5] SEMCOG's forecast are produced by the REMI (Regional Economic Models, Inc.) and METROPILUS (Metropolitan Integrated Land Use System) models (SEMCOG 2001).

population growth rates ranging from 11.7 percent in Oakland County to 80.0 percent in Livingston County. It is clear from the data that while Wayne County is a traditional population center (with Detroit constituting its core), it is in relative decline as compared to the other counties. These numbers are consistent with a pattern of urban migration that moves outward from the historical population center (Detroit) to less populated regions.

Table 7: SEMCOG County Member Projected Population Growth Rates

	Population			
County	1990	2000	2030 (Expected)	% Growth Expected 2000-2030
Livingston	115,645	156,951	282,552	80.0%
Macomb	717,400	788,149	930,420	18.1%
Monroe	133,600	145,945	196,554	34.7%
Oakland	1,083,592	1,194,156	1,333,537	11.7%
St. Clair	145,607	164,235	203,255	23.8%
Washtenaw	282,934	322,895	448,020	38.8%
Wayne	2,111,687	2,061,162	2,013,975	-2.3%
Total	4,590,465	4,833,493	5,408,349	11.9%

(SEMCOG 2002)

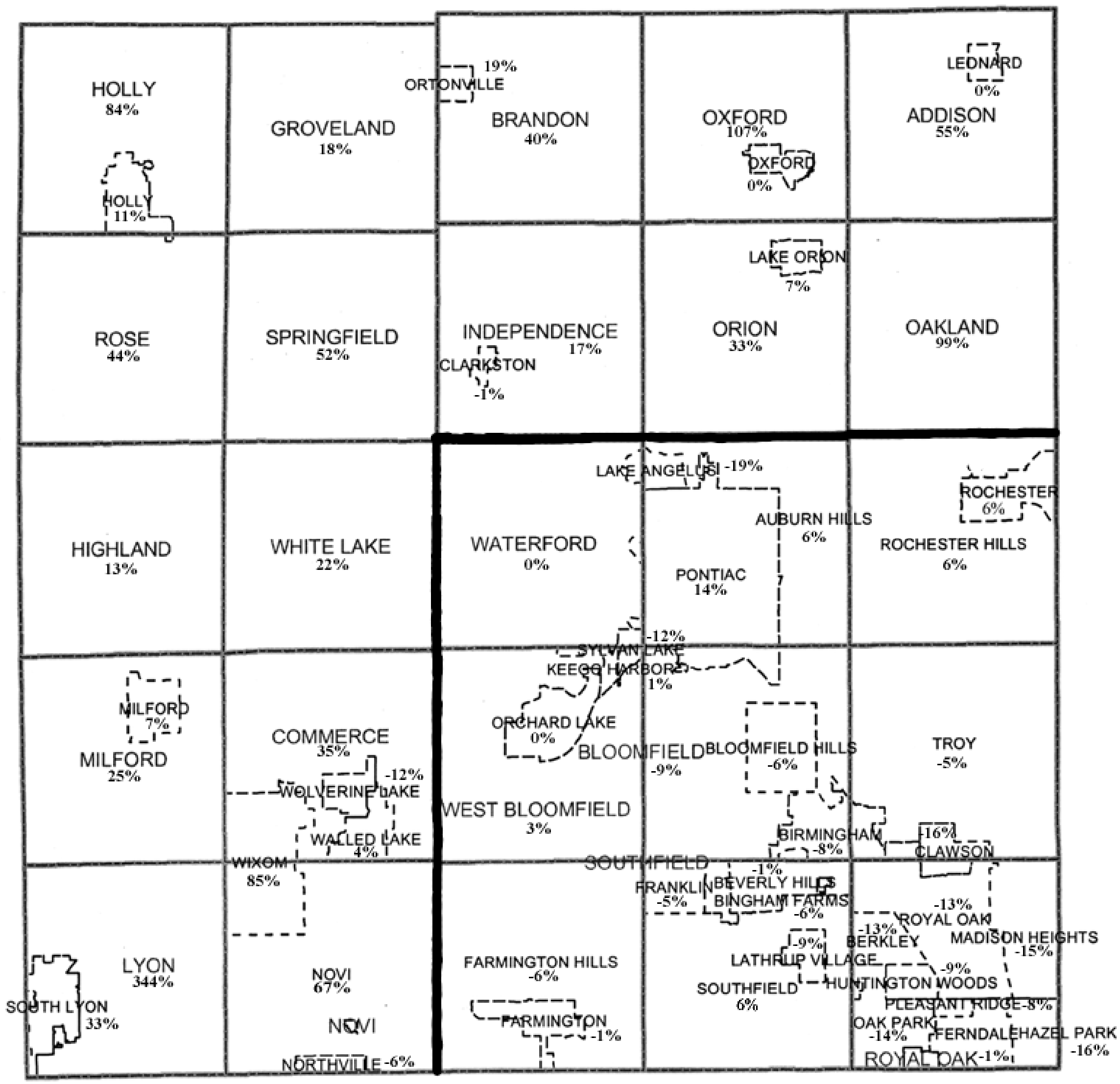
Within Oakland County (and the other counties as well), SEMCOG also provides data on expected population growth for 59 individual townships, villages, and cities.[6] This data is provided in Appendix Table 1. Percent expected population growth varies a great deal in Oakland County, ranging from –19.1 percent in Ferndale to 344.5 percent in Lyon Township. The mean expected percent growth over this time period is 17.7 percent. For a full set of summary statistics, see Appendix Table 2.

While these percentages vary considerably, by mapping them (see Figure 1) one can see that low and negative percentages are generally geographically clustered together in Oakland County's older neighborhoods. The communities in the South East quadrant of Figure 1 (delineated by the heavy black line) represent Detroit's more traditional

[6] Oakland County actually contains 61 municipalities. The SEMCOG data only specifies 59 of these because it is based on traffic analysis zones rather than political boundaries. Data for Novi and Novi Township are thus combined, as are Southfield and Southfield Township.

Oakland County suburbs. It is obvious from the map that growth rates are significantly larger outside of this area. This pattern is consistent with a trend of suburban expansion at the fringe and contraction at the center. For summary statistics that show this pattern more clearly, see Appendix Tables 3 and 4.

Figure 1: Oakland County Projected Percent Growth, 2000-2030



(SEMCOG 2002)

2.6 Zoning

Zoning can be roughly defined as "the division of a community into districts or zones in which certain activities are prohibited and others are permitted" (Fischel 1985, p. 21). It prescribes what type of development may be undertaken in each zone as well as what may not be undertaken. Zoning is thus a very powerful means of land use control because it provides the legal power to completely exclude certain uses. However, zoning is not meant to be a growth control in that it is not usually aimed at curbing sprawl growth.

Originally, zoning laws created a hierarchy of land uses, on the top of which stood single-family residential housing. Today, this hierarchy of protection no longer formally exists, but many still retain the belief that residential uses should be protected above others. In general, contemporary zoning ordinances are aimed at separating incompatible land uses. For example, industrial parks are typically prohibited from locating in residential areas, and vice versa. The general goal of zoning is to control the negative externalities that would inevitably result from such a land use mix (Field 2001).

The authority to zone was originally confirmed in the United States Supreme Court decision *Village of Euclid v. Ambler Realty Co.*, 272 U.S. 365 (1926). The *Euclid* decision established that in protecting the public welfare from nuisance[7], the constitutionally provided police power affords the necessary legal justification for zoning. Zoning laws were determined to be reasonable in general as long as they were based on comprehensive expert plans of community development. Essentially, this

[7] The legal definition of nuisance is "a condition or situation (such as a loud noise or foul odor) that interferes with the use or enjoyment of property" (Gardener 1999).

means that zoning laws are acceptable as long as community planning and zoning experts find that they support the general health and welfare of society.

The zoning power originally resides with the States, but in Michigan enabling acts delegate the authority to zone to local jurisdictions.[8] Michigan retains the power to withdraw zoning authority from local jurisdictions, but this rarely occurs. Today, nearly every local government in the United States either actively zones or has the authority to zone.

Various Michigan enabling acts have transferred the state power to zone to county and municipal (township, city and village) levels (Daneman, Decker, and Horn 2002). The situation is much the same across the country, as local authorities have traditionally controlled zoning. Michigan's power to transfer zoning authority to local governments was upheld in *City of Rochester v. Superior Plastics*, 192 Mich. App. 273 (1991). In this case the court confirmed that Rochester had the power to set a maximum permissible noise level for an industrial zone located in close proximity to a residential zone, and that this power is derived from the zoning enabling act.

The Institute for Public Policy and Social Research (IPPSR) at Michigan State University recently completed a survey of planning and zoning in Michigan (McGrain and Baumer 2004). Table 8 illustrates the extent of zoning in Michigan. It shows that approximately 75 percent of communities have a zoning ordinance. IPPSR notes that an additional 13 percent are subject to county zoning. Much of the remaining 12 percent consists of urban counties in which local governments are more likely to conduct zoning

[8] Michigan is thus known as a "Dillon Rule" state because the local government is granted authority by the State. There are also "Home Rule" states in which authority rests with local authorities unless specifically prohibited by the state (Richardson, Gough, and Puentes 2003).

independent of county government. It also shows that nearly all cities and villages have passed zoning ordinances.

Table 8: Adoption of Zoning Ordinances in Michigan

	Type of Community				
Zoning Ordinance Adopted?	City	Village	Township	County	Total
Yes	265	186	797	25	1,273
No	1	38	325	58	422
Total	266	224	1,122	83	1,695

(McGrain and Baumer 2004)

Several major types of zoning requirements can be distinguished. They are: minimum lot area and width, type of use to which the lot may be put (e.g., agricultural, residential, industrial, and commercial), maximum building height, maximum units per lot, minimum setbacks, and parking requirements (Fischel 2000). In general, they represent restrictions on the size and density of developments, as well as restrictions on type of use. Other types of restrictions also exist, but those listed are relatively ubiquitous. Among them, minimum lot size zoning is the restriction most commonly examined in statistical zoning studies (Fischel 1985). This is because it is the most frequently used method of regulating residential population density, and hence it is amenable to statistical analysis.

Anas, Arnott, and Small (1998) discuss the possibility that minimum lot size zoning can be a factor in the process of excessive suburbanization. Because minimum lot size restrictions are essentially a control on population density, if they are set too high they can have the unintended consequence of adding to sprawl. This is described in Field (2001) in terms of the identity:

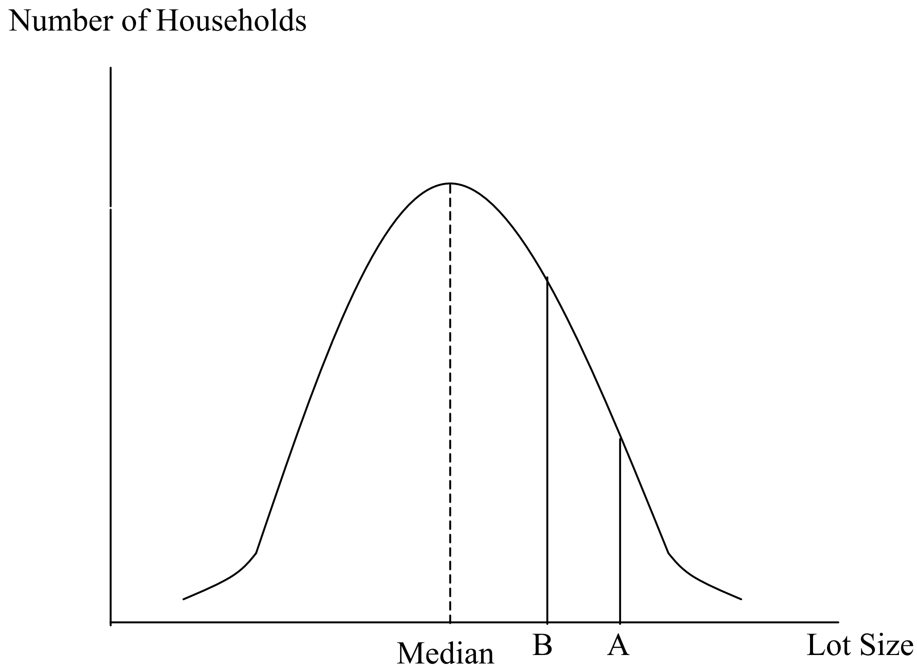
$$A \equiv NH \times A/NH \qquad (1)$$

This simply means that total residentially developed area, A, equals the product of the number of homes (NH) and the area consumed by each home (A/NH). Minimum lot size restrictions tend to increase the A/NH term, and therefore increase A.

This process can be exacerbated if zoning is exclusionary in nature. Exclusionary zoning is zoning that makes certain land uses impossible or only allows for a token amount of that use (Gardener 1999). For example, when municipalities do not have a zoning district for high-density, residential development because they wish to exclude low-income residents who cannot afford to purchase larger properties, they are practicing exclusionary zoning. These lower income families would pay lower property taxes than high-income residents but still receive full access to locally provided public goods if they were allowed to reside in the given community. If a government is motivated to exclude these low-income individuals, then they may do so with large minimum lot sizes that in turn could exacerbate sprawl.

Figure 2 depicts a frequency distribution of the number of households that would optimally prefer to buy land at different lot sizes (Adelaja 2004). This distribution is hypothesized to be bell-shaped for several reasons. First, as income rises, so does the ability to afford larger lots, and therefore rising income is a push factor with respect to increasing demand for large lot sizes. But the price of land, which is inversely related to lot size, is a factor that must also be considered. Larger lot sizes are more expensive, and therefore frequency of ownership of large lot properties will be lower. Thus, at some point, specifically the peak of the frequency distribution, lot size frequency begins to fall due to the rising price of land. Thus, the rising price of land is a mitigating factor in land consumption.

Figure 2: Residential Land Consumption with a Minimum Lot Size



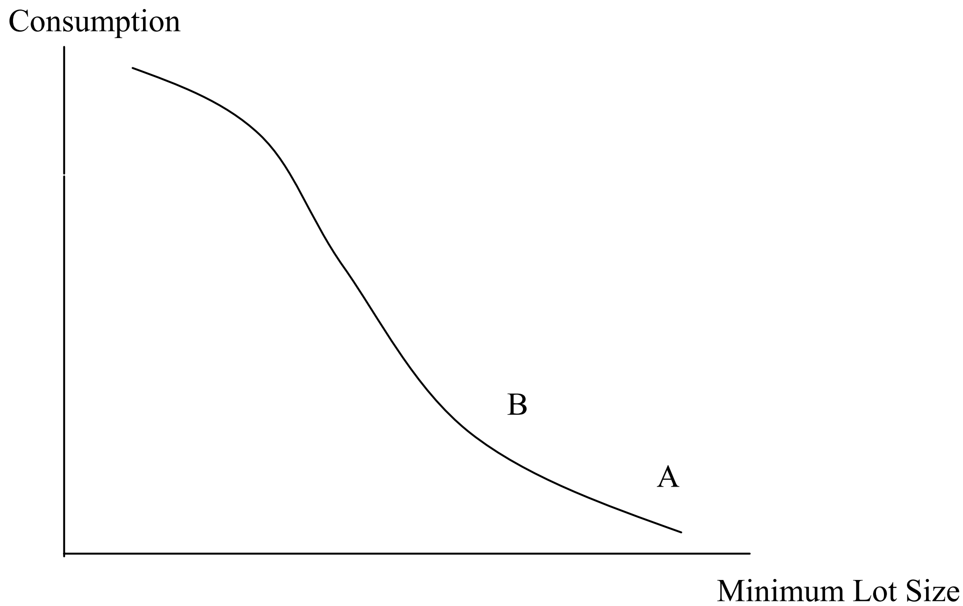
(Adelaja 2004)

Given the above frequency distribution, total land consumption can be defined as:

$$CONS = \sum_{i}^{n} N_i \cdot LS_i \qquad (2)$$

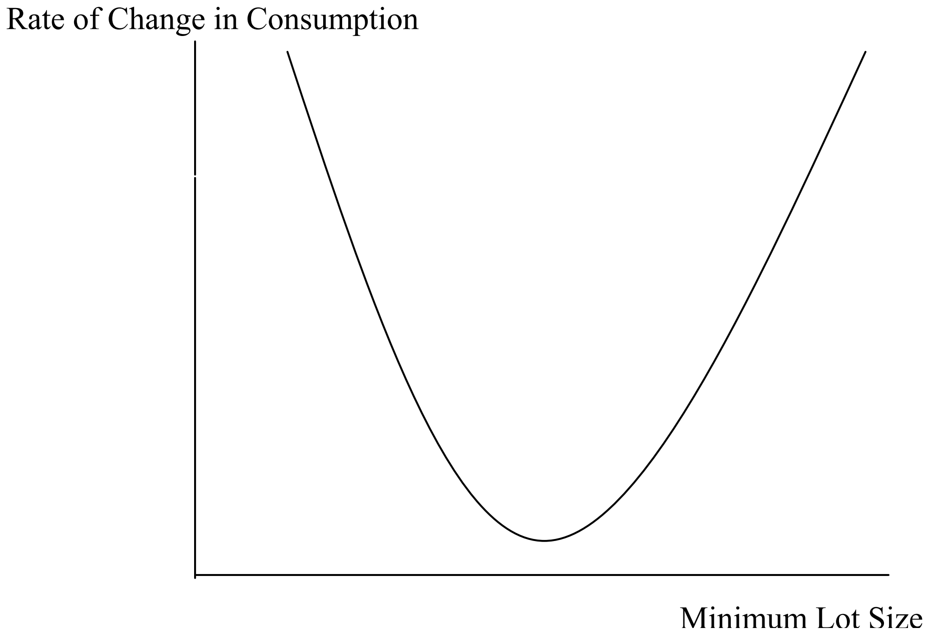
where N_i is the number of buyers at the i[th] lot size and LS_i is the i[th] lot size (Adelaja 2004). Therefore, if a very high minimum lot size is set at point A in Figure 2, then total land consumption will be $\sum_{i \geq A} N_i \cdot LS_i$. Moving the minimum lot size restriction from point A to point B will thus increase total land consumption. Figure 3 below maps the resulting implied relationship between minimum lot size and land consumption. It clearly shows that as minimum lot size increases, land consumption decreases, although in a nonlinear fashion. This result runs counter to that described by Anas, Arnott, and Small (1998) and Field (2001). It is different because it accounts for the fact that while higher minimum lot sizes increase the amount of land consumed per individual, they also limit the total number of individuals that are able to participate in the market.

Figure 3: Relationship between Land Consumption and Minimum Lot Size



Finally, we can calculate the rate of change in consumption of land (as a result of a change in minimum lot size) by finding the partial derivative of consumption with respect to minimum lot size (i.e., $\partial CONS / \partial MLS$). This yields the quadratic relationship depicted in Figure 4 (Adelaja 2004). At first the rate of change is declining, but it eventually turns and begins to increase. Thus, to the right of the point at which Figure 4 is minimized, increases in minimum lot size begin to increase the rate of change in land consumption.

Figure 4: Relationship between Minimum Lot Size and the Rate of Change in Consumption



Chapter 3 Literature Review

3.1 Introduction

In Chapter 2 the basic theories and trends in suburbanization were discussed, and the relationship between zoning constraints and land use was described. This was done with the goal of providing some background on the nature of the debate regarding the relationship between zoning and land development. In this chapter, previous empirical research is examined and summarized to provide a basis for a study of the effect of zoning on land development in Oakland County.

There are numerous examples of studies examining how zoning laws affect urban growth and development. These works are both conceptual and empirical. Empirical works tend to be of two major types. First, there are those that focus on how zoning affects housing and land values or prices. These price effects subsequently influence the expected returns of individual land parcels and therefore influence the likelihood of conversion to a new land use. Second, there are those studies that use econometric methods to consider land use change directly as the dependent variable. Zoning's effects on the land use market can thus be estimated with either prices or quantities. After discussing a conceptual model of land use change, the two major types of empirical works will be discussed.

3.2 Conceptual Model of Land Use Change

Many authors (including Bell and Irwin 2002; Bockstael 1996; and Carrion and Irwin 2002) describe a conceptual model of an individual's land use conversion decision in which the landowner maximizes either profits or expected utility. This can be applied to research at both aggregated and disaggregated levels. In general, the landowner chooses to change land use when the present value of net expected returns in the proposed use is greater than the present value of net expected returns in the current use. The one period static version[9] of the model as given in Bell and Irwin states that the landowner of a parcel k in current state u will choose a land use for k at time t that maximizes net expected returns. Therefore, parcel k in state u will be converted to state r in time t if the net returns are greater than those of converting to all other land uses $j \neq u$ (where j could also represent maintaining the current use). Mathematically, the condition is expressed as

$$R_{krt\,|\,u} \geq R_{kjt\,|\,u}; \forall j = 1,...,J \qquad (3)$$

where $R_{krt\,|\,u}$ equals the net expected returns to state u. Net expected returns are a function of a variety of variables that are hypothesized to affect the landowner's decision to convert to a new land use. For example, access to water and sewer infrastructure is likely to influence net expected returns to a residential use.

The above decision rule for land use conversion is very simplified. Other, more complex models, have been created to capture the dynamics of the development process (For example, Fujita 1982; Turnbull 1988; Tegene, Wiebe, and Kuhn 1999). These models attempt to account for the long-term nature of land use decisions explicitly. In particular, expectations about future development (issues of irreversibility and uncertainty) and changes in markets are of importance in the dynamic context. For the purposes of this analysis, however, only a simple static model is necessary.

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[9] The model can also be expressed over many periods or infinite periods. The major difference is that the timing of development becomes important, and discount rates must be included in the analysis (Bell and Irwin 2002).

While this simple static model is based on micro level decision making, it can still be applied to aggregate analyses. Yet there is an important tradeoff between aggregated and disaggregated modeling approaches that should be noted. One major advantage of an aggregate analysis is that, compared to a disaggregated approach, it may do a better job of endogenizing price changes and externalities because they will be encompassed within the aggregation. A disadvantage of aggregation is that much of the data's richness and detail may be lost. Both disaggregated and aggregated data can be used in models based on this static conceptual approach. These two situations are described in the following empirical models.

3.3 Empirical Models

3.3.1 Hedonic Zoning Models

Consider the first major type of empirical model. Many studies have attempted to measure the effects of zoning on the price of land or housing (e.g., Mark and Goldberg 1986; McMillen and McDonald 1993; Asabere and Huffman 1997; and Spalatro and Provencher 2001). This type of study generally estimates a hedonic price function in which one or more of the explanatory variables represent zoning policies. They thus attempt to measure the significance of zoning regulations by estimating prices rather than quantities. A typical hedonic price study would hypothesize that the price of housing or land (P) is a function of a vector of housing structural variables ($\vec{S}$), a vector of neighborhood variables ($\vec{N}$), a vector of accessibility variables ($\vec{A}$), a vector of policy variables ($\vec{Z}$), and a normally distributed stochastic error term (ε) (Perman et al. 2003). The values of each of these factors are capitalized into the price of land. In zoning studies, $\vec{Z}$ will represent a vector of zoning restrictions. For example, the equation

$$P_i = \alpha + \vec{S}_i \vec{\beta} + \vec{N}_i \vec{\gamma} + \vec{A}_i \vec{\delta} + \vec{Z}_i \vec{\tau} + \varepsilon_i \tag{4}$$

is a linear hedonic price function that includes all of the factors listed, as well as the intercept term α.[10] Structural variables are factors like number of bedrooms and square footage of living space. Neighborhood variables include factors like crime rate and school quality. Accessibility variables will account for the distance to employment centers and recreation. The coefficient vectors—$\vec{\beta}, \vec{\gamma}, \vec{\delta}$, and $\vec{\tau}$—consist of the implicit prices of each of the variables. They illustrate the change in price that occurs given a marginal change in any individual variable, holding all else constant.

If a zoning variable is statistically significant, then there is evidence that zoning policies can alter the expected returns to specific parcels of land, and therefore can have an effect on the developer's decision to convert to a different use (Irwin, Hsieh, and Libby 2002). The problem, then, is to find the direction and magnitude of this relationship between price and zoning policy, and then examine how this would affect the landowner's decision to convert. Yet as simple as this may sound, these hedonic models have yielded inconsistent results that provide few generally applicable conclusions.

For example, Mark and Goldberg (1986) investigate the argument that zoning is needed to control for negative externalities in the housing market. Zoning laws are generally designed to eliminate the negative externalities that tend to emerge when markedly different land uses are in close proximity to one another. They use time series analysis to estimate individual hedonic equations for each of 24 years in two different neighborhoods (a total of 48 equations). Sets of zoning dummy variables were included to measure the effects of zoning classification (e.g., commercial, industrial, residential,

[10] It is also common to use a double-log or semi-log model specification. If double-log is used, then the coefficient estimates of logarithmically transformed variables can be interpreted as elasticities.

etc.), neighboring and adjacent non residential land uses that could possibly affect a home’s value, and whether or not a rezoning of the parcel had occurred during the period of the study. They test three major hypotheses: (1) zoning classification affects housing price consistently over time, (2) sale prices fall when non single-family uses are permitted, and (3) sale prices rise when rezoning allows for higher densities and different uses.

Results provide little support for the first hypothesis. Zoning classification only sometimes affects sale price, but this is inconsistent over time. The second hypothesis is also not supported. Non single-family uses are shown to have both positive and negative price effects over time. The third hypothesis is not at all supported. The effects of rezoning on housing prices are inconsistent in that coefficients are sometimes estimated as positive and sometimes estimated as negative, depending on the year. Authors provide no explanation of what causes these temporal inconsistencies. In sum, these results are interpreted as meaning that zoning cannot be justified simply as a tool for dealing with negative externalities because these externalities do not exist, and also that zoning sometimes affects housing prices but the size and direction of these effects is inconsistent over time.

In contrast to Mark and Goldberg’s results, Spalatro and Provencher’s (2001) study of minimum frontage zoning on Wisconsin lakefront properties finds that these restrictions do have significant price effects. Minimum frontage zoning limits the subdivision of property by requiring that all lakefront homes have some minimum amount of lakefront. For example, if the minimum frontage restriction is 100 feet, then a property with less than 200 feet of frontage cannot be subdivided.

The authors hypothesize that this restriction induces both an economic loss in value due to its development-constraining effects and an economic gain in value due to its environmental amenity-preserving effects. The development effect is hypothesized to lower the value of land (by decreasing marginal willingness to pay) by restricting the flow of private goods and services otherwise available from the property. The amenity effect is hypothesized to increase homeowner utility. People will have higher willingness to pay when zoning regulations preserve environmental amenities like scenic views and water quality. This increases their willingness to pay for lakefront property and thus the value of the property rises.

Estimation of the hedonic function for Wisconsin lakefront properties illustrated that the development effect was negligible, while gains from the amenity effect were substantial. On balance, then, the minimum frontage zoning policy raised property values. Thus, the authors conclude that if this type of zoning were extended to other areas, it would likely increase their lake front property values as well.

Another hedonic study that found significant price effects from zoning policies was conducted in Charlotte, North Carolina (Jud 1980). Two explanatory dummy variables are defined to measure the relationship between zoning and market price per square foot. The first of these is set equal to one (zero otherwise) if the property is zoned exclusively single-family residential. The second zoning variable is set equal to one (zero otherwise) if the property has a minimum lot size restriction of greater than or equal to 15,000 square feet (0.34 acres).

Results show that the single-family residential zoning variable is significantly and positively correlated with the price of single-family housing. The estimated positive relationship is interpreted as being a result of the security that owners have in knowing with certainty that their neighbor's land use options are also limited. Because most neighboring properties probably fall under the same zoning classification, individuals know that they are shielded from possible future negative externalities. This is analogous to the amenity effect described in the Wisconsin Study in which positive price effects were interpreted as resulting from the environmental preservation stemming from minimum frontage restrictions. However, one might also hypothesize that a negative relationship exists between these two variables because the residential zoning classification could lower property values by limiting the owner's land use options. This would be analogous to the development effect described in the Wisconsin study.

It is also shown that the minimum lot size zoning variable has a significant and negative relationship with price. This is interpreted as being a result of zoning regulators setting minimum lot sizes above the market equilibrium, which leads directly to an increase in the supply of large lot residential property and a corresponding decrease in price. An alternative explanation of this negative relationship could be that the development effect is experienced as a result of the minimum lot size restriction limiting the landowner's development options.

Fischel (1990) has criticized Mark and Goldberg and similar studies because they assume that zoning is an exogenous variable. In an ordinary least squares model, if a right hand side variable is endogenous, then parameter estimates will be biased and inconsistent (Pindyck and Rubinfeld 1998). Realistically, the local politicians that usually make zoning decisions face pressures from a diversity of interest groups including homeowners (both current and potential), developers, and environmentalists.

Those who make zoning policy do not make their decisions in isolation from the local political process. In fact, through the variance process, potential builders can often get certain zoning requirements waived, calling into question their general effectiveness. If zoning is not binding, then it will have a diminished effect on housing prices. For a conceptual model and empirical study of zoning that addresses the endogeneity issue, see Gottlieb and Adelaja (2004).

Another important criticism made by Fischel (1995; 1990) of the Mark and Goldberg study (as well as similar studies finding that zoning does not capitalize into home values) is that it fails to account for the censored-sample problem. In claiming that zoning is not justified because there are no externalities for it to prevent, the authors simply fail to account for those externalities that zoning has already prevented. The study thus does not consider those negative externality producing land uses that zoning actually prevented the construction of, and thus the interpretation that no externalities existed in the first place is probably mistaken.

Fischel (1995) also discusses what were termed the development and amenity effects in the study of Wisconsin lakefront zoning restrictions, although he uses different terminology. The distinction between developed and vacant land is of central importance when examining these price effects. For already developed residential properties, he shows that the positive amenity effect will be greater than the negative development effect because current homeowners probably have no expectation that they will ever change the land use of their property, thus making the development effect negligible. This means that homeowners will in general favor zoning regulations because they increase property values. But the situation is different for undeveloped, vacant properties. Here, landowners have an expectation that they will be able to develop their properties to the most profitable uses. Zoning inherently limits these options, and hence lowers that value of vacant properties via the development effect.

If it is assumed that homeowners are wealth maximizers and that they have enough political clout to dominate other interest groups, then they will use their political strength to support zoning laws that increase the values of their residential properties (and, therefore, zoning is endogenous). The passage of stricter zoning laws will thus favor current homeowners (at least up to some threshold level), but be detrimental to owners of vacant land.

Given the above results, it is possible that zoning laws can contribute to the process of excessive suburbanization commonly known as sprawl. If zoning increases the value of residential properties and decreases the value of vacant properties, then any new would-be developers will be inclined to purchase and develop properties in different jurisdictions in which development has higher net expected returns because zoning regulations are less strict. Potential developers thus have two primary options. They can either attempt to develop properties closer to the central city, or they can develop properties farther away from the central city. When faced with this decision, it seems plausible that developers will choose the latter option because if they choose to develop in the central city they will likely have to incur the costs of demolishing whatever structures are already on the property. If they choose to develop in a more rural setting away from the city, they will not have to face this extra cost. In this way, zoning regulations can encourage decentralization.

As described in section 2.5, zoning regulations such as minimum lot size that restrict development densities can also exacerbate sprawl. This is a simple result of the fact that forcing people to live at low densities by definition spreads them out over more area. This simple phenomenon combined with the more complex one described above makes the statement that certain zoning regulations can lead to excessive suburbanization a strong hypothesis.

Pogodzinski and Sass (1991) and Fischel (1990) both provide surveys and analyses of studies that measure the effects of zoning regulations on housing prices. Fischel specifically points out that empirical economic research on the effects of zoning regulations on price supports neither the conclusion that land use controls are ineffective nor the conclusion that they are unnecessary. Rather, he concludes that they are important constraints and that they do affect housing values. This contrasts with Mark and Goldberg's (1986) finding that zoning only sometimes affects price but supports the findings of the Wisconsin and Charlotte case studies. Both Pogodzinski and Sass and Fischel note the diversity and inconsistency of these hedonic studies and suggest that there is still much research to be done in the area.

3.3.2 Land Use Change Models

A second group of models examines land use explicitly by estimating quantities rather than prices in a land use market. The first model of this type uses disaggregated data. If data is available at the parcel or plot-level, then it is possible to model land use within a discrete choice framework. While this is significantly more data intensive than the aggregated data approach, this type of model is attractive because the unit of observation corresponds to the decision-making unit—the parcel's owner makes all decisions regarding each of his or her properties. A formulation for such a situation is easily derived from the conceptual model provided above (Bell and Irwin 2002). First, we let $R_{krt\,|\,u}$ be composed of a present value factor, V, and a cost of converting factor, C, such that

$$R_{krt\,|\,u} = V_{krt\,|\,u} - C_{krt\,|\,u} \qquad (5)$$

Not all of the variables affecting V and C will be observable to a researcher. Thus, equation 3 can be rewritten in probabilistic terms and to include a stochastic element, η, as follows:

$$\begin{aligned} P(converting) &= P(R_{krt\,|\,u} + \eta_{krt\,|\,u} \geq R_{kjt\,|\,u} + \eta_{kjt\,|\,u}; \forall j = 1,..., J) \\ &= P(\eta_{kjt\,|\,u} - \eta_{krt\,|\,u} \leq R_{krt\,|\,u} - R_{kjt\,|\,u}; \forall j = 1,...J) \end{aligned} \qquad (6)$$

This formulation can then be used to estimate either a probit or logit type land transformation model of the structural form

$$P(converting) = f(X_i \beta) + \varepsilon_i \qquad (7)$$

For the case of binomial[11] choice probit, the function $f(X_i \beta)$ equals the cumulative distribution function of the standard normal distribution. If a logit specification is chosen, then $f(X_i \beta)$ is set equal to $1 \big/ (1 + e^{-X_i \beta})$ where e is the exponential operator. The variable i is an index of cross sectional observations, β is a set of parameters to be estimated, X is a vector of independent variables, and ε is the independently and identically distributed normal error term. The dependent variable here is categorical and represents whether or not a particular parcel was converted to a new use or not.

[11] Both probit and logit can also be formulated as multinomial choices.

Kline and Alig (2001) use a probit model to estimate the probability that forests and farmland in Western Oregon and Western Washington will be converted to developed uses. They find that increasing population pressures will likely lead to continued conversion of land to urban uses, and that this tendency will be more pronounced in areas where farmland and cities are in close proximity to one another. While this analysis was not concerned with zoning regulations, it is easy to see how the model could be extended to examine the effects of such policies on urban growth and development. One could simply redefine the equation as a binary choice between converting to a developed residential use and not converting. Zoning policies would then be included as explanatory variables.

Carrion and Irwin (2002) use a similar model for just this purpose. Specifically, they attempt to explain sprawl development at the urban-rural fringe as a function of zoning. They introduce an explanatory dummy variable representing whether or not each parcel is subject to a minimum lot size zoning restriction of greater than or equal to three acres (130,680 square feet). After implementing a spatial probit model, the authors find that their zoning policy variable is negative and significant. This implies that residentially zoned parcels with a minimum lot size of greater than three acres are less likely to be converted to developed uses. This is consistent with results from the Charlotte hedonic model in which the negative relationship between price and presence of a minimum lot size restriction implies lower expected returns to those parcels subject to minimum lot size restrictions, thus making undeveloped properties less likely to be developed.

Carrion and Irwin also show that, due to the uncoordinated nature of land use planning among local governments, it is possible that spillover effects could exist among and between communities. For example, if development in one community is deterred by strict local zoning policies, new developments may simply occur in neighboring communities that have less stringent land use controls. Given the variety of zoning ordinances that exist at a local level, it is probably a strong hypothesis that these spillover effects exist.

Recently, a third type of zoning study, based on the land use share model, has been cited in the literature (e.g., Irwin, Hsieh, and Libby 2002). This type of model estimates the significance of various factors in determining the proportion or share of land that is allocated to various uses. Because the land use variable is a proportion, this type of model is very useful in situations where only aggregate land use data is available. The county is thus a common level of investigation. This model type is based on a logarithmic transformation of the already described logit model. The binomial specification of the land use share model is derived from the logit model as follows

$$P_i = \frac{1}{1+e^{-X_i\beta}} \qquad (8)$$

Here, P_i is the probability that a given piece of land is in a given use in jurisdiction i.

Some simplification followed by the logarithmic transformation yields

$$\ln\left(\frac{P_i}{1-P_i}\right) = X_i\beta \qquad (9)$$

We then substitute the observed share, y_i, for the expected share, P_i, and add a stochastic error term ε_i such that

$$\ln\left(\frac{y_i}{1-y_i}\right) = X_i\beta + \varepsilon_i \qquad (10)$$

The dependent variable is thus the natural logarithm of the ratio of the share of land in use y_i to the share of land in use $(1-y_i)$. This binomial land use share model is easily extendable to the multinomial case in which more than two land uses are considered. A major advantage of this specification is that it is linear in parameters so estimation proceeds via ordinary least square (OLS) rather than by maximum likelihood as is required in the nonlinear probit and logit models. It is also easier to correct for autocorrelation (both spatial and non-spatial) and heteroskedasticity with a linear model specification.

In the standard logit model from which the land use share model is derived, estimated coefficients are difficult to interpret. It is therefore common to compute marginal effects by taking the partial derivative of the expected value of the dependent variable with respect to each explanatory variable ($\partial E(DEP)/\partial X_i$). For the binomial logit model, this is then interpreted as the effect of a marginal change in the explanatory variable on the probability that the dependent variable is equal to one (Pindyck and Rubinfeld 1998).

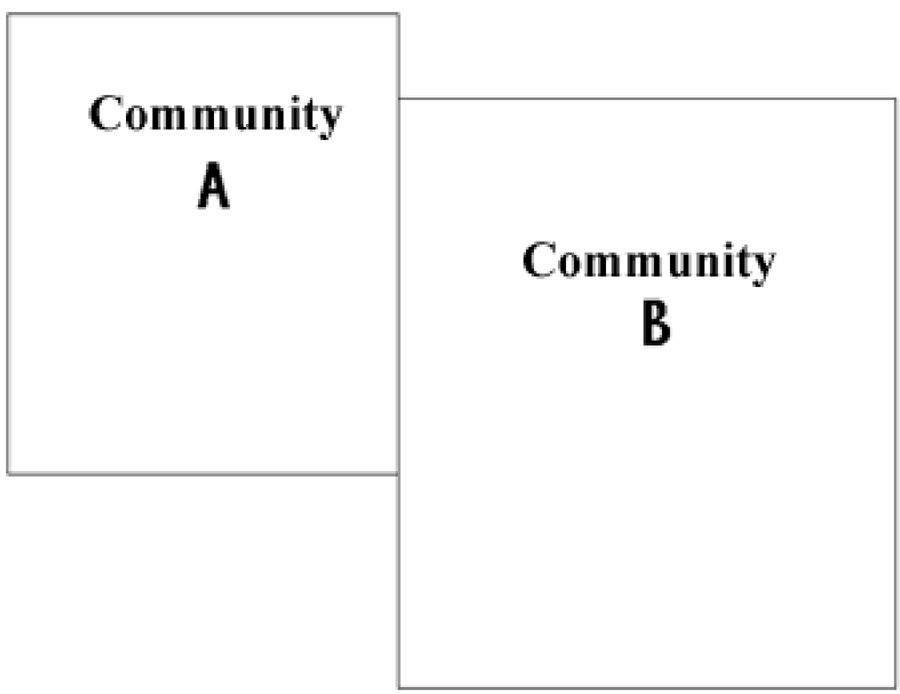
In the land use share model, y_i can be interpreted as a proxy for the probability of development that is captured by the logit model. It is therefore necessary to make an analogous adjustment if one wishes to know the marginal effects of a change in any X_i on y_i. In both models, therefore, we are ultimately concerned with how changes in the explanatory variables affect the likelihood of y_i. For the binomial land use share model, these marginal effects can be expressed as $\frac{dy_i}{dX_i} = (1-\hat{y})(\hat{y})\beta$ where $\hat{y}$ is the predicted value of y calculated at the means of all explanatory variables (Greene 1993). The β's are thus proportional to the marginal change in the likelihood of y_i (i.e., dy_i) because they are all multiplied by the same constant of proportionality. For example, if β_1 is twice as large as β_2, then a marginal increase in X_1 increases the probability of development by twice as much as a marginal increase in X_2.

Plantinga, Mauldin, and Miller (1999) use such a binomial land use share model to estimate the costs of carbon sequestration in Maine, South Carolina, and Wisconsin. Other studies (Wu and Segerson 1995; Hardie and Parks 1997; Miller and Plantinga 1999) use similar model specifications to examine a diversity of land use issues. Again, it is easy to see how zoning policy variables could be introduced into their models.

Irwin, Hsieh, and Libby (2002) conduct such an analysis. They estimate a land use share model using county level data from Ohio to examine the question of how rural zoning affects the relative allocation of urban to undeveloped land, i.e., $y_i/(1-y_i)$ where y_i is equal to the share of developed acreage in each county and $1-y_i$ is the share of undeveloped acreage. Taking the natural logarithm simply represents a monotonic transformation of this variable. Rural zoning is defined as zoning that is controlled at the county and township level, as opposed to the municipal level (city and village). Two explanatory zoning variables are defined. They represent (1) the proportion of land in each county that is governed by township level zoning regulations and (2) the proportion of land in each county that is governed by county level zoning regulations. For example, for variable (1) if 40 percent of the land in a county is under township jurisdiction, then the variable is specified as "0.4." The authors also specifically consider the possibility of the occurrence of spillover effects in which growth is pushed from one community to another as a result of zoning policies. To capture these effects, two additional zoning variables are included. The first is a weighted average proportion of land in *county zoning* from neighboring counties. The second is a weighted average proportion of land in *township zoning* from neighboring counties.

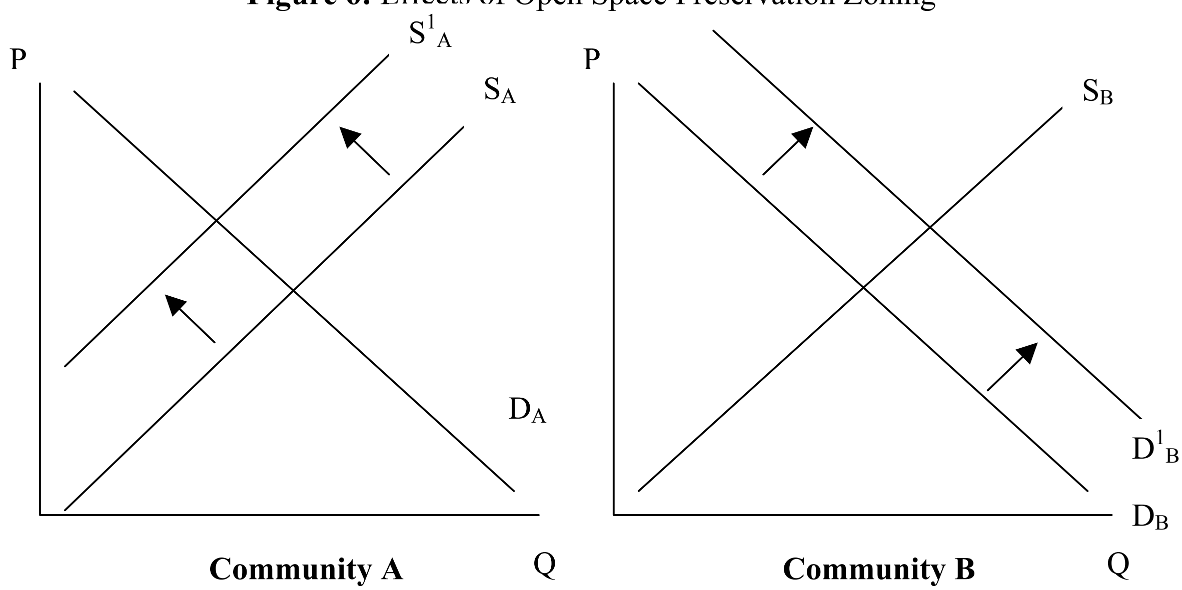
In considering the possibility of spillover effects among neighboring communities, the authors posit a simple model in which two jurisdictions, A and B, are neighbors (see Figure 5). Initially, there is no zoning in either jurisdiction, and the markets for urban land in each are in equilibrium. Zoning regulations can alter these equilibria by causing demand shifts, supply shifts, or a combination of the two.

Figure 5: Neighboring Communities



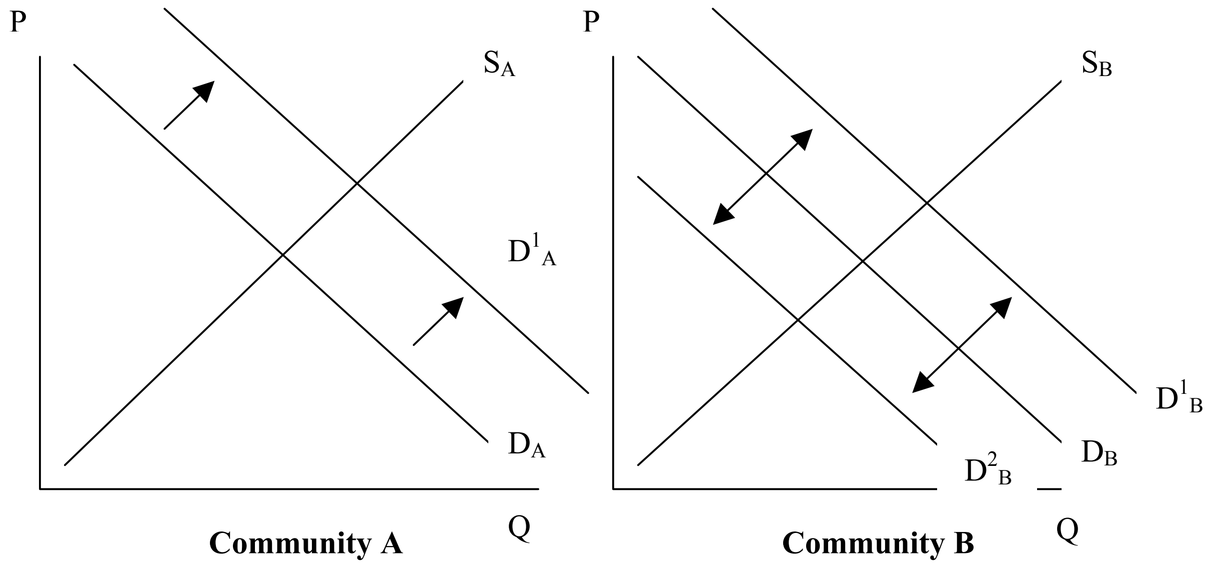
They then consider the effects of two different types of zoning in community A. First, open space preservation zoning that restricts development is considered in Figure 6. Clearly, such a policy will decrease the supply of land in A, thus increasing price and decreasing quantity of land. Due to substitution effects, this supply constriction in A should lead to a demand increase in B as potential homeowners move to where regulations are least stringent. This would also increase the price of land in jurisdiction B as well as the quantity of land.

Figure 6: Effects of Open Space Preservation Zoning



A second policy, nuisance zoning, could also be implemented in community A with the goal of separating incompatible uses and thereby eliminating negative externalities. This situation, shown in Figure 7, should increase the demand for urban land in A. However, prices in A will rise as a result, and price substitution could push potential buyers into B, thus shifting the demand curve in B. It is also possible that the increased amenity values that result from the nuisance zoning in A could be greater than this price substitution effect. Because this cross-amenity effect counters the price substitution effect, the net result is ambiguous.

Figure 7: Effects of Nuisance Zoning



There is also another possibility not discussed in the above analysis. Consider a situation in which A has a relatively less restrictive zoning policy than B. *Ceteris paribus*, demand for urban land should be relatively higher in A than in B. The resulting development in A (including jobs, shopping, etc.) could then make living near A, but not necessarily in A, an attractive option regardless of land prices. Hence, the quantity of urban land in B may also increase.

The major empirical finding of the Irwin, Hsieh and Libby study, consistent with the nuisance zoning policy above, is that the existence of township level zoning increases the relative allocation of urban to undeveloped land both in the county and in neighboring counties—meaning both the township level zoning variable and the weighted average proportion of land in township zoning variable were statistically significant. The implication of this is that township zoning encourages urbanization locally (within the county) and also creates spillover effects whereby increased development occurs in neighboring counties. This result corroborates the claim of Carrion and Irwin above that zoning can create spillover effects among communities. The study also finds that county level zoning does not have a statistically significant effect on the relative allocation of urban to undeveloped land.

Irwin, Hsieh, and Libby also investigate the possibility that their model is spatially autocorrelated. This means that the observations have correlated error terms across space. This is a direct violation of the Gauss-Markov Theorem, which states that the OLS error term has constant variance for all observations (Pindyck and Rubinfeld 1998). Autocorrelation is generally associated with time-series analysis rather than cross-sectional analysis. However, spatial autocorrelation of the OLS error term can be a serious problem in cross-sectional models because factors not observed by the researcher are likely to affect neighboring locations in a systematic manner (Anselin and Bera 1998, p. 239). Essentially, this means that locations tend to be surrounded by neighbors with very similar characteristics (positive spatial autocorrelation) or with very dissimilar characteristics (negative spatial autocorrelation). The authors test for this possibility and fail to reject the null hypothesis of no spatial autocorrelation.

In an OLS model, both spatial and non-spatial autocorrelation lead to inefficient but unbiased and consistent parameter estimates (Anselin 1988). This means that variance is not minimized and therefore parameter estimates are not the best linear unbiased estimators that are assumed by OLS. Another consequence is that the regression standard errors will be biased, thus invalidating hypothesis testing.

In order to correct the problem, a spatial weights matrix must first be constructed. The spatial weights matrix—W—is square, positive and symmetric. Each column and row represents an observation. The matrix elements, w_{ij}, are equal to 1 if the two locations are neighbors, and equal to zero if they are not. It is convention to set the diagonal elements equal to zero (LeSage 1999). At this point it becomes necessary to define what constitutes a "neighbor." Often those locations that share a border are somewhat arbitrarily defined as neighbors, although other specifications are possible.

The next step is to define the autoregressive error structure. For example,

$$y_i = X_i\beta + \varepsilon \text{, where } \varepsilon = \lambda W\varepsilon + \mu \qquad (11)$$

is a first order autoregressive error process where λ is an estimated spatial autocorrelation parameter, ε is a non-independent error term, and μ is an independently and identically distributed error term. If λ is equal to zero then clearly no autocorrelation is present.

Moran's I is one common statistic used to test for the presence of spatial autocorrelation. It is given as

$$I = \frac{N}{S_0}\left(\frac{e'We}{e'e}\right) \text{, where } S_0 = \sum_i \sum_j w_{ij} \qquad (12)$$

where e is a vector of OLS residuals, N is the number of observations, S_0 is a standardization factor, and W is the spatial weights matrix (Anselin and Bera 1998). Once a value for I is obtained, an asymptotically normal standardized z-value is calculated as

$$Z_{score} = \frac{I - E(I)}{std(I)} \text{ where } E(I) \approx -\frac{1}{N-1} \text{ and } std(I) = \sqrt{\frac{2}{\sum_i \sum_j w_{ij}}} \qquad (13)$$

where I is the estimated Moran statistic, $E(I)$ is its expected value, and $std(I)$ is its standard deviation. If the Z score is greater than 1.96, then there is evidence of spatial autocorrelation at the 95 percent confidence level.

An iterative procedure is commonly used to correct the model when there is evidence of spatial autocorrelation. First, the model $\beta's$ are estimated via OLS and the residuals, $\hat{\varepsilon}_i$, are calculated. The second step is to find the value for λ that maximizes the concentrated log-likelihood function:[12]

$$L_c = C - \frac{N}{2}\ln\left[\frac{\varepsilon'\Omega(\lambda)^{-1}\varepsilon}{N}\right] + \ln|I - \lambda W| \qquad (14)$$

where $\Omega(\lambda) = [(I - \lambda W)'(I - \lambda W)]^{-1}$

$\sigma^2\Omega(\lambda)$ is a nonspherical error covariance matrix. The third step is to take the λ just estimated and use it to reestimate the OLS model. These three steps are repeated until λ converges to its actual value (Anselin 1988 p. 183).

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[12] The concentrated log-likelihood function is derived from the log-likelihood function:

$$L = -\frac{N}{2}\ln(\pi) - \frac{N}{2}\ln(\sigma^2) + \ln|I - \lambda W| - \frac{(y - X\beta)'\Omega(\lambda)^{-1}(y - X\beta)}{2\sigma^2}$$

Under OLS, $\Omega(\lambda) = I$ (because $\lambda = 0$) and the above log-likelihood function reverts to the normal OLS log-likelihood function.

Chapter 4 Model Specification

4.1 Land Use Share Model

A land use share model similar to those discussed in Chapter 3 will be used to examine the effects of minimum lot size zoning restrictions on land use change in Oakland County, Michigan. Two major improvements are made on the specifications of previous models. First, the dependent variable will explicitly consider the change in developed acreage over a discrete period of time (1990-2000), rather than simply considering cumulative development to date as a function of only current period variables as is done in Irwin, Hsieh, and Libby (2002). Second, rather than using dummy variables, as is common in econometric models of zoning, or some other simplified measure of zoning, a weighted average minimum lot size variable will be used to examine the effects of lot size zoning restrictions on land development. This is an improvement because a weighted average will capture more information than a simple binary dummy variable. The use of a weighted average is also consistent with the specification of zoning spillover variables used in Irwin, Hsieh, and Libby.

Once again, the land use share model is generally specified as:

$$\ln\left(\frac{y_i}{1-y_i}\right) = X_i\beta + \varepsilon_i \qquad (15)$$

where X_i is a matrix of observed explanatory data, β is a vector of coefficients to be estimated, and ε_i is a normally distributed stochastic error term. y_i is defined as the change in developed acres from 1990 to 2000 divided by total undeveloped but developable[13] acreage over that same time for all observations $i = 1,2,3,...N$. In equation form,

$$y_i = \frac{L_{2000} - L_{1990}}{\overline{L}} = \frac{\Delta L}{\overline{L}} \qquad (16)$$

where L_{2000} and L_{1990} are total acres developed as of 2000 and 1990, respectively, and $\overline{L}$ is the total amount of land that is undeveloped but developable as of 1990. More succinctly, y_i is thus the share of developable acreage that was developed from 1990 to 2000. Given this the expression $y_i/(1-y_i)$ reduces to

$$\frac{y_i}{1-y_i} = \frac{\Delta L}{\overline{L} - \Delta L} \qquad (17)$$

Therefore, the expression $y_i/(1-y_i)$ is simply the ratio of the change in developed acres from 1990-2000 to acres of developable land not developed over the same time period. By introducing the element of change into this model, it is now more akin to the land transformation model than it is to the share models described in Chapter 3.

4.2 Explanatory Variables

The dependent variable is hypothesized to be a function of economic, demographic, and geographic variables, as well as push/pull factors and zoning policy. In general:

$$\ln\left(\frac{y_i}{1-y_i}\right) = f\,(\text{Income, School Quality, Crime, Taxes, Commute Time, Proximity to Population Center, Population Density, Minimum Lot Size}) \qquad (18)$$

[13] Land is "developable," meaning that areas that are inherently undeveloped such as lakes and rivers are factored out.

Income may be positively correlated with land development because with more money people can afford to purchase larger properties and build more structures. However, a negative relationship could also result if areas of high income use their affluence to prevent development from occurring in their neighborhoods. Here, the interpretation is that more affluent individuals may use their money to maintain the *status quo* (and thereby protect any positive amenity values that have been capitalized into their property values) in their communities by preventing development.

School quality is hypothesized to positively affect development because quality education systems are likely to attract new residents, and therefore new development, to a given area. This is one of the "pull factors" described in Chapter 2. It is also of note that the education system can be a "push factor" when it is of poor quality in a community. Thus, areas with poor education systems will experience less growth, *ceteris paribus*, than areas with high quality education systems.

Crime rates are also a "push-pull factor" in that low crime rates are hypothesized to increase development while high crime rates are hypothesized to slow development. Hence, theory suggests a negative relationship between crime rates and development.

The property tax rate is a third quality of life variable that probably affects an individual's decision of where to live. One hypothesis is that, *ceteris paribus,* high taxes and high levels of development are related because, in the long term, rapidly developing areas will need more revenue to provide new services (with high, up front fixed costs) to their citizens that were not necessary previous to the rapid development. For example, an already highly developed area is likely to have its own police and fire departments already established, while a newly developing area may not. Alternatively, it may simply be that high taxes are a disincentive to growth, while low taxes are an incentive. Given this hypothesis, less development will occur in areas with high taxes.

Average commute time is also hypothesized to affect development. A negative relationship would signify that areas with shorter average commutes are developing faster. This would be consistent with the theory that time spent commuting is an opportunity cost of living far from jobs, and that individuals consider this when they make location decisions.

Distance to population center may also affect development. A negative relationship between distance to population center and development could be observed because as one locates further from the city, costs of travel to city jobs and to urban amenities increase. This is consistent with the monocentric city model in which development occurs in concentric rings around the center city—prime land close to the city is developed first and used for high valued commercial uses while land farther away is used primarily for agriculture.

While both the commuting variable and distance to population center variable are measures of proximity, they are different in two important ways. First, the commute variable is measured in time while the distance variable is measured in miles. Therefore, the commute variable accounts for traffic congestion issues while distance to population center does not. Second, distance to population center is based on the assumption that people travel mostly between their residences and some city center. But in modern society, this is often not the case, as there tend to be multiple centers of population and jobs to which people frequently travel.

Population density should also affect development. A negative relationship (less density leads to more development) is hypothesized here because areas with greater population density are generally more developed that other areas, and therefore they have less potential for further development than other, less developed areas. A negative relationship is also consistent with the hypothesis that individuals prefer to move to and live in areas with lower population densities.

It is common in land use models to include measures of soil quality as explanatory variables. Soil quality is considered to be a proxy for the opportunity cost of using land for developed uses. Generally, soil quality is negatively correlated with development. This is because a property's highest valued use is more likely to be in agriculture if it has highly productive soils. In Irwin, Hsieh, and Libby (2002), soil quality was measured by the Department of Agriculture's Land Capability Class. Consistent with the theory, soil quality was negatively correlated with the level of development.

In Oakland County, however, soil quality is probably irrelevant to the overall level of development. This is simply because there is little land in agricultural use left in the county. In fact, only 4.4 percent of Oakland's total land area is in agricultural use, and most of this is located in the outlying townships (*Oakland County Land Use Statistics* 2002). It is likely that at some point in the past, soil quality would have been an important factor, but this has been eclipsed by the rising value of land for developed uses. For this reason, no measure of soil quality is included in the model.

The final variable in the model, the average minimum lot size in each community, is the focus of this analysis. What, then, would be the hypothesized relationship between

y_i (the share, or percentage, of developable land that is developed from 1990-2000) and average minimum lot size? Figure 4 above suggests that this relationship should be "U-shaped" and quadratic. Thus, at first, as minimum lot sizes increase, y_i should decrease at a decreasing rate. But then, at some level of minimum lot size to be estimated, y_i should begin to increase at an increasing rate. For this reason, a squared average minimum lot size explanatory variable is added in order to allow for a quadratic relationship. The point at which this curve is minimized would clearly be an important policy issue.

4.3 Post Testing

In any type of model in which the unit of analysis is politically defined (e.g., variables defined at the city, village, and township level), one would expect heteroskedasticity to be a problem. This is because government units with jurisdictions of unequal sizes are likely to produce non-constant error variances (Pindyck and Rubinfeld 1998). Therefore, the initial model will be tested for heteroskedasticity using White's Test. This is a very general test in that it allows the researcher to test the null hypothesis of no heteroskedasticity (i.e., homoskedasticity) without specifying what variable or variables are causing the problem. If the null hypothesis of homoskedasticity is rejected, then the model will be re-estimated using White's heteroskedasticity consistent covariance estimator.

Because of the relatively small sample size, the central limit theorem might not apply. If this is the case, then the t-test would be inappropriate for hypothesis testing if the residuals are not normally distributed. Therefore the model will also be tested for non-normality of residuals using the Jarque-Bera Test (JB Test) (1980). This is a joint test of the third and forth central moments (i.e., skewness and kurtosis, respectively). It is distributed chi square with two degrees of freedom, and has an expected value of two under the null hypothesis of normality.[14]

The model will then be tested for the presence of spatial autocorrelation using Moran's I statistic (equation 12) as described in Chapter 3. The spatial weights matrix, W, is specified such that the $w_{ij}'s$ are equal to 1 if the communities share a border of any length or meet at a vertex, and equal to zero otherwise. The Z score will then be calculated and interpreted. If the model tests positive for spatial autocorrelation, it will be corrected using the iterative maximum likelihood algorithm described in Chapter 3. If the model tests positive for both heteroskedasticity and spatial autocorrelation, then a robust covariance estimator will be implemented in addition to the iterative maximum likelihood method.

[14] Specifically, the test statistic is calculated as $J\hat{B} = \left[\frac{skewness^2}{6/N} + \frac{(kurtosis-3)^2}{24/N} \right]$, where N is the number of observations.

Chapter 5 Data

5.1 Dependent Variable—Land Consumption

The South Eastern Michigan Council of Governments (SEMCOG) has compiled land use and land cover data for the seven counties in the SEMCOG region for the years 1990 and 2000 (2004). Raw data from the Michigan Resource Inventory System (MIRIS) is updated by SEMCOG and tabulated into charts. The major land use categories included in the data set are: residential, under development, commercial/office/institutional, industrial, transportation, communication/utility, extractive/barren, cultural/outdoor recreation/cemetery, agricultural land/farmsteads, grass and shrub land, forest land, water, and wetland. These categories and their sub-categories are listed in Appendix Table 5. Appendix Table 6 gives the year 1990 and 2000 acreage in each category for the entire county.

Tabulated land use data is available for both 1990 and 2000 for 59 of the 61 cities, villages, and townships in Oakland County. This data was used to calculate the dependent variable as is described in Chapter 4. Using the land use and land cover categories listed above, the data was first aggregated into three groups—developed land, undeveloped land, and undevelopable land. The developed land group includes all land categorized as residential, under development, commercial/office/institutional, industrial, transportation, communication/utility, and extractive/barren. In addition, two of the three sub-categories of cultural/outdoor recreation/cemetery, specifically cemetery and public assembly/cultural/sports facility, were also included as developed uses. All other categories except water and wetland are considered undeveloped uses. The water and wetland categories are considered undevelopable. For the case of wetlands, this is because state and federal legislation prevents most infill of wetlands. Water, of course, is inherently not developable.[15] This is significant because approximately 6 percent (some 35,000 acres) of Oakland County's total area is covered by water.

Three of the communities—Ferndale, Keego Harbor, and Sylvan Lake—had to be removed from the data set because the change in acres developed from 1990 to 2000 was negative. Changes in developed acres for these three communities were only slightly below zero, and probably reflect the demolishing of a few developed uses. Because the natural logarithm of a negative number is undefined, these three observations were dropped. Also, the two communities that SEMCOG does not provide land use data for—specifically Novi Township and Southfield Township—were dropped due to lack of data.

5.2 Explanatory Control Variables

Various economic, geographic and demographic variables are hypothesized to have an effect on the rate of land development in any given area. The control variables included in this analysis are: median household income, per pupil spending, criminal offenses committed per capita, local tax burden, mean travel time to work, distance to population center (Detroit), and population density. Brief descriptions and summary statistics for these and all other variables in the model appear in Table 9.

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[15] It may be that the barren and extractive land use categories are also inherently undevelopable. However, Appendix Table 6 shows that these two uses are relatively small in Oakland County, and including them in the undevelopable category did not change the model results significantly.

Table 9: Summary of Data

Variable Abbreviation	Variable Description	Mean	Standard Deviation	Min/Max
DEP	Natural log of the ratio of the % of acres developed from 1990-2000 to the % of acres not developed	-1.56	1.75	-7.26/2.43
TAXBURD	Average Certified Tax Rate in Mills Times Average Median Housing Value, 1990-2000	1298.3	1036.91	249.49/5298.51
EDUC	Per Pupil Spending ($), 2002	8,795.09	1374.3	6,954/1,1645
CRIME	Index Offenses Per Capita, 2000	0.02	0.01	0.004/0.07
POPDEN	People Per Square Mile, Average of 1990 and 2000	2,324.19	1,910.44	102.86/7469.29
TRAVTIME	Mean Travel Time to Work, Average of 1990 and 2000	26.16	3.99	20.25/34.25
DISTDET	Driving Distance to Detroit in Miles	32.42	12.57	10.6/56.6
HINC	Median Household Income ($), Average of 1990 and 2000	67,281.86	27,541.07	22,766.12/184,395.70
WAMLS	Weighted Average Minimum Lot Size, Acres	51,261.89	79,105.1	4,386.86/312,816.8

For N = 54 observations.

Median household income data was acquired from both the 1990 and the 2000 US Census (*U.S. Census Fact Sheet* 2000). Median household income figures for 2000 are based on 1999 income figures and therefore are calculated in year 1999 dollars. Median household income figures for 1990 are similarly reported by the Census in 1989 dollars. In calculating the variable, the 1989 data was first inflated to 1999 dollars using the consumer price index. This was then averaged with the 1999 figures to form average median household income for the time period 1990-2000.

Similarly, population density was calculated for both 1990 and 2000 from the US Census (*U.S. Census Fact Sheet* 2000). These were then averaged to compute average population density from 1990-2000. Area figures for each community come from the GIS based Oakland County Land Use Statistics (*Oakland County Land Use Statistics* 2002).

The distance to population center variable was calculated as the driving distance in miles from each community's center to Downtown Detroit. This was computed by using Microsoft Streets and Trips 2002 software. This program is essentially an electronic road atlas that easily provides data on driving distance by major roads between any two points in the database. When only the name of the community is specified (and not any specific address) the program automatically makes its calculations from the geographic center of each community. Its algorithm chooses the route from each community's center to Downtown Detroit that has the shortest drive time.

Data describing mean travel time to work (in minutes) was obtained from both the 1990 and 2000 United States Census (*U.S. Census Fact Sheet* 2000). These were averaged to obtain mean travel time to work from 1990 to 2000. This variable should effectively capture two things that the distance to Detroit variable does not. First, because the unit of measure is time, it accounts for traffic congestion. Second, it also accounts for the fact that many individuals that drive to work do not work in Detroit.

A two variable system of categorical variables describing whether each community is a township, city, or village was also constructed in order to control for any variance that may result from such classifications. The first variable--labeled CTYDUM for City Dummy--equals 1 if the community is a city and 0 otherwise. The second variable--labeled VILDUM for Village Dummy--similarly equals 1 if the community is a village and 0 otherwise. Therefore, if both categorical variables equal 0, the community is a township.

It is also important to control for certain aspects of quality of life. Specifically, the model includes variables that account for the effects of crime rates, the quality of elementary education, and the level of taxation. These variables represent some of the push and pull factors commonly hypothesized to affect urban growth patterns.

The Michigan Uniform Crime Report publishes crime statistics by law enforcement agency (i.e., police department) that illustrate both the number of offenses committed and the number of arrests made in each jurisdiction (Michigan State Police. 2001). They compute an "index" that is the sum of all offenses for murder, rape, robbery, aggravated assault, burglary, larceny, motor vehicle theft, and arson. The offenses index for the year 2000 was used for this analysis.

The problem with the Uniform Crime Report index data is that all communities do not have their own police force. Some share law enforcement agencies and some are covered by the County Sheriff's Office or the Michigan State Police (MSP). This means that the observations on the crime data do not match up with the number of communities. For example, the MSP have jurisdiction over three townships—Groveland, Holly, and Rose—but only one number, the sum of the offenses for the three townships, is reported. Thus, both the Michigan State Police and the Oakland County Sheriff's Office were contacted in order to obtain disaggregations of the index number reported for each.

Once these disaggregations were obtained, the index was divided by year 2000 population in order to compute index offenses per capita. Thus, year 2000 index offenses per capita is the crime rate variable.[16]

Data on per pupil spending for 2002 is available online from Standard and Poor's (*School Evaluation Services* 2002).[17] This service reports per pupil spending and other Michigan educational data by Michigan school district.

In Oakland County, school district and community borders are not identical. In fact, there are more communities than school districts, and many communities send students to more than one school district. This presents a problem because the rest of the data set is reported by community, and therefore the per pupil spending data does not match up properly with the observations of the other variables. This problem was overcome by taking the average per pupil spending across the school districts that each community has students enrolled in. For example, if one community sends students to four different school districts, then the education variable is the average per pupil spending in these four districts. This assumes implicitly that the communities send equal numbers of students to each school district. This is probably not an accurate assumption, but disaggregated enrollment figures were not available. Theoretically, one would want to weight the per pupil spending data by the percent of total students attending each school district.

Tax rate data was acquired from both the 1990 and 2000 Michigan *Ad Valorem* Property Tax Levy Report. This report provides *ad valorem* rates in Michigan for

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[16] An average of 1990 and 2000 index offenses per capita would be preferable to the 2000 index alone. However, a disaggregation of the 1990 Uniform Crime Report data set was not available from the Oakland County Sheriff's Department, and therefore year 2000 data was used alone.
[17] Similar to the CRIME variable, no per pupil spending data was readily available for the years 1990 to 2001, and therefore year 2002 data was used.

county, township, city, and village certified taxes as well as for certified taxes based upon school district. These rates are expressed in mills. Township residents pay a township tax rate, city residents pay a city tax rate, and village residents pay both a village tax rate and the township tax rate. These tax rates are known as township certified taxes, city certified taxes, and village certified taxes, respectively. On top of this, all residents pay a tax based upon the school district to which they belong.

The tax burden variable was constructed as follows. First, because county tax rates are equal across the sample, they were not included in the tax variable. Taxes based upon school district affiliation were also not included in the variable. This is because this rate varies within each community in the sample.[18] For example, the City of Farmington Hills sends students to three different school districts, each of which has a different tax rate. Therefore, the average of the certified tax rate for each community for the years 1990 and 2000 is first computed. Next, a measure of housing value is computed from U.S. Census figures by averaging the 2000 median housing value with the 1990 median housing value inflated to year 2000 dollars. This is then multiplied by the average tax rate to obtain a measure of average tax burden for each community.

5.3 Explanatory Zoning Variables

The zoning ordinances of 60 Oakland County communities are available for examination from the county government. By photocopying the "schedule of regulations" sections and any similar relevant sections from these ordinances, data on minimum lot size restrictions was obtained. This data was then compiled into a spreadsheet to facilitate analysis.

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[18] Including this school tax variable could also make the tax variable overlap with the education variable discussed above.

There were several problems with the zoning data that led two of the observations to be excluded from the model. First, the City of Lake Angelus does not have any minimum lot size restrictions in its zoning ordinance. It chooses to regulate density by other means, and therefore it was discarded from the model. Second, the Village of Leonard was excluded because no up to date zoning map was available. Because Ferndale, Keego Harbor, Sylvan Lake, Novi Township, and Southfield Township were excluded due to problems with the dependent variable, this leaves 54 total observations with which to conduct the statistical analysis.

Most of these remaining 54 communities have more than one single-family residential zoning district. Each of these districts has its own minimum lot size. Non-residentially developed areas, such as commercial and industrial districts, are not typically regulated by lot size, and therefore the minimum lot size variable is based entirely on single-family residential properties.

For example, a community may have an “R1 District” for low-density single-family housing, an “R2 District” for medium-density single-family housing, and an “R3 District” for high-density single-family housing.[19] Thus, it is necessary to transform the data to create a weighted average of the minimum lot sizes in each community. The theoretically proper weight is the percentage of total single-family land area zoned for each classification. For instance, 45 percent of available single-family land may be zoned for R1, 30 percent for R2, and 25 percent for R3. Appendix Table 7 lists the various minimum lot sizes in each community.

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[19] The number of residential districts in Oakland County communities varies between 1 and 10. The names used to described the zoning districts in each community, e.g., R1 and R2, vary greatly from community to community.

These weights were acquired using several methods. First, each community was contacted in order to find out how many acres were included in each single-family residential zoning classification. These numbers were then used to calculate the percentage of total single-family land area in each zoning classification. In general, only those communities with GIS based zoning maps were able to provide this information. In those cases where this data was not directly available from the community, paper copies of zoning maps were acquired. By overlaying a transparent grid onto these maps, the necessary weights were estimated. These weights were then used to calculate the weighted average, the variance, and the standard deviation of minimum lot sizes in each community.

Chapter 6 Analysis

6.1 Regression Output

The land use share model regression output is reported in Table 10 and includes coefficient estimates, standard errors, t-statistics, and p-values. Logarithmic transformations were used on the TAX, TRAVTIME and HINC variables because, when plotted against the dependent variable, they appeared to have a log-linear relationship. Therefore, the coefficients for these three variables can be interpreted as elasticities. All other explanatory variables are in level form, and their coefficients are interpreted, ceteris *paribus*, as the change in the natural logarithm of the share ratio, $y_i/(1-y_i)$, resulting from a one-unit change in the explanatory variable.

Table 10: Regression Output

Variable Name	Estimated Coefficient*	Standard Error	t-Statistic	P-Value
Intercept	7.52	13.8	0.54	0.59
LNTAXBURD	0.34	0.42	0.80	0.43
EDUC	0.00082	0.00023	3.57	0.001
CRIME	-12.78	16.41	-0.78	0.44
POPDEN	-0.00096	0.00023	-4.23	0.00
LNTRAVTIME	9.07	2.35	3.85	0.00
DISTDET	-0.031	0.033	-0.93	0.36
LNHINC	-3.93	1.15	-3.40	0.001
WAMLS	-4.02e-5	1.19e-5	-3.39	0.002
$WAMLS^2$	8.96e-11	3.72e-11	2.41	0.02

*To find the mean marginal effects, dy/dX_i, as discussed in Chapter 3.3.2, multiply each coefficient estimate by $\hat{y}(1-\hat{y}) = 0.151$.

$N = 54$, $R^2 = 0.62$, $\bar{R}^2 = 0.54$, Model $F = 7.85$

Overall, the fit of the model is good. The R^2 is equal to 0.62 and the adjusted R^2 is 0.54. The model F statistic is also significant at the one percent level (p-value = 0.000), and hence the hypothesis that as a whole the explanatory variables have zero explanatory power is rejected. Six of the nine explanatory variables are significant at the five percent level. Of these six, five are significant at the one percent level as well.

Before interpreting the estimated coefficients, it should be noted that several explanatory variables discussed in previous chapters are missing from the model. First, an attempt was made to measure any possible zoning spillover effects that may exist in Oakland County. These effects were discussed at length in Chapter 3. Both of these variables, SPILL and SPILL^2 respectively, were not included in the final regression output (Table 10) because they were not statistically significant. For each community in the sample, this variable consisted of a weighted average of the WAMLS variables of each neighboring community. Neighbors were defined as they were when the spatial weights matrix was specified—any community that meets another at a vertex or a border is considered a neighbor. Weights were constructed as the percent of total land area in single-family residential use in each neighboring community. A squared term was also included on the hypothesis that a quadratic relationship similar to that estimated for WAMLS may exist. If spillovers exist, then the minimum lot size restrictions of neighboring communities should have an affect on the dependent variable. The regression output with these variables included appears in Appendix Table 8.

The two categorical variables (CTYDUM and VILDUM) described in Chapter 5 are also noticeably missing from the model output. These two variables were dropped because they were statistically insignificant and therefore added little to the model specification. The same is also true of the standard deviation and variance variables that were calculated from the minimum lot size data. Both were insignificant, and thus one can conclude that the amount that minimum lot sizes are dispersed about the mean does not have a statistically significant effect on land development.

We fail to reject the null hypothesis of no heteroskedasticity. Specifically, White's general heteroskedasticity statistic yielded a p-value of 0.44, and therefore there is no need to implement White's heteroskedasticity consistent covariance correction.

The model also tested negative for spatial autocorrelation. Specifically, Moran's I was computed as 0.084 (expected value of 0). This produced a p-value of 0.93. Given this value, we fail to reject the null hypothesis of no spatial autocorrelation. It was therefore unnecessary to correct for spatial autocorrelation in the model's error term.

The Jarque-Bera test results indicate that the model residuals are approximately normally distributed. Specifically, skewness and kurtosis of the residuals were estimated as 0.42 and 2.88, respectively (the expected values of the third and forth moment are 0 and 3). These values produced a chi squared distributed test statistic of 1.59 that corresponds to a p-value of 0.45. Similar normality tests also failed to produce evidence of non-normality.

6.2 Discussion of Results

Once again, six of the nine explanatory variables are statistically significant. These variables are per pupil spending, population density, mean travel time to work, median household income, and both the squared and non squared weighted average minimum lot size variables. The three variables that are not statistically significant are crime rate, tax burden, and distance to Detroit.

Given the primary purpose of this research—to investigate the relationship between minimum lot sizes and land development—it is of greatest importance that both the squared and the non-squared minimum lot size variables are significant. Specifically, the non-squared term is negative while the squared term is positive. This leads to the "U-shaped" parabolic relationship described in Panel A of Figure 6.

The point at which this curve is minimized can be found relatively easily. First, we take the following expression and solve for y_i:

$$\ln\left(\frac{y_i}{1-y_i}\right) = X_i\beta \qquad (19)$$

This simply yields the logistic model specified in Chapter 3. That is,

$$y_i = \frac{e^{X_i\beta}}{1+e^{X_i\beta}} \qquad (20)$$

Taking the partial derivative of this expression with respect to WAMLS gives the following expression:

$$\frac{\partial y_i}{\partial WAMLS} = \frac{\bar{y}_i(\beta_{WAMLS} + 2\beta_{WAMLS2}WAMLS)}{1+e^{\bar{X}_i\beta}} \qquad (21)$$

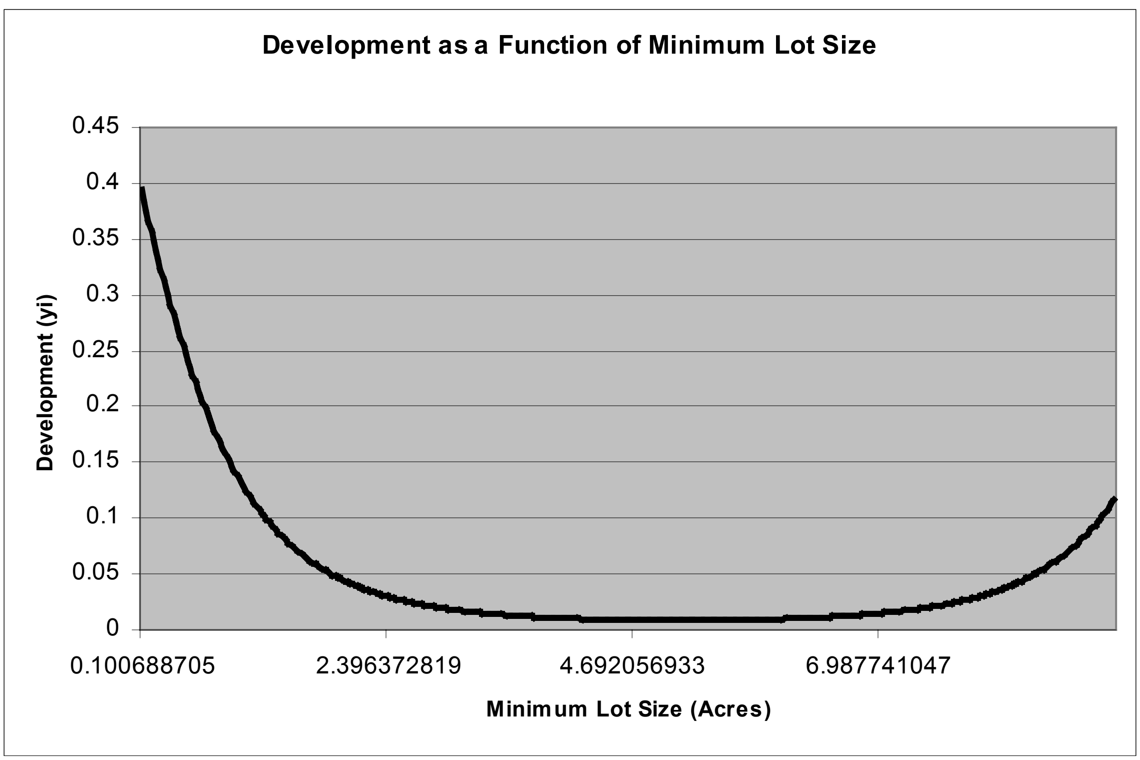
Setting equation 21 equal to zero and solving for WAMLS yields a minimum lot size of approximately 5.15 acres (224,330 square feet).[20] It is at this point that the percentage change in developed acreage from 1990-2000, y_i, begins to increase with minimum lot size. This is a relatively large figure, as only four of the communities considered in this

[20] The bars on the observed variables represent the fact that each variable was evaluated at its sample mean.

analysis exceed it.[21] This is an important result for policy purposes because it shows that only these four communities (of a total of 54 in Oakland County) have minimum lot size zoning constraints that are large enough to actually increase the rate of land development.

This relationship is easy to portray graphically. First, evaluate equation 20 at the sample means of all variables except WAMLS and WAMLS2 using the estimated coefficients. Second, by substituting into the resulting expression the range of data on WAMLS (0.1—9.2 acres) at a relatively small increment (e.g., 0.2 acres) we can plot the quadratic relationship between WAMLS and y_i. This is pictured in Figure 9. Essentially, this is a graph of the relationship between minimum lot size and development, holding all else constant.

Figure 8: Estimated Relationship between Development and Minimum Lot Size



[21] The communities are: Addison Township, Bloomfield Township, Highland Township, and Oxford Township

The coefficient signs of the control variables are also of policy importance, and their interpretations follow. First, the median household income variable is significant and has a negative coefficient. This matches with the hypothesis that in areas where income is higher, individuals use their wealth to protect their communities from development.

Second, the per pupil spending variable is also significant, and has a positive coefficient. This is consistent with the theory that education quality is a push-pull factor. Communities with higher quality education are producing a service that makes them a more attractive place to live, and thus they have higher levels of development.

The crime variable, index offenses per capita, has a negative coefficient, but is not statistically significant. The coefficient sign is as expected, and thus signals that areas with higher crime rates will have less development, *ceteris paribus*, because people prefer to live in as safe a neighborhood as possible. This variable's lack of statistical significance may be a result of it being based on year 2000 data, rather than the more desirable average of 1990 and 2000. Crime rates in the year 2000 should not have a statistical influence on land development from 1990 to 2000 unless they are essentially constant over that same period.

The tax burden coefficient is estimated as positive, but it is statistically not significant. This positive relationship may result from the fact that rapidly developing areas typically require more revenue per capita because they must make expensive up front investments in infrastructure. However, this variable has numerous possible effects, and it is difficult to interpret it, especially given that it is not statistically significant. A more relevant tax variable may be one that captures the amount of services provided per citizen per tax dollar. Given such a measure, a plausible hypothesis is that communities that provide more services per tax dollar collected will develop more quickly.

Mean travel time to work has a positive and statistically significant coefficient estimate. Theoretically, one would expect a negative relationship here because long commutes are a disincentive to growth; they make traveling to work more expensive. One possible explanation for this result is that travel time to work could be associated with the price of land, a variable that is not included in the model. All else equal, the price of land declines as one moves away from the city. So, people with longer commutes will tend to live on lower cost land. This possible relationship between travel time and land price may be the cause of the positive relationship between travel time and development.

The distance to Detroit coefficient is estimated as negative, although it is not significant. The sign is consistent with the monocentric city model in which areas further away from the city center are less developed (and develop more slowly) than closer areas. However, there is some debate about whether or not the monocentric city model is still relevant in modern, American cities. This is because in most modern cities, the traditional downtown area is no longer the only center of employment. The lack of statistical significance of this variable may thus signal the existence of other, satellite centers of employment and activity in and around Oakland County. For example, there is also a great deal of business and industry in the cities of Troy and Southfield, and it is also possible that people living in the northern part of the County may commute to jobs in the Flint area.

Population density was the most significant of the nine explanatory variables in the model. Its coefficient was estimated as negative, signaling that population is most dense in areas that experienced little development from 1990 to 2000. This may be the result of two factors. First, areas with high population density will in general have less undeveloped land available, and thus there is a physical constraint on development possibilities. Second, it may simply be that individuals prefer to develop in areas with lower population densities (perhaps because of increased benefits from privacy and environmental amenities, or possibly because less dense areas have fewer constraints to development). Preferences certainly play a strong part in the process of urban growth and development.

Chapter 7 Summary and Conclusions

This paper has discussed the theoretical causes of sprawl style development and focused on one type of public policy, minimum lot size zoning, which has been hypothesized to affect the rate of land development. Results of the land use share multiple regression model have shown that in Oakland County development is a quadratic function of average minimum lot size. At first, as average minimum lot size in a community increases, the rate of development declines because minimum lot sizes deter growth by limiting the number of households that are able to participate in the market for residential property. But as minimum lot size increases, the rate of land development will actually begin to increase due to the increase in per capita consumption that larger minimum lot sizes entail. At average minimum lot sizes of greater than 5.15 acres (224,330 square feet), minimum lot size begins to increase the rate of development.

The results of this research clearly have policy relevance. They show that minimum lot sizes of greater than 5.15 acres can actually increase the rate of development, and therefore they cease to be of value as a policy tool for controlling the rate of land development, and may even exacerbate sprawl. Certain communities with very large lot sizes that are meant to control growth may actually be making the problem worse by using large lot zoning. Planning and zoning officials in the cities, villages, and townships of Oakland County could consider this result when making future decisions about minimum lot size regulations.

The results also support theory regarding the other various factors that affect land use change. Estimates of the effects of push-pull factors like education quality, crime rate, and tax burden on development have the proper hypothesized signs, although only the education variable is significant. Explanatory variables describing household income, commute time, and population density are also shown to be significant.

However, because the project's scope was limited to Oakland County, it is difficult to generalize the results to other rapidly urbanizing areas in Michigan. A similar but larger study area that encompassed all Michigan counties experiencing rapid suburbanization would certainly be of even greater value. This would allow for more general policy conclusions to be made about the effects of minimum lot size zoning on development.

The major problem with such a study would obviously be data availability and the difficulties associated with standardizing data from many different sources. Up to date land use and land cover data is simply not available for many Michigan communities and the time involved with standardizing minimum lot size information would also be considerable. There would also be numerous problems in obtaining and standardizing the data on the control variables.

A significant limitation of this model is that it fails to consider the possibility that minimum lot size zoning may not be an exogenous variable. Statistical studies of zoning have often been criticized because of the assumption that zoning regulations are handed down exogenously from some external source (Fischel 1990). In fact, it is likely that zoning is endogenously determined, and therefore different statistical methods (e.g., instrumental variables estimation) should be used to account for this. Further research is thus needed to examine the possibility of endogenous zoning and its statistical implications.

It would also be useful to further examine the possibility that zoning spillovers occur between neighboring communities. While this research finds no statistically significant evidence of such a relationship for Oakland County, it may be that these spillovers exist elsewhere in Michigan. A finding that these spillovers did exist would certainly be important information for policy makers at the local level, in that it would imply a need for greater communication and coordination among the planning and zoning agencies of neighboring communities.

APPENDIX

Appendix Table 1: Oakland County Projected Population Growth Rates

Community	Population 1990	2000	2030 (Expected)	% Growth Expected 2000-2030
Oakland County	1,083,592	1,194,156	1,333,573	11.7%
Addison Twp.	4785	6107	9440	54.6%
Auburn Hills	17076	19873	21013	5.7%
Berkley	16960	15531	13552	-12.7%
Beverly Hills Village	10643	10437	10352	-0.8%
Bingham Farms Village	1001	1030	967	-6.1%
Birmingham	19997	19291	17800	-7.7%
Bloomfield Hills	4288	3940	3710	-5.8%
Bloomfield Twp	42473	43023	39180	-8.9%
Brandon Twp	10799	13230	18509	39.9%
Clarkston	1005	962	957	-0.5%
Clawson	13874	12732	10654	-16.3%
Commerce Twp	22228	30349	41019	35.2%
Farmington	10132	10423	10317	-1.0%
Farmington Hills	74652	82111	76823	-6.4%
Ferndale	25026	22105	17880	-19.1%
Franklin Village	2644	2937	2793	-4.9%
Groveland Twp	4705	6150	7239	17.7%
Hazel Park	20051	18963	15860	-16.4%
Highland Twp	17941	19169	21681	13.1%
Holly Twp	3257	3902	7167	83.7%
Holly Village	5595	6135	6790	10.7%
Huntington Woods	6336	6151	5595	-9.0%
Independence Twp	23717	32581	38103	17.0%
Keego Harbor	2932	2769	2805	1.3%
Lake Angelus	328	326	264	-19.0%
Lake Orion Village	3029	2715	2916	7.4%
Lathrup Village	4329	4236	3863	-8.8%
Leonard Village	357	332	332	0.0%
Lyon Twp	8695	11041	49076	344.5%
Madison Heights	32196	31101	26564	-14.6%
Milford Twp	6610	8999	11235	24.9%
Milford Village	5511	6272	6685	6.6%
Northville (Part)	3367	3352	3156	-5.9%
Novi (and Novi Twp)	33148	47579	79264	66.6%
Oak Park	30462	29793	25634	-14.0%
Oakland Twp	8227	13071	26083	99.6%
Orchard Lake	2286	2215	2216	0.1%
Orion Twp	21047	30748	40948	33.2%
Ortonville Village	1252	1535	1830	19.2%
Oxford Twp	9004	12485	25884	107.3%
Oxford Village	2929	3540	3546	0.2%
Pleasant Ridge	2833	2594	2375	-8.4%
Pontiac	71166	66337	75544	13.9%
Rochester	7178	10467	11126	6.3%

Rochester Hills	61718	68825	72585	5.5%
Rose Twp	4926	6210	8933	43.9%
Royal Oak	65493	60062	52233	-13.0%
Royal Oak Twp	5011	5446	5399	-0.9%
South Lyon	6612	10036	13871	38.2%
Southfield (and Southfield Twp)	75695	78322	73671	-5.9%
Springfield Twp	9927	13338	20326	52.4%
Sylvan Lake	1893	1735	1523	-12.2%
Troy	72884	80959	77046	-4.8%
Walled Lake	6278	6713	6992	4.2%
Waterford Twp	66692	73150	72863	-0.4%
West Bloomfield Twp	54507	64860	66986	3.3%
White Lake Twp	22608	28219	34313	21.6%
Wixom	8550	13263	24484	84.6%
Wolverine Lake Village	4727	4415	3875	-12.2%

(SEMCOG 2002)

Appendix Table 2: Summary Statistics of SEMCOG Population Growth Projections for Oakland County

Variable	Mean	Standard Deviation	Minimum	Maximum
1990 Population	18,3766.0	21,945.7	328	75,695
2000 Population	20,240.5	23,329.3	326	82,111
Expected 2030 Population	22,607.6	24,292.6	264	79,264
Expected Percent Growth 2000-2030	17.7%	52.4%	-19.1%	344.5%

Appendix Table 3: Summary Statistics of SEMCOG Population Growth Projections for Oakland County's Outlying Areas

Variable	Mean	Standard Deviation	Minimum	Maximum
1990 Population	9,315.6	8,247.7	357	33,148
2000 Population	12,230.3	11,597.3	332	47,579
Expected 2030 Population	18,380.5	18,436.2	332	79,264
Expected Percent Growth 2000-2030	43.1%	67.3%	-12.2%	344.5%

Appendix Table 4: Summary Statistics of SEMCOG Population Growth Projections for Oakland County's Southeastern Area

Variable	Mean	Standard Deviation	Minimum	Maximum
1990 Population	26,540.5	26,914.7	328	75,695
2000 Population	27,475.6	28,586.8	326	82,111
Expected 2030 Population	26,425.6	28,342.1	264	77,076
Expected Percent Growth 2000-2030	-5.9%	8.1%	-19.1%	13.9%

Appendix Table 5: SEMCOG Land Use/Cover Categories and Subcategories

Land Use/Cover Category	Subcategories
Residential	Multiple-Family Residential/High Rise; Multiple-Family Residential/Low Rise; Single-Family Residential/Duplex; Manufactured Home Park
Under Development	Developing Single-Family Residential; Developing Undefined
Commercial/Office/Institutional	Primary/Central Business District; Shopping Center/Malls/Retail Centers; Secondary Mixed Business Area; Institutional Establishment; Office/Research Center or Park; Vacant Commercial
Industrial	General Industrial; Industrial Park; Automotive Test Track Roadway; Vacant Industrial
Transportation	Air Transportation Facility; Runway; Rail Transportation Facility; Rail Road Track; Water Transportation Facility; Road Transportation Facility; Roadway
Communication/Utility	Communication; Utility; Electrical Transmission Line; Gas Pipeline and Storage; Oil Pipeline and Storage; Solid Waste Disposal Site; Sewage Treatment and Transmission; Water Treatment and Transmission
Extractive/Barren	Open Pit/Above Ground Extractive; Sand and Gravel Pit; Underground Extractive; Oil or Gas Well; Beach and Riverbank
Cultural/Outdoor Recreation/Cemetery	Public Assembly/Cultural or Sports Facility; Outdoor Recreation; Cemetery
Agricultural Land/Farmstead	Cropland; Orchard/Bush Fruit/Vineyard/Ornamental Horticulture; Confined Feeding Operation; Permanent Pasture; Other Agricultural Land; Farmstead
Grass and Shrub Land	Herbaceous Open Land; Shrub Land
Forest Land	Northern Hardwood; Central Hardwood/Oak; Aspen/White Birch; Pine; Other Upland Conifer; Christmas Tree Plantation
Water	Stream and Waterway; Lake; Reservoir
Wetland	Shrub/Scrub Wetland; Lowland Hardwood; Lowland Conifer; Mixed Wooded Wetland; Aquatic Bed; Emergent Wetland; Flats

(SEMCOG 2004)

Appendix Table 6: Acreage in Each SEMCOG Land Use/Cover Category for Oakland County as a Whole

Land Use/Cover Category	Acres in 1990	Acres in 2000	Change
Residential	194,840	230,893	36,053
Under Development	7,195	9,674	2,479
Commercial/Office/Institutional	29,504	33,366	3,862
Industrial	15,777	18,961	3,184
Transportation	7446	7,642	196
Communication/Utility	2,462	2,275	-187
Extractive/Barren	7,074	7,400	326
Cultural/Outdoor Recreation/Cemetery	17,879	22,787	4,908
Agricultural Land/Farmstead	66,603	42,920	-23,683
Grass and Shrub Land	95,460	70,799	-24,661
Forest Land	50,028	47,089	-2,939
Water	27,674	28,310	636
Wetland	58,517	58,362	-155
Total	**580,458**	**580,458**	**≈0**

(SEMCOG 2004)

Appendix Table 7: Minimum Lot Size Restrictions for Each Community

Community Name	Lot Sizes in Acres
Addison Twp	10, 5, 3, 2, 1, 0.57, 0.28
Auburn Hills	0.46, 0.19, 0.17, 0.15, 0.14
Berkley	0.28, 0.2, 0.15, 0.1
Beverly Hills Village	0.57, 0.37, 0.28, 0.2, 0.14
Bingham Farms Village	1.4, 0.7, 0.4, 0.23
Birmingham	0.21, 0.46, 0.14, 0.1
Bloomfield Hills	2, 1.5, 1, 1, 0.75
Bloomfield Twp	0.69, 0.5, 0.46, 0.37
Brandon Twp	2.5, 1, 0.46, 0.34
Clarkston	0.37, 0.28
Clawson	0.12
Commerce Twp	0.46, 0.29
Farmington	0.41, 0.34, 0.29, 0.23, 0.19
Farmington Hills	0.68, 0.54, 0.41, 0.34, 0.23, 0.2
Franklin Village	3, 1.5, 0.69, 0.52, 0.34, 0.28
Groveland Twp	10, 2.5, 1, 0.69
Hazel Park	0.14, 0.12
Highland Twp	10, 5, 3, 1.5, 0.5, 0.32
Holly Village	0.28, 0.17
Holly Twp	5, 2.5, 1.5, 1, 0.5
Huntington Woods	0.69, 0.21, 0.16, 0.14, 0.12
Independence Twp	3, 1.5, 1, 0.34
Lake Orion Village	0.19, 0.18, 0.17
Lathrup Village	0.21
Lyon Twp	2.5, 1, 0.5, 0.34
Madison Heights	1, 0.17, 0.13
Milford Village	0.5, 0.34, 0.22, 0.2, 0.17
Milford Twp	3, 1.5, 0.28
Northville (Part)	0.28, 0.17
Novi	1, 0.5, 0.41, 0.28, 0.23
Oak Park	0.14
Oakland Twp	2.3, 1.7, 1.38, 1, 0.9, 0.7, 0.6, 0.5, 0.45, 0.38
Orchard Lake	1.38, 0.92, 0.46, 0.34
Orion Twp	2.5, 1.5, 0.69, 0.32, 0.25, 0.19
Ortonville Village	0.34, 0.28
Oxford Village	0.29, 0.22, 0.17
Oxford Twp	20, 10, 5, 2.5, 1, 0.57, 0.28
Pleasant Ridge	0.1
Pontiac	0.14
Rochester	0.34, 0.22, 0.19, 0.17, 0.14
Rochester Hills	0.46, 0.34, 0.28, 0.22
Rose Twp	10, 5, 1.5, 1, 0.5
Royal Oak	0.14, 0.3
Royal Oak Twp	0.14, 0.09
South Lyon	0.34, 0.28, 0.23, 0.2
Southfield	0.46, 0.21, 0.17
Springfield Twp	2.5, 1.5, 1, 0.5

Troy	0.69, 0.5, 0.34, 0.24, 0.19, 0.17
Walled Lake	0.28, 0.22
Waterford Twp	1, 0.28, 0.23, 0.21
West Bloomfield Twp	0.34, 0.29, 0.23
White Lake Twp	5, 2, 1, 0.46, 0.37, 0.28
Wixom	0.34, 0.29, 0.17
Wolverine Lake Village	0.28, 0.21, 0.17

Appendix Table 8: Regression Output with Spillover Variables

Variable Name	Estimated Coefficient	Standard Error	t-Statistic	P-Value
Intercept	11.37	14.6	0.78	0.44
LNTAXBURD	0.36	0.44	0.83	0.41
EDUC	0.00085	0.00024	3.61	0.001
CRIME	-15.65	17.05	-0.92	0.36
POPDEN	-0.00099	0.00023	-4.26	0.00
LNTRAVTIME	8.57	2.45	3.50	0.00
DISTDET	-0.030	0.035	-0.87	0.39
LNHINC	-4.19	1.21	-3.45	0.001
WAMLS	-3.93e-5	1.22e-5	-3.21	0.003
WAMLS2	8.73e-11	3.78e-11	2.31	0.026
SPILL	7.27e-6	7.92e-6	0.92	0.36
$SPILL^2$	-3.31e-11	3.46e-11	-0.96	0.34

$N = 54$, $R^2 = 0.62$, $\bar{R}^2 = 0.53$, Model $F = 6.35$

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