SCALE EFFECTS AND THE DETERMINANTS OF PARCEL SUBDIVISION:
A DISCRETE-TIME HAZARD ANALYSIS

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ABSTRACT

BEV WILSON: Scale Effects and the Determinants of Parcel Subdivision: A Discrete-Time Hazard Analysis
(Under the direction of Yan Song)

Many of the theories that inform planning analysis and policy-making implicitly acknowledge the importance of space in the form and function of urban areas, but this understanding is highly abstract and in many ways, functions as a black box with limited transparency. This dissertation takes a closer look at the spatial relationships that help to shape urban form and in an effort to move beyond geographic determinism and allow for a more nuanced view of the drivers of residential development patterns. The primary research question asks which factors from existing theory and the literature help to explain the timing and location of land parcel subdivision events. This question is addressed through a combination of qualitative (limited survey) and quantitative (regression analysis) techniques, described in detail in a subsequent chapter.

Large-scale residential subdivisions represent an intense, localized change in land use and I hypothesize that these events exert a "priming effect" on subsequent land use decisions. I argue that this "priming effect" is detectable after controlling for covariates and a second research question asks if there is empirical evidence of scale-dependence. A third research question focuses on the spatial extent of this hypothesized "priming effect" and is examined by conducting a sensitivity analysis of the distance threshold used to derive the “priming effect” measure. The present research seeks to link the presence of large residential subdivisions to an elevated rate of residential development in the immediate vicinity. Detection of an effect provides further support for the importance of growth management policy and the influence of residential land developers on the evolution of intra-metropolitan urban form. The results of the study suggest that land availability and prices, demographic factors, accessibility, and the availability of infrastructure are the most important predictors of land parcel subdivision events. Strong evidence is found in support of the hypothesized "priming effect" and the implications for planning practice in terms of general growth management policy and the development review process are offered.

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CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 Introduction and Research Questions

"Location, location, location" is the mantra long associated with the real estate industry, but the importance of spatial relationships also permeates many facets of planning theory and practice. Many of the theories that inform planning analysis and policy-making implicitly acknowledge the importance of space in the form and function of urban areas, but this understanding is highly abstract and in many ways, functions as a black box with limited transparency. This dissertation takes a closer look at the spatial relationships that help to shape urban form and in an effort to move beyond geographic determinism and allow for a more nuanced view of the drivers of residential development patterns. The primary research question asks which factors from existing theory and the literature help to explain the timing and location of land parcel subdivision events. This question is addressed through a combination of qualitative (limited survey) and quantitative (regression analysis) techniques, described in detail in a subsequent chapter. A second research question asks if there is empirical evidence of a "priming effect" between land parcel subdivision events in prior and subsequent time periods, and if so, is this effect scale-dependent? A third (and final) research question focuses on the spatial extent of this hypothesized "priming effect" and is examined by conducting a sensitivity analysis of the distance threshold used to derive the "priming effect" measure.

Land consumption in the United States is increasing (Table 1.1) and according to the National Resources Inventory 2003 (NRI), the amount of developed land nationwide has steadily increased over the past two decades. This figure rose 18.7% between 1982 and 1992, 12.8% from 1992 to 1997, and 10.8% between 1997 and 2003.

Table 1.1: Land Cover/Use By Year With Margins Of Error (Millions Of Acres).

Land Use	1982	1992	1997	2001	2003
Cropland	419.9 (2.1)	381.3 (2.0)	376.4 (2.0)	369.5 (2.0)	367.9 (2.4)
CRP Land	0.0 (N/A)	34 (N/A)	32.7 (N/A)	31.8 (N/A)	31.5 (N/A)
Pastureland	131.1 (1.4)	125.2 (1.3)	119.5 (1.2)	119.2 (1.8)	117 (1.8)
Rangeland	415.5 (3.5)	406.8 (3.3)	404.9 (3.3)	404.9 (3.4)	405.1 (3.5)
Forest Land	402.4 (2.7)	403.6 (2.7)	404.7 (2.7)	404.8 (2.7)	405.6 (2.7)
Other Rural Land	48.2 (1.3)	49.4 (1.4)	50.4 (1.4)	50.1 (1.4)	50.2 (1.4)
Developed Land	72.9 (0.8)	86.5 (1.0)	97.6 (1.0)	105.2 (1.3)	108.1 (1.4)
Water Areas	48.6 (0.1)	49.4 (0.1)	49.9 (0.1)	50.3 (0.2)	50.4 (0.2)
Federal Land	399.1 (N/A)	401.5 (N/A)	401.7 (N/A)	401.9 (N/A)	401.9 (N/A)

Source: Natural Resources Conservation Service, 2007.

Federal databases like the NRI are one of the only sources of data on land conversion that allows for consistent comparison across geographic areas. However, a limitation of this database is its coarseness in terms of the number of land cover/land use categories represented, as well as its spatial resolution. Although statistics on the amount of land consumed specifically by residential development are not readily available at the national,

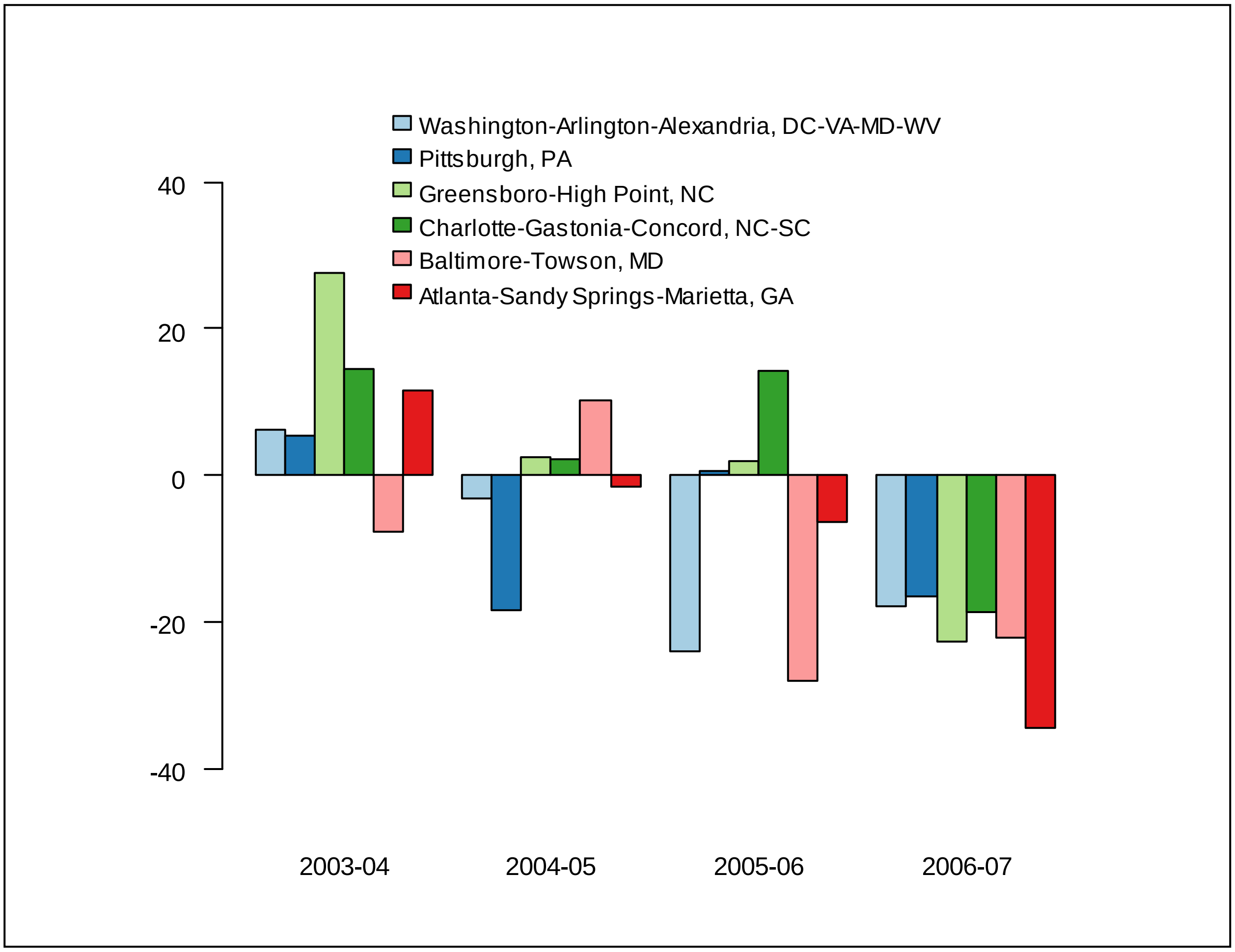

Figure 1.1: Percent Change In Building Permits Issued For Selected MSAs.

state, or metropolitan levels, some insight can be gleaned by considering the number of residential building permits issued. Figure 1.1 shows the percent change in the number of residential building permits[1] issued for selected metropolitan statistical areas (MSAs) over the last five years (U.S. Census Bureau, 2008). The building permits data presented above for selected metropolitan areas paints a mixed picture. The larger MSAs shown (Atlanta,

[1] Previous years are not included here due to changes in MSA definitions.

Washington and Baltimore) have experienced the largest downturns, while smaller MSAs (Charlotte, Greensboro, and Pittsburgh) have maintained a relatively strong degree of growth. These trends could potentially be attributed to a variety of factors including growth controls, slowing population growth, larger economic shifts, or the availability of developable land. The impacts of the recent housing crisis and economic collapse are also reflected across the board in the final time period.

Urbanization proceeds as a series of unilateral decisions made by developers, landowners, and other actors within the context of local government planning and regulations, and in many metropolitan areas the dominant pattern of development over the past several decades has been urban sprawl (Wheeler, 2008). Definitions of urban sprawl abound, but distinguishing characteristics include development that is "relatively low-density, noncontiguous, automobile dependent" and "consumes relatively large amounts of farmland and natural areas" (Bengston *et al*., 2004: 271). Land use planning and regulation in the United States is informed by strong individual property rights and the need to efficiently provide facilities and infrastructure to support new and existing development. Brueckner (2000) argues that urban sprawl is a manifestation of market failure in that the true costs of this pattern of development are not reflected in prices of land, housing, and commercial space. Instead, significant environmental, fiscal, and social costs are transferred onto the larger society and growth management has emerged as a policy response to the myriad negative impacts that accompany urban sprawl (Ewing, 1997; Levinson, 1997; Meltz *et al*., 1999). The primary objective of growth management efforts have therefore, been to mitigate the negative effects of this pattern of development, while simultaneously respecting individual preferences, property rights, and demand (population driven) for residential and associated land uses.

1.2 Research Significance

Although much has been written on urban sprawl and the growth management programs and policies that have emerged in response to its undesirable consequences, the empirical research has often been conducted at coarse scales with aggregated data. This study embraces recent developments in data collection, storage, and analysis that allow for research at very disaggregate levels by adopting individual land parcels as the primary unit of analysis. Similarly, there is an abundance of empirical evidence establishing the ongoing trend towards decentralization and movement away from the monocentric past to the polycentric present and future. However, much of the theoretical basis for land use planning decisions and policy analysis relies upon the increasingly unrealistic assumptions and constraints of the monocentric model. This study attempts to reconcile these traditional ways of thinking about urban systems with the new realities that are evolving on the ground in urban areas. This involves developing new methods for accommodating multiple employment and activity centers rather than operating from the assumption of a single exogenously determined central business district. This also requires revisiting our understanding of spatial relationships to move beyond simple linear distance calculations towards more comprehensive and robust representations of spatial effects. Finally, this reconciliation involves cultivating an appreciation for scale and temporal effects when studying complex systems and phenomena like residential development. This is the logic behind modeling larger parcel subdivision events (large, intense land use change) and other parcel-level development (smaller, less intense land use change) separately.

The literature does not lack studies of land parcel conversion and the factors that influence the timing and location of this phenomenon (Irwin and Bockstael, 2002; Bockstael and Irwin, 2003; Carrión-Flores and Irwin, 2004), but our understanding of how large parcel conversions, in particular, affect subsequent residential development patterns requires further research. By understanding the factors that help to explain parcel subdivision events and their capacity to induce further residential development, planners, elected officials, and researchers can make inroads in terms of managing growth, crafting public policy, and refining our understanding of how urban systems function. Another unique feature of the current research is the use of geoprocessing scripts to perform a change analysis at the parcel level that covers the entire study area. As planning research moves toward more disaggregate units of analysis, automated methods for data manipulation and processing become more essential.

1.3 Policy Significance

One of the most common mechanisms of urban sprawl is leapfrog development, which occurs when developers build large subdivisions on the urban fringe, often motivated by such considerations as tax avoidance, availability of infrastructure, open space premiums, and negative externalities. Opponents argue that this pattern of development is inefficient and contributes to the fragmentation of urban areas with social, environmental, and economic consequences (Ewing, 1997). Others maintain that this pattern of development is organic and allows for infill between existing centers of development and newly established outposts on the urban fringe (Ohls and Pines, 1975; Holcombe, 1999). The proposed research seeks to link the presence of large residential subdivisions to an elevated rate of residential development in the immediate vicinity. Detection of an effect would provide further evidence for the importance of residential subdivisions and the decisions of residential land developers on the evolution of intra-metropolitan urban form.

In addition to empirical and methodological contributions, this dissertation also provides insight into the site selection and land acquisition processes and behavior of residential developers. To some extent, the residential developers are taste-makers and their decisions frame and influence subsequent residential development patterns (and in many cases infrastructure provision) in a critical manner. Therefore, one of the keys to understanding what drives urban sprawl and residential development patterns in general, is understanding how developers choose sites and examining the cumulative effects of those decisions (i.e., induced residential development). Our understanding of the urban system is far from complete and empirical research examining the temporal and spatial relationships between parcel subdivision events at a disaggregate (intra-metropolitan) level can contribute to improved planning decisions and policy-making.

1.4 Organization

The next chapter reviews the urban theories that provide the basis for the conceptual and statistical models, as well as the relevant literature and theory pertaining to the behavior and decision-making processes of residential land developers. A summary of the empirical research related to the conversion of land parcels for residential use and the application of the spatial analysis used here in the planning literature is also provided. The third chapter outlines the conceptual framework and research design, while establishing key linkages between existing theory and empirical research and the specific goals and methods of the current study. Chapter 4 describes the larger economic and policy context of the study area and how key factors like the recent economic downturn and local growth management policy may have influenced development patterns. The fifth chapter describes the research data sources used, derivation of variables, and specific methods used to operationalize and test the hypotheses and relationships described in the third chapter. The results of applying these methods and techniques to Mecklenburg County, NC are presented and explained and interpreted in Chapter Six. The final chapter summarizes and synthesizes the findings of the dissertation, briefly assesses the implications of observed trends for environmental outcomes, offers policy recommendations, and suggests areas for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

This chapter reviews key literature directly relevant to the current research. The primary research question seeks to identify the factors that influence the timing and location of land parcel subdivision events and prior research in this area is available from a variety of disciplines and at a number of scales. The policy implications of this dissertation lie primarily within the realm of the growth management and urban sprawl debate and therefore, a summary of important work from this strand of the literature is presented. Chapter 3 focuses on the behavior of the land developer, the site selection process, and land acquisition, so these topics are not treated here. A brief recounting of the classical land economics tradition that serves as the backdrop for each of the aforementioned discussions is offered as a point of departure.

2.2 Land Economics and Bid-Rent Theory

The classical land economics approach to understanding land use (and by extension, urban form) is grounded in larger microeconomic theory and makes several key behavioral assumptions. All actors within the urban system are assumed to be rational, self-interested, and ultimately motivated by utility maximization. Within the classic land economics framework, utility is typically defined as the benefit derived from consuming land (the commodity of immediate interest) and a second composite good, which represents all other commodities and services. An individual actor's (e.g., household, firm) willingness to pay for land is informed by personal preference and available income. Actors compete with one another for land within this larger framework and the each parcel is allocated to the highest bidder (Alonso, 1964: 16). The centerpiece of the land economics and bid-rent theory approach is the tradeoff of land consumption for accessibility, with the rents paid at a given location reflecting the price of its specific level of accessibility to the central business district.

One of the earliest examples of the land economics approach to studying land use change and urban form is the work of von Thünen, who proposed a rudimentary model relating location within a region with a single market to land rent. Several key assumptions underlie this approach: (1) the existence of a single market where all (agricultural) goods are traded, (2) all land is owned by absentee landlords, (3) land is of the same quality, and (4) producers of the same good utilize the same technology and face the same costs of production (McCann, 2001: 94). The result is a concentric circle configuration characterized by a negative land-rent gradient and intuitively as distance to the center increases, transportation costs rise and land rents must fall in order to offset this effect (McCann, 2001: 95). Uses that can pay (bid) the highest rents or that have the strongest preferences for a central location (e.g., perishable products) will occupy the land closest to the center.

The basic tenets of the von Thünen model were applied to urban areas by Alonso (1964) who asserts that individuals will trade off amenities such as larger lots and lower density neighborhoods for higher transportation costs. However, one of the key differences between the Alonso model and von Thünen's rings is the substitutability of inputs. If a household or firm is allowed to tradeoff transport costs for housing consumption at variable rates, the linear land-rent gradient becomes a curve and the influence of preferences takes on a larger role.

Bid-rent theory has been used to explain the massive move towards suburban development after World War II and continues to inform the way we think about urbanization and the spatial structure of cities (Carrión-Flores and Irwin, 2004; van der Veen and Otter, 2001). For example, if income rises or transportation costs fall without an accompanying increase in population, this simplified model predicts decentralization (Alonso, 1964: 142). However, if the influence of rising income and falling transportation costs can be tempered with policy, we might anticipate more compact urban development patterns.

Although most closely associated with households, bid-rent theory can also be used to explain firm location behavior. The firm's output is a function of the amount of land consumed and all other goods consumed as part of the production process, while its budget constraint is a function of revenues, rent paid, and other operating costs (Alonso, 1964: 50) and the expectation is that a firm's willingness-to-pay or bid decreases as distance from the city center increases as a consequence of rising transport costs. Differences in the degree of market-orientation and other preferences coupled with revenue produce structure in the spatial distribution of firms by economic sector under the basic bid-rent model (McCann, 2001). Essentially, the set of agricultural crops allocated in space by the von Thünen model are replaced with various sectors of the economy (e.g., manufacturing, retail, services).

2.3 Evolving Urban Spatial Structure

The unambiguous and dominant trend in development patterns in practically all metropolitan area of the United States since World War II has been decentralization[2] (Anas *et al*., 1998; Glaeser and Kahn, 2001; Wheeler 2008). This term refers to the movement of population (and by extension businesses and municipal services) away from the established city center towards the urban fringe, motivated (at least) in part by public policy. The central business district, which traditionally informed how planners and researchers conceived urban systems, has declined in importance as housing and jobs have shifted away from downtown areas. Although conceptually attractive and not without some degree of explanatory power, the monocentric model (i.e., classical land economics) and its accompanying notions of accessibility-housing tradeoffs are unable to explain the patterns of development increasingly observed across the nation's urban areas (Heikkila *et al*., 1989; Bailey, 1999; Filion *et al*., 1999; Irwin and Bockstael, 2002).

Decentralization is not a new phenomenon; in fact, the first wave of suburbanization began in the early 1900s when the streetcar, and then the automobile, dramatically altered transportation costs for urban households (Anas *et al*., 1998). While the classic structure of urban areas evolved out of necessity given the limitations and constraints of the industrial era, as these tethers were loosened firms, households, and activities were increasingly free to disperse (Friedmann and Miller, 1965: 316). Manufacturing firms began to move outward following World War II, primarily to take advantage of lower land costs, and a relatively steady outflow of firms and jobs has continued ever since (Anas *et al*., 1998). Employment

[2] Urban sprawl is a particular development pattern that falls underneath the umbrella of decentralization, but has certain characteristics that are inefficient or undesirable (Downs, 1999).

decentralization has also been emphasized as a factor shaping urban spatial structure (Carlino 1985; Garreau, 1991; Gordon and Richardson, 1996; Bogart and Ferry, 1999). Over time, accessibility has emerged as a key organizing principle for intra-metropolitan spatial structure and both households and firms react, to some extent, to past location decisions of one another as the relative accessibility and attractiveness of land parcels within a given metropolitan area fluctuate.

There are many factors that contribute to the decentralization trend, which stands as the primary culprit in the erosion of the monocentric model's credibility. The contribution of highway construction to decentralization is evident from a study of 139 metropolitan statistical areas (MSAs) between 1950 and 1990 published by Baum-Snow (2007). The data indicate that the construction of highways, originating with the Federal Aid Highway Act of 1944, accounts for "about one-third of the decline in aggregate central city population relative to that in entire metropolitan areas between 1950 and 1990" (Baum-Snow, 2007: 791). During this period, employment decentralization occurred at a faster clip than did residential decentralization and in addition to the influence of improved transportation infrastructure and faster travel times, another potential explanation for this phenomenon is the jobs-follow-people hypothesis (Baum-Snow, 2007). Rising incomes allowed households to consume more land and larger houses, which are typically found on the periphery (Rappaport, 2005). Other frequently cited stimuli for residential decentralization include federal subsidies encouraging home ownership (Rappaport, 2005). However, despite the liberating influence of transportation infrastructure improvements (and information technology) and other factors on the location choices of both firms and households, we observe neither complete dispersion, nor the disappearance of discernible spatial structure in the metropolitan areas of the United States. Instead, the trend is towards polycentricity, which represents a middle-ground between the bookends of monocentricity and complete dispersion[3].

2.4 Theories of Decentralization

A variety of hypotheses have been offered in an attempt to explain the decentralization phenomenon within the context of land economics and bid-rent theory (Natural Evolution Theory) and also to extend the land economics and bid-rent theory framework to account for other driving forces (Public Choice Theory). Natural Evolution Theory emphasizes changes in transportation technologies and rising incomes as factors that conspire to produce both population and employment decentralization (Mieszkowski and Mills, 1993). On the other hand, Public Choice Theory emerged from the work of Tiebout (1956) and instead focuses on the importance of social and fiscal variables in understanding the location choices of households (Mieszkowski and Mills, 1993). Rather than extending the monocentric model, Tiebout's work expanded the canon of factors considered when studying residential location decisions, and indirectly, development patterns.

The natural evolution theory of suburbanization is an extension of the classic land economics framework. The basic argument is that the reduction in travel costs associated with highway construction (and subsidies) coupled with the widespread availability of automobiles resulted in the decentralization of residences, followed by firms (Mieszkowski and Mills, 1993). The Natural Evolution Theory combines elements of the Chicago School (e.g., Hoyt's emphasis on housing filtering; Harris and Ullman's multi-nucleated model) with

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[3] Gordon and Richardson (1996) provide an overview of dispersion versus polycentricity as a model of urban form.

the basic notion of the land consumption-transport costs tradeoff. This allowed the familiar framework and conventions of the monocentric city to persist without necessitating a radical rethinking of how urban systems function.

An alternative explanation for the suburbanization phenomenon comes from public choice theory (Mieszkowski and Mills, 1993). Tiebout (1956) argued that households "vote with their feet" in order to maximize their utility and match their preferences for service provision with the levels of service offered by existing jurisdictions. If the assumptions of the model hold (e.g., mobile and knowledgeable households, large choice set, similar cost structures), then public goods and services are efficiently allocated as jurisdictions compete for residents by tweaking the "market basket" of public goods and services provided. It is the mobility of households that makes the model functional and compelling, but also is the target of some of its harshest critiques. For example, the concentration of poverty in central city areas is often cited as a consequence of Tiebout choice and municipal fragmentation when mobility constraints prevent all households from "voting with their feet" (Downs, 1999). There are indeed many candidate explanations for decentralization (municipal fragmentation, consumer preferences for low-density, flight from blight, provision of public infrastructure, government subsidies (mortgage, highway), zoning and growth controls, and land speculation) but each of these factors can also be placed within the larger context of public choice theory articulated above.

Musterd and van Zelm (2001) point to the increasing plurality of household lifestyles, preferences, and by extension residential choices in the United States and a key factor behind suburbanization. The authors assert that the monocentric model is useful as a heuristic, but is limited in its predictive or explanatory capacity. Because households increasingly have the means to pursue their residential choice preferences (rising incomes, limited regulatory intervention), heterogeneity influences urban spatial structure in complex ways.

> "Today, many more households have the means to realise a better fit between the type of household they represent and the character of the residential environment. And if such a fit cannot be realised in their direct environment, a solution further away may be looked for, especially since today many people can afford to travel longer distances" (Musterd and van Zelm, 2001: 692).

The preceding statement extends the classic Tiebout choice concept because households have the power to essentially create subcenters that fit their needs (if they do not already exist) due to increasing income and decreasing importance of proximity to traditional centers. Residential development plays a critical role in the evolution of urban spatial structure, hence its selection as the focal point of this dissertation research.

Baer and Marando (2001) argue that the public choice phenomenon contributes to proliferation of suburban jurisdictions and, by extension, polycentric urban form. Both Mieszkowski and Mills (1993) and Bayoh *et al*. (2006) found evidence to support both theories and that they are not (necessarily) mutually exclusive. From a policy perspective, if the natural evolution view is accepted, the appropriate response would be to facilitate decentralization by investing in transportation infrastructure and otherwise subsidizing suburban development. However, the public choice hypothesis implies that decentralization is a result of a mismatch between the level of services and public goods provided in central cities and the preferences of (mobile) households.

There is empirical evidence of a trend towards polycentric urban form from several urban areas around the United States including Atlanta (Gong and Wheeler, 2002), Chicago (McMillen and McDonald, 1997), Los Angeles (Heikkila *et al*., 1989; Giuliano and Small, 1991), and San Francisco (Cervero and Wu, 1998). Ingram (1998) considers development patterns in industrial and countries and concludes that cities around the world exhibit evidence of a trend towards decentralization of both population and employment. While each of the studies cited above focus on the location of employment, a recent study by Griffith and Wong (2007) use spatial regression to analyze population density in the 20 largest metropolitan areas in the United States and identify six of these as polycentric in form: Los Angeles, Washington DC, San Francisco, Detroit, Atlanta, and Cleveland.

The preceding discussion focuses on explaining the phenomenon of decentralization and linking it to polycentric urban form, but does little to address its normative implications or establish a rationale for planning intervention. Brueckner (2000) fills this gap by framing urban sprawl as a confluence of market failures including transportation subsidies, under-valuation of open space amenities, inefficient allocation of infrastructure costs, coupled with rising incomes with personal preferences (Tiebout choice). In doing so, the author provides a justification for policy intervention in addition to a series of instruments for addressing these problems. Mills (1981) offers a cautionary admonition and argues that urban development is a dynamic process and that “it does not follow just because a land-use configuration is inefficient at one moment in time, that it is inefficient in the larger scheme of things.” Uncertainty on the part of land owners is hypothesized to result in speculative behavior, which contributes to discontinuous patterns of development. This is the most familiar explanation of leapfrog development found in the economics literature (Irwin and Bockstael, 2002: 32). Mills' position foreshadows the third and final strand of theory discussed here, namely that urban growth does not necessarily proceed along a smooth trajectory and perhaps, a longer-term view is needed.

2.5 The Bigger Picture: Diffusion and Coalescence

Once the reality of decentralization and polycentricity has been firmly established, a logical next question concerns how to reinterpret existing theory and formulate policy within this new context. The effect of multiple subcenters on commuting, land prices, and development patterns is an area that has borrowed heavily from the monocentric tradition. One of the earliest approaches to reconciling traditional notions of accessibility and spatial interaction with multiple subcenters involved calculating the familiar negative exponential density function for each subcenter and vertically summing the heights of these surfaces to determine the overall influence (across all subcenters) at a given location (Song, 1992: 5). Other studies have used of gravity-based metrics to accommodate the existence of multiple centers (Helling, 1998; Bailey, 1999; Buliung and Kanaroglou, 2006).

In his book *Self-Organizing Economy*, Paul Krugman makes several intriguing assertions. The first of these is that firm location behavior is the result of complex interactions between centripetal (attractive) and centrifugal (repellant) forces which can be understood by reinterpreting central place theory on an intra-metropolitan level. This link to central place theory becomes more interesting in light of empirical results from the Los Angeles area that indicate "a relationship between the number and relative size of subcenters" (Redfearn, 2007). For Krugman, centripetal forces contribute to clustering and can include such factors as shared markets (market potential) and labor pools, knowledge spillovers, and inter-industry linkages (supply chain). On the other side of the equation are the centrifugal forces like shared markets (competition) and congestion, which tend to result in scattering or discontinuous firm location choices (Krugman, 1996: 91). Krugman concludes that the evolution of intra-metropolitan agglomerations is an example of a self-organizing, emergent phenomenon the outcome of which cannot be fully anticipated *a priori* because firms make location decisions in response to the decisions of other firms and the urban landscape is constantly in flux (Krugman, 1996: 89). The notion of push and pull factors as drivers of location decisions and contributors to emergent urban form can be generalized to households and land developers.

Krugman's focus on centripetal and centrifugal forces is mirrored in the argument of Dietzel *et al*. (2005) who describe an oscillating process of diffusion and coalescence characterizing the growth of urban areas. The authors assert that urban growth proceeds under two alternating phases or regimes, diffusion and coalescence, which when taken together provide a more comprehensive description of observed development patterns (Dietzel *et al*., 2005: 179) and this concept can easily be extended to a discussion of urban sprawl. During the diffusion phase, a seed takes root some distance from the established urban core. Over time infill or outward growth from the established urban core and emerging center close the gap and bring what were previously islands of urban development into the fold, which represents the coalescence phase. Eventually, the pendulum swings back to diffusion and further leapfrog development occurs. Dietzel *et al*. (2005) imply that this process is constantly occurring at multiple scales within the urban system. The hypothesized "priming effect" draws upon this concept, but with less of a focus on isolation and a greater emphasis on the influence that large residential subdivision decisions exert on subsequent residential development decisions.

2.6 Growth Management Policy

In the United States, urbanization proceeds as a series of unilateral decisions made by developers or individual landowners within the context of local government planning and regulation (Bockstael and Irwin, 2003). Land use decisions are also informed by strong individual property rights on one hand and the necessity of efficiently providing supporting facilities and infrastructure on the other and as a result, growth management has emerged as a policy response to the myriad negative impacts (e.g., fiscal, environmental, social, transportation) that accompany urban sprawl (Meltz *et al*., 1999; Ewing, 1997).

The primary objective of growth management efforts has been to mitigate the negative effects of this pattern of development, while simultaneously respecting individual preferences, property rights, and increasing demand (population driven) for residential and associated land uses. The hydrologic consequences of urbanization are well-documented (Weng, 2001; Arnold and Gibbons, 1996) and impervious surfaces, which typically accompany development, increase the volume, rate, and pollutant content of storm water leaving a site and each of these factors influences one or more aspects of the local ecosystem from stream channel morphology to flood frequency to aquatic habitat. Development also consumes agricultural and forest land, affects wildlife through habitat loss and fragmentation, and contributes to global warming via increased automobile dependence (Ewing, 1997). Studies have also linked urban sprawl to increases in vehicle miles traveled (Cervero and

Wu, 1998), with attendant implications for air quality (Stone Jr., 2008) and by extension, climate change (Ewing *et al*., 2008).

The fiscal implications of urban growth are less clear. Conventional wisdom holds that development is good for the public coffers, but Carruthers and Úlfarsson (2003) studied the effect of urban form on twelve measures of public expenditure: total direct, capital facilities, roadways, other transportation, sewerage, trash collection, housing and community development, police protection, fire protection, parks, education, and libraries. Based on an analysis of 283 metropolitan counties, they found that "the per capita cost of most services declines with density (after controlling for property value) and rises with the spatial extent of urbanized land area," with the exception of sewer service (Carruthers and Úlfarsson, 2003). The authors then leverage this finding to argue for market-based approaches to growth management.

From a practical perspective, jurisdictions have four possible strategies for influencing individual behavior: regulation (require it), facilitation (make it easier), information (raise awareness), and incentives (Balch, 1980: 36). Growth management programs around the nation have drawn upon each of these strategies and an understanding of how these approaches relate to policy objectives is essential in determining which combination of policies are most likely to yield the desired results. By enhancing our understanding of how residential land development proceeds under polycentric conditions and within the larger context of household and firm decentralization, planners and policy-makers are better equipped to craft more effective regulations and policy interventions.

2.7 Drivers of Land Use Change at the Parcel Level

There are several ways of thinking about land use change at the parcel level. From an economic perspective, land use change at the parcel level involves converting a vacant or undeveloped plot to a new use or changing the current use and the decision to convert undeveloped land or to change (intensify) the existing use is influenced by a variety of factors including economic, social, and personal considerations. In urban areas and along the fringe, economic factors have received the most attention, partly due to the lack of measures for the other types of factors.

Zax and Skidmore (1994) use a hazard model to investigate the effect of tax rate changes on the probability of parcel conversion. The objective of their study is to pinpoint specific changes in that precipitate parcel conversion from year-to-year using a sample of 224 parcels in Douglas County, Colorado that were undeveloped in 1986. Key independent variables examined in this study include tax rate, frequency of sale, and change in valuation. Intuitively, we might expect an increase in property taxes to decrease the probability of development. However, there is evidence that when increases in the tax rate are known (anticipated), the effect is an increase in the short-term probability of development (Zax and Skidmore, 1994).

Bockstael (1996) brings together concepts from several disciplines to model the probability of land parcel conversion within the Patuxent watershed in Maryland. The key contribution of this study is the formalization[4]of the decision (on the part of a land owner) to convert a given parcel from one state (use) to another as a function of the present value of

[4] McMillen (1989) adopts a similar approach.

expected returns under the current state, less the costs of converting the parcel now and the expected returns under alternate states minus conversion costs. In this way, familiar statistical approaches like discrete-choice modeling can be applied to study and forecast land use change at a disaggregate level. The author uses hedonic regression to estimate the value of land parcels under agricultural and residential use as a function of: lot size, distance to city centers, distance to highways, water frontage, zoning designation, land use mix, and political jurisdiction. The results of the hedonic regression analyses are then used as independent variables in a probit model of conversion probability alongside controls for the difficulty and cost of conversion (i.e., soils, slops, sewer availability, estimated clearing costs). This approach served as a starting point for the present dissertation project, but here drivers of land conversion are extended to include major residential subdivisions, which represent an intense land use change and potentially influence subsequent development patterns.

Carrión-Flores and Irwin (2004) estimate a probit model of land use conversion at the parcel level for Medina County, Ohio. Spatial statistics are used to quantify sprawl at a regional scale, while the basic methodology established by Irwin and Bockstael (2002) is used to model parcel conversion at the local scale. Significant findings include the importance of topographical characteristics (e.g., soils) to conversion probability and the limited range of urban accessibility as a factor in parcel conversion. The authors also adopt a spatial sampling scheme to address potential spatial autocorrelation in the data.

Newburn and Berck (2006) combined aspects of the parcel conversion research of Bockstael and Irwin with the flexibility of the discrete choice modeling framework to study suburban and rural residential development in Sonoma County, California. The authors estimated a random-parameter logit model at the parcel level to account for differences in zoning and land use regulations among jurisdictions within the county and found that land use regulations have different effects in suburban and rural areas. Specifically, policies regarding the provision of sewer infrastructure had little effect on the rate or location parcel conversion in rural areas.

Changing demographics and local spillover effects are two examples of social factors that conceivably affect land use change at the parcel level. Sheer population growth increases demand for housing and other developed land uses and demographic changes (e.g., influx of young professionals) can impact the types of residential development that are favored (Kim *et al*., 2005). An intuitive example might be the general preference for larger lots by families with children or the tendency for retirees to "down-size" to apartments and condominiums. Aside from population increase and demographic shifts, the preferences of households have clear implications for the rate and location of new development. In many rural areas, the proliferation of second homes has been linked to a desire to be near natural amenities and preference for warmer climates (McGranahan, 1999; Irwin and Bockstael, 2001).

Spillover effects can also be significant, albeit difficult to measure, factors. Irwin and Bockstael (2002) hypothesize that negative externalities (e.g., traffic congestion, loss of open space amenities) among neighboring residential developments may exert a repelling effect, thereby resulting in low-density, discontinuous development patterns. A hazard model is then used to represent fixed and unobserved effects on the probability of conversion at a given point in time. The authors find evidence of "negative spillovers among exurban land parcels converted to residential subdivisions" that supports their hypothesis of negative interactions among residential developments as a contributor to urban sprawl (Irwin and Bockstael, 2002: 52). These findings are contrary to the chief hypothesis adopted here, that the presence of prior subdivision activity in the vicinity actually stimulates future residential development. Stated differently, Irwin and Bockstael argue that there is evidence of a repellant effect between subdivisions along the urban fringe in the sense that negative externalities (traffic congestion) and a preference for more bucolic surroundings tend to lower the probability of nearby parcels being developed. This assertion is tested and evaluated by the present study.

Perhaps the most interesting, but also most difficult to study and measure, factors that drive land use change at the parcel level are personal characteristics specific to the individual land owner. Individual expectations and speculative behavior are prime examples of these difficult to measure factors. Life cycle considerations can also be important in that many land owners rely on land holdings as a source of retirement income and parcels change ownership when the original owners die and leave the property to heirs (Gobster and Rickenbach, 2004). Finally, personal values (non-monetary) and general attachment to an undeveloped tract can also influence whether a parcel becomes developed (Alig *et al*., 2004). The difficulty of measuring and accounting for factors like these contributes to the difficulty of modeling land use change at a disaggregate level.

2.8 A Spatial Perspective for Planning Research

Fueled by the emergence of geographic information systems (GIS) as a key component of the toolkit for planning practice and research (Drummond and French, 2008) and the increasing availability of spatial data, the planning practitioner and researcher are becoming more aware of the importance of space. Planning research in particular, has moved beyond simply manipulating and displaying geographic data towards more sophisticated forms of spatial data analysis. Geostatistical tools like correlograms have been employed to study economic growth (Wheeler, 2001) and spatial regression models are represented in the planning literature with applications ranging from modeling housing prices (Yu *et al*., 2007) to the fiscal implications of urban sprawl (Carruthers and Úlfarsson, 2008). As a discipline, planning has always been interested in where phenomena occur and by embracing an increasingly spatial perspective, this linkage becomes stronger. The present study reflects this spatial perspective by focusing on hypothesized scale effects among land parcel subdivision events and exploring the spatial extent of hypothesized "priming effect."

2.9 Summary

This chapter recounted the land economics and bid-rent literature that forms the basis for this and many other land use change studies. It also discussed the larger trend towards decentralization and polycentricity that has characterized post-WWII development patterns in the United States. Leading theories that attempt to explain decentralization are presented and the emergence of growth management policy as a response to the negative consequences of urban growth were briefly discussed. The present study draws heavily on the work of Bockstael (1996) and Irwin *et al*. (2003) and these studies are cited as an effective means of understanding and modeling the drivers of land use change at the parcel level. The final section addresses the importance of space to planning practice and research and notes the progress that has been made towards integrating spatial analysis tools and techniques. The next chapter presents the conceptual framework for understanding and modeling land parcels subdivision events and the review of key literature continues with an emphasis on the behavior and decision-making processes of land developers.

CHAPTER 3: CONCEPTUAL FRAMEWORK

3.1 Overview

This chapter offers a conceptual framework for understanding and exploring the determinants of land parcel subdivision events, as well as the temporal and spatial relationships between these events. The importance of land developers within the framework of residential development is explained and key literature on the behavior and decision-making processes of these actors is reviewed. The conceptual framework is based primarily on two strands of literature: land economics and organizational decision-making. The first two sections of this chapter explain the rationale behind focusing on the land developer within the larger context of the dissertation and briefly reviews some of the key literature on organizational decision-making, as relevant to residential development. The next sections present a conceptual model of the land parcel subdivision process and describe how the land economics literature informs both the site selection and land acquisition components. The final section explains how temporal and spatial effects are conceptualized within the context of the current study.

3.2 The Engine of Real Estate Markets

"If you build it, they will come." This statement underscores the fact that developers are the engine of real estate markets and their decisions largely determine the amount, location, and character of residential property and housing available (Bourne, 1976; Hepner, 1983; Bookout, 1990). At a very basic level, land developers select sites and implement development plans that they believe will earn a profit, given prevailing trends in local housing markets, employment, and demographics. A series of studies conducted by researchers at the University of North Carolina at Chapel Hill during the 1960s were some of the earliest to focus on the behavior and decision-making processes of developers (Chapin and Weiss, 1962; Weiss *et al*., 1966; Kaiser, 1968). According to the first of these studies, some land development projects are "priming actions" while others are "secondary actions," with the former distinguished by a "structuring"[5] and "timing" effect on subsequent development (Chapin and Weiss, 1962: 2). Priming actions such as the location of industry, commercial uses, or transportation are conceived as facilitating secondary actions like residential location choices. In the present study, this basic idea is extended to include major residential subdivisions, which represent an intense land use change, as having a priming effect on subsequent development patterns.

Related studies by Weiss *et al*. (1966) and Kaiser (1968) operate from a basic conception of the land developer development firm as maximizing a profit function subject to budget constraints within the existing regulatory framework. The locational decision (site selection) is thus, explained by the characteristics of each candidate site (physical, locational, and institutional), characteristics of the actors (developers, land owners, and consumers), and contextual (socioeconomic and policy) factors. A key implication of the North Carolina studies (Goldberg, 1974; Leung, 1986) and the current discussion is that although land developers wield considerable power in determining growth patterns and shaping urban form,

[5] The structuring effect refers to the influence on the location and intensity of secondary actions attributable to the priming actions.

their ultimate goal is to be responsive to the market and to anticipate the needs and preferences of the targeted consumers (Weiss *et al*., 1966: 3). Because land developers are such key figures in the determining residential development patterns and its implications for urban form, it is essential to better understand their behavior and decision-making processes.

3.3 Developer Behavior

Micro-economic theory suggests that producers (and by extension, firms) adhere to a strategy of profit-maximization to inform and guide decision-making. There are several key underlying assumptions that are typically associated with this approach including rationality, perfect information, unlimited computational capacity, no considerations that cannot be quantified (or assigned a monetary value), and no unresolvable conflicts among competing objectives (Herrnstein, 1990). However, this "classical theory of the firm was never intended to be a managerial or administrative theory," but "was intended to be a theory of markets—to describe the determination or prices and resource allocations by business firms under varying ideal market conditions within a larger general theory value" (Kenney, 1972: 28). These lofty and unrealistic assumptions drew criticism, most notably from Herbert Simon who introduced the notions of "bounded rationality" and "satisficing" and marked a shift toward more realistic and behavioral theories of organizational decision-making (Simon, 1957). The implications of Simon's theory for understanding the behavior of land developers is that it allows for a wider array of considerations to enter the decision-making calculus. Rather than pursuing profit-maximizing (optimal) outcomes, land developers operating under conditions of bounded rationality instead pursue satisfactory outcomes, with realized profits as one element (Kenney, 1972). Other considerations including values, long-term viability, and public perception can then enter into the equation and the threshold for what is considered an acceptable outcome can fluctuate over time.

In an updated version of their original 1963 text, Cyert and March (1992) build upon this basic idea of bounded rationality to articulate a general theory of how firms (a specific type of organization) make decisions. Firms are conceived as goal-oriented and adaptive organizations that pursue satisfactory outcomes given available information and expectations. Land development is first and foremost a business venture, so basic goals for land development firms are likely to focus on production, sales, profit, and market share (Cyert and March, 1992). Within a given metropolitan area, the cost of inputs such as land, capital, and labor are comparable across firms, so efficiency, adaptability, information, and market savvy are important sources of competitive advantage (Muth, 1989:16). Perhaps the most significant implication of *A Behavioural Theory of the Firm* for understanding developer behavior is its emphasis on process, which is sets the stage for the conceptual model presented in the following section and the subsequent discussion of two of the most important components of the land parcel subdivision process.

The development process is fraught with uncertainty and there are many junctures along the way that could conceivably derail even the best managed projects. This fact alone helps to explain the reluctance of many developers to deviate from tried-and-true methods to embrace more innovative forms of residential development (e.g., New Urbanism, transit-oriented development). Likewise, the magnitude of investment required to support some multi-family and high-rise projects can serve as a deterrent for small or inexperienced firms, given that the failure of such a project could conceivably end in bankruptcy. In the literature, risk-aversion and satisficing behavior have been linked to discontinuous urban growth patterns through two mechanisms (Barnard and Butcher, 1989: 679). The first holds that land parcels that are most desirable based on their physical and locational characteristics are scattered and therefore, these parcels are developed first regardless of the implications for urban form or service provision. The second hypothesis states that under-valued land parcels are discontinuous in their spatial configuration and are developed more quickly. From a services provision perspective, a more compact and contiguous pattern of development is more efficient and a key implication of the Cyert and March (1992) perspective is that increasing the predictability and transparency of the regulatory process will encourage developers to make decisions that generate greater returns, but also contribute to more efficient land use patterns.

Another consequence of uncertainty and satisficing behavior is a tendency to treat each development project as a discrete entity, rather than as an overall portfolio that includes both current and future projects (Mohamed, 2006). One explanation for this approach is that each project “must unambiguously pay for itself” in order to successfully justify the proposal to lenders or investors (Mohamed, 2006: 33). However, measures designed to reduce uncertainty and encourage more efficient development patterns may backfire. Mohamed (2006) argues that a more predictable and transparent regulatory process may actually reinforce the satisficing behavior of developers by allowing them to quickly move from one project to the next once the profit target has been met. Also, the perceived costs and complexity of pursuing projects in established areas may sometimes lead to suboptimal site selection choices that are inefficient from a growth management perspective (Byun and Esparza, 2005).

3.4 A Conceptual Model of Land Subdivision

Subdivision of a land parcel for residential use is the culmination of a long process that involves many actors and decisions. Chief among these actors is the land developer by virtue of the site selection and land acquisition processes described above. However, the regulatory framework and development review process within each jurisdiction also plays a role. Figure 3.1 provides a graphical representation of the parcel subdivision process[6] and reflects the basic relationships between land developers, land owners, and local government.

The starting point for the land subdivision process, as depicted in Figure 3.1, is with a general idea for a development project, informed by the availability of financing, housing demand, and the local regulatory framework. Financing is a key component of successful real estate ventures and the goals of the land developer are generally "to raise the maximum amount of funds at the lowest possible cost and to share as much of the risk as they can with their financial backers" (Bookout, 1990: 101). The goals of investors and lenders are similar in that they each seek the highest possible return, while minimizing their exposure (Corgel *et al*., 1998: 191). This shared risk-aversion and profit incentive is what links these two actors within the land development system and the ability to harness enough financing is one of the primary factors in whether a proposed project moves past the initial stages (Bookout, 1990).

A successful development project must be marketable, which means that there must be adequate demand for housing of the same type, price range, and character to ensure acceptable absorption rates. The market analysis is a fundamental component of the development process and assesses the feasibility of the proposed project, given current and

[6] Healey (1991) provides a review of conceptual models of the development process with an emphasis on their treatment of agency.

expected trends in the demand for and supply of housing in the targeted area (Bookout, 1990: 15). Examples of factors influencing the demand for housing include: household income, population trends, existing housing stock, mortgage conditions, expectations for the future, consumer preferences, and seasonality (Corgel *et al*., 1998: 276). Experienced developers are able to anticipate changes in housing demand and other market forces to deliver products that meet the needs and match the preferences of their target markets despite the inherent complexity and uncertainty of the land development process.

The regulatory framework also helps to shape the specific characteristics of a proposed project. Despite attempts to reduce uncertainty and facilitate an orderly development process by streamlining regulatory processes, in many areas government regulations are still deemed an obstacle by developers and chief among these were subdivision ordinances, building codes, and zoning (Ben-Joseph, 2003). These basic land use controls have been around for a long time, but regulatory frameworks are becoming more sophisticated as more local governments are implementing growth management policies as a means of mitigating the negative consequences of rapid growth. Adequate public facilities ordinances, moratoria, and urban service limits are examples of policy instruments that could potentially impact or negate the feasibility of a candidate parcel for development. These policies are still relatively new and potentially add to the uncertainty of the land development process in jurisdictions in which they are implemented (Pendall, 1999).

After considering these three factors and deciding on the specifics of a proposed project, the land developer derives search criteria (either formally or internally) and begins the search for land parcels that are likely candidates, given the type, size, character of the

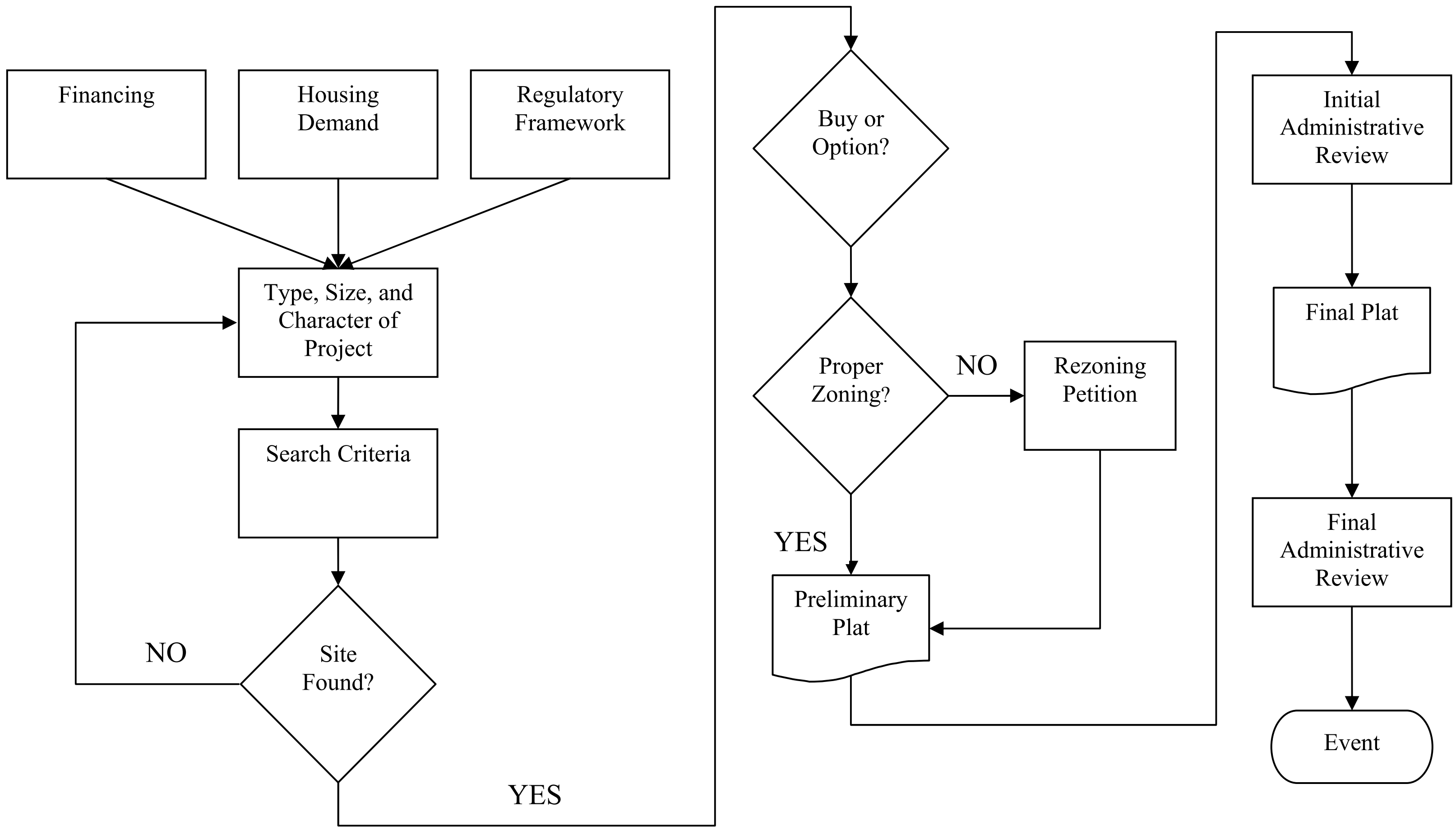


Figure 3.1: Conceptual Model Of Land Parcel Subdivision.

project. This search could be contracted out to brokerage firms or conducted in-house using a variety of strategies and techniques including: “windshield surveys,” geographic information systems (Barnett and Okoruwa, 1993), or through established networks and relationships within the industry (e.g., builders, lenders). If no suitable candidates are identified, some characteristics of the planned project may be modified or the idea may be shelved until conditions are more favorable. If a suitable candidate(s) is found, the land owner is contacted and negotiations to option or purchase the land may begin. If these negotiations are successful, the next step in process may involve submitting a rezoning petition. If the property is properly zoned, then the subdivision approval process begins with the preparation and submission of a preliminary plat. The preliminary plat typically includes: a formal application, proposed number of units and lot sizes, construction schedule, and site plan (Bookout, 1990: 199). After initial review and approval by local government staff, a final plat is submitted that includes a more detailed site plan and addresses concerns raised during the initial review. Following final review and approval, the plat is recorded and the next phase in the development process begins (construction permits). Arguably, the most important elements of the model presented in Figure 3.1 are the site selection and land acquisition components[7] and the following sections treat each of these in greater detail.

3.5 Site Selection Considerations

It is not enough to simply understand the overall psychology of the land development community, it is also necessary to identify the factors that make a site an attractive candidate for residential development. To some extent, site selection considerations or search criteria

[7] Both are identified as key decisions in residential land conversion process model offered by Weiss *et al*. (1966) and Kaiser and Weiss (1970).

(see Figure 3.1) vary depending on the type and size of the proposed project. However, the same characteristics that make a given location attractive to home-buyers or renters on the demand side, also influence its appeal for land developers on the supply side through enhanced marketability of the finished product (Chapin and Weiss, 1962).

3.5.1 Physical Characteristics

The physical characteristics of a candidate site are important because they influence the market value of the product and the costs of development. An example of physical characteristics enhancing the attractiveness of a site is adjacency to amenity features like protected open space (Geoghegan, 2002) or waterbodies. On the other hand, the presence of wetlands or steep slopes add complexity and cost to the development process and typically reduce the overall attractiveness of a candidate site (Bookout, 1990: 52).

3.5.2 Accessibility

Bid-rent theory, as articulated by Alonso (1964), asserts that households tradeoff land consumption for accessibility, with the rents paid at a given location reflecting the price of its specific level of accessibility to the central business district. As the traditional assumption of a single centralized employment center becomes less plausible the importance of accessibility remains, but must be renegotiated. Proximity to destinations including employment centers, shopping centers, and recreational opportunities are important, but ease of accessing key transportation infrastructure like freeways is also significant.

3.5.3 Policy Context

There are several ways in which policy factors influence the attractiveness of a land parcel for development. Perhaps the most obvious of these is the zoning designation. If a given site is not already zoned for residential use, a prospective developer will need to navigate the local rezoning process, which can increase the time and cost (fees) involved in bringing a project to market (Goldberg, 1974; Bourne, 1976; Hepner, 1983). The property tax rate (Bayoh *et al*., 2006) and quality of local schools (Kim *et al*., 2005; Munroe, 2007) are also important considerations for the site selection process by virtue of their influence on the location choices of households. Finally, the availability of public infrastructure is critical to the attractiveness of candidate sites for residential development (Chapin and Weiss, 1962; Lee, 1979).

3.5.4 Demographics

The demographic and socioeconomic characteristics of the neighborhood or immediate area surrounding a candidate land parcel are also important considerations. Early examples of the importance of socioeconomic factors in understanding residential development patterns is reflected in the work of Chicago School researchers like Burgess (1925) and Hoyt (1939). Hoyt's sector model emphasizes the role of high income groups in determining residential development patterns. Essentially, new construction occurs in areas deemed attractive to high income groups (e.g., along transport routes, high social prestige) and when these households relocate, existing housing stock filters down the socioeconomic ladder. The supply side focus of the sector model provides a contrast to the earlier concentric zones model, which is demand-driven as social class improve their circumstances and moves on to more desirable neighborhoods. Phe and Wakely (2000) continue this tradition and argue that the social status of a neighborhood is a more relevant in explaining residential location behavior than many of the more conventional factors.

3.6 Land Acquisition

Land owners represent the other half of the supply-side equation. Intuitively, the decision to sell a currently developed parcel is driven by utility maximization and involves discounting future revenue, given current conditions and uncertainty. Undeveloped parcels may be sold to developers for subdivision, built upon by the owner, sold to local jurisdictions for public uses and facilities, or remain undeveloped. If we assume that land owners (like land developers) are profit-maximizers who seek to minimize uncertainty, an important consideration is speculation and strategic behavior. Capozza and Helsley (1989) formulate a simple model of urban land conversion and derive mathematical relationships between the price of land at the periphery, the time of conversion, and the implications of speculative behavior on larger development patterns (urban sprawl). The authors found that the optimal point for parcel conversion, from the perspective of the landowner, is when the net present value of the parcel is maximized, accounting for agricultural rents, cost of conversion, and discount rates. Carrión-Flores and Irwin (2004) expand upon the Capozza and Helsley model by introducing an interest rate and discounting the expected future benefits (Carrión-Flores and Irwin, 2004: 893).

Perceptions of the present of a land parcel tend to vary as neither developers nor land owners have perfect information. The implication for the location of development is that those parcels with below-market perceived present value are the most likely to be developed, if the other minimum requirements of the planned project are also met (Goldberg and

Ulinder, 1976; Barnard and Butcher, 1989). The price of land is also contingent on larger economic conditions with a significant premium associated with favorable expectations about future growth (Guntermann, 1997).

Irwin and Bockstael (2002) hypothesize that the expectations of (undeveloped) landowners are the driving force behind subdivision and by extension, urban sprawl. Here, the basic calculus involves weighing the costs of conversion (infrastructure, administrative fees) and value under current use versus expected value post-conversion (Irwin and Bockstael, 2002: 39). Conversion costs are a function of topography, infrastructure availability, administrative fees and the post-conversion value is a function of proximity to employment centers, natural amenities, lot size, and neighborhood characteristics. However, this conceptualization of the decision to sell or retain land breaks down if the land owner is holding the property for non-economic reasons (Kaiser and Weiss, 1970). In situations like this, interpersonal skills and establishing relationships are critical to successfully acquiring targeted properties. A study by Leung (1986) found that large firms were more efficient at implementing projects, but were out-performed by smaller firms in negotiations with land owners. The explanation for this disparity hinged on the observation that “large and nonlocal firms rely more on financial and organizational resources” while “small firms rely more on local connections and knowledge” (Leung, 1986: 31).

A common strategy employed by developers to minimize risk is to option land rather than purchasing it outright. Options allow developers to hedge themselves against unforeseen problems like abrupt changes in market conditions or failure to secure to necessary approvals and permits. Typically, the landowner receives a small payment for the right to purchase the land at a later date,[8] thereby allowing greater flexibility and limiting financial exposure (Bookout, 1990: 105). Loans and joint ventures are examples of common sources for funding purchasing land parcels.

3.7 Conceptualizing Temporal and Spatial Effects

Subdivision of a vacant parcel for development represents an intense, localized change in land use. As such, these events help to frame and structure the location, timing, and character of subsequent development and there are several reasons why a temporal relationship should exist between land parcel subdivision events. Given the overall aversion to risk that characterizes the land development process, it is not surprising that proven markets are intuitively appealing to land developers. Further, the establishment of new islands of residential development along the urban fringe or pockets of redevelopment in established neighborhoods are intuitively likely to impact the value and price of land and housing in the immediate vicinity by virtue of simple spillover effects. This is the same basic contagion mechanism that provides the rationale and basis for using Euclidean zoning as a tool for safeguarding home values (Muth, 1989: 25). Finally, large-scale projects can influence the extension of public infrastructure into areas that may or may not have been targeted for development. Depending on the regulatory framework and policies of the given jurisdiction, the developer may have the ability to influence the timing and location of infrastructure investments. For example, Hanley and Hopkins (2007) found that single family residential development was not limited by sewerage capacity as many developers were able to afford the costs associated with early extension, when this option existed. These are all

[8] Developers may also pay the taxes and other costs associated with maintaining the property during the specified option period.

potential explanations for why observing one or more subdivision events in a prior time period might affect the probability of observing events at subsequent time periods. In addition to temporal relationships, this dissertation also explores spatial relationships.

The spatial effects examined here are of two basic varieties: scale effects and the spatial extent of temporal (inducement) effect described above. Intuitively, one would expect the "priming effect" for a larger subdivision event to be larger in magnitude than that of smaller parcels that experience an event. Stated differently, the "variables influencing a process may or may not change with scale, but a shift in the relative importance of variables often occurs" (Turner *et al*., 1989: 248) and larger subdivisions are expected to exert a greater effect. The point becomes immediately clear, for example, when traffic impacts are considered for a major versus a minor residential subdivision. Although the possible existence of scale effects can be justified through an appeal to intuition, the present study seeks to formally test for empirical evidence. In general, scale effects are expected to be less pronounced than temporal effects, but this assertion is one of the key hypotheses examined by the present study.

In addition, a sensitivity analysis will be conducted to provide insight into the spatial extent of the hypothesized "priming effect" and a detailed description of the sensitivity analysis and derivation of the associated measures is presented in the following chapter. A study focusing on the relationship between land prices and expectations about future growth in the Phoenix metropolitan area and concluded that "land value are sensitive to the level of residential activity occurring within two to three miles of a parcel but not to activity that is only within one mile of a parcel" (Guntermann, 1997: 13). The dissertation research builds on this study adopted by applying the sensitivity analysis to a model of land subdivision rather than land sales price.

3.8 Summary

This chapter explains the importance of land developers and their decision-making processes within the context of residential development outcomes and overall urban form. It also provides a conceptual model of the land parcel subdivision process and examines the site selection and land acquisition components in greater detail. Finally, the conceptualization of the temporal and spatial relationships between observed parcel subdivision events is explained. The next chapter introduces the study area and describes the overall economic and policy climate during the study period. In addition to the recent housing crisis and economic downturn, growth management policy actions within the study area are discussed to provide a context for interpreting the results of the subsequent analyses.

CHAPTER 4: POLICY FRAMEWORK AND ECONOMIC CONDITIONS

4.1 Overview

The study area for the dissertation research is Mecklenburg County, North Carolina, which encompasses seven municipal jurisdictions and is roughly 526 square miles in area. Charlotte is by far the largest and most dominant of these entities, but smaller municipalities in the northern and southern portions of the county (see Figure 4.1) are increasingly challenged by growth pressures and have pursued a variety of strategies in response to these conditions. According to the U.S. Census Bureau, the population of the county increased by 19% between 2000 and 2006 to just over 827,000 residents. Regional coordination among jurisdictions is facilitated by a number of organizations, including the Centralina Council of Governments and Mecklenburg Union Metropolitan Planning Organization. This chapter provides a brief overview of the land subdivision process and key growth management initiatives within Mecklenburg County and its immediate vicinity. It also paints a general picture of the economic climate and real estate industry within the county since 2000, which is important for understanding the results of the analyses presented in Chapter Six.

4.2 The Study Area: Mecklenburg County, NC

Charlotte is the largest of seven municipalities (Cornelius, Davidson, Huntersville, Matthews, Mint Hill, and Pineville) in Mecklenburg County and Table 4.1 shows population[9] by municipality and for the county as a whole for the three most recent Decennial Censuses.

Table 4.1 : Population Change, 1980–2000.

Jurisdiction	1980	1990	2000	% Change 80-90	% Change 90-00
Charlotte	314,447	395,934	540,828	25.9	36.6
Davidson	3,241	4,046	7,139	24.8	76.4
Cornelius	1,460	2,581	11,969	76.8	363.7
Huntersville	1,294	3,014	24,960	132.9	728.1
Matthews	1,648	13,651	22,127	728.3	62.1
Mint Hill	7,915	11,567	14,992	46.1	29.6
Pineville	1,525	2,970	3,449	94.8	16.1
Municipal	331,530	433,763	625,464	30.8	44.2
Unincorporated	72,740	77,670	69,990	6.8	-9.9
Mecklenburg County	404,270	511,433	695,454	26.5	36

Charlotte is also the largest city in North Carolina (or South Carolina) and the second largest financial center in the United States (Munroe, 2007: 337). The city has not experienced a tax increase since 1987, which one of the factors that makes it an attractive location for businesses and households (City of Charlotte, 2000). Traditionally recognized as a textile producing center, Charlotte has experienced a series of corporate relocations that have redefined its identity as a major financial center and stimulated population growth (City of Charlotte, 2000). Charlotte's central city has experienced many of the problems plaguing

[9] Source: US Census Bureau as compiled by Charlotte-Mecklenburg Planning Commission.

urban areas around the country including high rates of poverty, crime, and disinvestment. Beginning with the *City Within A City* quality of life reports of 1993 and 1997 and continuing with the biennial (2000 through 2006) *Charlotte Neighborhood Quality of Life Study* series, the city has collected and analyzed a variety of social, economic, and physical data at the neighborhood level to serve as a tool for monitoring trends and informing policy.

A recent study using satellite imagery to examine sprawl across the United States found that Charlotte ranked fourth out of 40 U.S. metropolitan areas, with 1990 population greater than 1 million, in terms of the amount of undeveloped land in the square kilometer surrounding an average development in 1976 and 1992 (Burchfield *et al*., 2006: 605). The top two positions in both 1976 and 1992 were held by Atlanta and Pittsburgh. The Charlotte area has been characterized by explosive growth for the past two decades and although steps have been taken to influence the location, rate, and type of new development (e.g., transit corridors, transit-oriented development, New Urbanist subdivisions), it is unclear whether the parallels between Charlotte and Atlanta will be stronger in the future or if alternative patterns of development will take hold. Like many jurisdictions faced with rapid urban development, it has taken time for Charlotte-Mecklenburg to respond to these challenges. Key steps have been taken to address urban growth including the institution of a long-range planning process, coordination of capital improvements, establishment of transit corridors (light rail), and encouragement of mixed-use and transit-oriented development.

Coordination between the City of Charlotte and Mecklenburg County in particular is relatively high with several examples of joint department and services (e.g., police department, utility). One factor that historically contributed to this closer relationship between the city and county is that discrepancies in development standards between jurisdictions tended to create problems when outlying areas were annexed by the city. Charlotte annexes on a two-year cycle in an effort to recapture tax revenue (population) migrating outward to suburban areas, but still places demands on city services and infrastructure and much of Charlotte's growth can be traced to a series of annexations that began in 1991 (City of Charlotte, 2000). Annexation laws in North Carolina allow municipalities to appropriate new growth as it occurs and the existence of a consolidated city-county school system exerts a dampening effect on one of the contributing factors in the "white flight" phenomenon documented in many urban areas (City of Charlotte, 2000).

The overall rate of population increase is accelerating for the county as a whole and for the municipalities, but population growth slowed between 1990 and 2000 for the three southern jurisdictions of Matthews, Mint Hill, and Pineville (see Figure 4.1). The rapid growth in the southern portion of Mecklenburg County that occurred between 1980 and 1990 (most notably, Matthews) was likely fueled by the completion of portions of I-485, also known as the Charlotte Beltway. Likewise, current growth in the northern municipalities may be stimulated in part by continuing work on the northern segments of I-485 scheduled for completion in 2007 and 2016. Despite the presence of seven municipal jurisdictions within the county, significant examples of intergovernmental cooperation are readily available. For example, the City of Charlotte and Mecklenburg County have operated a joint utility since 1972 when the respective water and sewer systems were combined (Charlotte-Mecklenburg Utilities, 2007). Since that time, surrounding municipalities (Cornelius, Davidson, Huntersville, Matthews, Mint Hill, and Pineville) have joined the utility which consists of 72 sewage lift stations and 7,924 miles of water and sewer pipe (Charlotte-Mecklenburg Utilities, 2007). The trend towards decentralization is apparent in Mecklenburg County

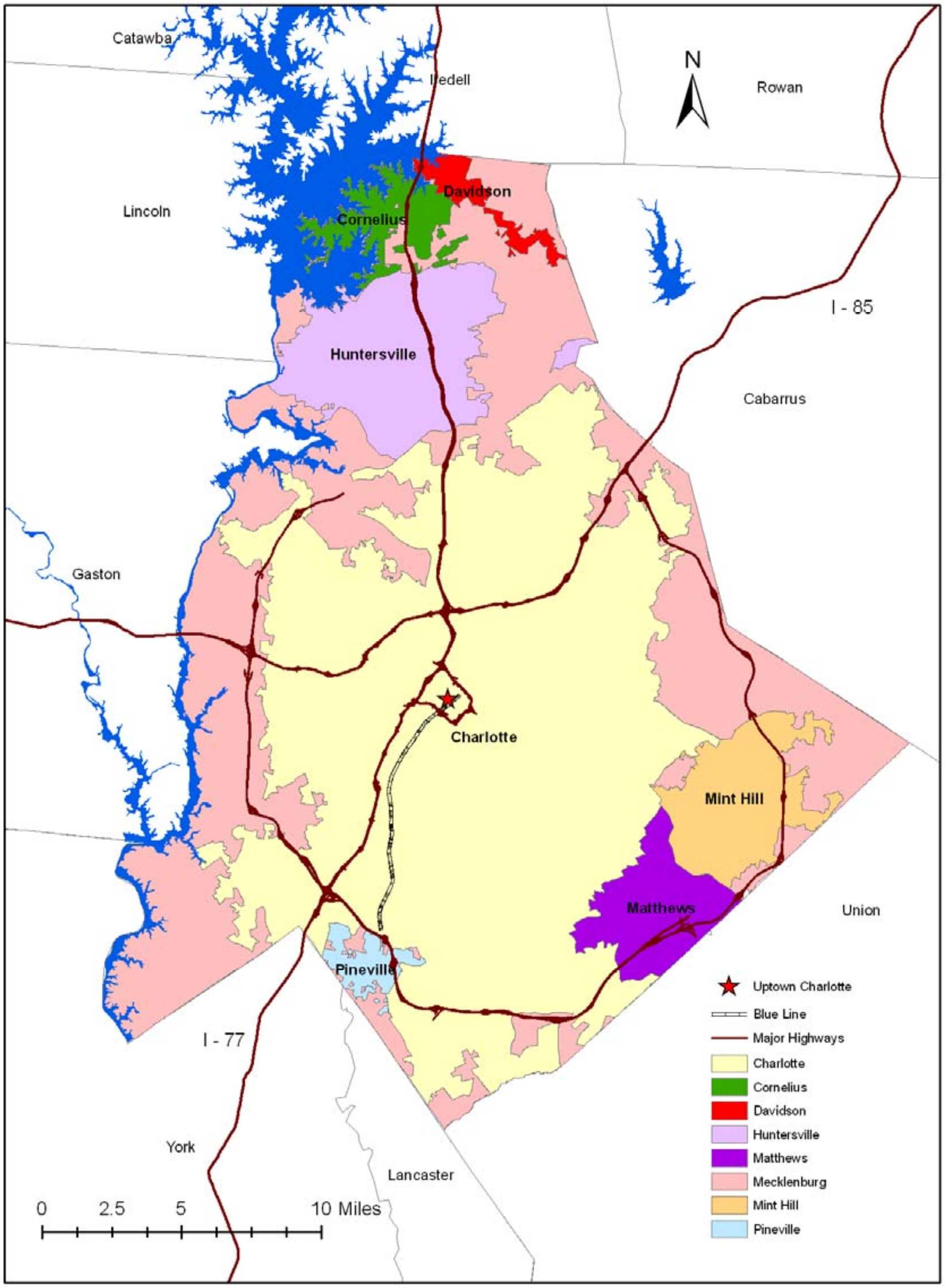


Figure 4.1: Municipal Jurisdictions In Mecklenburg County, 1999.

where Wilson and Song (2009) found that single-family residential development occurred most heavily in the urban fringe areas (outer suburbs and rural greenfields) between 2000 and 2003.

New Urbanist development is also making a mark in the local housing market. Birkdale Village, Monteith Park, Rosedale, and Vermillion are all neotraditional developments located in the town of Huntersville situated northwest of Charlotte along the southeastern shores of Lake Norman. Ayrsley, located in southwest Charlotte near the Wylie corridor and I-495, boasts a mix of residential, commercial, and office uses. First Ward Place in downtown Charlotte is billed as affordable housing and includes not only a mix of housing types (single-family, apartments) but also a mix of incomes (housing assistance, market rate mortgages). The project was funded in part by a $41.6 million HOPE VI grant from the Department of Housing & Urban Development designed to stimulate redevelopment in downtown Charlotte.

4.3 The Subdivision Process

The subdivision approval process in the City of Charlotte and Mecklenburg County is unified[10] and the other municipalities have procedures that are more or less the same. This process typically consists of two phases: the preliminary plan and the final plat. The preliminary plan phase involves initial submittal of the plan for the proposed project and may include sketches, the layout of lots, street construction details, and drainage and applicants are expected to enlist the aid of licensed surveyors, engineers, or landscape architects in preparing these materials. Next, the local planning and engineering departments will review

[10] Residential subdivision proposals located within the city or in the unincorporated areas of the county are administered by the Charlotte-Mecklenburg Planning Commission Subdivision Administrative Staff. In other municipalities, the Planning Board (or Town Commissioners) is the decision-making authority.

the preliminary plan for compliance with applicable regulations and standards as well as compatibility with established plans. An assessment of the likely impacts of the project or proposed action, both immediate and cumulative, within the context of established goals and objectives that incorporates data from a variety of sources is the centerpiece of the review process (Kaiser *et al*., 1995: 439). If all reviewers approve, the preliminary plan is accepted and the applicant may move forward with the second phase of the process.

The final plat involves submitting a more detailed version of the preliminary plan that may include exact dimensions of lots, locations of right-of-ways, and other specific information used for administrative (deed and title) work. The final plat is reviewed by local planning and engineering staff and the approved map is recorded. At this point, work on the project may begin, but additional permits may also be required (e.g., building permits, certificate of occupancy).

4.4 Local and Regional Growth Management Efforts

Growth management policies like growth moratoria and adequate public facilities ordinances have not been widely implemented in North Carolina (Ducker, 2003). Most states are more closely aligned with the Dillon Rule paradigm, which holds that municipalities and local jurisdictions only have those powers that are expressly delegated by the state government (Richardson *et al*. 2003), although some have argued that "home rule," which affords greater autonomy to local jurisdictions, would enable elected official and policy makers to craft more effective responses to urban sprawl and cope with the pressure or rapid growth. Bluestein (2006) cites several cases that suggest that North Carolina's position lies somewhere between these two camps. Because the Charlotte metropolitan area is one of the fastest growing in the United States, it is no surprise that these regulatory tools are appearing with increasing frequency as communities attempt to respond to the challenges of rapid growth.

There were several incidents that occurred during the study period that may have affected the number and spatial distribution of observed events (i.e., pattern of residential land parcel subdivision). First, the towns of Davidson (in 1999, 2000, 2004), Huntersville (in 2002), Cornelius, and Pineville (both in 2007) imposed development moratoria during the study period. Second, Charlotte-Mecklenburg Utilities imposed a 14-month moratorium on new sewer extensions (beginning in June 2003) within the McDowell Creek waste water treatment plant service area (Beshears, 2004). Although this was not a political decision and simply reflected a lack of treatment capacity, it had a dampening effect on development within the northwest portion of Mecklenburg County (e.g., Huntersville, Cornelius, Lake Norman). Figure 4.2 presents a timeline of these events along with other notable growth management-related actions and events in Mecklenburg County, its municipalities, and neighboring jurisdictions.

Adequate public facilities ordinances were also implemented in and around Mecklenburg County during the study period. Cabarrus County borders Mecklenburg to the northeast and is home to the fast-growing cities of Concord and Kannapolis. In 1998, it adopted an adequate public facilities ordinance to help stem the tide of development and ease school overcrowding and enacted a six-month moratorium on new subdivisions in unincorporated areas in December of 2004 (Glassberg, 2004). In June of 2001, the Town of Davidson adopted an adequate public facilities ordinance to prevent the rate of development

Figure 4.2: Growth Management Timeline.

December 1999	Davidson enacts six-month moratorium on development in the town’s 4,000 acre ETJ (Dodd and Jacobus, 2000).
November 2000	Davidson enacts six-month moratorium on new subdivisions and commercial development to adopt new zoning rules and an open space preservation plan (Dodd and Jacobus, 2000).
June 2001	Davidson adopts adequate public facilities ordinance based on police, fire, and parks capacity (Dodd, 2001).
July 2001	The towns of Troutman (Iredell County) and Belmont (Gaston County) adopt development moratoria for six and seven months, respectively (Wrinn and Moore, 2001; Depriest, 2001).
February 2002	Huntersville enacts one-year moratorium on residential subdivision proposals to draft and adopt new zoning and subdivision ordinances (Mitchell, 2003).
April 2002	U.S. Supreme Court upholds legality of development moratoria (*Tahoe-Sierra Preservation Council Inc. v. Tahoe Regional Planning Agency*).
June 2003	Charlotte-Mecklenburg Utilities stops accepting new applications for sewer line expansions in McDowell Creek WWTP service area, which includes Cornelius, Davidson, and Huntersville (Beshears, 2003).
September 2004	McDowell Wastewater Treatment Plant expansion completed and 14-month moratorium on sewer extensions in northern Mecklenburg County is lifted (Beshears, 2004).
October 2004	Davidson adopts one-year moratorium in eastern portion of town (NC 73 corridor).
December 2004	Cabarrus County enacts six-month moratorium on new subdivisions in unincorporated areas (Glassberg, 2004).
April 2005	Lancaster County enacts one-year moratorium on new subdivisions in the panhandle area bordering Union and southern Mecklenburg counties (Bell, 2005; Eichel, 2006).

February 2006	Lincoln County rejects proposal to adopt adequate public facilities ordinance (George, 2006).
June 2006	Iredell County (heavily agricultural) rejects proposal to increase minimum lot sizes and enact a six-month residential development moratorium (Ni, 2006).
October 2006	Union County adopts slow-growth (adequate public facilities) ordinance to address school overcrowding (Oliver, 2006).
February 2007	Cornelius adopts five-month moratorium on all new multi-family development projects and all new residential subdivision plans (Tierney, 2007a).
April 2007	Pineville enacts one-year moratorium in selected areas of town while land use plan and growth management rules are revised (Valle, 2007).
November 2007	Union County voters reject land transfer tax by a margin of almost 5 to 1. Tax measure has failed in all other counties that have voted on it as well.
December 2007	Huntersville adopts adequate public facilities ordinance based on police, fire, and parks capacity (Tierney, 2007b).
January 2008	The town of Weddington (Union County) enacts an 18-month moratorium on most commercial and residential development (Basen, 2008).
September 2008	Superior Court judge rules against a group of developers and builders who sued Union County to throw out the Adequate Public Facilities Ordinance (Harrington and Torralba, 2008).

from outpacing the capacity of key public infrastructure and services to serve new development. The ordinance focused on traffic impacts, law enforcement, fire protection, and parks facilities (level of service) as the basis and justification of the regulations[11]. One of the key objectives of the ordinance was to "discourage suburban sprawl and to promote the small town character of Davidson as called for throughout the Davidson Planning Ordinance" (Town of Davidson, 2003). The ordinance was controversial and drew opposition, primarily from land owners within the town's 4,400 acre extraterritorial jurisdiction (Dodd, 2001).

Union County, which borders Mecklenburg to the southeast, followed suit and adopted its own slow-growth ordinance in October 2006 to address chronic school overcrowding. Between 2000 and 2006, the rate of population growth in Union County (42%) was significantly higher than the 19% increase observed in Mecklenburg County (Weir, 2007). The ordinance required developers to either delay construction until existing capacity could be expanded or pay a fee for each unit constructed in areas with overcrowded schools (Oliver, 2006). In September 2008, a Superior Court judge ruled against a group of developers and builders who sued Union County to have the ordinance overturned, providing encourage for growth management advocates in the region (Harrington and Torralba, 2008). The most recent example is from December 2007 when the Town of Huntersville adopted its own adequate public facilities ordinance. Like Davidson, the Huntersville ordinance focuses on police, fire, and parks and developers have the option to "withdraw the proposal, build in phases or reduce the proposal, or help pay for new facilities" if the town's facilities are at capacity (Tierney, 2007).

[11] Schools were not included because the town does not administer public schools (Charlotte-Mecklenburg Schools).

4.5 Economic Conditions

Intuitively, the larger economic climate also plays a role in the number of location of land parcel subdivision events observed over time. Historically known as a textile center, an influx of professionals drawn by Charlotte's financial services and distribution industries has fundamentally changed the local economy (City of Charlotte, 2000). From multiple professional sports franchises to its emergence as a center for NASCAR (Lowe's Motor Speedway is located in nearby Concord), the Charlotte area has become a destination for entertainment that is both a cause and consequence of the demographic changes associated with this in-migration. Between 2000 and 2006, the Mecklenburg County economy has become more diverse with manufacturing (14.4% to 11.4%) and wholesale trade (5.4% to 5.0%) sectors experiencing significant declines in percent of total county employment[12]. The manufacturing that remains in the area is also changing with the Goodrich Corporation (aerospace and defense) serving as one high-profile example of this shift (Charlotte Chamber of Commerce, 2008a). Further evidence of the growth and diversification of the regional economy is the North Carolina Research Campus in Kannapolis (neighboring Cabarrus County) that will focus on biotechnology, nutrition, agriculture, and health research and development (N.C. Research Campus, 2008).

Sectors that gained ground during this period include: Health Care and Social Assistance (12.4% to 13.3%), Accommodation and Food Services (8.7% to 9.5%), and Professional, Scientific, and Technical Services (6.0% to 6.7%). The construction (5.2% to 5.5%) and finance (5.8% to 6.1%) sectors also registered significant gains relative to their

[12] Source: U.S. Census Bureau, County Business Patterns (http://www.census.gov/epcd/cbp/index.html).

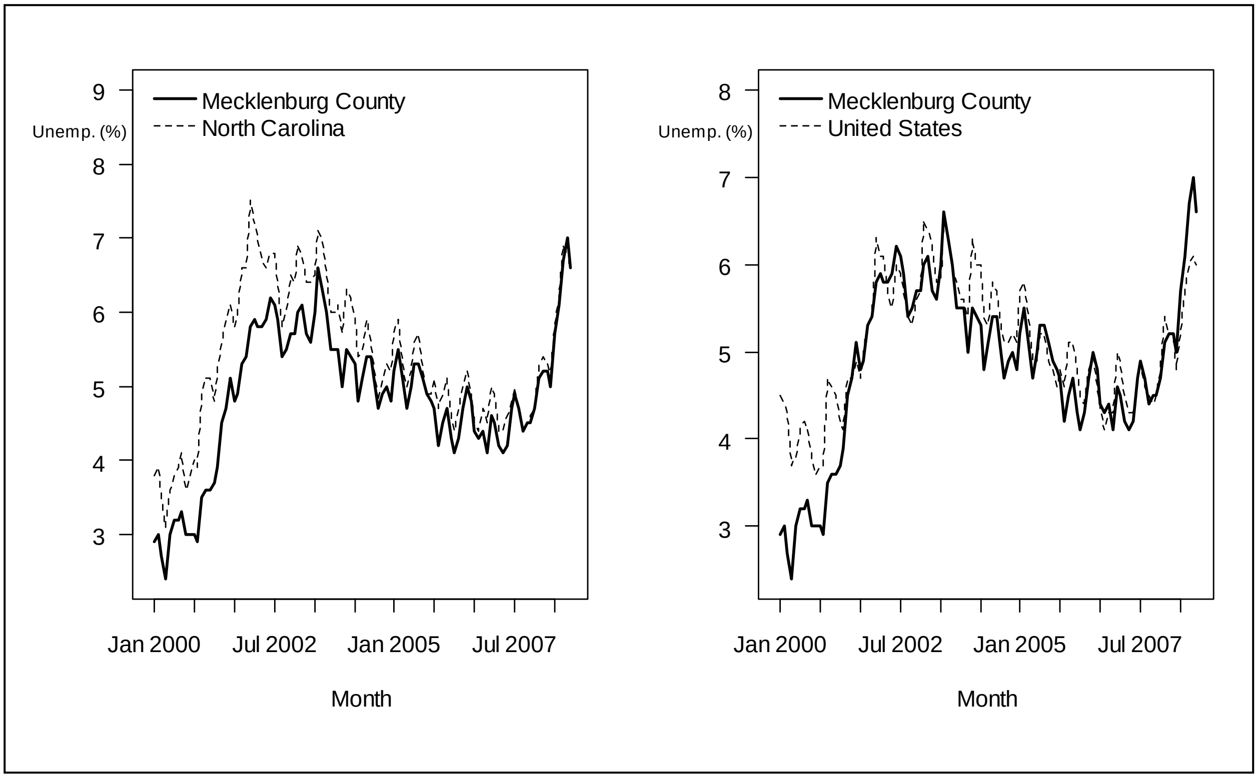


Figure 4.3: Monthly Unemployment Rate (Not Seasonally Adjusted).

2000 levels. Paralleling the increase in construction industry employment, the price of land for residential purposes in Mecklenburg County has risen drastically (Eichel, 2006; Cimino, 2007). However, just as a booming economy has contributed to the growth of the construction and real estate industries, the effects of an economic downturn can spillover into these arenas.

Beginning in late 2005 and early 2006, the effects of the larger economic crisis began to impact real estate markets across the country, including Mecklenburg County. Figure 4.3

shows the unemployment rate[13] in Mecklenburg County relative to the statewide and nationwide rates by month, from January 2000 to September 2008. For most of the time period, unemployment in Mecklenburg County is far below that for the state, until roughly the Summer of 2007 when the lines converge. Unemployment in Mecklenburg County also is historically less than the nation as whole, but with the recent downturn in the economy and significant increases in local unemployment, the rates are now very similar. The local unemployment rate peaked between June 2002 and August 2003, then declined steadily before rising again in 2008. Despite adding over 7,000 households, per capita income in Mecklenburg County fell slightly between 2002 and 2003, providing further evidence of economic challenges during this period (Charlotte Chamber of Commerce, 2008b). Broad economic shifts such as changes in the labor market are not immediately manifest in housing markets. However, the effects of a souring economy are apparent in the housing starts statistics[14] presented in Figures 4.4 and 4.5 allowing for a temporal lag. As shown in Figure 4.4, the trend in both the region and nation is towards a drastic decline in single-family housing starts beginning roughly in March 2006. Multi-family starts have held relatively constant at the national level, but account for a smaller overall share of residential construction. Data compiled for the South region, which includes North Carolina and 16 other states exhibit a similar pattern (Figure 4.5).

[13] Source: U.S. Bureau of Labor Statistics, (http://data.bls.gov/PDQ/outside.jsp?survey=la).

[14] Source: U.S. Census Bureau, Residential Construction Branch, http://www.census.gov/const/www/newresconstindex.html

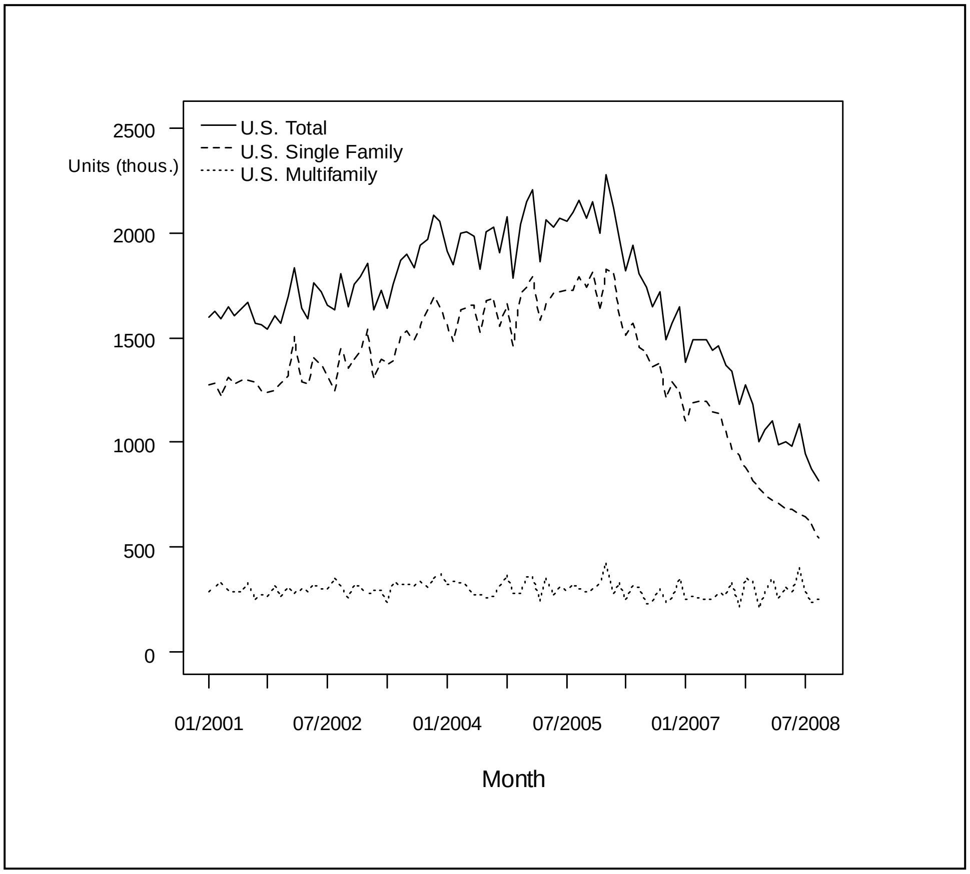


Figure 4.4: Housing Starts, United States (seasonally adjusted): 2001-2008.

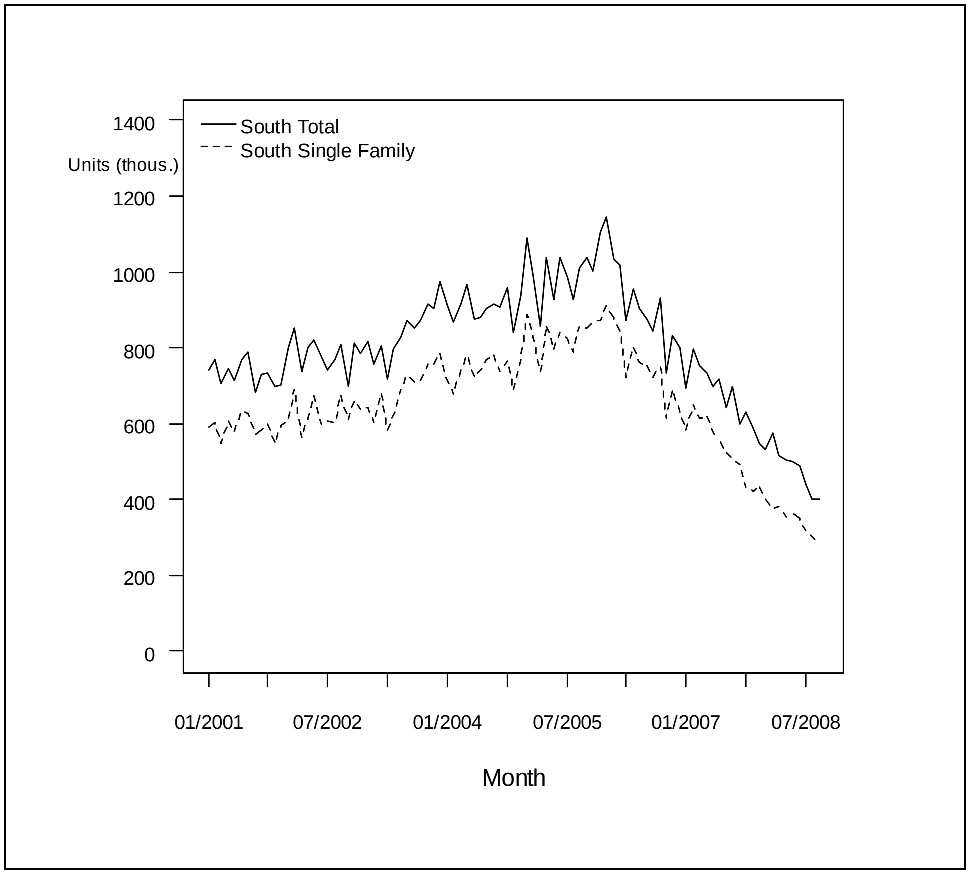


Figure 4.5: Housing Starts, Southern Region (seasonally adjusted): 2001-2008.

Real estate markets have historically been characterized by cyclical patterns and explanations for this phenomenon have focused on three factors (Corgel *et al.*, 1998: 283):

- The length of time required to bring projects to market
- Unwillingness of lenders to stop lending when markets are saturated
- Reluctance of lender to resume lending once conditions recover

Barras (1994) provides a more detailed discussion of residential building cycles, but to paraphrase, periods of low economic activity result in shortages of property in subsequent periods. As demand recovers, restricted supply leads to sharp increases in rents and property values, signals that trigger a wave of development and building. However, due to the time lag between housing demand increases and when these new products come to market, rents and property values continue to rise in the mean time. Once most of this new construction becomes available, the business cycle often has slowed and is accompanied by reduction in lending and an increase in interest rates to check inflation. With the waning of the boom, demand for property declines and the result is falling rents and property values coupled with surplus housing. Reduced access to credit exacerbates the economic slowdown and hits companies still holding unsold properties particularly hard with “depressed values, high levels of vacancy, and widespread bankruptcies in the property sector” (Barras, 1994: 186). There is also evidence to suggest that economic downturns tend to be sharper and shorter in duration than the economic recoveries (Neftçi, 1984).

The preceding discussion helps to place the cyclical nature of real estate markets and observed trends at the national and regional levels in context so that at the local level, the number and acreages of preliminary subdivision approvals for the City of Charlotte and Mecklenburg County can be examined over time. Figure 4.6 shows the number (left panel) and total acreage (right panel) of all single family and multifamily subdivisions approved by the City of Charlotte and Mecklenburg County (municipalities are not included) by year. The decline in subdivision approvals in 2002 is likely due (in part) to the moratoria and sewer capacity issues described in Section 4.4 and the decrease in 2005 possibly reflects the recent economic slow-down and general market cyclicality. Although multi-family subdivision approvals did follow a similar trajectory, the fluctuation in the both the number and total acreage is much more stable, relative to single family subdivision approvals.

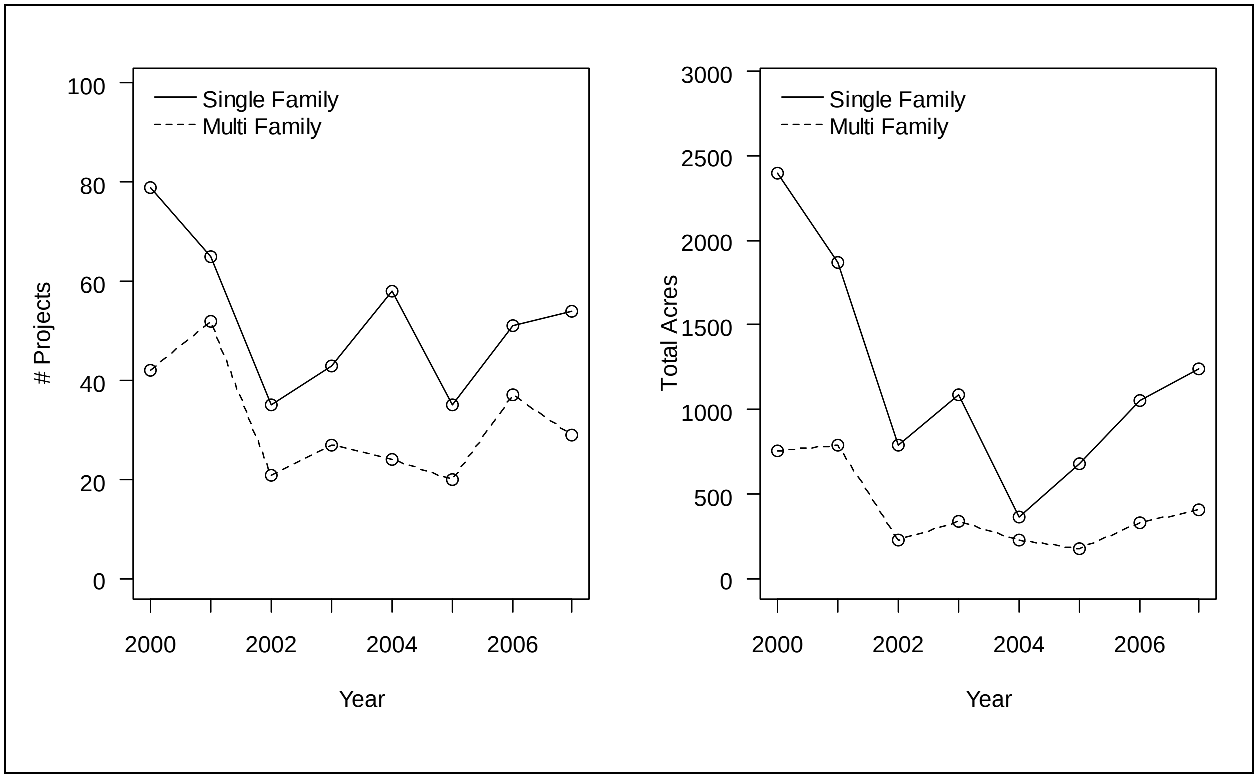


Figure 4.6: Single And Multi-Family Subdivision Approvals: 2000-2007.

The pattern for mixed use non-residential subdivision approvals in the Charlotte and Mecklenburg County (municipalities are not included) is much different. Mixed use developments have been permitted in Mecklenburg County since 1992 and the first project in the city limits was Phillips Place, located near South Park (Kirkpatrick, 2008). There are fewer approvals for mixed use subdivisions with the city and county jurisdictions during the study period, but the number of approvals remained constant during the moratoria and sewerage capacity problems of 2002 and 2003. In fact, the total acreage of mixed use projects approved steadily increased during the early portions of the study period. This could be attributed to the smaller overall number of projects, which could be more easily dispersed

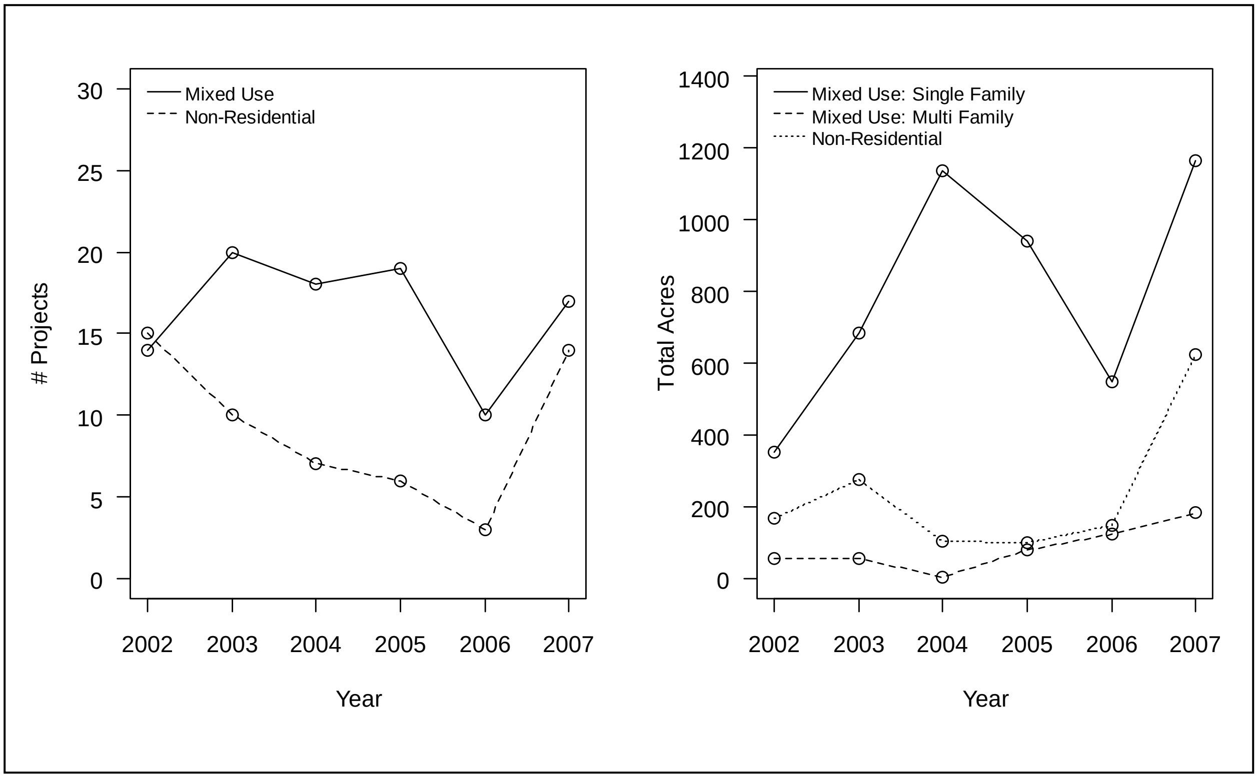


Figure 4.7: Mixed Use And Non-Residential Subdivision Approvals: 2000-2007.

across a wider geographic area and therefore, less affected by these factors. However, the dip in approvals seen in Figure 4.6 for single family and multi-family subdivision is apparent in the 2006 mixed use approvals downturn of Figure 4.7.

Non-residential subdivisions, on the other hand, follow an opposite trajectory. In the early portions of the study period the number of approvals declines sharply, but recovers just as the number of residential approvals falls. This phenomenon is attributable to an increasing emphasis on non-residential development in Mecklenburg County as housing demand cools (Smith, 2006; Hall 2006). The reasoning is that office and commercial development can now be built to serve the abundance of residential development that occurred in prior years and this switch may help local developers to weather the current downturn in the residential market.

Table 4.2 presents data from all local jurisdictions (Charlotte, Mecklenburg County, smaller municipalities) on the number and type of building permits[15] issued between 2001 and 2007. The overall pattern from the subdivision housing starts and subdivision approvals data is also detectable here, but at yet another temporal lag. The first column of the table shows building permits for one and two family residential structures and the sharp decline between 2002 and 2003 is there, but the drop in housing starts and subdivision approvals at around 2005 is not reflected in these data. Understanding and explaining this discrepancy is where the previous discussion of the cyclical nature of real estate markets becomes particularly relevant. One hypothesis is that issuance of a building permit does not obligate

Table 4.2: Residential Building Permits Issued (All Jurisdictions).

Period	Residential (1 and 2 Family)	Apartments (Multi-family)	Condos (Multi-family)
2001	7,945	824	465
2002	8,097	127	593
2003	1,868	284	264
2004	8,872	393	421
2005	9,780	380	843
2006	10,383	438	2,475
2007	7,664	181	1,505
TOTAL	54,609	2,627	6,566

the recipient to actually begin construction. Developers are reluctant to invest in new projects if the existing inventory of housing is not being absorbed by the market and perhaps rather than flooding an already sluggish market, many may opt to delay projects that have been

[15] Mecklenburg County Land Use and Environmental Services Agency (LUESA), Code Enforcement.

approved until conditions improve. This helps to explain discrepancies in the number of building permits issued (Table 4.2), the number of subdivisions approved (Figures 4.6 and 4.7), and the number of actual housing starts in a given time period (Figures 4.4 and 4.5).

When considering these trends and the data presented here, it is also important to remember the "pipeline effect" of real estate markets. The time between approval of a proposal, the onset of construction, and occupancy can take years with the possibility of many intervening factors to delay or derail the project. This explains why some degree of development occurs within a given jurisdiction (like Davidson) in the midst of a moratorium if permits that were previously issued (i.e., in the pipeline) are honored. Stated differently, the inherent lag effect of real estate development means that examination of the data and trends presented above should allow for the effect of an action like a moratorium to manifest itself in later time periods. Similarly, the uncertainty of real estate development projects, particularly in a volatile economic climate, helps to explain why building permits and preliminary subdivision approval statistics may not tell the whole story of conditions on the ground.

4.6 Summary

This chapter focused on the policy framework of Mecklenburg County and its constituent jurisdictions as it relates to the subdivision of land parcels for development and efforts to meet the challenges of rapid growth. Several municipal and county jurisdictions have adopted growth moratoria and adequate public facilities ordinances in response to these pressures and the success of several high-profile mixed use projects contribute to a changing climate for residential development in the area. The real estate markets in Mecklenburg

County have benefitted greatly from the strong and diversifying economy, but these linkages also help to explain recent fluctuations in the residential land development and housing construction. There is evidence suggesting that at least in the short-term, many developers are shifting their focus to non-residential projects in light of softening housing demand and a weakening economy. The next chapter provides an overview the datasets and analysis methods employed to address the research questions posed on Chapter 1.

CHAPTER 5: DATA AND METHODOLOGY

5.1 Overview

This chapter describes the variables (dependent and independent) used in each component of the analysis and the data sources from which they were derived. Spatial datasets were a key source of information, but data in a variety of formats were utilized. It also outlines the methods employed and presents an overview of how the components of the dissertation relate to one another. A mixed methods approach was adopted to allow for more robust inference as well as to provide a richer context for the results and findings.

5.2 Local Government Data Sources

In many ways, this dissertation is an adjunct of the *Advanced Modeling System for Forecasting Regional Development, Travel Behavior, and the Spatial Pattern of Emissions* project, funded by the U.S. Environmental Protection Agency and focusing on the Charlotte, NC metropolitan area. Many of the datasets used for the dissertation research were first gathered to support this larger effort. A variety of spatial datasets (primarily in ESRI shapefile format) were acquired from local partners at the Charlotte-Mecklenburg Planning Department, Charlotte Department of Transportation, and the Land Use and Environmental Services Agency (LUESA). Chief among these were parcel shapefiles that show the boundaries of each lot as well as numerous attributes at one-year increments between 2000 and 2008. These datasets are the basis of the parcel change analysis through which, the dependent variable for the survival analysis models was generated. Examples of other spatial datasets employed include: parks, shopping centers, wetlands, building permits, and land cover. Non-spatial data were also acquired from local sources including information on vacant land parcels sold within the county, which were used to estimate hedonic models of land value.

5.3 State and Federal Government Sources

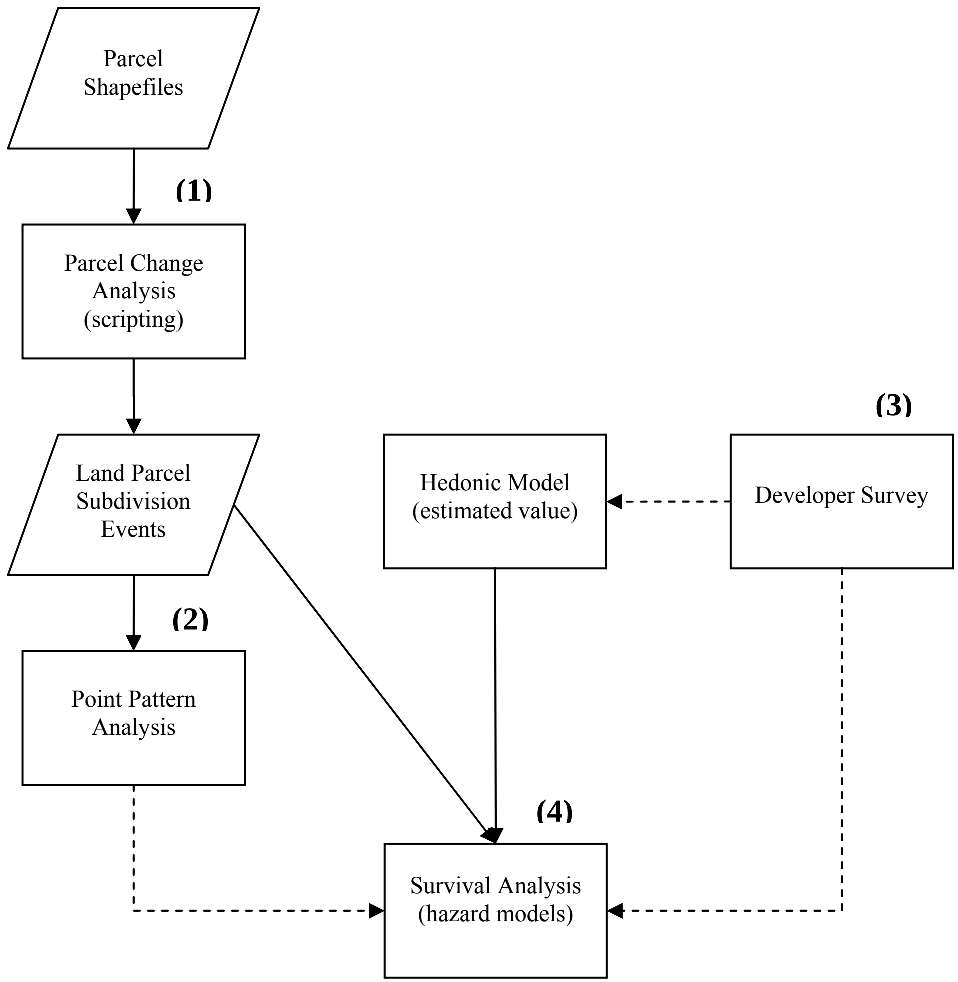
State and federal agencies also provided several datasets used to conduct the dissertation research. The N.C. Department of Transportation makes a variety of spatial data available to the public including street networks and topographic information (20’ contours) and these data were useful in deriving independent variables for the regression analyses. The N.C. Department of Revenue compiles and maintains historical information on property tax rates at the county and municipality levels statewide, which were also used as controls. Finally, a variety of demographic and social measures compiled by the U.S. Census Bureau and distributed at the block group (SF3) and traffic analysis zone (CTPP) levels were also used.

5.4 Analysis Components: Linkages and Purpose

A variety of methods have been employed to address the research questions posed in Chapter 1, and Figure 5.1 provides an overview of the linkages as well as a brief description of the purpose of each of these components of the dissertation research. The first component is the parcel change analysis, which uses Python scripting and a series of parcel shapefiles to determine if and when vacant land parcels, which met the criteria for inclusion in the sample, experienced a subdivision event. In many ways, this procedure is the foundation of the dissertation research in that its results are used as inputs to both the point pattern and survival analysis components.

The second component of the research treats the results of the parcel change analysis (event locations) as a spatial point pattern and uses standard techniques to test to for evidence of spatial structure. The objective here is simply to determine if the location of observed land parcel subdivision events exhibits a discernible pattern (e.g., clustering, dispersion), but because the influence of covariates is not directly represented, this analysis is exploratory in nature and intent. However, the point pattern results do provide some general insight into the extent of spatial interaction among observed events, hence the dashed line connecting it to the survival analysis component.

The third component of the research is an online survey of land developers having completed at least one project within the study area over the past decade. The purpose of the survey was to identify relevant independent variables for the regression models and to provide a richer context for the results. The target response rate of 8 to 10 participants was exceeded (N = 12) but again, the results were never intended to be statistically analyzed and therefore, sample size was not a consideration. The survey responses did influence the choice of independent variables for the survival analysis and its supporting hedonic regression model, hence the dashed connecting lines shown in Figure 5.1 above.



Purpose of Analysis Components

(1) Parcel Change Analysis: identify when and where land parcels subdivision events occur.

(2) Point Pattern Analysis: test for spatial structure in observed event locations (exploratory).

(3) Developer Survey: identify relevant variables and provide context for regression results.

(4) Survival Analysis: identify determinants; test for evidence of "priming effect" and scale dependence.

Figure 5.1: Components Of The Research Project.

The fourth component of the research involves the estimation of parallel discrete-time hazard models. These models are designed to identify the determinants of land parcel subdivision events, test for evidence of a hypothesized "priming effect" on subsequent development, and provide insight into the spatial extent of the "priming effect." These models offer a basis for evaluating the plausibility of the main hypothesis that large land parcel subdivision events are more influential than clusters of small land parcel subdivision events in predicting and explaining observed patterns. The results of the parcel change analysis are used to derive the dependent variable (probability of observing an event in current time period, given that no event has previously occurred) and a key independent variable, an estimate of the market value of the land parcel, is calculated using a separate hedonic regression model. The hedonic model is based on sales information for vacant land parcels in the study area and the parameter estimates from the fitted model are used to predict the sale price of the vacant land parcels in the survival analysis sample.

5.5 Parcel Change Analysis

In order to explore and statistically analyze the determinants of parcel subdivision events in Mecklenburg County, NC, a definition of an event must first be established. For the purposes of this dissertation, an event is defined as a vacant land parcel at time t_i splitting into two or more land parcels at time t_{i+1}. Figure 5.2 shows the Highland Meadows project as a graphical representation of a typical parcel subdivision event as defined above. The Charlotte-Mecklenburg Planning Department documents subdivision approvals, but the time lag and between approval and completion, coupled with the uncertainty of whether approved projects actually move forward contributed to the decision to use of the above definition of

2001 2002

Figure 5.2: Highland Meadows Parcel Before And After Subdivision.

parcel subdivision events. The goal of the parcel change analysis is to identify which of the land parcels in the original sample experience a subdivision event during each of the six time periods, and this task is accomplished through the use of scripting. The sample (attempted population) used for the parcel change analysis and discrete-time hazard analysis consists of 6,103 land parcels identified as vacant in 2001, based on information in the parcel shapefile.

A total of 1,986 of these were designated as macro-level parcels because they were greater than 10 acres in area[16] and the remaining 4,117 parcels comprised the micro-level sample. This distinction is based on the Charlotte-Mecklenburg county subdivision ordinance, which specifies that a “division of a tract in single ownership whose entire area is no greater than two acres into not more than three lots, where no street right-of-way dedication is involved and where the resultant lots are equal to or exceed the standards of the appropriate zoning classification” is not subject to the provisions of the ordinance. This provision has been in place since a May 1989 amendment and is the rationale for adopting a minimum threshold of two acres for the present study. Figure 5.3 shows the spatial distribution of the micro-scale and macro-scale parcels included that were identified as vacant in 2001 and included in the analysis. As shown below, both samples are spatially well-distributed within the borders of Mecklenburg County. Notable exceptions are the northwest corner of the county, which is covered by Lake Norman and the central and south-central areas of Charlotte, which understandably does not have very many macro-scale parcels identified as vacant at the initial time period.

The ArcGIS software suite performs a variety of spatial data processing, manipulation, and analysis functions and it is possible to access these functions with Python scripting language. This dissertation makes use of Python scripting to automate and streamline many of the spatial data processing and manipulation tasks necessary to support the larger analysis components. This approach makes it possible to iteratively perform geoprocessing operations on all land parcels in a given shapefile more quickly and efficiently than would be possible if the tasks were completed by hand using the application menus.

[16] The Charlotte-Mecklenburg subdivision ordinance sets a threshold of 10 acres for major subdivisions. A minor subdivision is greater than 2 acres, but less than 10 acres.

Figure 5.3: Spatial Distribution Of Vacant Parcels.

The algorithm for identifying parcel subdivision events, at both scales, is outlined below:

Step 1: Loop through each parcel in the sample at the current time period and using the unique parcel identifier, select the corresponding parcel identifier from the subsequent time period shapefile.

Step 2: If the total acreage of the parcel changed by more than 10% (to account for rounding error and small variations in the topology of the polygons themselves), flag it as a potential subdivision event (and evaluate "successor" parcels), else treat it as a non-event.

Step 3: If the parcel identifier is not found in the subsequent time period shapefile, flag it and execute a second script that selects the parcels from the subsequent time period shapefile that are inside the boundary of the original parcel. If two or more "successor" parcels are found, flag the original parcel as having experienced an event.

Step 4: Execute a third script to determine the proportion of "successor events" that were under residential use[17] at the end of the study period. If parcels flagged as potential events had at one-half of these "successor" parcels under residential use, these were considered true parcels subdivision events.

Each of these tasks was completed at the macro-scale and micro-scale for each of the six time periods studied and as described above, a candidate event must have at least half of its "successor" parcels under residential use at the end of the study period to be considered a valid event. The purpose of the parcel change analysis is to identify when and where land parcel subdivision events occur and within the context of the dissertation research, changes in the boundaries of a land parcel (tax lot) in locally maintained spatial datasets as defined above, is taken as an indicator of land subdivision and by extension, a likely precursor to construction and occupancy. In this way, the observed land parcel subdivision events are directly linked to the overall pattern of land use and residential development within the study area.

5.6 Point Pattern Analysis

The location of events in space and the presence or absence of discernible pattern in their configuration is often of interest to analysts and is a common starting point for more

[17] Residential uses included: condominiums, single-family residential, multi-family residential, and manufactured housing.

sophisticated spatial modeling. In keeping with this convention, the results of the parcel change analysis were used as inputs for a spatial point pattern analysis, intended to provide insight into the overall spatial and temporal pattern of observed parcel subdivision events. The current research relies on *K*-function (and *L*-function) analysis to investigate the pattern of events over time, through space, and across scales.

Point pattern analysis is typically exploratory in nature, in that the objective is detect evidence of pattern or spatial structure in the observed data (Bailey and Gatrell, 1996; 76). If we think about the observed event locations as a single realization from a data generating process, the standard model for testing departures from the null hypothesis of Complete Spatial Randomness (CSR) is essentially Poisson (Cliff and Ord, 1981: 88). Existing tests of this type require the specification of a study area boundary and typically assumes stationarity. A spatial process is considered stationary or homogenous if it exhibits (Cliff and Ord, 1981: 88):

- No interaction between areal units (attraction or dispersion)
- No grouping of individuals (point clusters)
- Neighboring units do not necessarily display similar traits

As noted by Bailey and Gatrell (1996: 96), this amounts to asserting that "any event has an equal probability of occurring at any position" within the study area. In reality, these assumptions are rarely met, which makes testing an observed point pattern against CSR less meaningful and potentially misleading. Common alternatives to relying on CSR and the assumption of stationarity as the null hypothesis for point pattern analysis include: (1) allowing the background intensity of events to vary over the study area and estimating this parameter and (2) adopting a case-control approach under the random labeling hypothesis.

Each of these approaches is employed to analyze the locations of observed land parcel subdivision events and test for evidence of spatial structure.

Early point pattern methods were plagued by the difficulty of testing for statistical significance in the (likely) presence of spatial dependence and also by the influence of edge effects (Ripley, 1981: 153). The most basic of the methods (e.g., nearest neighbor statistics) used the distances between observed events to test for deviations from the expectation under the null hypothesis (i.e., CSR) and provide insight into the first-order properties (global trends) of the point pattern. However, for those events located near the boundary of the study area, the probability of observing neighbors on the opposite side of the boundary is zero, regardless of whether this is an accurate reflection of reality (i.e., the point pattern is observed within a given boundary, but potentially extends beyond its edges). A number of border correction methods have been introduced to obtain unbiased estimators for spatial statistics applications including: use of observations outside the boundary only for the calculation of statistic for observations inside the boundary "plus-sampling," using only those observations unaffected by border effects "minus-sampling", and weighting the contribution of points inside the boundary to offset the censoring of additional information outside the boundary (Diggle, 1979; Ripley, 1981; Baddeley, 1998). A "minus-sampling" approach is used to correct for edge effects within the present study.

The *K*-function was introduced by Ripley (1976) and is an example of second-order analysis tool designed to test for interaction (clustering or dispersion) across a series of distance classes or lags. The standard *K*-function measures the number of events or observations within a specified distance or spatial lag of a given event, thereby providing a more nuanced picture of the spatial pattern within a given dataset (Bivand *et al.*, 2008). The expressions [1a] and [1b] are equivalent and in the former, A is the size of the study area, N is the total number of observations, and the remaining term is the sum over all pairs of observations i and j for distances between zero and d (Getis, 1984: 175).

$$\hat{K}(d) = \frac{A \sum k(i,j)}{N(N-1)} \tag{1a}$$

$$K(d) = \lambda^{-1} E\left[N_0(d)\right] \tag{1b}$$

In [1b], lambda is the total number of events per unit area (intensity) and the remainder of the expression is the expected number of events within a distance d of an arbitrary event. If the pattern is a homogeneous Poisson process, then $K(d) = \pi d^2$ and deviations from the expectation indicate clustering (above expectation line) or dispersion (below expectation line). In addition to the assumptions of outlined above by Cliff and Ord (1981), a homogeneous Poisson process is also characterized by a constant intensity (lambda) across the study area, and further implying (Bivand *et al*., 2008):

- The location of one event does not influence the location of other events
- There are no regions of the study area where events are more likely to be observed

Because the stationarity assumption of a homogeneous Poisson process is unlikely to be met for the current study, the intensity at each location is estimated using the "leave-one-out" kernel smoothing approach suggested by Baddeley *et al*. (2000). Kernel smoothing uses a bandwidth parameter (controls the degree of smoothing) and kernel (moving, three-dimensional function) to derive an estimate of the intensity, given an observed set of data (Bailey and Gatrell, 1995). Again, it is necessary to estimate the intensity because the observed point pattern is "the outcome (a realization) of a spatial stochastic process" and the goal is establish a more meaningful null hypothesis than complete spatial randomness (Bailey and Gatrell, 1996: 258). Baddeley *et al*. (2000) propose a modified version of the classic *K*-function, which takes violation of the above assumptions into account, and this inhomogeneous *K*-function and was utilized as part of the exploratory point pattern analysis (as input to the *L*-function described below). The expectation of the inhomogeneous *K*-function is equivalent to that of the standard *K*-function and is interpreted in the same way. The key difference is that the intensity (lambda in [1b]) is allowed to vary from location-to-location across the study area.

Several studies have used *K*-function analysis within an urban planning and regional science context including Getis (1984), Barff (1987), Feser and Sweeney (2000), and Maoh and Kanarglou (2007). Barff (1987) uses a sample of manufacturing plants in Cincinnati, Ohio to study the relocation (decentralization) behavior of these facilities. A series of linear regression models as well as point pattern analysis (*K*-function) are used to analyze the data. This study is one of the earliest applications of spatial statistics to study firm location decisions and finds both a trend towards plant decentralization and significant levels of clustering on the periphery among movers. Feser and Sweeney (2000) use point pattern analysis (difference of *K*-functions) to study agglomeration effects among manufacturing firms in North Carolina. They hypothesize that the strength of economic linkages between firms based on input-output tables influences the probability of colocation. The authors found evidence to suggest that economic linkages (horizontal and vertical) do influence agglomeration for some, but not all firms. Finally, Maoh and Kanarglou (2007) use a variety of methods, including *K*-functions, to explore firm clustering in Hamilton, Ontario.

A common transformation of the raw *K*-function to a square-root scale has the effect of linearizing the plot of *K(d)* for a Poisson process and stabilizing the variances, which makes hypothesis testing using simulation envelopes more reliable (Ripley,1981: 160).

$$\hat{L}(d) = \left(\frac{\hat{K}(d)}{\pi} \right)^{1/2} \qquad [2]$$

In [2], the approximate mean is *d* and the approximate variance is $1/2\pi N^2$ (Getis, 1984: 175) and rather than the expectation following a 45° line as when the *K*-function is plotted, the expectation of the transformed *L*-function is a horizontal line at the origin.

One technique for moving beyond the unrealistic assumption of stationarity (constant intensity) is the use of generalized forms of the standard *K*-function and *L*-function that allow intensity to vary across the study area as described above. A second approach is rooted in epidemiological applications and involves treating one set of points or events as cases and a second set as controls and comparing the spatial distribution of these via their associated *K*-functions. This approach assumes that the locations of the cases and controls are fixed, but that the set of cases and controls observed each represent a realization of a heterogeneous Poisson process over the same study area (Waller and Gotway, 2004: 163). The question of interest becomes whether the observed cases and controls deviate from the null model of a homogeneous Poisson process in the same way.

$$K_{diff}(d) = K_{cases}(d) - K_{controls}(d) \qquad [3]$$

By randomly assigning "case" labels to a sample of the observed event locations, the presence of clustering can be detected (Diggle and Chetwynd, 1991; Bailey and Gatrell, 1995). Within this framework, the expected value of K_{diff} for any distance class d is zero and positive values indicate clustering in the cases beyond that observed for the controls (Waller and Gotway, 2004: 172). It should be noted here that these approaches are designed to test for the presence of clustering, but do not identify the location of event clusters.

Kernel estimation uses a bandwidth parameter (that controls the degree of smoothing) and kernel (moving, three-dimensional function) to derive an estimate of the intensity, given an observed set of data (Bailey and Gatrell, 1995). The result can be displayed as a 2D or 3D grid and provides insight into the locations of areas of higher event activity. By using the Mean Square Error (MSE) criterion suggested by Diggle (1985) to select the bandwidth parameter, an estimate of the intensity of land parcel subdivision events was generated. In addition to identifying regions of the study area that experienced high event rates, these estimates resurface in Chapter 7 when the implications of the observed land development patterns or environmental outcomes are discussed.

5.7 Developer Survey

A limited survey of developers who have completed residential projects in Mecklenburg County was conducted to inform the specification of the statistical models and to place the findings of the study in context. A series of questions (see Appendix B) designed to collect information on the site selection and land acquisition processes as well as other information relevant to understanding the overall pattern of development in Mecklenburg County, NC were drafted based on the existing developer behavior literature (Kaiser, 1968; Goldberg, 1974; Bourne, 1976; Goldberg and Uliner, 1976; Leung, 1986; Mohamed, 2006) and surveys of developer attitudes (Kenney, 1972; Hepner, 1983; Ben-Joseph, 2003; Levine and Inam, 2004). After receiving Institutional Review Board (IRB) approval, an initial set of 15 candidates (sampling frame) were identified using a variety of methods including Charlotte-Mecklenburg Chamber of Commerce directories, local subdivision approvals records, personal contacts in the local real estate industry, and newspaper articles. A solicitation email explaining the purpose of the study and asking the recipient to participate was distributed, followed by a second email with a link to an online survey version of the questionnaire. Several rounds of follow-up emails revealed that some candidates preferred to receive the questions via email or to give their responses over the telephone and these requests were accommodated. The survey responses were not intended to be statistically analyzed and responses from a total of 12 participants were received over a six week period.

5.8 Survival Analysis

The present study applies survival analysis methods to study the determinants of parcel subdivision events thereby, fully exploiting the longitudinal dataset constructed from the parcel shapefiles and supporting spatial data. Discrete-time survival analysis is employed because the exact date when a land parcel experienced a subdivision event is unobserved and because the precise definition of when the event occurs is open to debate. The subdivision event could be considered complete at variety of points in the process: purchase or option of the land, subdivision application approval, final plat, groundbreaking, construction, and occupancy. However, rather than wrestle with these issues, for the purposes of this dissertation, an event is defined as a vacant land parcel at time t_i splitting into two or more land parcels at time t_{i+1} with the additional constraint that at least one-half of the “successor” parcels be under residential uses at the end of the study period. Parcel shapefiles were collected for each year beginning in 2001 and ending in 2008, yielding a time interval of one year.

The results of the parcel change analysis are used to derive the dependent variable for the discrete-time hazard models. However, before moving into a discussion of the regression framework, it is important to clarify some terminology. Survival analysis often begins with life tables as a means of "summarizing the sample distribution of event occurrence" (Singer and Willett, 2003: 326). At each time period, the life table presents the number of observations capable of experiencing and event (the risk set), the number of observations that experienced and event during the time period, and the number of observations that did not experience an event (survivors). Although not exactly the same as when applied within the context of demographic studies, this general approach is extended to the land parcel subdivision events identified via the parcel change analysis. Hazard is defined as the probability of event occurrence the present time period T_i, given that it has not previously occurred and is represented as follows (Singer and Willett, 2003):

$$h(t_{ij}) = \Pr[T_i = j | T_i \geq j] \qquad [4]$$

The actual probabilities [4] are not observed, but because continuing as part of the risk set depends on not having experienced an event in a prior time period, the ratio of the number of observations experiencing an event during a given time period to the total number of observations at risk during that time period [5] represents maximum likelihood estimates of the discrete-time hazard function (rate) for a given period (Singer and Willett, 1993).

$$\hat{h}(t_j) = \frac{n\ events}{n\ at\ risk} \qquad [5]$$

The hazard rate represents the risk specific to each individual time period and periods of greater hazard are characterized by an increased risk of experiencing an event. By contrast, the survivor rate provides an estimate of the likelihood that a given observation will survive, or not experience an event (Singer and Willett, 2003):

$$S(t_{ij}) = \Pr[T_i > j] \qquad [6]$$

Like the hazard rate, the survivor rate is inherently conditional—both depend on the observation not having experienced an event in a preceding time period.

$$\hat{S}(t_j) = \frac{n\ with\ no\ event\ by\ end\ of\ \ period\ \ j}{n\ in\ dataset} \qquad [7]$$

The hazard and survivor functions (rates at each period) can be estimated separately for groups based on the values of independent variables and the used as exploratory tools when plotted (Singer and Willett, 2003). Stated differently, estimates of the hazard and survivor functions can be “recovered” using parameter estimates from a fitted regression model that links observed events to time. Differences in the plotted hazard or survivor functions point to cross-group differences that may be investigated further within a regression context, where the effect of covariates can be properly controlled.

Discrete-time survival analysis allows for the inclusion of time varying and time-invariant predictors and can be estimated using standard statistical software and model specifications (Singer and Willett, 1993). It is also preferable to the Cox model when there are many time-varying covariates in the model and eliminates the problem of tied survival times that can lead to unreliability and non-convergence (DeMaris, 2004). The most commonly used link functions for discrete-time hazard models are the logit and complementary log-log transformations and an example of the former that includes the main effect of time is given below (Singer and Willett, 2003):

$$\text{logit } h(t_{ij}) = [\ \alpha_1 D_{1ij} + \alpha_2 D_{2ij} + \ldots + \alpha_J D_{Jij}\ ] + [\ \beta_1 X_{1ij} + \beta_2 X_{2ij} + \ldots + \beta_J X_{Jij}\ ] \qquad [8]$$

In [8], D is a binary variable indicating time period and α is an estimate of the parameter associated with the effect of time period on the dependent variable (probability of experiencing an event in the current time period, given that an event was not experienced in a prior time period) and the independent variables outlined in Table 5.1 are represented between the second brackets. Including the main effect of time is the most general specification of the discrete-time model, but may not always be the most parsimonious. Alternate specifications of the effect of time were considered, including a single constant model that eliminates the influence of time and several polynomial approximations. The results of this examination are summarized in Appendix C, but the more general specification was ultimately retained.

The complementary log-log transformation and corresponding discrete-time hazard model specification are given in [9a] and [9b], respectively:

$$\text{clog-log} = \log\left(-\log\left(1 - \text{probability}\right)\right) \qquad [9a]$$

$$\text{clog-log } h(t_{ij}) = [\ \alpha_1 D_{1ij} + \alpha_2 D_{2ij} + \ldots + \alpha_J D_{Jij}\ ] + [\ \beta_1 X_{1ij} + \beta_2 X_{2ij} + \ldots + \beta_J X_{Jij}\ ] \qquad [9b]$$

The differences between models that use the logit and complementary log-log link functions are most pronounced when hazard is high (Singer and Willett, 2003: 425). However, other considerations that may favor use of the complementary log-log[18] link function include: (1) a desire to parallel the proportional hazards assumption of the continuous time hazard model, and (2) when interval-censored data are being analyzed (Singer and Willett, 2003: 426).

The logit specification of the discrete-time hazard model imposes a proportional odds assumption and the complementary log-log specification imposes a proportional hazards assumption (Singer and Willett, 2003: 421). The proportional hazards assumption holds that the effect of each independent variable does not vary across time periods (Singer and Willett, 2003: 451). Interval censored data refers to those cases where the event of interest occurs in continuous time, but the available information regarding event occurrence is limited to discrete-time intervals (Singer and Willett, 2003: 426).

Due to the inherent conditionality of hazard framework, the estimation dataset necessarily exhibits a person-period structure (Kleinbaum and Klein, 2005). For parcels that do not experience an event in either of the six time periods, the dataset contains six separate rows or entries for those observations with the values of dependent and independent variables at each point represented. On the other hand, parcels that experience an event before the final time period have fewer entries in the dataset because continuing as part of the at-risk sample

[18] Estimation of the models using a complementary log-log link had a negligible effect on the parameter estimates and did not alter inference.

for the subsequent time periods is contingent upon not having experienced an event in a previous period.

Table 5.1 lists each of the independent variables included in the discrete-time hazard models as well as their expected effect on the likelihood of parcel subdivision. The first set of predictors is a series of dummy variables indicating the time period. These measures are designed to capture the shape of the baseline (logit) hazard function and provide a measure of the background differences in the likelihood of parcel subdivision across time periods (i.e. main effect of time). The results of the hedonic regression analysis described in Section 5.8.1 are used as a key predictor in the discrete-time hazard models. This measure represents the estimated market value of the vacant land parcels in both the macro-scale and micro-scale samples at the beginning of the study period. The original intention was to use this as a time-varying independent variable, but the lack of time-varying measures in the hedonic regression model itself makes this approach infeasible. Despite this limitation, including an explicit measure of the market value for these parcels is essential to the theoretical and practical validity of the hazard analysis. The aggregation indicator is a dummy variable that denotes parcels that are subsumed into a larger parcel[19] during a given period. Although less convenient due to increased transaction costs and negotiation, parcel aggregation is intuitively an indication of an intent to develop at a given location, and is included for this reason. The third measure of land market conditions focuses on the supply of land and is operationalized as the proportion of total area in Census block group containing the parcel of interest classified as vacant at the beginning of the study period.

[19] Parcels that are aggregated are still assessed at each subsequent time period as candidates for an event.

Table 5.1: Hazard Model Independent Variables, Hypothesized Effect, And Source.

Time			
Time period indicator	Time-Variant	Unclear	Main effect of time
Land Market Considerations			
Estimated land value	Time-Invariant	Positive effect	Hedonic regression
Parcel aggregation indicator	Time-Variant	Positive effect	Parcel change analysis
Proportion vacant land in block group	Time-Invariant	Positive effect	Derived from spatial dataset
Demographics and Neighborhood Character			
Percent college graduates in block group	Time-Invariant	Positive effect	Census 2000
Number of demolitions within quarter mile	Time-Invariant	Positive effect	Local sources
Land use mix (entropy measure)	Time-Invariant	Negative effect	Derived from spatial dataset
Built environment typology class	Time-Invariant	Unclear	Wilson and Song (2009)
Proportion non-urban uses within quarter mile	Time-Invariant	Positive effect	Derived from spatial dataset
Accessibility			
Logged distance to I-485 (finished by 2001)	Time-Invariant	Positive effect	Derived from spatial dataset
Distance to I-485 (when complete)	Time-Invariant	Positive effect	Derived from spatial dataset
Logged distance to nearest downtown[20]	Time-Invariant	Unclear	Derived from spatial dataset
Policy Factors			
Infrastructure availability proxy	Time-Invariant	Positive effect	Ratio of street length to parcel size
Tax rate	Time-Variant	Negative effect	Charlotte-Mecklenburg Planning
Non-residential neighborhood	Time-Invariant	Negative effect	Neighborhood Development Dept.
Rezoning duration (average number of days)	Time-Invariant	Negative effect	Local sources
Moratorium in place (proportion of year)	Time-Variant	Negative effect	Local sources
"Priming Effect" Measure			
Nearby events of opposite scale (or all events) in prior period	Time-Variant	Positive	Parcel change analysis

[20] Includes Uptown Charlotte and downtown areas of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, and Pineville.

Five measures are included to capture the effect of demographics and neighborhood character on the likelihood of parcel subdivision. The first measure is derived from the 2000 Decennial Census and represents the percent of the population at the block group level, that has a college degree. The second measure is based on U.S. Department of Commerce permit reports available from the Mecklenburg County Land Use and Environmental Services Agency (LUESA) and is the number of demolitions permits issued within a one-quarter mile radius of each parcel in 2000 and 2001. This measure is intended to capture the contribution of the razing of existing structures to the overall amount of land available for development in each block group. However, issuance of a permit does not necessitate demolition (Dye and McMillen, 2007), so some caution is warranted in assessing the parameter estimate associated with this measure. The third variable is an entropy measure [10] derived from a 1999 land cover dataset available for the entire county using the approach adopted by Cervero and Kockelman (1997):

$$Entropy = \frac{-\sum_{k} (p_i)(ln\, p_i)}{ln\, k} \qquad [10]$$

Here, p_i is the proportion of each of the land cover types specified in the dataset located within one-quarter mile of the parcel centroid and k is the number of possible land cover types ($k = 12$). The fourth measure is a dummy variable indicating whether the land parcel is located within a block group designated as either “urban neighborhoods” or “inner suburbs” according to the methodology described in Wilson and Song (2009). These clusters were chosen as exemplars of compact urban form and walkability. The final measure is the proportion of non-urban uses located within a quarter-mile radius of each parcel. This provides a more complete picture of the land use mix within the immediate vicinity than relying solely on the entropy measure (i.e., evenness of distribution). These measures are intended to capture and represent the social prestige and overall character of the immediate vicinity.

Two measures of accessibility relative to the I-485 beltway are included in an effort to test for speculative behavior. The first measure is the distance from each parcel to the nearest I-485 ramp that was completed at the start of the study period (2001) and the second measure is the distance to the designated ramps for the completed project. If the second measure is most important in the regression models, the implication is that planned transportation infrastructure has a greater impact on the residential development patterns that existing infrastructure. The third accessibility measure is the distance from each parcel to the nearest downtown area for each of the seven municipalities within Mecklenburg County. The intent here, is to capture the effect of urban versus suburban character on the likelihood of land parcel subdivision.

Five policy measures are also included in an effort to capture the influence of land use controls and planning on the probability of land subdivision. Historical data on the location and extent of water and sewer infrastructure within the county was not available from the local utility, and a proxy suggested by Suen (2005) was used instead. This variable was derived as the ratio of street length to parcel size within a given block group, with the implicit assumption that (holding street length constant) infrastructure is more readily available in areas with smaller lots. The property tax rate is included as a time-varying predictor and location within a neighborhood designated non-residential by the Charlotte-Mecklenburg Neighborhood Development department is used as a control variable. The average duration of the rezoning process in each jurisdiction (in days) is included as an independent variable capturing the relative difficulty of navigating the rezoning process and as an indicator of the costs of developing at a particular location. The final policy variable is time-varying and is the proportion of each time period (year) that a given land parcel is subject to a growth moratorium (number of months). This variable therefore ranges from 0 to 1 and provides a measure of the influence of growth moratoria on the probability of land subdivision (Bento *et al*., 2007). The final independent variable is the "priming effect" measure, which is the number of parcel subdivision events observed within the specified distance radius in the previous time period. The strength of scale effects versus temporal effects is evaluated by limiting the "priming effect" measure to events of the opposite scale in the former and including all events that meet the distance criterion in the latter.

In the present case, the dependent variable is the probability (likelihood of an event) that a parcel subdivides during a given time period and is expressed a function of linear predictors [11] as given by Pampel (2000).

$$Pr(event) = Y_i^* = \beta_1 X_{i1} + \beta_2 X_{i2} + \mu_i \qquad [11]$$

The exact probability of parcel subdivision cannot be directly observed, so a binary logit model is used to model this continuous latent variable as a binary observed variable through a measurement equation [12] (Pampel, 2000). The value of *tau* represents the threshold at past which the probability of development corresponds to an observable change in the state of the parcel.

$$Y_i = \begin{cases} 1 & if\ Y_i^* > \tau \\ 0 & if\ Y_i^* \leq \tau \end{cases} \qquad [12]$$

Estimation of the model in [11] could potentially generate probabilities that are less than zero and greater than one, which by definition cannot be true. To address the issue, the original probabilities from [11] can instead be written as odds [13] (the likelihood of an event relative to non-occurrence of that event), which removes the upper limit of one from the dependent variable, as odds may range from zero to infinity (Pampel, 2000).

$$O_i = \frac{Pr(event)}{1-(Pr(event))} \qquad [13]$$

The final step involves taking the logarithm of the odds, which removes the lower limit of zero from the dependent variable, as the log odds or logit may range from negative infinity to positive infinity [14] (Pampel, 2000).

$$log\left(\frac{Pr(event)}{1-(Pr(event))}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \qquad [14]$$

The *betas* represent the estimated change in log odds of parcel subdivision, given a one unit increase in the corresponding independent variable. However, odds ratios (exponentiated coefficients) rather than raw regression coefficients will be interpreted to assess the effect of each independent variable on the likelihood of parcel development. The rationale behind the binary logit specification is that transforming probabilities to log odds allows the estimation of the dependent variables as a linear function of independent variables without contravening any of the basic characteristics of probabilities.

Discrete-time hazard models are based on several assumptions that will be briefly reviewed here and chief among these is the proportionality assumption. As articulated by

Singer and Willett (2003: 367), each observation essentially has a unique logit hazard function, by virtue of the function's dependence on the values of each covariate included in the model. Because we assume that effect of each independent variable on the log odds of event occurrence (subdivision) is constant over time, the logit hazard functions have an identical shape and the distance between these logit hazard functions is constant over time (proportional odds assumption). Although the logit hazard function is assumed remain constant over time, there is flexibility in how its shape is defined. Several smooth polynomial specifications were considered, but the main effect of time, which includes a dummy variable for each time period was ultimately retained (see Appendix C).

Like other forms of linear regression, discrete-time hazard analysis rests on a linearity assumption. Specifically, "the model assumes that vertical displacements in logit hazard are linear per unit of difference in each predictor" (Singer and Willett, 1993: 182). Tenability of this assumption can be assessed by including nonlinear terms (e.g., interactions) or through the use of graphical methods. The former approach was adopted and is covered in Chapter 6. The model specification adopted here also assumes no unobserved heterogeneity, hence the lack of an error term. The implication here is that observations (land parcels) are distinguished solely by differences in the predictors included in the model and omission of an important variable results in "pooling the several hazard profiles for the heterogeneous populations defined by values of the ignored predictor" (Singer and Willett, 1993: 184). Omitted variable bias is always a concern for statistical modeling, but predictors suggested by the literature, informed by theory, and based on the results of the developer survey were included in the regression analyses in an effort to minimize this threat.

5.8.1 Hedonic Regression Analysis

In order to account for the effect of the market in the discrete-time hazard model, transaction data for vacant land parcels sold in 2000 within Mecklenburg County were used to estimate a hedonic regression model. After evaluating and refining the model, the fitted parameters were used to predict the value of each land parcel in the hazard model sample at the initial time period. An alternate model specification that included price per acre as the dependent variable was considered, but did not fit the data as well as the specification ultimately adopted[21]. Here, the dependent variable is the observed sales prices for vacant parcels in 2000 (log transformed) and the goal is to model this quantity as a function of measures that can be classified as: (1) physical characteristics, (2) accessibility, (3) policy context, and (4) demographics.

$$Y = \alpha + X\beta + \varepsilon \qquad [15]$$

As shown in [15], the logged sales price for vacant land parcels in Mecklenburg County is a function of measures of the four hypothesized drivers of land value specified above. Table 5.2 shows these measures as well as their source and hypothesized effect on sales price (these are all vacant land parcels). The physical characteristics of each parcel are represented in the model using seven independent variables: (1) a dummy variable indicating frontage along (or containment of) a water body, (2) a dummy variable indicating frontage along a stream, (3) mean slope, (4) a dummy variable indicating the presence of soils unsuitable for septic systems (SSURGO data), (5) a dummy variable indicating the presence of wetlands, (6) proportion forest cover in 1999, and (7) logged parcel size in acres.

[21] It also resulted in predictions that were far outside the realm of probability.

Table 5.2: Independent Variable Description And Hypothesized Effect.

Measure	Description	Hypothesized Effect
Physical Characteristics		
Water body frontage	Parcel shares boundary with or contains all or part of a water body (binary)	Positive
Stream frontage	Parcel is adjacent to or crossed by a river or stream (binary)	Positive
Slope	Mean slope (degrees) for parcel derived from 20' contours	Negative
Poor soils	Parcel is on poorly drained soils: hydrologic group D (binary)	Negative
Wetlands	Presence of wetlands on the parcel (binary)	Negative
Forest cover	Proportion of parcel classified as forest in 1999	Negative
Parcel size	Size of parcel in acres	Positive
Accessibility		
Employment potential	Inverse distance to each TAZ times total workers at each TAZ standardized by total workers in county (CTPP)	Positive
Shopping potential	Inverse distance to each major shopping center times total square footage at each shopping center standardized by total square footage	Positive
Distance to freeway ramp	Distance to nearest freeway ramp in 1999	Negative
Policy Context		
School district	Schools below state performance guidelines[22]	Negative
Tax rate	Property tax rate in 2000	Negative
Unincorporated	Located in unincorporated area in 1999	Positive
Zoning	Zoned for residential uses	Positive
Demographics		
Population density	Persons per acre in Census block group in 2000	Negative
Income	Per capita income in Census block group in 1999 (in thousands)	Positive

[22] Districts where high schools did not meet state performance guidelines during the 2001-2002 year (i.e., greater than 60% at grade level).

Water body frontage, stream frontage, and parcel size are expected to exert a positive effect on the sales price, while higher slope, poor soils, wetlands, and forest cover are expected to have a negative impact. Water frontage is typically considered an amenity and can be expected to increase the market value of a land parcel (Siderelis and Perrygo, 1996). The presence of soils unsuitable for septic systems, steeper slopes, wetlands, or significant forest cover on the other hand, can pose challenges to the development of a site. Grading, clearing, and drainage requirements are common examples of how these factors impact development costs. In addition to influencing development costs, the presence of forest can also act as an amenity (Tyrväinen and Miettinen, 2000), thereby increasing expected returns. Finally, the size of the parcel is itself important because it largely determines the number of units or structures that can be built.

The second group of variables focuses on accessibility and includes: (1) employment potential, (2) shopping potential, and (3) distance to freeway access points. Distance to the nearest freeway ramp is expected to have a negative effect on sales price, as major roads are a key component to site accessibility. In contrast, each of the potential measures is expected to have a positive effect on the sales price. The employment potential variable attempts to capture the influence of decentralized employment on the sales price for each parcel in the sample. The fundamental assumption that proximity to employment subcenters increases the attractiveness of a land parcel for residential development is a characteristic of the monocentric model and the land economics approach to understanding urban form. Urban areas are becoming more polycentric and households value accessibility to a variety of destinations and although the journey to work may have become less important (Giuliano and Small, 1993; Filion *et al*., 1999), workplaces still rank among those valued destinations for many individuals and households (Cervero *et al*., 1999; Rodríguez, 2002). The accessibility benefits of a parcel, in terms of workplace trips, decline as the distance to employment subcenters increases and this spatial variation in access to jobs was represented using a simple inverse-distance weighting scheme.

$$s = \frac{1}{d^p} \qquad [16]$$

In the equation above, s represents weight or influence attached to a traffic analysis zone centroids as an employment center, given its distance d from a given parcel. The exponent p is a parameter that controls how quickly the influence of employment subcenters declines as distance increases and is typically set to 1 or 2 for spatial analysis applications.

$$employment \quad potential_j = \sum_{i=1}^{n} totemp_i * s_{ij} \qquad [17]$$

The employment potential at parcel j is simply the product of the total employment at traffic analysis zone i and s, which represents the strength of that TAZ's influence across space, given its distance, for each parcel j summed across all TAZs. This approach uses basic spatial analysis concepts to derive an employment accessibility measure that accommodates employment decentralization. This approach differs from the linear distance measures to city-centers (Baltimore, Washington DC, other towns) used by Irwin and Bockstael (2002) and by Irwin *et al*. (2003). A similar measure is applied to census tracts in Atlanta by Helling (1998), census tracts in Toronto by Bailey (1999) and METRO defined centers in Portland by Buliung and Kanaroglou (2006).

The third set of independent variables captures the influence of policy factors on development patterns. In addition to a dummy variable for low-performing schools, the property tax rate, unincorporated status, and zoning designation in 2001 were included as controls. Because this study focuses on residential subdivision events, the quality of local schools is an important consideration. Several studies have documented linkages between residential property values and public school performance (Jud and Watts, 1981; Clark and Herrin, 2000; Munroe, 2007), and this relationship is particularly important in North Carolina where significant portions of public school funding is drawn from local property tax revenues (Jones *et al*., 2003). Similarly, property tax rates can influence the attractiveness of housing units to potential home-buyers and the zoning designation can affect the time (rezoning process) and therefore, the cost of bringing a project to market. Intuitively, properly zoned land should be favored for development, although several authors have argued that the discretionary and political nature of zoning decisions suggests an endogenous relationship between land use and zoning designation (Brownstone and De Vany, 1991; Thorson, 1994).

The importance of demographic and social characteristics to residential property values, and by extension land prices, cannot be overstated. Urban theorists from Burgess (1925) and Hoyt (1939) to Tiebout (1956) have explained how these considerations shape and drive location decisions and ultimately, urban spatial structure. Two measures of general demographic characteristics derived from Decennial Census 2000 data collected at the block group level were included in the model. These are control variables that capture the population density and income differences for parcels located in different areas of the county. Population density is included as a control variable and is expected to exert a negative effect on land prices based on the findings of several prior studies of housing prices (Irwin, 2002;

Geoghegan, 2002; Armstrong and Rodríguez, 2006). The economic context of an area can also influence its attractiveness for investment and homebuyers (Ryan and Weber, 2007), so median household income is also included as an independent variable. Land prices in areas with higher median household income values are expected to be higher than other areas of the county.

In addition to standard regression diagnostics, the hedonic regression models were evaluated for the presence of spatial autocorrelation in the residuals. Spatial autocorrelation is a simple concept that is has gained increasing attention with the advent of geographic information systems (GIS) and the proliferation spatial data sources (Anselin and Bera, 1998). At a very basic level, spatial autocorrelation (alternately known as spatial dependence) refers to conditions where observation that are closer together in space also tend to exhibit similar measurements on some parameter of interest (Anselin, 1988: 11).

Within a linear regression context, the existence of spatial autocorrelation is problematic for statistical inference. Typically, the results of *t*-tests (significance indicators) are unreliable and the value of the R^2 statistic is inflated (Anselin, 1988). Another potential issue is differentiating spatial heterogeneity and substantive spatial autocorrelation. Spatial heterogeneity refers to “structural instability over space” and is frequently indicative of an omitted, spatially structured independent variable (Anselin, 1988: 119). The inclusion of additional covariates and the use of dummy variables are examples of strategies to stabilize the model. Every effort should be taken to address spatial heterogeneity before resorting to the estimation of a spatial regression model.

The first task is to determine the nature of the autocorrelation observed in the sample data and a variety of statistics exist for initial tests of this kind including Moran’s *I*, Geary’s

C, and the Getis-Ord *G*. Once the existence of substantive spatial autocorrelation has been established, LaGrange Multiplier tests are commonly used to facilitate model specification (Anselin, 1988; Anselin *et al*., 1996). There are two alternatives to OLS that account for spatial autocorrelation within the data: the spatial lag model and the spatial error model. The spatial lag model is preferred when the observed autocorrelation derives from an actual spillover process within the study area. A spatial lag model is an extension of the standard linear regression model with the addition on the right-hand side of the equation of a spatial lag term which is "…a weighted average of the values in neighboring locations" (Anselin, 1992: 7). The simple spatial lag model takes the following form (Anselin and Bera, 1998: 246):

$$y = \rho Wy + X\beta + \varepsilon \tag{18}$$

where:

y	is a matrix of observations on the dep. variable
ρ	is an autoregressive parameter (to be estimated)
Wy	is the lagged dependent variable
X	is a matrix of independent variables
β	is a vector of coefficients fit to the variables in X
ε	is a vector of error terms

The weights matrix W takes into account the distance between observations and ρ is the strength of the relationship or the intensity of autocorrelation. The spatial weights matrix can be defined in a variety of ways. Perhaps the most basic of these is as a contiguity matrix where two observations are considered neighbors (coded as 1) if they share an areal boundary and non-neighbors (coded as 0) otherwise. A distance decay function is also a common specification as well as using the *k* nearest neighbors of each observation as its effective neighborhood. This latter approach has the added advantage of controlling for observations that may have few or no neighbors under an alternative specification. However, contiguity matrices are typically row standardized, which ensures that the weights applied across each observation sum to one thereby, taking into account variation in the number of neighbors an observation may exhibit.

The choice of spatial weights matrix often exerts considerable influence on the results (Tiefelsdorf, *et al*., 1999). This critical decision is typically based on *a priori* knowledge of the phenomenon under study or driven by either computational convenience or established convention (Getis and Aldstadt, 2004; Dray *et al*., 2006). The present study uses a data-driven approach that relies on basic geostatistics and the method presented by Dray *et al*. (2006) to select the spatial weights matrix used for assessing the residuals of the hedonic regression models for evidence of spatial autocorrelation. Briefly, this approach involves:

- Fitting a (exploratory) spatial correlogram to the observed dependent variable
- Generating a set of candidate connectivity matrices (distance-based)
- Extract eigenvectors from candidate connectivity matrices
- Fit stepwise OLS model of dependent variable as a function of eigenvectors
- Choose connectivity matrix that minimizes Akaike's information criterion (AIC)
- Repeat the previous four procedures for coding schemes and distance decay functions

If the OLS residuals show evidence of spatial autocorrelation, kriging (Bailey and Gatrell, 1995) and a spatial filtering specification (Tiefelsdorf and Griffith, 2007) are considered as alternatives.

The spatial error model is preferred when all the process generating the autocorrelation cannot be identified (and modeled using covariates) or when the objective is to obtain consistent parameter estimates for the independent variables that are included in the model.

The error model involves the inclusions of a lagged error term, which acknowledges the presence correlation in the errors of spatially proximal observations but does not attempt to formally introduce these effects into the model specification.

$$y = X\beta + \varepsilon \qquad [19]$$

$$\varepsilon = \lambda W\varepsilon + u \qquad [20]$$

where:

y is a matrix of observations on the dep. variable
X is a matrix of independent variables
β is a vector of coefficients fit to the variables in X
ε is a vector of autocorrelated error terms
λ is an autoregressive parameter (to be estimated)
W is the spatial weights matrix
u is a vector of i.i.d. error terms

Both the spatial lag and spatial error models are distinguished from an OLS model by the existence of lag term in the fixed effects and error term components of the regression model, respectively. The endogeneity introduced by incorporation of the lag term calls for the use of maximum likelihood estimation, generalized least squares, or instrumental variables approaches (Anselin, 1988). A lag term is essentially a weighted average that takes into account the distance between observations in a given dataset.

$$Wy = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} y_j \qquad [21]$$

where:

W is an (n by n) spatial weights matrix
y is an (n by 1) vector of observations on dep. variable

A correlogram or variogram can be used to determine the range of autocorrelation in the process being studied and this knowledge can inform the sampling strategy. If all samples are taken such that no two observations are closer than the estimated range of autocorrelation, the assumptions of parametric statistical tests are not violated.

The non-parametric spatial filtering approach described by Griffith (2003) and Tiefelsdorf and Griffith (2007) represents an alternative method for addressing spatial autocorrelation. The method involves extracting a series of synthetic variables from the spatial weights matrix for the study area and using one or more of these as additional predictors in the model. The spatial lag and error models as well as the spatial filtering approach were considered as candidates for the hedonic regression analysis in the event of significant spatial autocorrelation in the OLS residuals.

5.9 Summary

This chapter provided a brief discussion of the datasets and data sources used to conduct the present research. An overview of how each of the analysis components relate to one another was also offered as well as detailed descriptions of each of the methods employed: (1) parcel change analysis procedure, (2) point pattern analysis techniques, (3) survey of developers (3) discrete-time hazard analysis, and (4) hedonic regression modeling. For the regression analyses, a description of each of the independent variables used was presented, as well as the hypothesized effect on the dependent variable and its source. The stage has now been set for the following chapter, which presents the results of each component of the study outlined here.

CHAPTER 6: ANALYSIS AND RESULTS

6.1 Overview

This chapter details the empirical analysis whose foundation has been established by the preceding chapters. A discussion of the parcel change analysis results is followed by presentation of an exploratory, spatial point pattern analysis of the events across scales and time periods. The chapter concludes by detailing the discrete-time hazard analysis results and presenting the results of an analysis of the sensitivity of the models to changes in the radius of the inducement variable. The estimation of the hedonic regression model and use of its parameters to derive a measure of the market value of each land parcel is also discussed.

6.2 Parcel Change Analysis Results

The full sample for the parcel change analysis consists of 4,117 micro-scale parcels and 1,986 macro-scale parcels listed as vacant in the 2001 parcel shapefile obtained from local government sources. However, in order to construct a measure and test for a "priming effect," the number of events occurring in the previous time period must be determined. Therefore, the discrete-time hazard analysis actually begins in the 2002 to 2003 time period for the micro-level (N = 3,972) and macro-level (N = 1,802) regression models. The results of the parcel change analysis are presented in Tables 6.1 and 6.2 and for each time interval, the number of land parcels that are at risk of subdivision is listed as well as the number of events and non-events observed. The final two columns of these tables present the proportion of events and non-events (relative to the at-risk sample) observed during each period. There were 360 total macro-scale parcels and 352 total micro-scale parcels that transitioned to residential use between 2002 and 2008. To place these results in context, a study that examined parcel subdivision within Calvert County, Maryland, (Irwin *et al*., 2003) identified a total of 1,962 candidate parcels for the period 1993 through 2000 and observed 163 subdivision events.

In both Table 6.1 and Table 6.2, the proportion of events observed starts off high, declines over the second and third periods, increases during the fourth period, and declines drastically over the final two periods[23]. The proportion of parcels in the sample experiencing an event during the study period is low, and this due in part to the constraint that at least one-half of the "successor" parcels be under residential use at the end of the study period. Lifting this constraint results in a significant increase in the number of observed parcel subdivision events both at the macro-scale and micro-scale (512 and 557 total events, respectively), but does not change the overall trend in the distribution of events over time. Another factor contributing to the relatively low proportion of observed parcel subdivision events is the lower threshold of two acres for inclusion in the micro-level sample. This threshold is based on the Charlotte-Mecklenburg subdivision ordinance and the fact that modeling the pattern of development among very small parcels of land is likely to be difficult due to inherent stochasticity. These tables are intended to provide a very basic description of the distribution of events over time and pave the way for more sophisticated analyses.

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[23] This pattern is consistent trends in housing market indicators at the regional and national levels described in the preceding chapter.

Table 6.1: Subdivision Events At Macro Scale (N = 1986).

		Number			Proportion Of	
Year	Time Interval	At Risk	Events	Survived	Events	Non-Events
0	2001 – 2002	1986	184	1802	0.0926	0.9074
1	2002 – 2003	1802	93	1709	0.0516	0.9484
2	2003 – 2004	1709	70	1639	0.0410	0.9590
3	2004 – 2005	1639	50	1589	0.0305	0.9695
4	2005 – 2006	1589	101	1488	0.0636	0.9364
5	2006 – 2007	1488	24	1464	0.0161	0.9839
6	2007 – 2008	1464	22	1442	0.0150	0.9850

Table 6.2: Subdivision Events At Micro Scale (N = 4117).

		Number			Proportion Of	
Year	Time Interval	At Risk	Events	Survived	Events	Non-Events
0	2001 – 2002	4117	145	3972	0.0352	0.9648
1	2002 – 2003	3972	59	3913	0.0149	0.9851
2	2003 – 2004	3913	62	3851	0.0158	0.9842
3	2004 – 2005	3851	66	3785	0.0171	0.9829
4	2005 – 2006	3785	119	3666	0.0314	0.9686
5	2006 – 2007	3666	30	3636	0.0082	0.9918
6	2007 – 2008	3636	16	3620	0.0044	0.9956

The baseline hazard and survivor rates were plotted at the macro-scale[24] and micro-scale[25] based on the results of the parcel change analysis and are presented in Figure 6.1 and Figure 6.2. The hazard rate is identical to column six of Tables 6.1 and 6.2. In contrast, the estimated survivor rate, is calculated relative to the original sample size, rather than the number of parcels at-risk during a given time period.

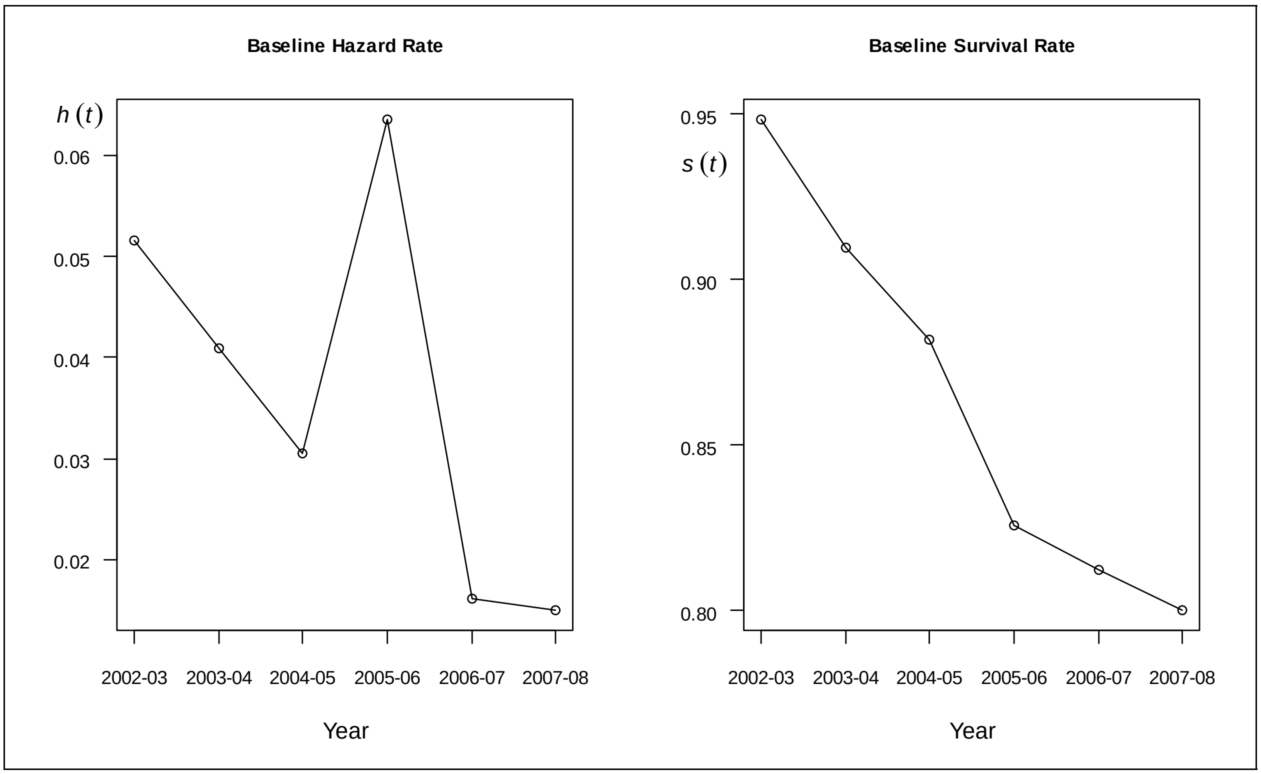


Figure 6.1: Empirical Baseline Hazard And Survivor Rates: Macro-Scale.

[24] The Charlotte-Mecklenburg subdivision ordinance sets a threshold of 10 acres for major subdivisions. A minor subdivision is greater than 2 acres, but less than 10 acres.

[25] Parcels of 2 acres or less are not subject to the provisions of the subdivision ordinance unless they require street right-of-way dedication. The micro scale sample consists of parcels between 2 and 10 acres in size.

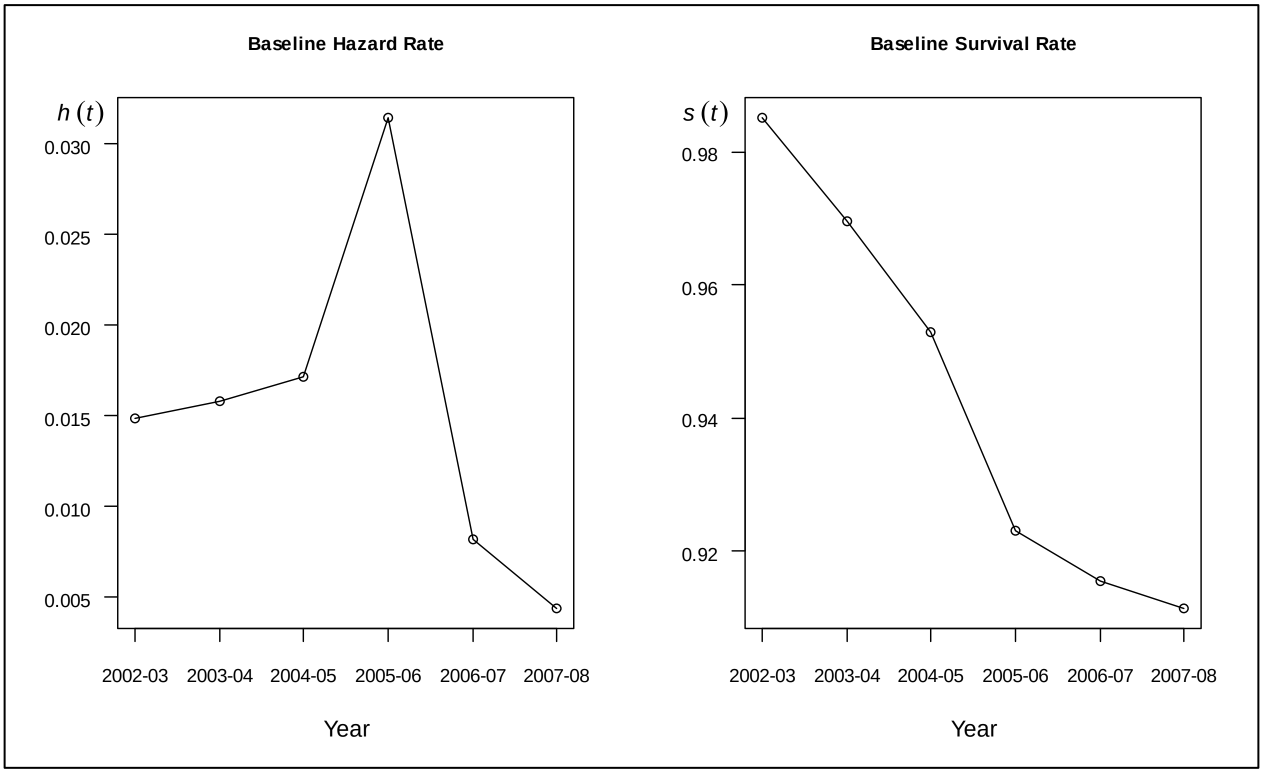


Figure 6.2: Empirical Baseline Hazard And Survivor Rates: Micro-Scale.

The baseline hazard rate represents the overall probability of observing an event in the associated time period, without controlling for the influence of covariates. Later in the survival analysis component of the dissertation, baseline hazard is captured by including time as main effect, while controlling for important covariates. The estimated hazard rate reflects the rise and fall of the proportion of events within the at-risk sample at each time period and the sharp decline in the final two time periods is apparent. In the second panel, the estimated survivor function shows a steady decline in the probability that a given parcel will survive the current time period, and this makes intuitive sense because new observations are not allowed to enter the analysis. Hazard rates are lower and survival rates higher at the micro-scale, relative to the macro-scale. However, the general pattern of an uptick in observed events between 2005 and 2006 followed by severe declines in the final two time periods is still apparent.

6.3 Point Pattern Analysis Results

Point pattern analysis involves examining and testing the spatial configuration of observed events to determine if there is evidence of a systematic pattern (Bailey and Gatrell, 1995: 76). In most instances, the analysis of point patterns is descriptive or exploratory in nature, designed to provide general insight into phenomenon studied. This dissertation draws upon basic point pattern techniques to assess the degree of clustering:

- Across time periods (i.e., year to year)
- Within scales (e.g., do large parcels cluster with large parcels)
- Across scales (e.g., are large parcels clustered relative to small parcels)

In order to address the above question, *K*-function analysis was applied to the results of the parcel change analysis. However, before the results of these analyses are presented, the spatial distribution of events at both scales for all six time periods is shown in Figure 6.3 and Figure 6.4.

As shown in Figure 6.3, subdivision events at the macro-scale are concentrated along the western border of the county, in the northern municipalities, and in the Mint Hill and Matthews areas in the southeast across all time periods. In the western portion of the county, development is potentially fueled by the availability of vacant land and the influence of amenities like Lake Norman in the north and Lake Wylie in the south.

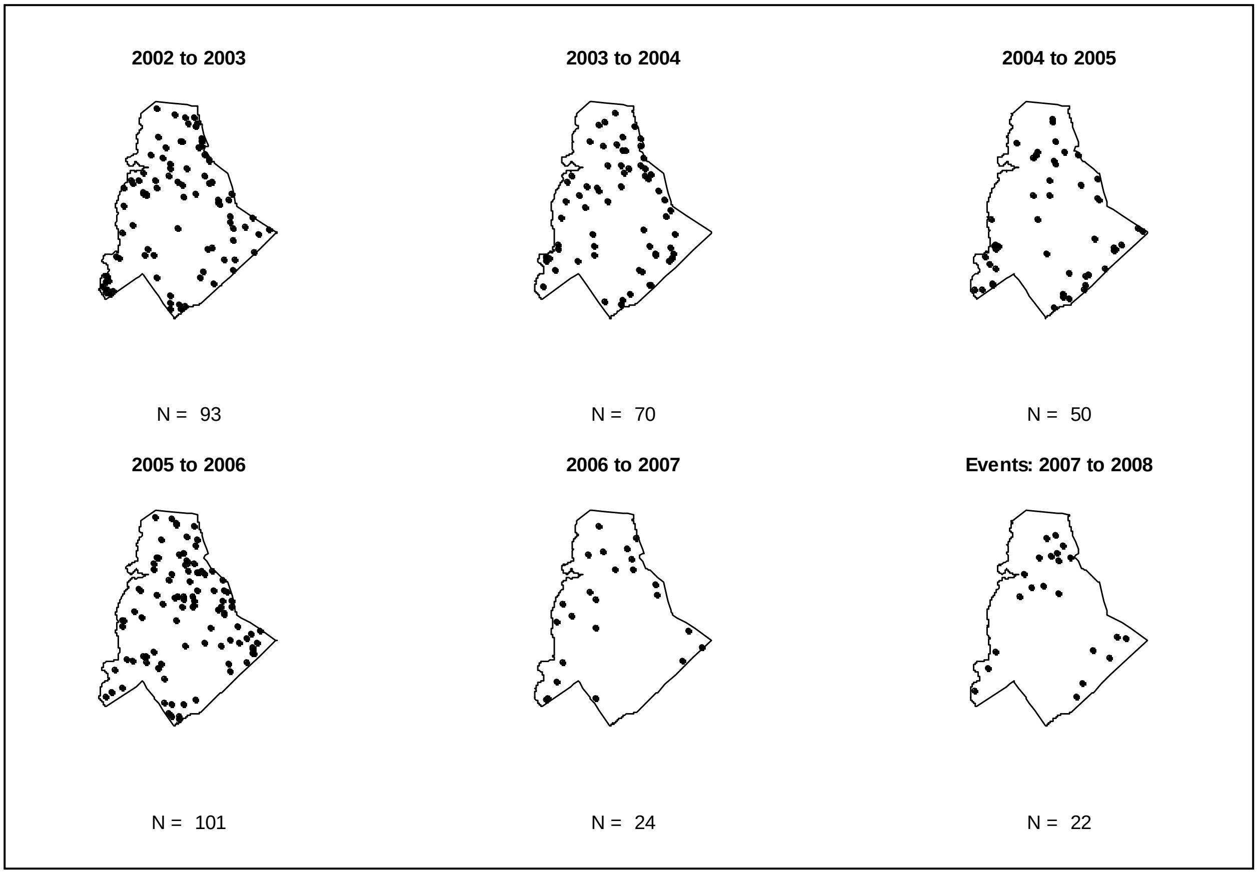


Figure 6.3: Spatial Distribution Of Macro-Scale Events By Time Period.

The northern municipalities of Huntersville, Cornelius, and Davidson are attractive to developers in part because of their proximity to Charlotte and ease of access to the city center via Interstate 77. These areas are also more affluent, on average, than most other areas of the county. Growth in the southern portion of the county and in Mint Hill in particular has been driven by the I-485 beltway and the general trend towards decentralization that characterizes not only Charlotte, but many other metropolitan areas around the nation. Figure 6.4 shows similar trends at the micro-scale, but perhaps with more variation. Even in the final two time periods where the overall number of events declines,

Figure 6.4: Spatial Distribution Of Micro-Scale Events By Time Period.

the northern municipalities, in particular, are well-represented.

6.3.1 Are The Observed Events Clustered Without Regard To Scale?

As described in Chapter 5, the standard *K*-function is commonly used to test for clustering, but because it assumes that the intensity of the point pattern is constant across the study area, it is often a problematic choice. Because these assumptions are not met for the present application, an inhomogeneous *L*-function, where the intensity of the underlying point process is estimated via a "leave-one-out" kernel smoothing approach outlined in

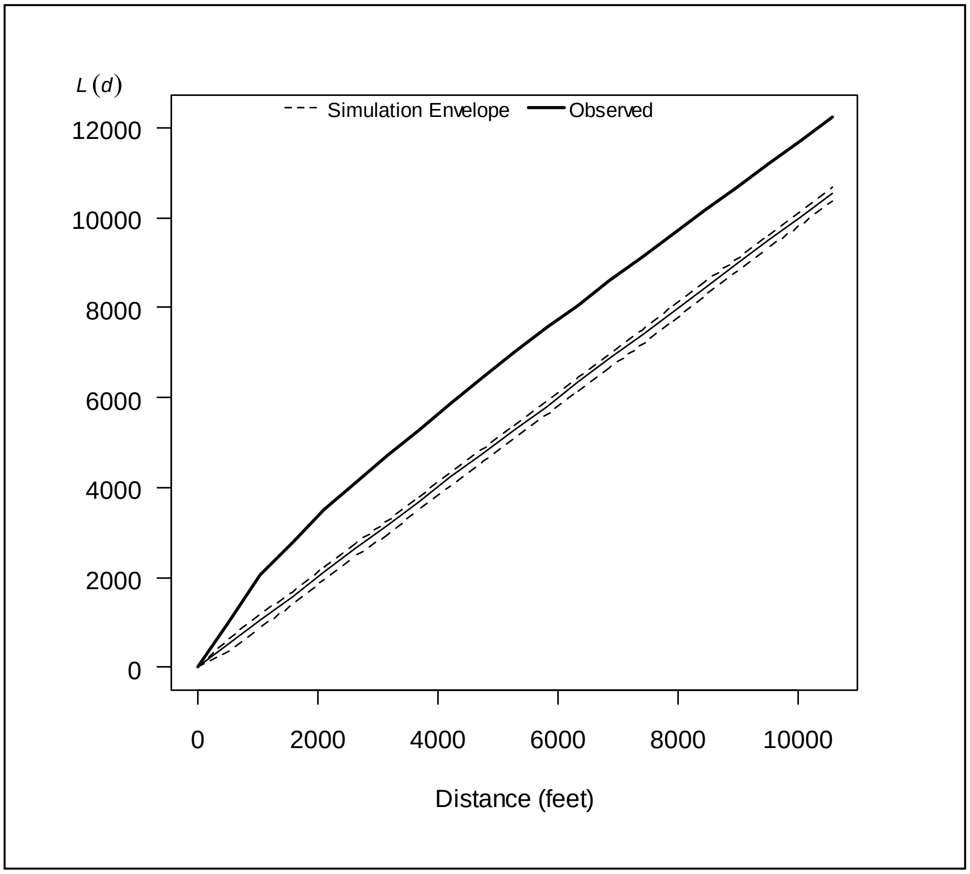


Figure 6.5: Inhomogeneous *L*-function For All Observed Events.

Baddeley *et al*. (2000), is estimated instead. Figure 6.5 shows the results of the *L*-function (variation of *K*-function) analysis used to test for spatial pattern within the observed events across all time periods and scales. After accounting for variations in background intensity, there is evidence of significant clustering among the observed events (observed line is above the expectation line) across all distance lags. The expectation line for the standard *L*-function is a horizontal line at the origin, but the inhomogeneous *L*-function has an expectation equal to the distance, which yields a 45° line relative to the origin, as with the *K*-function (Baddeley, 2008). The heavy line represents the observed values of inhomogeneous *L*-

function estimated at distance lags of 528 feet (one-tenth mile) to a maximum distance of two miles. The dashed lines represent upper and lower values of pointwise envelopes, derived by generating realizations of a uniform Poisson point process with the same intensity as the observed data. As such, the envelopes provide some insight into the statistical significance of deviations from the expectation (thin solid line). This approach was applied to the events observed in each of the study time periods, but rather than present the *L*-function plots as above, the results are summarized in Table 6.3.

Table 6.3: Inhomogeneous *L*-Function Analysis Of All Events By Time Period.

Year	Time Interval	Total Events	Range of Clustering
0	2001 – 2002	329	0.1 miles to 2 miles
1	2002 – 2003	152	0.2 miles to 2 miles
2	2003 – 2004	132	0.1 miles to 2 miles
3	2004 – 2005	116	0.2 miles to 0.4 miles; 0.7 miles to 2 miles
4	2005 – 2006	220	0.1 miles to 2 miles
5	2006 – 2007	55	No Significant Evidence
6	2007 – 2008	38	1.6 miles to 1.9 miles

When all observed events are considered (regardless of scale), there is evidence of clustering in all but one of the study time periods and in most cases, clustering is evident across all distance lags. A logical next question is whether this pattern of clustering holds when the observed events are examined by scale. It should be noted here that *L*-function estimates presented have been corrected for edge effects using the reduced sample estimator suggested by Ripley (1988).

6.3.2 Are The Macro-Scale Events Clustered?

When examined separately, the observed macro-scale events exhibit a pattern of clustering consistent with that of the overall sample of events. As shown in Figure 6.6, beginning at 0.2 mile the observed macro-scale events follow a clustering pattern at each of the subsequent distance lags even after accounting for variations in intensity across the study area. This trend is also apparent when the macro-scale events are examined across time periods. Table 6.4 shows the results of the *L*-function analysis and although there are more fluctuations here than with the full sample of all observed events, all but two time periods were associated with some degree of significant clustering.

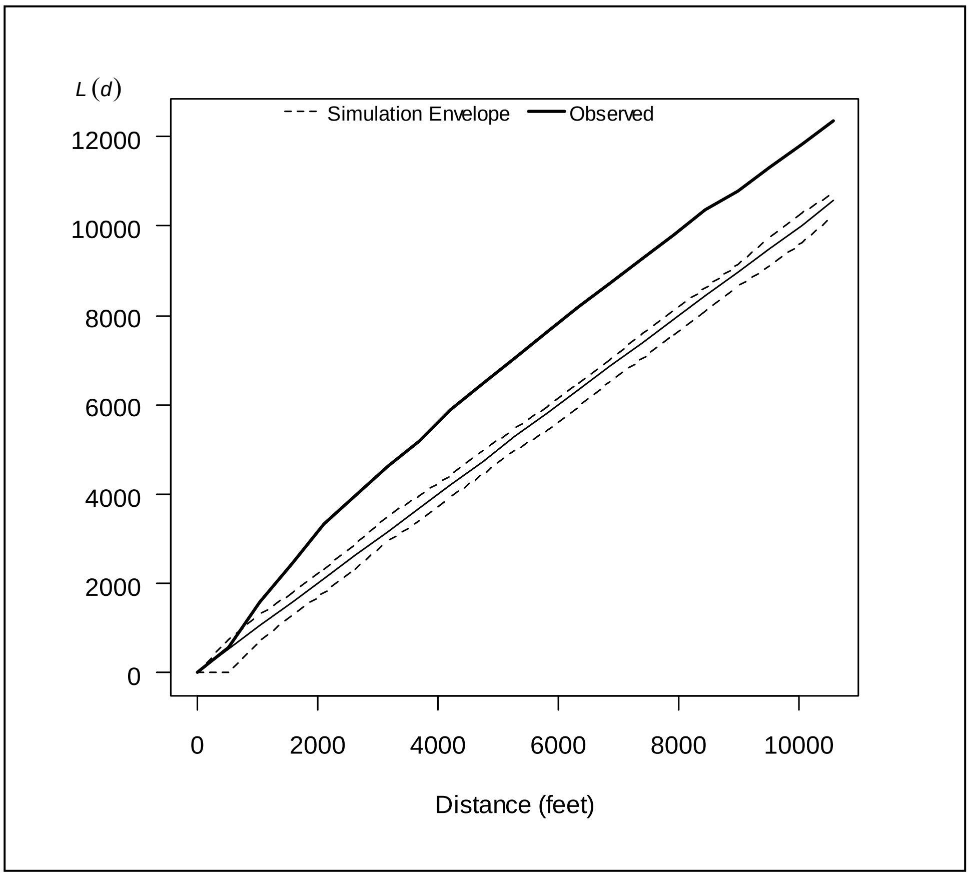


Figure 6.6: Inhomogeneous *L*-function For All Macro-Scale Events.

Table 6.4: Inhomogeneous *L*-Function Analysis Of Macro Events By Time Period.

Year	Time Interval	Total Events	Range of Clustering
0	2001 – 2002	184	0.3 miles to 2 miles
1	2002 – 2003	93	0.5 mile; 1.1 miles to 1.8 miles
2	2003 – 2004	70	0.2 miles to 0.4 miles; 0.6 mile
3	2004 – 2005	50	0.2 miles to 1.7 miles
4	2005 – 2006	101	0.1 miles to 2 miles
5	2006 – 2007	24	No Significant Evidence
6	2007 – 2008	22	No Significant Evidence

Thus far, the exploratory spatial point pattern analysis has found evidence of clustering across the sample of all observed events as well as at the macro-scale. The process was repeated for events observed at the micro-scale and the results are described below.

6.3.3 Are The Micro-Scale Events Clustered?

The micro-scale land parcel subdivision events are clustered, based on the inhomogeneous *L*-function shown in Figure 6.7. Evidence of clustering begins at the first distance class and continues across all subsequent classes, which is reflected in the position of the observed curve (heavy line) above the expectation line and outside of the simulation envelopes. Again, these envelopes represent a pointwise Monte Carlo test of the *L*-function value for each distance lag at an alpha level of approximately 0.05 (Baddeley and Turner, 2005). The results of the *L*-function analysis as applied to micro-scale events observed at each time period are presented in Table 6.5 and the trend towards clustering is more pronounced than with the macro-scale events. There is only one time period where

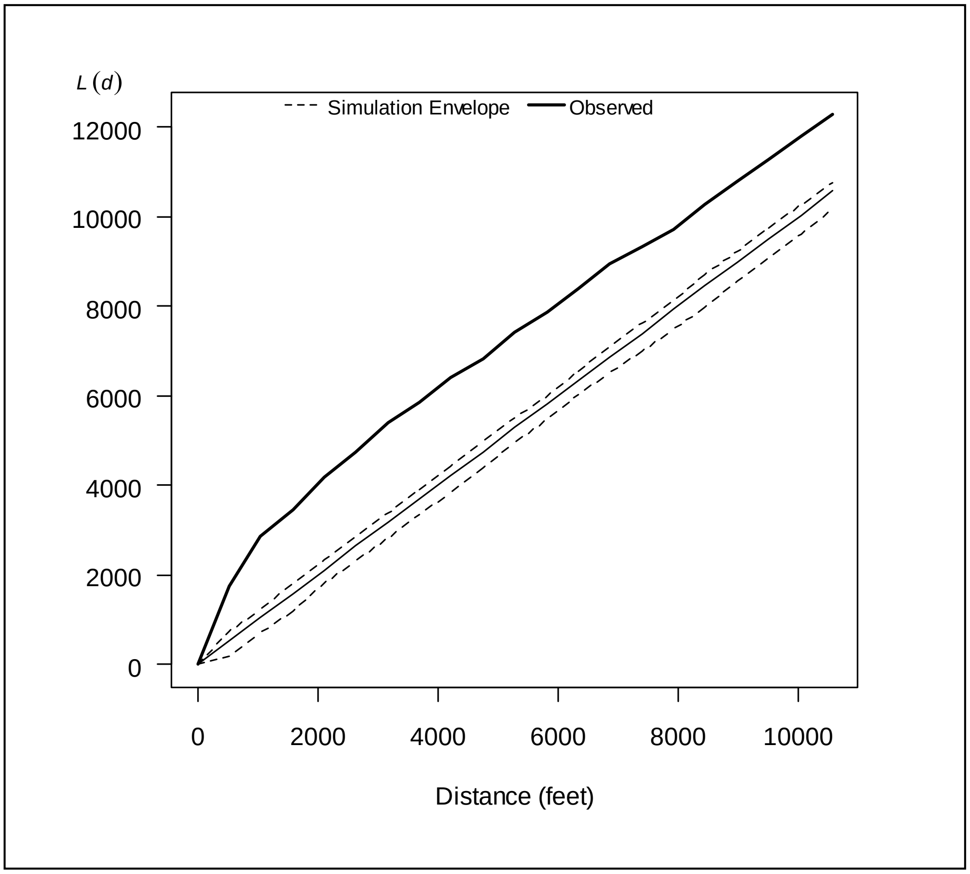


Figure 6.7: Inhomogeneous *L*-function For All Micro-Scale Events.

evidence of clustering was not observed and the pattern of clustering is more consistent and covers more distance lags here than in Table 6.4 (macro-scale events). The use of the inhomogeneous *L*-function provides a more realistic null hypothesis when examining point patterns for evidence of spatial structure. Allowing intensity to vary over the study area means that more robust inferences can be made about the presence or absence of clustering, but it is important to remember that these techniques are exploratory in nature. The expected value of the *L*-function is adjusted to accommodate non-stationarity, but the test of significance still relies on simulating random point patterns with the same intensity as

Table 6.5: Inhomogeneous *L*-Function Analysis Of Micro Events By Time Period.

Year	Time Interval	Total Events	Range of Clustering
0	2001 – 2002	145	0.1 miles to 2 miles
1	2002 – 2003	59	0.1 miles to 2 miles
2	2003 – 2004	62	0.1 miles to 2 miles
3	2004 – 2005	66	No Significant Evidence
4	2005 – 2006	119	0.1 miles to 1.8 miles
5	2006 – 2007	31	0.1 miles to 0.8 miles; 1.2 miles to 1.9 miles
6	2007 – 2008	16	0.1 miles to 0.6 miles

the observed data as a reference distribution. The random labeling hypothesis and a case-control approach provide further insight into the spatial structure of the observed events.

6.3.4 Do The Macro- and Micro-Scale Events Exhibit The Same Pattern?

The random labeling hypothesis (Diggle, 1983) is an alternate way of thinking about and testing for spatial pattern. As described by Waller and Gotway (2004), the key question is not whether two observed point patterns are independent, but rather whether the observed cases (point pattern A) appear to be more than a random subset of all potential event locations. This approach is adopted to test whether the observed macro-scale land parcel subdivision events (cases) are significantly different from micro-scale events (controls) in terms of the degree of clustering. Here, we assume that the cases and controls arise from the same data generating process and use a difference of *K*-functions approach to test this assumption:

$$K_{11}(d) = K_{22}(d) = K_{12}(d) \qquad [22]$$

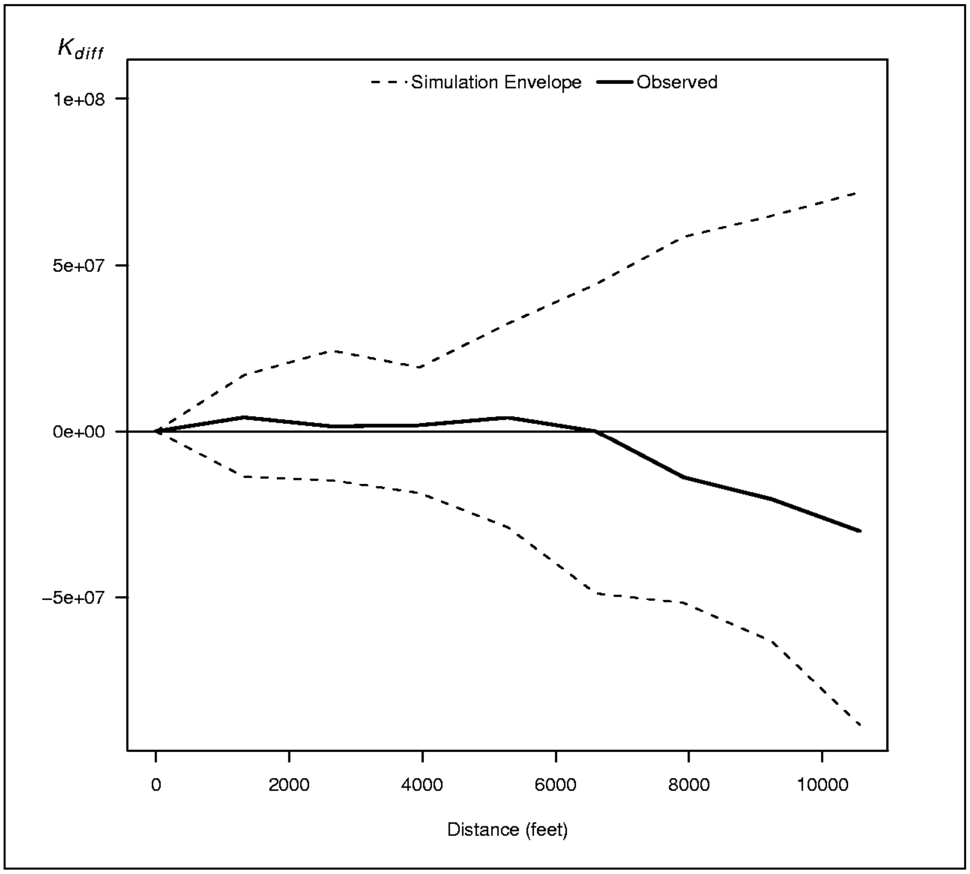


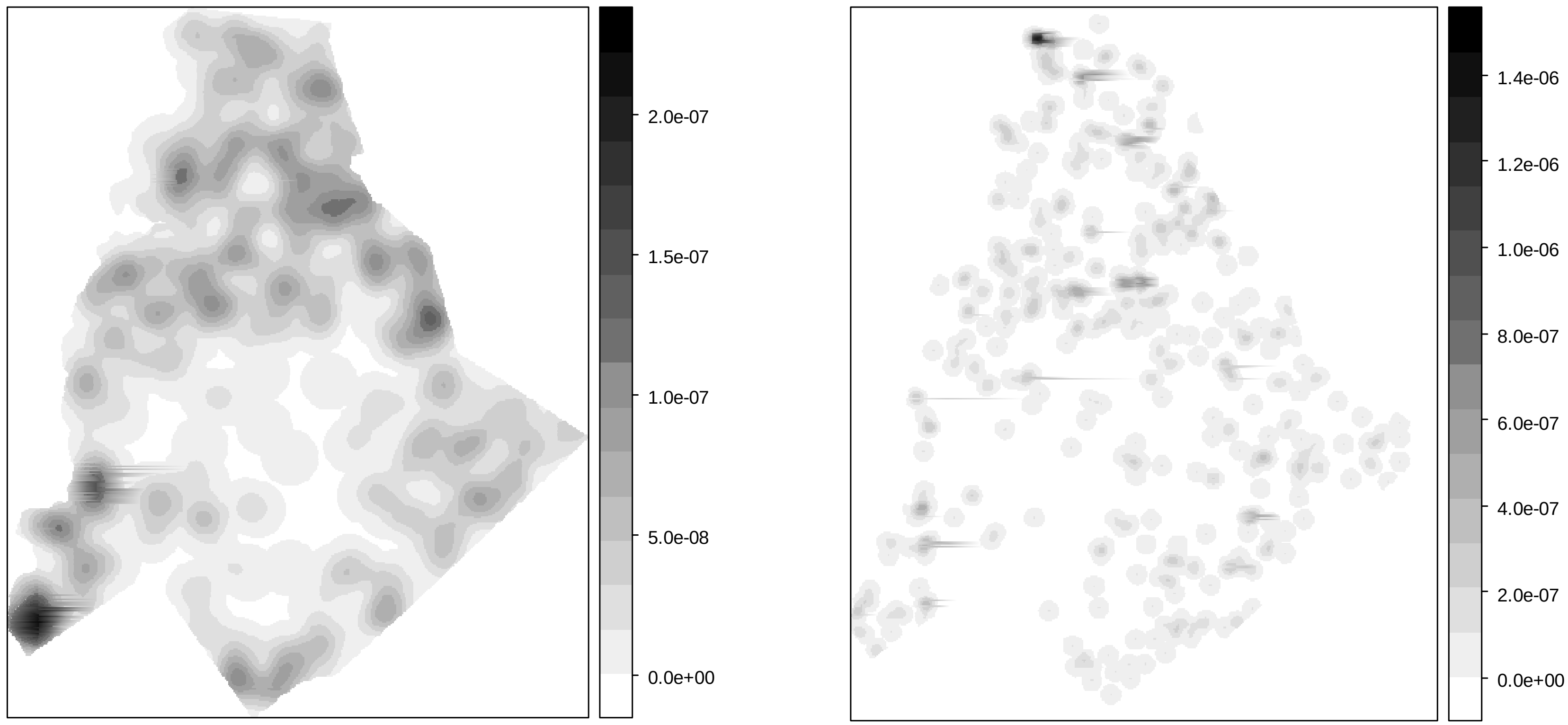
Figure 6.8: Difference Of *K*-Functions: Macro- And Micro-Scale Events.

When the two *K*-functions are subtracted, “peaks then represent spatial clustering of cases over and above the natural environmental spatial clustering of controls” (Bailey and Gatrell, 1995: 128). Figure 6.8 shows the difference of *K*-functions for observed macro-scale and micro-scale events as well as simulation envelopes generated by randomly assigned case-control labels to locations in both datasets, calculating the *K*-function for each of these realizations, and returning the minimum and maximum observed values for each distance class. Although this is not a formal test of significance, it does provide some indication of how likely it is that the observed configuration of cases and controls could have emerged by chance. There is evidence of an elevated degree of clustering among macro-scale events relative to micro-scale events over roughly the first 12 distance classes (1.2 miles), but based on the random labeling simulations (envelopes displayed), there is reason to doubt the statistical significance of this pattern.

6.3.5 Where Is intensity Highest?

The preceding discussion has focused on detecting the presence of clustering in the locations of land parcel subdivision events, but does not help identify where the clusters might be concentrated. Kernel estimation, which was employed to derive an estimate of intensity across the study area for use in the inhomogeneous *L*-function analyses, is one technique that can be useful for this purpose. These methods were originally developed to estimate a probability density function, but have been adapted to provide an estimate of intensity (Bailey and Gatrell, 1995). Within the context of point pattern analysis, a density function is the probability of observing an event at a given location, while the intensity function is the expected number of events per unit area at a given location (Waller and Gotway, 2004: 130). The key parameter in kernel estimation is the bandwidth, which controls the degree of smoothing across the observed event locations. Figure 6.9 shows kernel smoothing estimates of the intensity of observed events at both scales.

The Mean Square Error (MSE) criterion suggested by Diggle (1985) was used to select the bandwidth parameter (shown in Figure 6.9) and a standard quartic (biweight) kernel was chosen. As indicated by the legend to the right of each panel, the areas with darker shading are associated with a higher expected number of events per unit area (intensity), which is a useful and efficient way to visualize the distribution of observed



Macro Events, Bandwidth = 5808 feet, Quartic Kernel **Macro Events, Bandwidth = 2112 feet, Quartic Kernel**

Figure 6.9: Kernel Smoothing Estimate Of Intensity For Observed Events.

events. In the left panel, the fringe areas of the study area clearly experienced more activity than the central areas and this trend is also apparent in the micro-scale events depicted in the right panel. The implications of the land development, and large residential subdivision events in particular, occurring with such high intensity in outlying areas are discussed in more detail in Chapter 7.

The spatial point pattern analysis was designed to provide basic insight into the distribution and spatial pattern of the observed parcel subdivision events across time periods and scales. The *L*-function analyses suggest the presence of significant clustering of observed events overall, within scales, and across time periods after allowing for variations in intensity across the study area (non-stationarity). However, the difference of *K*-functions results suggest that although macro-scale events may exhibit a slightly higher degree of clustering than micro-scale events, this conclusion could potentially be due to chance. Finally, the kernel estimation results help to visualize where event intensity is highest within the study area and foreshadow questions about the implications of land development patterns. These measures are exploratory in that they do not control for confounding factors, a key advantage of regression analysis, but are valuable in that they demonstrate the importance of a spatial perspective.

6.4 Developer Survey Results

Forty developers with previous experience in Mecklenburg County were identified and approached and of these, twelve were surveyed about their approach to the site selection and land acquisition processes. A majority of respondents were affiliated with limited liability companies that were relatively small in size. A total of four of these firms have fewer than five employees, four have between five and 24 employees, one has between 25 and 99 employees, one has between 300 and 499 employees, and two firms have more than 500 employees. When asked to describe their firms' typical project four respondents chose "*Single-Family Residential*", one chose "*Multi-Family Residential*", three chose "*Urban Village*", and the remaining four chose "*Infill Development*". Three-quarters of respondents identified the Charlotte area as their firm's primary market the number of units built in a typical year ranged from 20 to 1000, for the eight respondents who provided an answer and the size of residential projects also exhibited considerable variation. Only one firm completes more than five projects in a typical year and nearly all respondents explained that the strength or weakness of the market coupled with the size of the project often means that no residential projects are completed in a given year. The consensus is that this number ebbs and flows based on a variety of factors. It is important to note the diversity of the local development community. In addition to variations in the size and legal status (e.g., partnership versus corporation), the type of projects undertaken by local firms and range of services also tends to vary. Some firms engage only in land development, while others are also home-builders and therefore, take a more integrated and comprehensive approach to residential development.

The survey was designed to provide basic insight into the site selection process and when asked for a general description of their approach, respondents offered a range of responses from the specific:

> "Use Polaris [local online GIS] to identify potential sites in attractive infill areas. Also keep open lines of communication with brokers and other developers so that you can "hear" about a good opportunity. We look for close in in-fill development sites just on the edge between "good" and "bad" areas because you have the potential for lower land costs while still borrowing from the energy of a "good" area."

> "Identify demographic trends in an area. Field research to understand site, accessibility. Competitive review and operational review to understand rent expectations. Letter of Intent to a buyer with 90 to 120 days of due diligence. Conduct due diligence tests. Present to Board of Directors. Upon approval, land takedown occurs."

to the very general:

> "Look for A+ sites only with good visibility and access."

> "Gut instinct."

Several themes emerged from the responses to this question including a need to balance access to high growth areas with a desire to maintain and promote livability and some respondents mentioned transit-oriented development, sustainability, urban sprawl. Of course the standard considerations of accessibility, land price, schools, and taxes were also well-represented. In fact, a desire for "high visibility" sites that are "one or two turns off the freeway" were recurrent themes. A particularly interesting question asked respondents to identify a residential project they considered successful and to explain what factors led them to chose that particular project as an example of success. All of the responses were either high-profile mixed use projects (e.g., Birkdale, The Ardsley, Eastfield Village, Morrison), high-density downtown projects (e.g., Camden Dilworth, Dilworth Walk, Trademark), or luxury neighborhoods (e.g., Heydon Hall). Common themes that emerged in the reasons respondents gave for choosing these projects included: walkability (3), profitability (3), proximity to shopping (2), and location.

When asked how they typically learn about available land, most respondents identified relationships within the industry (e.g., builders, brokers) as the most common and important avenue. Other sources of information included "windshield surveys," the Charlotte-Mecklenburg online GIS (POLARIS), Metrostudy reports, and word-of-mouth. Once identified, candidate parcels are typically optioned rather than purchased, and the time between initial option or purchase and development can range from six months to three years, according to respondents.

In terms of specific factors, the size of the parcel is an important consideration, but the minimum acreage that firms consider naturally depends on the nature of the project. For the high-density and multi-family firms, this threshold ranged from ¾ acre to one acre, but for firms specializing in single-family projects, the threshold ranged from eight acres to 100 acres. This is another example of how the diversity of firms operating within the local residential market has implications for observed development patterns. Another key consideration is zoning and practically all respondents agreed that it is better to purchase properly zoned land than to enter the rezoning process, which can range between five and sixteen months in Charlotte-Mecklenburg. However, a trade-off to consider is that large tracts in the path of growth usually need to be rezoned and more affordable land tends to be located on the periphery. The rezoning process in Huntersville, Davidson, Matthews, and Mint Hill were rated most demanding by the respondents, with Mecklenburg County deemed more difficult than the City of Charlotte for rezoning petitions. However, despite the challenges of rezoning, 70% of respondents request rezoning more often than they purchase properly zoned land. In terms of required permits, respondents rated Huntersville, Cornelius, Davidson, and Matthews the most difficult jurisdictions in which to operate.

As one respondent noted during a phone interview, "everyone's development costs are similar and everyone's returns are similar," so the key to profitability is cost-cutting. This observation is reflected in responses that indicated that holding labor, land, and capital costs constant, slope and topography were overwhelmingly chosen as the factors exerting the most influence on the profitability of a residential project. When asked if their firms have a specific policy or strategy in terms of pioneering new locations or allowing others to “prove the market” and follow, only two respondents unequivocally stated that they aim to lead. Based on the responses most firms either do not have a set policy or prefer to follow established projects or key retailers like grocery stores.

Although the sample size is small, the responses to the survey questions shed some light on the decision process of land developers operating within Mecklenburg County. The site selection process is market-driven, which means that different types of projects (e.g., downtown condos, large-lot single-family) have very different needs in terms of acreage, location, and amenities. The development community is close-knit and information spillovers are key to successfully identifying and acquiring available land for proposed projects. Relationships between brokers, developers, and builders are also very important as cooperation is essential to each party’s long-term success. Perhaps the most enduring and fundamental characteristic is that land development is a business and profit-maximization is a necessary consideration throughout the planning and development process. An awareness of the preferences of the target market for a particular project as well as the competition within a geographic area are also key. Responsiveness to the market can lead to mixed-use projects or subdivisions with a range of products (price range) as developers seek to minimize uncertainty regarding sales and limit the financial exposure inherent in undertaking such a large investment. These responses also help to corroborate the theory and literature from which the independent variables in the hedonic regression and discrete-time hazard models were drawn.

6.5 Survival Analysis Results

As described in Chapter 5, the results of the parcel change analysis are the basis for deriving the dependent variable for the survival analysis component of the dissertation research. The results of this procedure are detailed in Section 6.2, but another key element of the survival analysis warrants a more detailed treatment here. A separate hedonic regression model is estimated and the parameters are then used to estimate the overall market value of land parcels in the sample as a proxy for their value to residential land developers. The results of this analysis are then incorporated as a key independent variable in the discrete-time hazard models. Since these models are estimated at two scales with 10 acres serving as the delineation threshold, the hedonic regression analysis also follows this approach.

6.5.1 Hedonic Regression Results: Macro-Scale

Table 5.2 lists the independent variables used to model the (log transformed) sales prices for vacant parcels in 2000. Scatter plots were used to test for non-linear relationships between the dependent variable (logged sales price) and the continuous independent variables, but these graphics are not presented here. In the original specification, the employment potential variable and the distance to Uptown Charlotte variable raised collinearity concerns (i.e., variance inflation factor greater than 5). The correlation between these variables was less than -0.88, so the distance to Uptown Charlotte variable was removed. The rationale is that employment potential captures the effect of the central business district as the single largest employment center in the study area as well as the influence of other employment centers. Similarly, *n-1* dummy variables were initially included to capture the effect of school district on land value, based on the findings of Munroe (2007). However, collinearity led to inclusion of a single dummy variable representing school districts with "Priority" status based on end-of-grade tests during the 2001-2002 school year and the results of the macro-level model are presented in Table 6.6.

Table 6.6: Macro-Scale OLS Parameter Estimates (N = 90).

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
(Intercept)	8.4463	5.2455	0.1117	
Physical Characteristics				
Water body frontage	-0.4619	0.3971	0.2486	
Stream frontage	-0.4895	0.2414	0.0462	*
Slope	-0.2684	0.0828	0.0018	**
Poor soils	0.2470	0.3507	0.4834	
Wetlands	0.9578	0.6490	0.1443	
Forest cover	0.1657	0.4554	0.7170	
Parcel size	1.3990	0.1802	0.0000	***
Accessibility				
Employment potential	3.0723	4.7358	0.5186	
Shopping potential	3.7596	1.8220	0.0426	*
Distance to freeway ramp	-0.2090	0.1528	0.1756	
Policy Context				
School district [26]	0.1517	0.2605	0.5620	
Tax rate	-0.6511	0.7579	0.3931	
Unincorporated	0.2061	0.2662	0.4412	
Zoning	0.0392	0.2013	0.8461	
Demographics				
Population density	0.1172	0.0854	0.1740	
Income	0.0693	0.4497	0.8779	
Adjusted R-squared	0.4959			
F-statistic	6.472 on 16 and 73 DF			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

[26] Districts where high schools did not meet state performance guidelines during the 2001-2002 year (i.e., greater than 60% at grade level)

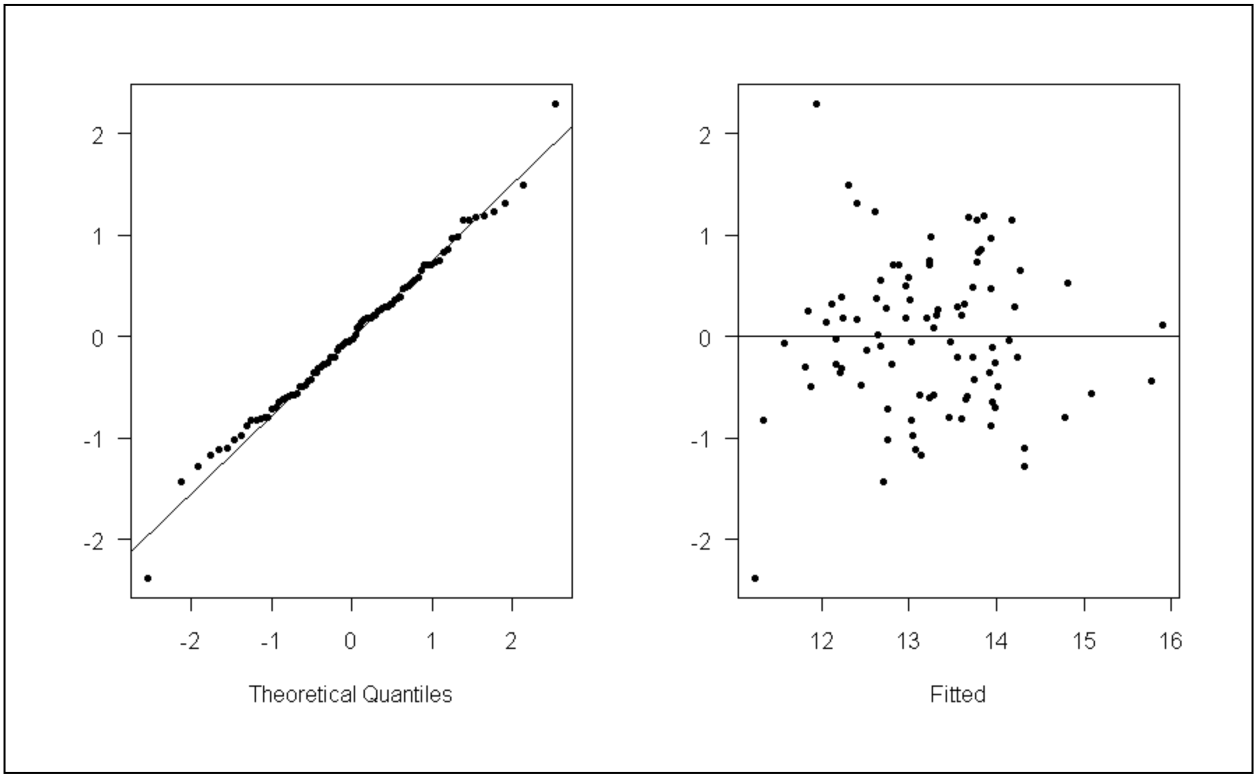


Figure 6.10: Diagnostic Plots For Macro-Scale Regression.

Standardized regression coefficients indicate that the most important predictors (in order) are: parcel size, slope, shopping potential, and stream frontage. A Breusch-Pagan test revealed no evidence of heteroskedasticity ($\chi^2 = 16.19$, $p = 0.43$) and this conclusion is corroborated by the normal Q-Q and residuals (response minus fitted values) plots shown in Figure 6.10. The normal quantile-quantile plot (left-side) indicates the presence of two potential outliers in the upper right and lower left of the graph. These observations were identified based on their extreme residuals and are investigated further (first panel of Figure 6.11). Both of these observations are located in Huntersville and the first of the parcels (10.75 acres) sold for $7,000 and appears to have been an intra-family transaction (based on

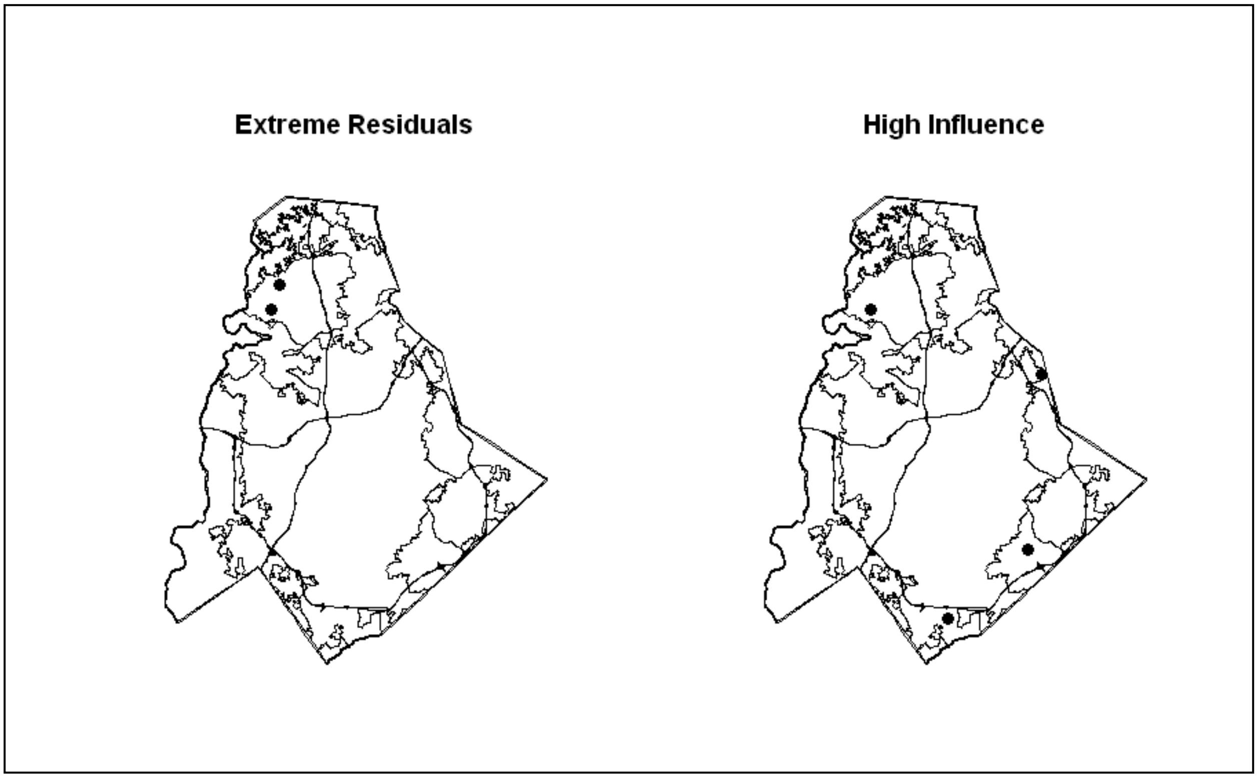


Figure 6.11: Extreme Residual And High Influence, Macro-Scale Model.

property records). The other parcel (10.73 acres) sold for more than \$1.5 million and is now the Douglas Park neighborhood. The model over-predicts the sales price of the first Huntersville parcel and under-predicts the sales price of the other.

The influence of each observation on the predicted value of the dependent variable was evaluated using DFFITS and four observations exceeded the threshold of $2\sqrt{p/n}$ suggested by Belsey *et al*. (1980). The second panel of Figure 6.11 shows the location of these four observations with respect to the major highways and jurisdictional boundaries within Mecklenburg County. One of these observations (lower right) is located in Matthews, sold for \$3 million, and the parcel is now a Lowe's Home Improvement store. The observation located in the bottom center of the map sold for over $3 million and is currently an apartment complex. The parcel in the upper left of the map is the located in Huntersville, sold for over $1.5 million, and is now the Douglas Park neighborhood. The fifth parcel is located near UNC-Charlotte (upper right) and sold for $3 million, but remains undeveloped, according to public tax records. The original sales prices for each of these parcels were verified in the Mecklenburg County online real estate system as accurate and therefore, these observations remained as part of the analysis.

In order to test the residuals of the regression model for the presence of spatial autocorrelation, the spatial weights matrix must be specified. Following the procedure of Dray *et al*. (2006) outlined in the previous chapter, a correlogram of the dependent variable was calculated as an exploratory tool to guide the spatial weights matrix selection process. As shown in Figure 6.12, the range of spatial autocorrelation in the dependent variable falls below zero at approximately 4.7 miles, rises, then declines again at roughly 6.8 miles. The *correlog* function in the *spdep* package was used to estimate the correlogram and the statistical significance of Moran's *I* at each distance class (Bjørnstad and Falck, 2001).

Next, a series of binary connectivity matrices were generated using one-mile intervals with 10 miles as the maximum. The connectivity matrices are binary and represent whether observations are neighbors in space. For example, if the distance threshold is five miles, then all parcels in the sample that are within five miles or less of one another are considered neighbors (coded as 1) and all pairs of observations that do not meet this threshold are not considered neighbors (coded as 0). The eigenvalues and eigenvectors of these binary connectivity matrices are extracted and those with an absolute value greater than 0.25 are set aside as candidates in the stepwise regression model used in the next phase of the spatial

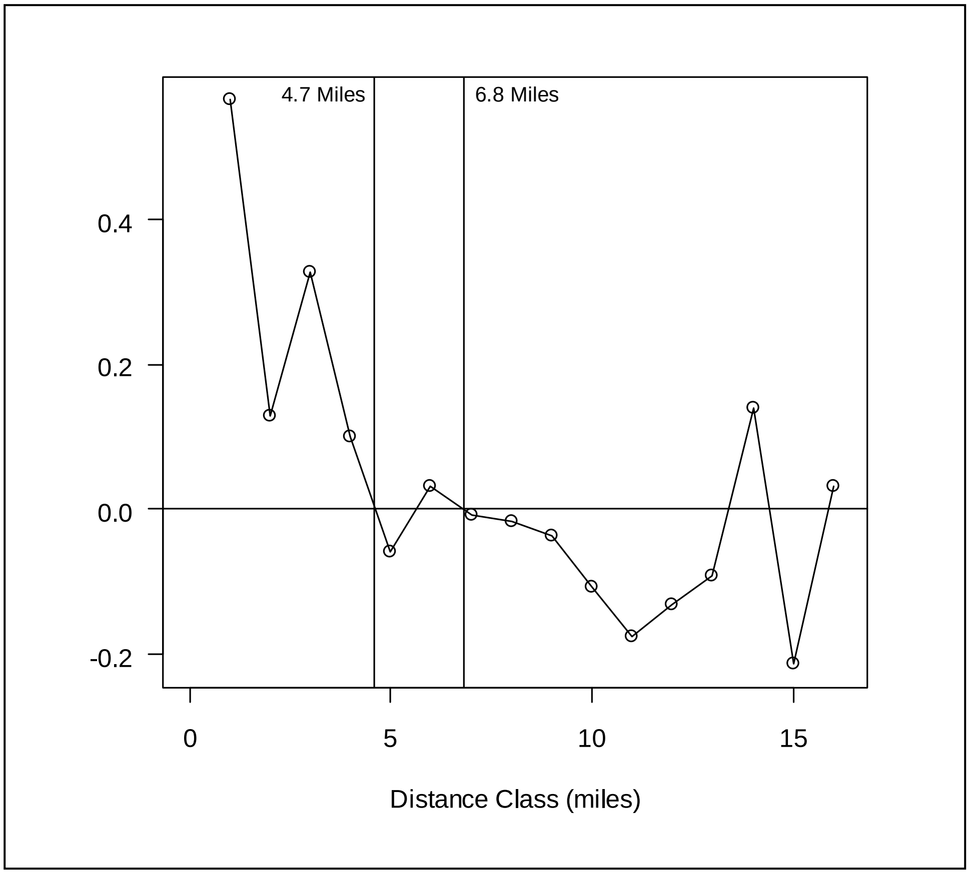


Figure 6.12: Correlogram Of Logged Sales Price At Macro-Scale.

weights matrix selection process. Griffith (2003: 114) explains that retaining only those eigenvectors whose eigenvalues meet this criterion ensures that “each selected map pattern accounts for a minimum amount of spatial autocorrelation contained in the georeferenced variable *Y*.”The eigenvectors themselves represent latent spatial structure in configuration of the polygons or grid cells being analyzed in a way that is similar to principal components analysis (Gould, 1967; Griffith, 2000). These eigenvectors may be used as covariates to mitigate the impacts of spatial autocorrelation within a regression context or as tool for selecting the spatial weights matrix. The spatial filtering approach introduced by Griffith

(2000; 2003) and Tiefelsdorf and Griffith (2007) suggests stepwise regression as a means of identifying the subset of candidate eigenvectors that capture the greatest amount of residual spatial autocorrelation.

The extracted eigenvectors for each of the ten connectivity matrices were then used in ten separate stepwise regression analyses where the dependent variable is the logged sales price and the independent variables are the eigenvectors extracted from the connectivity matrices. Akaike's information criterion (AIC) is used to assess goodness of fit across the ten regression models and to identify the most appropriate connectivity matrix for the macro-scale dataset (Getis and Aldstadt, 2004). However, given the relatively small sample size, a bias correction is applied to raw AIC values for each regression model (Dray *et al*., 2006):

$$AIC_C = \frac{AIC + 2K\,(K+1)}{n - K - 1} \qquad [23]$$

The primary effect of the bias correction [23] is a penalty for the inclusion of additional independent variables. This is particularly important when the sample size is small, as too liberal a selection procedure can exhaust the available degrees of freedom. The results of the stepwise regression analyses for each of the candidate connectivity matrices[27] are presented in Table 6.7. Based on the corrected AIC values, the seven mile threshold is the most plausible of the candidates examined (minimizes criterion) and this conclusion is also consistent with the correlogram of the dependent variable presented in Figure 6.13 above.

To improve the realism and theoretical validity of the spatial weights matrix, this binary connectivity matrix can be weighted such that land parcels designated as neighbors (within a seven mile radius) are weighted using a distance-based scheme.

[27] Threshold distances less than four miles resulted in unconnected observations (zero neighbors).

Table 6.7: Selection Procedure For Macro-Scale Connectivity Matrices.

Distance	Raw AIC	AIC_C
1 Mile	–	–
2 Miles	–	–
3 Miles	–	–
4 Miles	-153.40	407.20
5 miles	-120.56	305.51
6 Miles	-162.27	377.46
7 Miles	-70.28	137.72
8 Miles	-107.68	328.49
9 Miles	-119.56	265.87
10 Miles	-65.74	233.80

The appeal of applying distance-based weights to the binary connectivity matrix is that it allows closer neighbors to exert greater influence than more distant neighbors (Bivand *et al*., 2008: 253). Three candidate weighting schemes or approaches were considered:[28] inverse distance, inverse distance squared, and the distance decay function suggested by Griffith and Lagona (1998) and shown below [24].

$$A = \left(1 - \frac{d_{ij}}{\max(d_{ij})}\right) \qquad [24]$$

In addition to the weighting schemes, a variety of coding schemes can be applied to the spatial weights matrix to make it a closer representation of reality and Tiefelsdorf *et al.* (1999) provides a basic overview. The row-standardized coding scheme (denoted *W*) rescales the weights assigned to all neighbors of a given observation so that they sum to one. This has the effect of compensating for discrepancies in the number of neighbors across observation (i.e., some observations may have far fewer or far more neighbors than others). This approach has been criticized for inherently emphasizing observations located on the fringe of

[28] Each of the candidates are based on the initial binary connectivity matrix with seven miles as the threshold for neighbor relationships. The three weighting schemes describe the nature of the decay in the strength of influence as distance increases.

the study area that tend to be less connected and have fewer neighbors. In contrast the globally-standardized coding scheme (denoted *C*) rescales all weights across all observations (not just within each observation) such that these sum to the total number of observations. Here the effect is to emphasize observations located in the center of the study area that tend to have more neighbors. Finally, the *S*-coding scheme introduced by Tiefelsdorf *et al*. (1999) is designed to stabilize the variance induced by variations in the size and spatial configuration (i.e., number of neighbor connections) of the area units. Using the binary connectivity matrix as a point of departure, the steps described above were repeated to determine which weighting and coding schemes performed best for the current dataset.

Table 6.8: Macro-Scale Selection Procedure For Weighting And Coding Schemes

Weighting Scheme	Coding Scheme	AIC_C
IDW	B	217.64
IDW^2	B	70.57
Griffith and Lagona (1998)	B	146.06
IDW	C	3.43
IDW^2	C	2.30
Griffith and Lagona (1998)	C	0.38
IDW	W	6.32
IDW^2	W	265.87
Griffith and Lagona (1998)	W	1.44
IDW	S	2.15
IDW^2	S	57.26
Griffith and Lagona (1998)	S	0.60

As shown in Table 6.8, the Griffith and Lagona (1998) weights applied to the seven mile threshold for establishing connectivity and incorporating the *C*-coding scheme is the spatial weights matrix suggested by this empirically-driven selection procedure. Intuition may suggest that one of the distance-decay weighting schemes would improve the performance of the model, but the distribution of the observations in space for this particular dataset does not fit this pattern.

The selected spatial weights matrix was used to test for the presence of spatial autocorrelation. The univariate global Moran's *I* test indicated a moderate degree of positive spatial autocorrelation ($I = 0.291$, $p = 0.000$, two-tailed) in the dependent variable, but the Moran's *I* for residuals test indicated no autocorrelation in the OLS residuals ($I = -0.007$, $p = 0.316$, two-tailed). This lack of evidence of spatial autocorrelation in the residuals leads to the conclusion that the parameter estimates are unbiased and efficient.

6.5.2 Survival Analysis Results: Macro-Scale

In order to address the third research question[29] posed in Chapter 1, a sensitivity analysis was conducted to assess how the strength of the "priming effect" measure varies with distance. This entailed estimating the discrete-time hazard model repeatedly, each time with a different distance threshold used to derive the "priming effect" measure. The results of the discrete-time hazard model for the macro-scale parcels, using a one-tenth mile radius for the "priming effect" measure, are presented in Table 6.9. Each of the six time indicators (main effect of time) is significant, which means that controlling for the influence of the other independent variables in the model, there is still a detectable effect associated with time (i.e., the time period matters)[30]. Taken as a group, the coefficients associated with the time indicators are maximum likelihood estimates of the logit hazard function (Singer and Willett,

[29] What is the spatial extent of the hypothesized "priming effect?"

[30] A chi-square test was used to compare the full model to a restricted model that only included the time indicator variables. The time-only model was rejected in favor of the model that includes substantive predictors.

Table 6.9: Hazard Model Estimates at One-Tenth Mile: Macro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-4.0380	1.0534	0.0001	***
Period 2	-4.2215	1.0546	0.0001	***
Period 3	-4.5850	1.0397	0.0000	***
Period 4	-3.8001	1.0373	0.0002	***
Period 5	-5.2349	1.0670	0.0000	***
Period 6	-5.3196	1.0676	0.0000	***
Land Market Considerations				
Estimated land value in 2001	0.0911	0.0521	0.0806	.
Parcel aggregation indicator	0.7334	0.2528	0.0037	**
Proportion vacant land in block group	0.4761	0.5375	0.3757	
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0020	0.0035	0.5724	
Number of demolitions within quarter mile	0.1761	0.0563	0.0018	**
Land use mix (entropy measure)	-1.5371	0.5461	0.0049	**
Built environment typology class	0.2593	0.2170	0.2321	
Proportion non-urban uses within quarter mile	-0.2944	0.2900	0.3101	
Accessibility				
Logged distance to I-485 (finished by 2001)	-0.0013	0.0710	0.9852	
Distance to I-485 (when complete)	0.0663	0.0323	0.0402	*
Logged distance to nearest downtown[31]	0.2015	0.0980	0.0398	*
Policy Factors				
Infrastructure availability proxy	0.0176	0.0059	0.0029	**
Tax rate	-0.3488	0.3494	0.3181	
Non-residential neighborhood	-2.3551	0.7223	0.0011	**
Rezoning duration (average number of days)	0.0000	0.0023	0.9907	
Moratorium in place (proportion of year)	-0.8186	0.4183	0.0503	.
"Priming Effect" Measure				
Nearby micro events in prior period	0.3278	1.0552	0.7561	
Model Summary				
AIC	2953.079			
Log-likelihood	-1453.540			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

[31] Includes Uptown Charlotte and downtown areas of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, and Pineville.

2003: 387) and changes in the relative magnitude of the coefficients indicate whether the probability of observing an event rises, falls, or holds steady over time. The values in Table 6.9 suggest that this probability is high in the first two periods, declines in the third period, recovers in the fourth period, and falls again in the final two periods.

The parcel aggregation indicator is highly significant and has an odds ratio of 2.08, which suggests that parcels that are merged with one or more parcels are more than twice as likely to experience an event. The number of demolition permits issued in a quarter-mile radius of the parcel is significant has a positive effect on the odds of observing a subdivision event with an associated odds ratio of 1.19. The implication is that a one unit increase in the number of demolition permits is associated with a 19% increase in the odds of observing a subdivision event. The land use mix measure is also highly significant, but carries a negative sign and an odds ratio of 0.21. Therefore, a one unit increase in the entropy land use measure is associated with a drastic (79%) decrease in the odds of observing a subdivision event. The distance to the completed I-485 beltway is significant with a positive effect (odds ratio of 1.06) on the dependent variable. The distance to the nearest downtown area is significant and exerts a positive influence (odds ratio of 1.22) as does the infrastructure proxy (odds ratio of 1.01). Location within a non-residential neighborhood drastically reduces the odds of subdivision with an associated odds ratio of 0.09 (decrease of 91% in odds of observing an event). The moratorium measure is marginally significant and exerts a negative effect, reducing the odds of observing an event by 56% (odds ratio of 0.44). Finally, the “priming effect” measure is not significant and the model fit is not very high as measured by the likelihood ratio index (R^2 = 0.0544).

Table 6.10: Hazard Model Estimates at One-Quarter Mile: Macro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-4.0328	1.0333	0.0001	***
Period 2	-4.1969	1.0341	0.0000	***
Period 3	-4.5603	1.0199	0.0000	***
Period 4	-3.7760	1.0175	0.0002	***
Period 5	-5.2163	1.0471	0.0000	***
Period 6	-5.2944	1.0476	0.0000	***
Land Market Considerations				
Estimated land value in 2001	0.0917	0.0508	0.0710	.
Parcel aggregation indicator	0.7303	0.2528	0.0039	**
Proportion vacant land in block group	0.4498	0.5373	0.4025	
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0021	0.0035	0.5526	
Number of demolitions within quarter mile	0.1777	0.0562	0.0016	**
Land use mix (entropy measure)	-1.5687	0.5456	0.0040	**
Built environment typology class	0.2589	0.2169	0.2327	
Proportion non-urban uses within quarter mile	-0.3096	0.2897	0.2853	
Accessibility				
Logged distance to I-485 (finished by 2001)	-0.0027	0.0711	0.9702	
Distance to I-485 (when complete)	0.0659	0.0323	0.0416	*
Logged distance to nearest downtown	0.2013	0.0980	0.0400	*
Policy Factors				
Infrastructure availability proxy	0.0176	0.0059	0.0028	**
Tax rate	-0.3619	0.3484	0.2989	
Non-residential neighborhood	-2.3063	0.7222	0.0014	**
Rezoning duration (average number of days)	0.0000	0.0023	0.9880	
Moratorium in place (proportion of year)	-0.8106	0.4184	0.0527	.
"Priming Effect" Measure				
Nearby micro events in prior period	0.3638	0.2474	0.1414	
Model Summary				
AIC	2951.236			
Log-likelihood	-1452.618			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 6.11: Hazard Model Estimates at One-Half Mile: Macro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-4.0743	1.0338	0.0001	***
Period 2	-4.2096	1.0341	0.0000	***
Period 3	-4.5728	1.0201	0.0000	***
Period 4	-3.7908	1.0175	0.0002	***
Period 5	-5.2608	1.0481	0.0000	***
Period 6	-5.3028	1.0477	0.0000	***
Land Market Considerations				
Estimated land value in 2001	0.0932	0.0508	0.0665	.
Parcel aggregation indicator	0.7431	0.2528	0.0033	**
Proportion vacant land in block group	0.4469	0.5377	0.4059	
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0019	0.0035	0.5908	
Number of demolitions within quarter mile	0.1769	0.0562	0.0016	**
Land use mix (entropy measure)	-1.5656	0.5456	0.0041	**
Built environment typology class	0.2680	0.2168	0.2165	
Proportion non-urban uses within quarter mile	-0.2995	0.2896	0.3010	
Accessibility				
Logged distance to I-485 (finished by 2001)	-0.0085	0.0713	0.9049	
Distance to I-485 (when complete)	0.0664	0.0323	0.0398	*
Logged distance to nearest downtown	0.1983	0.0980	0.0430	*
Policy Factors				
Infrastructure availability proxy	0.0177	0.0059	0.0029	**
Tax rate	-0.3744	0.3483	0.2824	
Non-residential neighborhood	-2.2895	0.7220	0.0015	**
Rezoning duration (average number of days)	0.0000	0.0023	0.9928	
Moratorium in place (proportion of year)	-0.7963	0.4186	0.0572	.
"Priming Effect" Measure				
Nearby micro events in prior period	0.2573	0.1008	0.0107	*
Model Summary				
AIC	2947.788			
Log-likelihood	-1450.894			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 6.12: Hazard Model Estimates at One Mile: Macro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-4.1100	1.0366	0.0001	***
Period 2	-4.2013	1.0366	0.0001	***
Period 3	-4.5668	1.0224	0.0000	***
Period 4	-3.7886	1.0197	0.0002	***
Period 5	-5.2933	1.0512	0.0000	***
Period 6	-5.2829	1.0500	0.0000	***
Land Market Considerations				
Estimated land value in 2001	0.0914	0.0507	0.0717	.
Parcel aggregation indicator	0.7415	0.2528	0.0033	**
Proportion vacant land in block group	0.4409	0.5372	0.4118	
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0015	0.0035	0.6652	
Number of demolitions within quarter mile	0.1805	0.0562	0.0013	**
Land use mix (entropy measure)	-1.5397	0.5450	0.0047	**
Built environment typology class	0.2707	0.2167	0.2115	
Proportion non-urban uses within quarter mile	-0.2849	0.2893	0.3248	
Accessibility				
Logged distance to I-485 (finished by 2001)	-0.0220	0.0714	0.7585	
Distance to I-485 (when complete)	0.0695	0.0323	0.0317	*
Logged distance to nearest downtown	0.1968	0.0978	0.0443	*
Policy Factors				
Infrastructure availability proxy	0.0175	0.0059	0.0033	**
Tax rate	-0.3935	0.3477	0.2577	
Non-residential neighborhood	-2.2730	0.7223	0.0017	**
Rezoning duration (average number of days)	0.0001	0.0023	0.9598	
Moratorium in place (proportion of year)	-0.7756	0.4188	0.0641	.
"Priming Effect" Measure				
Nearby micro events in prior period	0.1481	0.0512	0.0038	**
Model Summary				
AIC	2946.091			
Log-likelihood	-1450.046			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

If the radius of the "priming effect" measure is increased to one-quarter mile, the model parameters change slightly and the overall model fit improves a little (log-likelihood increases slightly), but the "priming effect" measure is also not significant, as shown in Table 6.10. Increasing the radius of the "priming effect" measure to one-half mile does not change the overall inference and improves model fit slightly, but most importantly the "priming effect" measure becomes significant (Table 6.11). Finally, at a distance of one mile (Table 6.12), the "priming effect" measure is significant and the estimates for all other predictors are essentially unchanged. At a distance of one mile (Table 6.12), the effect of proximity to micro-scale events in the previous time period is positive and the associated odds ratio is 1.15. Of the distance thresholds tested, the log-likelihood is maximized at one-mile as shown in a plot of the log-likelihood function at each of the radii tested in Tables 6.9 through 6.12, provided in Figure 6.13.

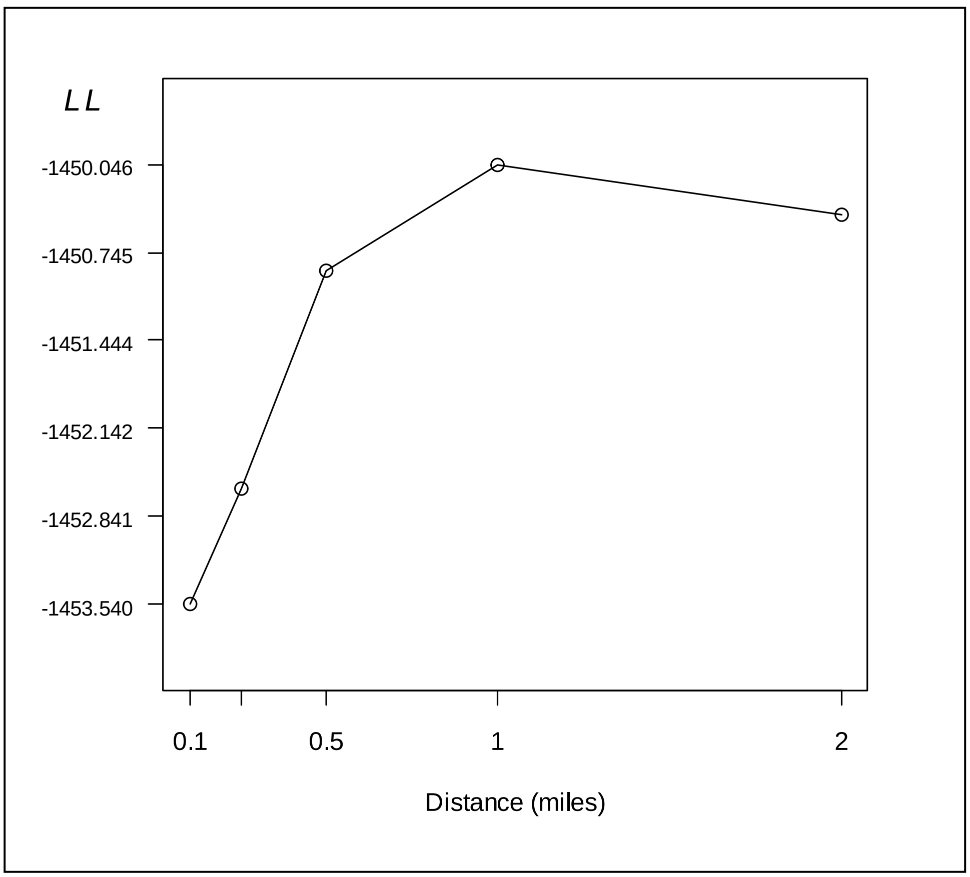


Figure 6.13: Log-likelihood Of Macro-Scale Model At Various Distance Radii.

As shown in Figure 6.13, the log-likelihood function peaks at the one mile distance threshold and begins to decline beyond that point (estimates for two mile threshold are not presented here in tabular form). This analysis provides some support for the hypothesis that proximity to parcel subdivision events of a smaller scale in the previous time period is associated with an increase in the odds of observing an event at the macro-scale. However, it is instructive to also consider the effect of proximity to all parcel subdivision events regardless of scale. The discrete-time hazard model was re-estimated using an “priming effect” measure that consisted of the total number of all parcel subdivision events within the specified distance radius in the previous time period. The results for one of these models are presented in Table 6.13.

Using a one-mile threshold, the “priming effect” measure is significant and the overall model fit is a slight improvement over the base model (Table 6.12) that only considers proximity to micro-scale events in the previous period. This improvement is also reflected in Figure 6.14, which shows the log-likelihood of the micro-scale event only and all events models across the selected distance thresholds. However, the distance to the nearest downtown measure that was a significant predictor in the base model is only marginally significant and the effect of the “priming effect” measure decreases in magnitude. Using a “priming effect” measure that includes all parcel subdivision events rather than limiting this number to the micro-scale results in a greater log-likelihood across almost all distance thresholds (with the exception of two miles). The implication is that there is a scale effect detectable at approximately the one mile threshold, but proximity to events in the previous time period without regard to scale is a more significant predictor of the odds of subdivision that also offers slight gains in overall model fit.

Table 6.13: Hazard Model Estimates at One Mile: Macro Level, All Events.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-4.2791	1.0417	0.0000	***
Period 2	-4.3155	1.0391	0.0000	***
Period 3	-4.6428	1.0243	0.0000	***
Period 4	-3.8434	1.0214	0.0002	***
Period 5	-5.3922	1.0532	0.0000	***
Period 6	-5.3166	1.0517	0.0000	***
Land Market Considerations				
Estimated land value in 2001	0.0982	0.0507	0.0529	.
Parcel aggregation indicator	0.6944	0.2534	0.0061	**
Proportion vacant land in block group	0.3233	0.5425	0.5513	
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0009	0.0035	0.8049	
Number of demolitions within quarter mile	0.1777	0.0563	0.0016	**
Land use mix (entropy measure)	-1.4913	0.5462	0.0063	**
Built environment typology class	0.2666	0.2168	0.2188	
Proportion non-urban uses within quarter mile	-0.2610	0.2893	0.3669	
Accessibility				
Logged distance to I-485 (finished by 2001)	-0.0242	0.0713	0.7342	
Distance to I-485 (when complete)	0.0693	0.0321	0.0307	*
Logged distance to nearest downtown	0.1791	0.0974	0.0659	.
Policy Factors				
Infrastructure availability proxy	0.0178	0.0060	0.0029	**
Tax rate	-0.3564	0.3478	0.3055	
Non-residential neighborhood	-2.2513	0.7220	0.0018	**
Rezoning duration (average number of days)	-0.0001	0.0023	0.9694	
Moratorium in place (proportion of year)	-0.7420	0.4196	0.0770	.
"Priming Effect" Measure				
Nearby events of all scales in prior period	0.1264	0.0341	0.0002	***
Model Summary				
AIC	2940.689			
Log-likelihood	-1447.344			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

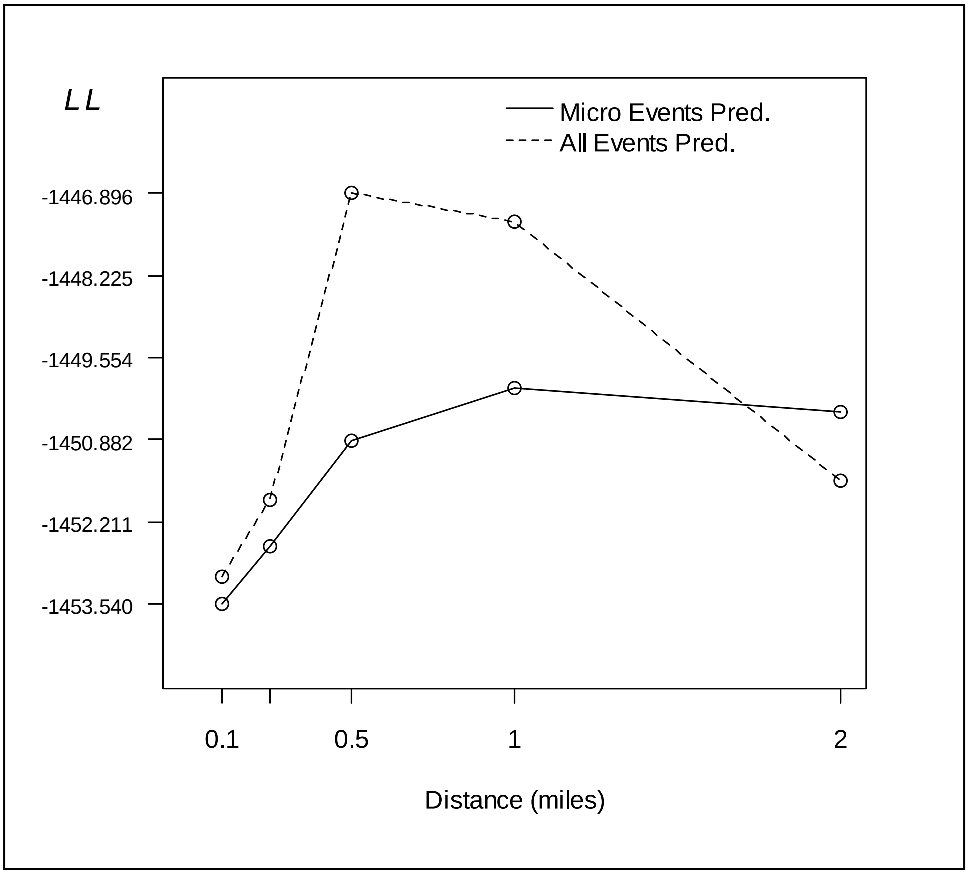


Figure 6.14: Log-likelihood Of Macro-Scale Models At Various Distance Radii.

The discrete-time hazard model specification used here assumes that the effect of the independent variables is constant across time and exerts an identical effect in each period (Singer and Willett, 1993). A series of interaction terms derived from each of the significant predictors and the time indicator variables was used to assess the validity of this proportionality of odds assumption (Kleinbaum and Klein, 2005) and at the macro-scale, there was no evidence to warrant retaining these interactions. Stated differently, this examination yielded no compelling evidence of non-proportionality.

A Vuong test of non-nested models was performed to formally assess the statistical significance of the differences depicted in Figure 6.14 using predicted probabilities. The null hypothesis of the test is that the two models compared (all events model versus micro-scale events only) are indistinguishable (Vuong, 1989) at the one mile distance threshold. The result of the test implies that the scale and temporal effects are comparable at a distance of one-mile.

6.5.3 Hedonic Regression Results: Micro-Scale

A sample of 158 micro-scale parcels (greater than two acres and less than 10 acres) sold in 2000 was used to estimate a hedonic regression model of the same type and using the same specification as at the macro-scale (see Section 6.5.1). The results of the initial model are presented in Table 6.14 below. In the macro-scale model stream frontage, slope, shopping potential, and parcel size were the only significant predictors of sales price. However, at the micro-scale, distance to freeway access points, residential zoning designation, and per capita income are all highly significant in addition to parcel size. Standardized regression coefficients indicate that the most important predictors (in descending order) are: residential zoning designation, parcel size, per capita income, and distance to nearest freeway access point. Variance inflation factors were calculated for each of the independent variables and none of these values approached the adopted threshold value (maximum value of 3.59). The residuals are not normally distributed based on the normal quantile-quantile plot shown in the first panel of Figure 6.15, and the residuals plot (response minus fitted values) in the second panel suggests the presence of potential outliers.

A total of six observations (right panel of Figure 6.15) were selected for further investigation based on their DFFITS values (exceeded threshold of $2\sqrt{p/n}$). These seven anomalous parcels ranged in sales price from \$385,000 to \$2.5 million and the property records yielded no unusual information or insights that would justify their removal from the sample. A Breusch-Pagan test revealed evidence of heteroskedasticity ($\chi^2 = 46.93$, $p = 0.0000$) although, this conclusion is complicated by a few key considerations. First, the residuals plot in the second panel of Figure 6.15 does not fit any of the classic archetypes associated with non-constant error variance. Aside from the cluster of observations in the bottom center of the graph, the residuals plot looks reasonably healthy. As a precaution, the seven observations with residuals less than negative two (left panel of Figure 6.15) were examined further. Not surprisingly, the sales prices of these parcels ranged from \$1,000 to \$16,000 and the negative residual implies that the model overestimated their value. Based on information in the property records, two of these parcels were transferred from a developer to a home owners association, two represent intra-family transactions, one was sold to the county, one is now an office building, and the remaining parcel was sold to a privately owned water utility. Unfortunately, there were no discernible patterns in the independent variable values of these observations that would suggest the incorporation of a specific (omitted) covariate as a means of alleviating heteroskedasticity, if it in fact existed in the data.

As shown in Figure 6.16, these two sets of parcels (left and right panels of Figure 6.15) that have been identified as potentially problematic are located primarily in the southern portion of the county and within incorporated areas. This is interesting because the effects of spatial autocorrelation within a regression context are similar to those of heteroskedasticity, so much that it is often difficult to distinguish the two phenomena

Table 6.14: Micro-Scale OLS Parameter Estimates (N = 158).

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
(Intercept)	10.2569	0.9690	0.0000	***
Physical Characteristics				
Water body frontage	0.3606	0.5269	0.4949	
Stream frontage	-0.3929	0.2099	0.0633	.
Slope	-0.1235	0.0759	0.1060	
Poor soils	-0.4013	0.2107	0.0589	.
Wetlands	-0.6932	0.6868	0.3146	
Forest cover	-0.0331	0.2492	0.8947	
Parcel size	0.8027	0.2036	0.0001	***
Accessibility				
Employment potential	0.8724	2.2811	0.7027	
Shopping potential	1.1042	0.8913	0.2174	
Distance to freeway ramp	-0.2604	0.1158	0.0261	*
Policy Context				
School district [32]	-0.1567	0.2143	0.4658	
Tax rate	1.1523	0.7960	0.1499	
Unincorporated	0.0989	0.3344	0.7680	
Zoning	-1.1375	0.2122	0.0000	***
Demographics				
Population density	-0.0570	0.0531	0.2848	
Income	0.0221	0.0079	0.0056	**
Adjusted R-squared	0.3758			
F-statistic	6.908 on 16 and 141 DF			

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

[32] Districts where high schools did not meet state performance guidelines during the 2001-2002 year (i.e., greater than 60% at grade level)

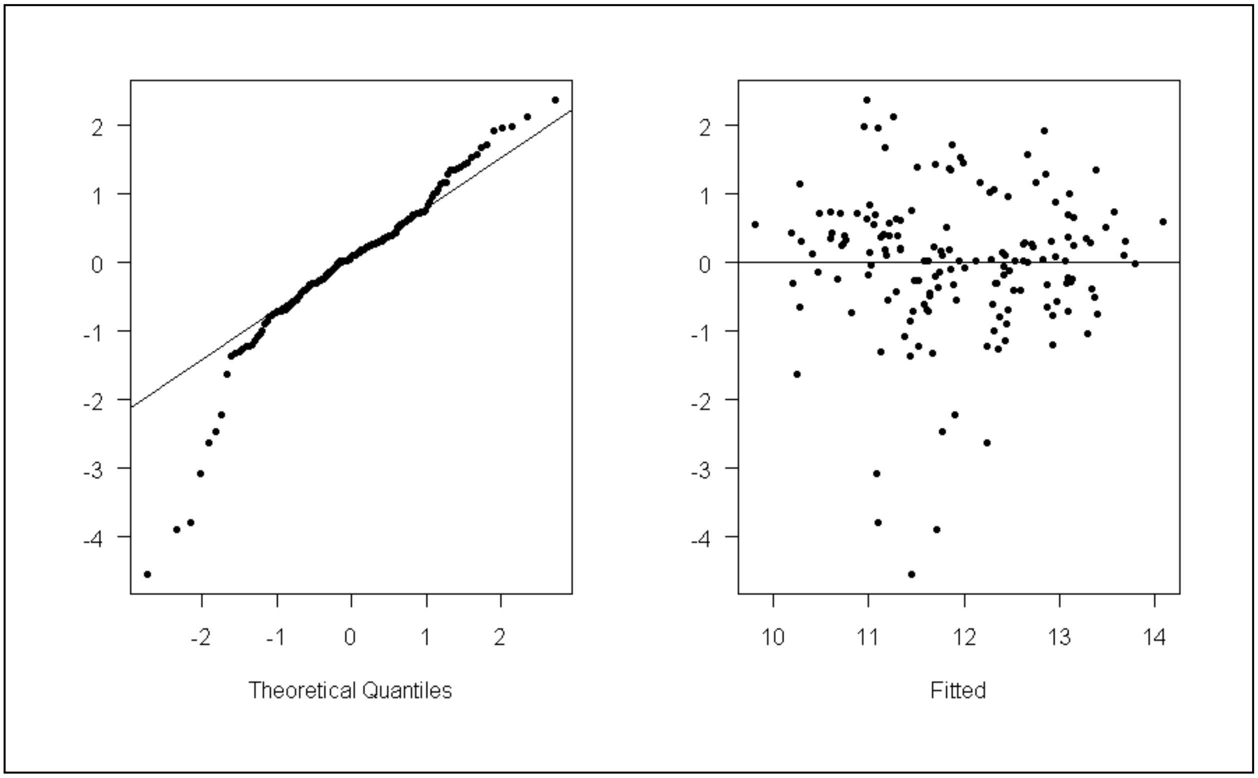


Figure 6.15: Diagnostic Plots For Micro-Scale Regression.

(Kelejian and Robinson, 2004: 80). Within a linear regression context, the existence of spatial autocorrelation is problematic for statistical inference because “the estimators are inefficient, and the variance estimator is downwards biased, thereby inflating the observed value of R^2” (Cliff and Ord, 1981: 199). In fact, spatial processes often induce heteroskedasticity if appropriate measures capturing the non-stationarity are not included in the model or through non-stationarity of functional forms or parameters in space (Anselin, 1988: 119). Based on simulation studies, Anselin (1988: 121) concludes that the “when the error terms fail to be independent, the distributional properties of several parametric tests for heteroskedasticity are no longer valid” and “the Breusch-Pagan test in particular is sensitive to this." In light of this warning, a heteroskedasticity-consistent covariance matrix[33] is estimated for the model and the results are presented in Table 6.15. Under this scenario, soil drainage capacity becomes significant at 0.05 alpha level, but the overall inference is essentially unchanged. These results coupled with the lack of a clear pattern in the residuals plot (Figure 6.15), leads to the conclusion that the departure from normality and potential presence of spatial autocorrelation are perhaps more legitimate concerns.

The standard test for the presence of spatial autocorrelation in OLS residuals is the Moran's *I* statistic, which is asymptotically normally distributed (Cliff and Ord, 1981: 205). However, in the present case we have strong evidence from the normal quantile-quantile plot and a Shapiro-Wilk test ($W = 0.9189$, $p = 0.0000$) that the residuals are not normal. Fortunately, Tiefelsdorf and Boots (1995) derived a modified version of Moran's *I* that is robust to non-normality, but first the spatial weights matrix must be selected using the procedure described above for the macro-scale model. This approach begins with plotting a correlogram of the dependent variable (micro-scale), as shown in Figure 6.17.

[33] The HC3 estimator is used here.

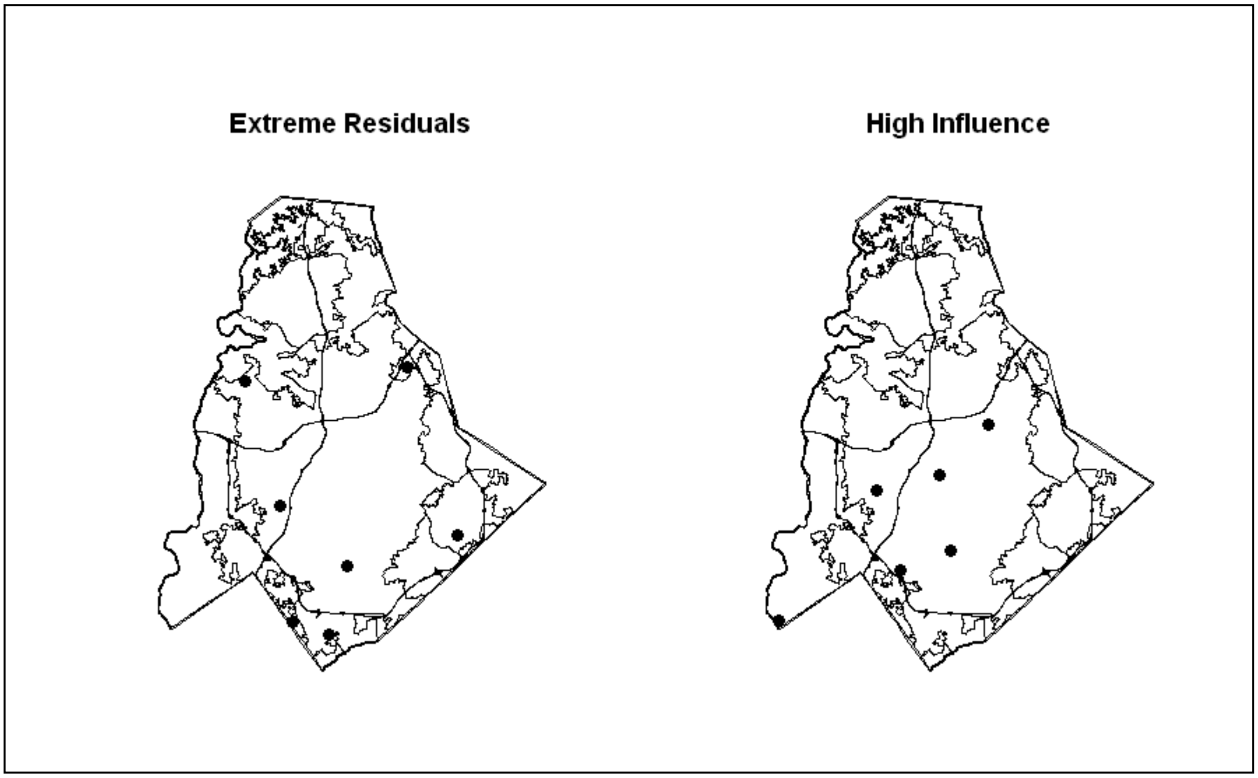


Figure 6.16: Extreme Residual And High Influence, Micro-Scale Model.

Table 6.15: Micro-Scale Heteroskedasticity-Consistent Parameter Estimates (N = 158).

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
(Intercept)	10.2569	0.9103	0.0000	***
Physical Characteristics				
Water body frontage	0.3606	0.7203	0.6170	
Stream frontage	-0.3929	0.2132	0.0670	.
Slope	-0.1235	0.0738	0.0960	.
Poor soils	-0.4013	0.2023	0.0490	*
Wetlands	-0.6932	1.1627	0.5520	
Forest cover	-0.0331	0.3007	0.9130	
Parcel size	0.8027	0.1811	0.0000	***
Accessibility				
Employment potential	0.8724	2.8537	0.7600	
Shopping potential	1.1042	1.1085	0.3210	
Distance to freeway ramp	-0.2604	0.1152	0.0250	*
Policy Context				
School district [34]	-0.1567	0.2464	0.5260	
Tax rate	1.1523	0.8680	0.1860	
Unincorporated	0.0989	0.3615	0.7850	
Zoning	-1.1375	0.2143	0.0000	***
Demographics				
Population density	-0.0570	0.0827	0.4920	
Income	0.0221	0 .0075	0.0040	**
Adjusted R-squared	0.4394			
F-statistic	11.46 on 16 and 141 DF			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

[34] Districts where high schools did not meet state performance guidelines during the 2001-2002 year (i.e., greater than 60% at grade level)

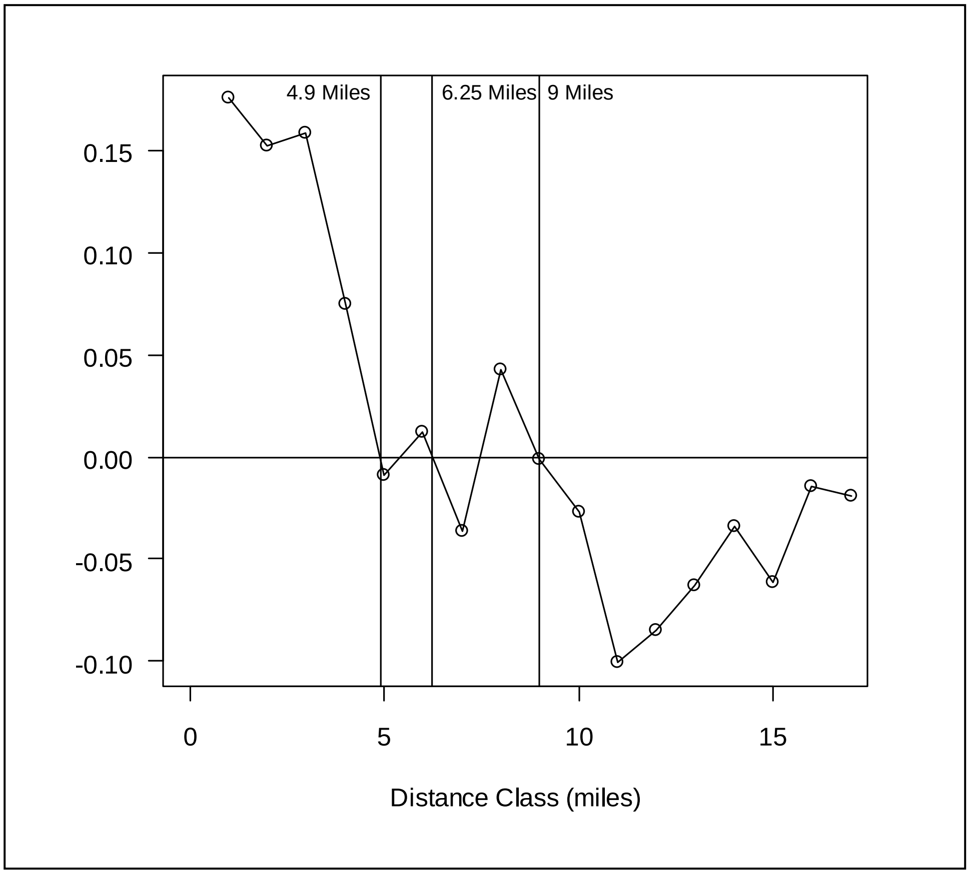


Figure 6.17: Correlogram Of Logged Sales Price At Micro-Scale.

The range of spatial autocorrelation in the dependent variable falls below zero at approximately 4.9 miles, rises, then declines again at roughly 6.25 miles before finally falling below zero at the 9 mile mark. Next, a series of binary connectivity matrices ranging from one to twelve in one-mile increments were created as part of the first phase of the spatial weights matrix selection process. The same eigenvector extraction and stepwise regression procedure was conducted and the results[35] are presented in Table 6.16.

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[35] Threshold distances less than three miles resulted in unconnected observations (zero neighbors).

Table 6.16: Selection Procedure For Micro-Scale Connectivity Matrices.

Distance	Raw AIC	AIC_C
1 Mile	—	—
2 Miles	—	—
3 Miles	-102.19	352.59
4 Miles	-49.20	161.42
5 miles	-90.83	366.31
6 Miles	-195.46	476.50
7 Miles	-125.59	281.50
8 Miles	-131.96	394.30
9 Miles	-8.05	174.68
10 Miles	-91.75	127.53
11 Miles	-141.66	394.12
12 Miles	-66.76	443.48

Based on the corrected AIC values, the ten mile threshold is the most plausible of the candidates examined (minimizes criterion) and this conclusion is also consistent with the correlogram of the dependent variable presented in Figure 6.16 above. Next, the same set of weighting and coding schemes were evaluated during phase two of the spatial weights matrix

Table 6.17: Micro-Scale Selection Procedure For Weighting And Coding Schemes.

Weighting Scheme	Coding Scheme	AIC_C
IDW	B	615.52
IDW^2	B	40.92
Griffith and Lagona (1998)	B	8.73
IDW	C	2.54
IDW^2	C	1.70
Griffith and Lagona (1998)	C	1.52
IDW	W	3.92
IDW^2	W	21.41
Griffith and Lagona (1998)	W	1.51
IDW	S	2.91
IDW^2	S	38.08
Griffith and Lagona (1998)	S	1.77

selection process and the results are presented in Table 6.17. Based on the corrected AIC values, the Griffith and Lagona (1998) weighting function applied to the ten mile threshold for establishing connectivity, with the *W*-coding scheme is the spatial weights matrix choice for the micro-scale model. A Moran's *I* test using the selected matrix proved evidence of a very small degree of positive spatial autocorrelation in the residuals ($I = 0.062$, $p = 0.001$).

A thorough analysis of the macro-scale and micro-scale regression models led to the conclusion that the OLS estimates in both cases, are acceptable. However, in order to evaluate the predictive capacity of the OLS parameters, a more practical approach is to make an out-of-sample prediction. A second sample of vacant land parcels sold in 2001 were identified and the same set of independent variables were prepared for these parcels. The parameter estimates for each of the independent variables from Tables 6.6 and 6.14 were used to predict the logged sales price for parcels in the new 2001 sample. The predictive capability of each model was assessed using the root mean squared error (RMSE) of the actual logged sales price and the model predicted logged sales price[36]. The RMSE for the out-of-sample prediction was 0.972 at the micro-scale and 1.213 at the macro-scale. As a point of reference, the RMSE for the original hedonic regression sample was 1.047 at the micro-scale and 0.746 at the macro-scale. The implication is the micro-scale estimates performed better than the macro-scale estimates for the out-of-sample prediction application. This limited test of the predictive capacity of the parameter estimates should be interpreted with caution, but indicates a slight decrease in the error at the micro-scale and an increase in error at the macro-scale (relative to the initial hedonic regression model). The parameter estimates were then used to predict sales price (market value) of each parcel in the macro-

[36] RMSE was calculated as the square root of the variance of the residuals and can be interpreted in the same units as the dependent variable.

scale and micro-scale samples at the beginning of the study period. These predicted values were then used as an independent variable in the discrete-time hazard models. At the macro-scale, predicted values ranged from $13,435.17 to $35,627,592.49 and from $14,183.22 to $4,622,692.98 at the micro-scale for an individual land parcel.

6.5.4 Survival Analysis Results: Micro-Scale

The results of the discrete-time hazard model for the micro-scale parcels, using a one-tenth mile radius for the "priming effect" measure, are presented in Table 6.18. Each of the six time indicators is significant, which means that controlling for the effect of the other independent variables in the model, there is still a detectable effect associated with time and the coefficients follow a different pattern of fluctuation than was observed in the macro-scale models. The estimated (baseline) probability of observing an event is relatively constant over the first three time periods, roughly doubles during the fourth time period and declines sharply in the final two time periods[37].

The parcel aggregation indicator is highly significant and exerts a positive effect on the odds of observing an event (odds ratio of 2.26). The proportion of vacant land in the block group is also significant and carries an odds ratio of 2.85, which implies that a one unit increase in the proportion vacant land is associated with a 185% increase in the odds of observing an event. The percentage of college graduates in the corresponding block group is also significant and positive, with an associated odds ratio of 1.01. The number of demolitions permits issued is significant and is associated with a 11% increase in the odds of observing an event for a one unit increase (odds ratio of 1.11). The distance to (completed) I-

[37] A chi-square test was used to compare the full model to a restricted model that only included the time indicator variables. The time-only model was rejected in favor of the model that includes substantive predictors.

485 is marginally significant with estimates comparable to those from the macro-scale model (odds ratio of 1.05). At the one-tenth mile distance threshold, the “priming effect measure is not significant and the non-residential neighborhood indicator and rezoning duration measures are only marginally significant.

Table 6.18: Hazard Model Estimates at One-Tenth Mile: Micro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-4.2187	0.9582	0.0000	***
Period 2	-4.1539	0.9539	0.0000	***
Period 3	-4.0985	0.9495	0.0000	***
Period 4	-3.4802	0.9451	0.0002	***
Period 5	-4.8415	0.9660	0.0000	***
Period 6	-5.4695	0.9811	0.0000	***
Land Market Considerations				
Estimated land value in 2001	-0.0948	0.0738	0.1992	
Parcel aggregation indicator	0.8186	0.2017	0.0000	***
Proportion vacant land in block group	1.0478	0.4809	0.0294	*
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0144	0.0035	0.0000	***
Number of demolitions within quarter mile	0.1100	0.0386	0.0044	**
Land use mix (entropy measure)	0.0458	0.4932	0.9259	
Built environment typology class	0.2164	0.1804	0.2304	
Proportion non-urban uses within quarter mile	0.3345	0.3053	0.2733	
Accessibility				
Logged distance to I-485 (finished by 2001)	0.1237	0.0780	0.1127	
Distance to I-485 (when complete)	0.0582	0.0314	0.0632	.
Logged distance to nearest downtown	0.0342	0.0974	0.7255	
Policy Factors				
Infrastructure availability proxy	0.0097	0.0066	0.1374	
Tax rate	-0.1249	0.3783	0.7413	
Non-residential neighborhood	-0.9824	0.5146	0.0562	.
Rezoning duration (average number of days)	-0.0037	0.0021	0.0839	.
Moratorium in place (proportion of year)	-0.0587	0.3624	0.8714	
“Priming Effect” Measure				
Nearby macro events in prior period	-0.3818	0.9705	0.6940	
Model Summary				
AIC	3488.897			
Log-likelihood	-1721.448			

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

As shown in Tables 6.19 through 6.21, increasing the distance radius for the "priming effect" measure results in incremental improvement in the fit of the overall model. This is most pronounced at one-half mile, where the log-likelihood reaches its peak (see Figure 6.18). In this model, the "priming effect" measure is highly significant and exerts a positive effect on the dependent variable. The associated odds ratio of 1.48 indicates a 48% increase in the odds of observing an event for each additional macro-scale event within the half-mile radius. Here, the estimated market value of the land parcel is also significant, but carries a negative sign (odds ratio of 0.85). This result could be interpreted as evidence of a cost-minimization imperative that is more pronounced for smaller-scale developers or as potential evidence of strategic behavior on the part of land owners (i.e., holding out for higher prices).

Figure 6.18 clearly shows that given the available data, the model using the one-half mile radius for the "priming effect" measure performs best (maximizes the log-likelihood function). This series of regression models provides some support for the hypothesis that proximity to macro-scale parcel subdivision events in the previous time period is associated with an increase in the odds of observing an event at the micro-scale. However, the effect of proximity to all parcel subdivision events regardless of scale should also be considered. The discrete-time hazard model was re-estimated using an "priming effect" measure that consisted of the total number of all parcel subdivision events within the specified distance radius in the previous time period. The results for one of these models are presented in Tables 6.22 below.

The model that includes the all events "priming effect" measure outperforms the macro-scale only model at each of the distance thresholds considered (in terms of model fit)

Table 6.19: Hazard Model Estimates at One-Quarter Mile: Micro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-3.5813	0.9429	0.0001	***
Period 2	-3.5215	0.9398	0.0002	***
Period 3	-3.4193	0.9326	0.0002	***
Period 4	-2.8014	0.9285	0.0026	**
Period 5	-4.1737	0.9499	0.0000	***
Period 6	-4.7837	0.9656	0.0000	***
Land Market Considerations				
Estimated land value in 2001	-0.1601	0.0706	0.0234	*
Parcel aggregation indicator	0.7946	0.2021	0.0001	***
Proportion vacant land in block group	1.0712	0.4846	0.0271	*
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0149	0.0035	0.0000	***
Number of demolitions within quarter mile	0.1099	0.0383	0.0041	**
Land use mix (entropy measure)	0.1253	0.4975	0.8011	
Built environment typology class	0.2184	0.1799	0.2247	
Proportion non-urban uses within quarter mile	0.2790	0.3066	0.3628	
Accessibility				
Logged distance to I-485 (finished by 2001)	0.1033	0.0789	0.1906	
Distance to I-485 (when complete)	0.0616	0.0312	0.0485	*
Logged distance to nearest downtown	0.0201	0.0969	0.8356	
Policy Factors				
Infrastructure availability proxy	0.0089	0.0066	0.1805	
Tax rate	-0.0333	0.3730	0.9289	
Non-residential neighborhood	-0.9366	0.5144	0.0686	.
Rezoning duration (average number of days)	-0.0037	0.0021	0.0789	.
Moratorium in place (proportion of year)	0.0021	0.3606	0.9954	
“Priming Effect” Measure				
Nearby macro events in prior period	0.4239	0.1924	0.0276	*
Model Summary				
AIC	3481.257			
Log-likelihood	-1717.629			

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

Table 6.20: Hazard Model Estimates at One-Half Mile: Micro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-3.7425	0.9477	0.0001	***
Period 2	-3.6841	0.9445	0.0001	***
Period 3	-3.5158	0.9349	0.0002	***
Period 4	-2.8825	0.9305	0.0020	**
Period 5	-4.2899	0.9524	0.0000	***
Period 6	-4.8484	0.9680	0.0000	***
Land Market Considerations				
Estimated land value in 2001	-0.1556	0.0708	0.0279	*
Parcel aggregation indicator	0.7916	0.2021	0.0001	***
Proportion vacant land in block group	0.9736	0.4862	0.0453	*
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0146	0.0035	0.0000	***
Number of demolitions within quarter mile	0.1109	0.0382	0.0038	**
Land use mix (entropy measure)	0.1960	0.5001	0.6952	
Built environment typology class	0.2278	0.1805	0.2069	
Proportion non-urban uses within quarter mile	0.2943	0.3080	0.3393	
Accessibility				
Logged distance to I-485 (finished by 2001)	0.0955	0.0790	0.2269	
Distance to I-485 (when complete)	0.0686	0.0312	0.0281	*
Logged distance to nearest downtown	0.0278	0.0972	0.7748	
Policy Factors				
Infrastructure availability proxy	0.0091	0.0067	0.1695	
Tax rate	-0.0351	0.3722	0.9249	
Non-residential neighborhood	-0.9222	0.5146	0.0731	.
Rezoning duration (average number of days)	-0.0038	0.0021	0.0727	.
Moratorium in place (proportion of year)	0.0182	0.3586	0.9595	
“Priming Effect” Measure				
Nearby macro events in prior period	0.3972	0.0968	0.0000	***
Model Summary				
AIC	3470.796			
Log-likelihood	-1712.398			

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

Table 6.21: Hazard Model Estimates at One Mile: Micro Level.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-3.7286	0.9498	0.0001	***
Period 2	-3.6042	0.9417	0.0001	***
Period 3	-3.5138	0.9341	0.0002	***
Period 4	-2.8806	0.9292	0.0019	**
Period 5	-4.2825	0.9524	0.0000	***
Period 6	-4.8564	0.9662	0.0000	***
Land Market Considerations				
Estimated land value in 2001	-0.1558	0.0706	0.0274	*
Parcel aggregation indicator	0.7932	0.2022	0.0001	***
Proportion vacant land in block group	1.0451	0.4870	0.0319	*
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0148	0.0035	0.0000	***
Number of demolitions within quarter mile	0.1106	0.0384	0.0040	**
Land use mix (entropy measure)	0.1113	0.4971	0.8229	
Built environment typology class	0.2338	0.1805	0.1953	
Proportion non-urban uses within quarter mile	0.3044	0.3060	0.3197	
Accessibility				
Logged distance to I-485 (finished by 2001)	0.1037	0.0790	0.1892	
Distance to I-485 (when complete)	0.0646	0.0312	0.0383	*
Logged distance to nearest downtown	0.0197	0.0967	0.8385	
Policy Factors				
Infrastructure availability proxy	0.0092	0.0066	0.1659	
Tax rate	-0.0152	0.3735	0.9675	
Non-residential neighborhood	-0.9231	0.5146	0.0728	.
Rezoning duration (average number of days)	-0.0038	0.0021	0.0691	.
Moratorium in place (proportion of year)	0.0057	0.3614	0.9874	
“Priming Effect” Measure				
Nearby macro events in prior period	0.1004	0.0597	0.0925	.
Model Summary				
AIC	3482.719			
Log-likelihood	-1718.359			

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

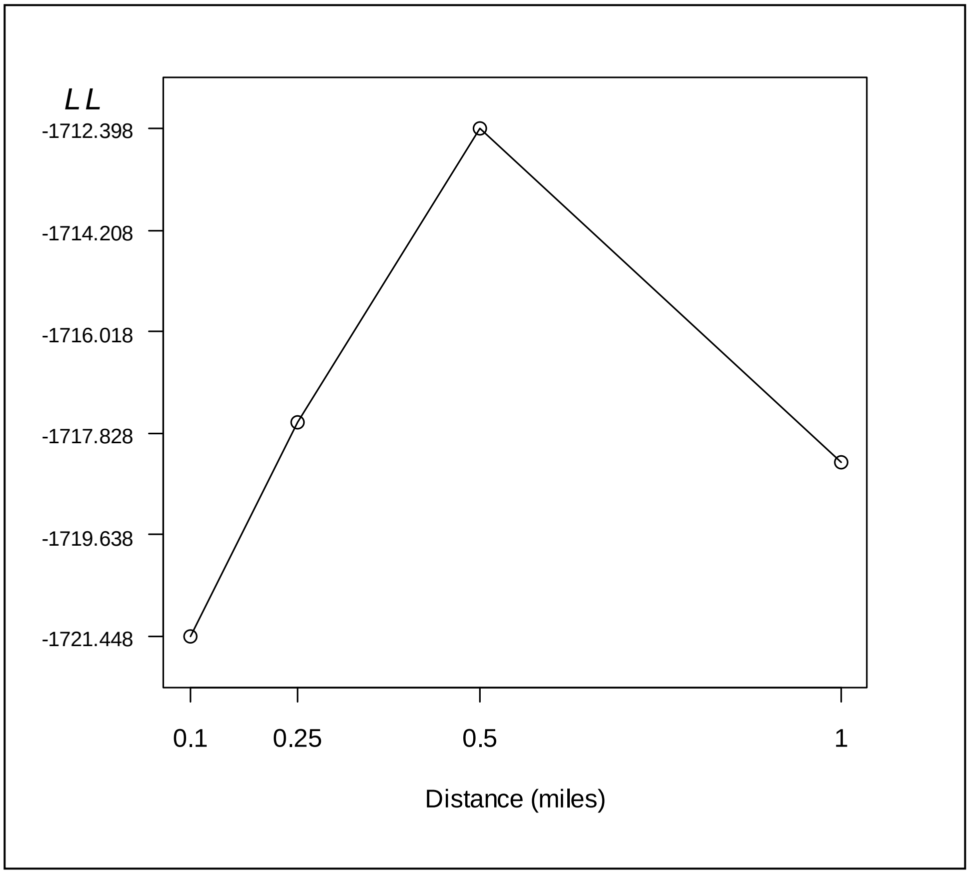


Figure 6.18: Log-likelihood Of Micro-Scale Model At Various Distance Radii.

with the exception of one-half mile (see Figure 6.19), where they are practically identical. The implication is that the magnitude of the scale effect is equivalent to the effect of proximity to events in the previous time period, without regard to scale (temporal effect) at the one-half mile distance threshold. This is important given that the one-half mile distance threshold is also the where the log-likelihood function is maximized for the model specifications considered. This finding is consistent with intuition and the initial hypothesis that if the “priming effect” is detectable, the effect of larger parcels on smaller parcels is greater than in the alternative (i.e., smaller parcels on the probability of subdivision for larger parcels).

Table 6.22: Hazard Model Estimates at One-Half Mile: Micro Level, All Events.

Measure	Estimate	Std. Error	Pr (> | t |)	Signif.
Period 1	-3.6627	0.9458	0.0001	***
Period 2	-3.5217	0.9410	0.0002	***
Period 3	-3.4517	0.9340	0.0002	***
Period 4	-2.8223	0.9303	0.0024	**
Period 5	-4.2869	0.9544	0.0000	***
Period 6	-4.7843	0.9675	0.0000	***
Land Market Considerations				
Estimated land value in 2001	-0.1552	0.0707	0.0282	*
Parcel aggregation indicator	0.8216	0.2017	0.0000	***
Proportion vacant land in block group	0.9488	0.4874	0.0515	.
Demographics and Neighborhood Character				
Percent college graduates in block group	0.0146	0.0035	0.0000	***
Number of demolitions within quarter mile	0.1105	0.0384	0.0040	**
Land use mix (entropy measure)	0.0927	0.4973	0.8522	
Built environment typology class	0.2126	0.1801	0.2379	
Proportion non-urban uses within quarter mile	0.2576	0.3066	0.4008	
Accessibility				
Logged distance to I-485 (finished by 2001)	0.0960	0.0791	0.2250	
Distance to I-485 (when complete)	0.0583	0.0313	0.0626	.
Logged distance to nearest downtown	0.0253	0.0975	0.7949	
Policy Factors				
Infrastructure availability proxy	0.0094	0.0066	0.1570	
Tax rate	-0.0575	0.3732	0.8775	
Non-residential neighborhood	-0.9176	0.5146	0.0745	.
Rezoning duration (average number of days)	-0.0035	0.0021	0.1040	
Moratorium in place (proportion of year)	0.0541	0.3600	0.8806	
"Priming Effect" Measure				
Nearby events of all scales in prior period	0.2045	0.0469	0.0000	***
Model Summary				
AIC	3471.189			
Log-likelihood	-1712.594			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

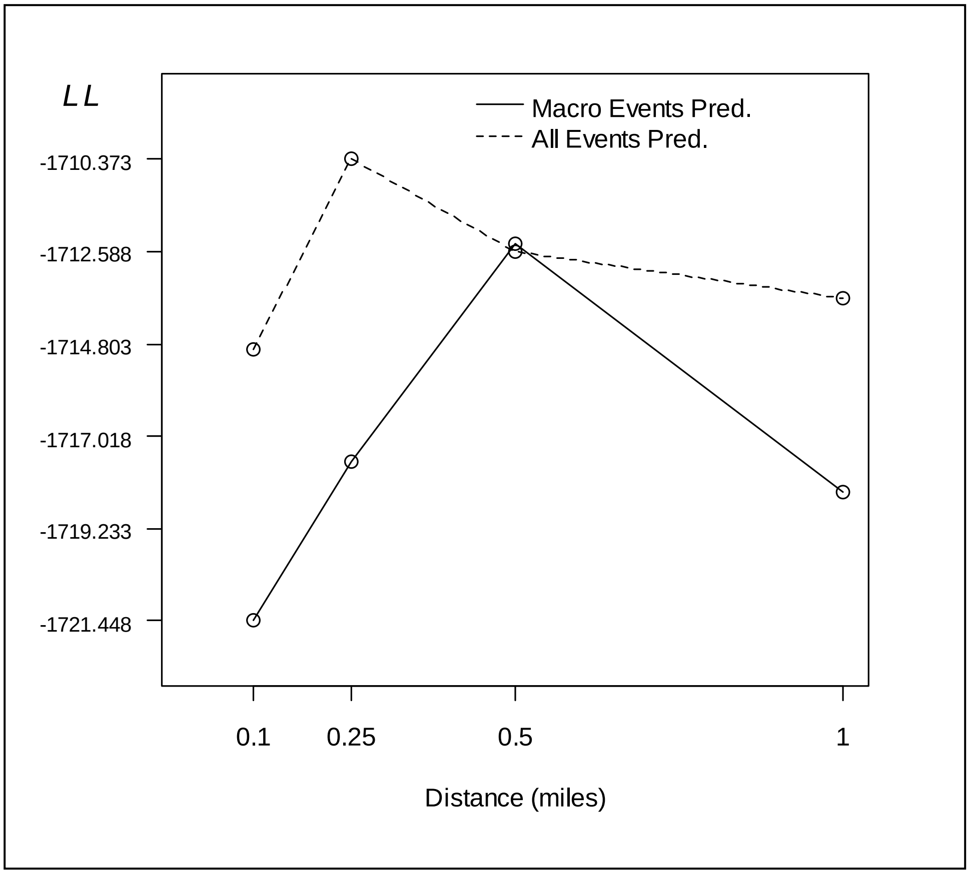


Figure 6.19: Log-likelihood Of Micro-Scale Models At Various Distance Radii.

One of the assumptions of the discrete-time hazard model specification used here is that the effect of the independent variables is constant across time periods (Singer and Willett, 1993). The validity of this proportionality assumption was assessed by interacting the each of the significant predictors with the time indicator variables and re-estimating the models. At the micro-scale, there appeared to be a marginally significant interaction effect between proximity to the I-485 beltway and time, but the initial (proportional) model was retained after considering the change in the log-likelihood function as well as parsimony.

As with the macro-scale models, a Vuong test of non-nested models was performed to formally assess the statistical significance of the differences depicted in Figure 6.19 using predicted probabilities. The null hypothesis of the test is that the two models compared (all events model versus macro-scale events only) are indistinguishable (Vuong, 1989) at a distance threshold of one-half mile. The results of the test suggest that at one-half mile, the all events and scale effects models are indistinguishable and therefore, the importance of the scale effect is comparable to that of temporal effect.

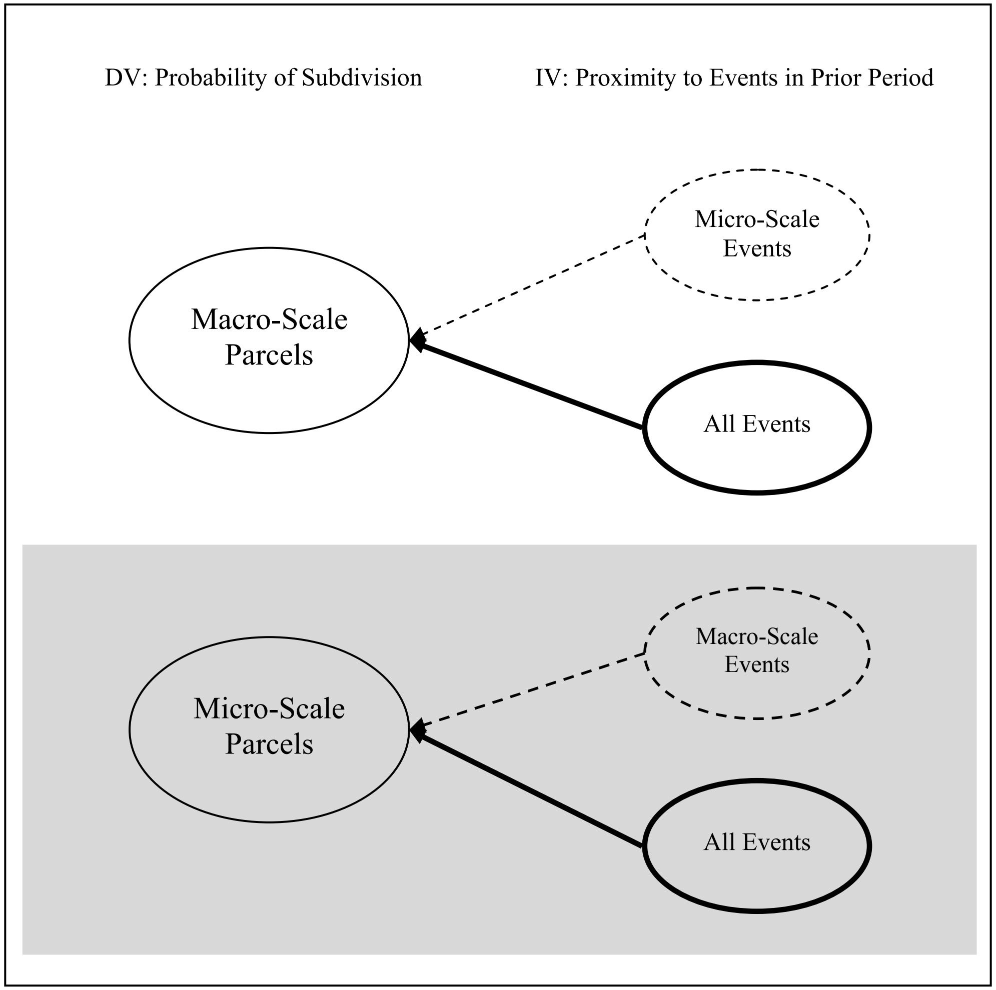
6.6 Summary

This chapter presented the results of the empirical analyses described in Chapter 5. The results of the parcel change analysis were presented as well as a summary and synthesis of the survey responses from a limited sample of local developers. Basic point pattern analysis techniques were applied to the datasets derived by the parcel change analysis and evidence of clustering at varying distances was detected within scales, across scales, and across time periods. Parallel regression models were estimated to test the primary hypothesis that large subdivision events (macro-scale) are associated with a higher degree of development in later time periods as well as a key competing hypothesis. The results of the regression models identified key predictors of parcel subdivision events at both scales and found that the original hypothesis is more plausible, given the present data.

A sensitivity analysis was performed to explore the spatial extent of the hypothesized "priming effect" and determined that one mile for macro-scale parcels (Figure 6.13) and one-half mile for micro-scale parcels (Figure 6.18) offered the best performance based on an assessment of log-likelihood functions. Finally, a comparison of the log-likelihood functions suggests that the scale effect is roughly equivalent to the temporal effect when the outcome is probability of subdivision at the micro-scale (Figure 6.19), but this conclusion does not hold at the macro-scale (Figure 6.14). Stated differently, the difference in log-likelihood at the accepted distance threshold is greater for larger parcels than for smaller parcels. This suggests that the scale effect is more pronounced when considering the probability of subdivision for smaller parcels. However, these results should be interpreted with caution as they represent conditions for the examined study area and study period only. Further, the results of the Vuong tests suggest that any observed differences in the scale effects and all events models at both the macro-scale and micro-scale are slight, at best. Given these caveats, a summary of the model results is presented in Figure 6.20 where for each dependent variable, the best fitting model at the identified distance threshold (one-half and one mile) is shown with a heavy, solid line. Again, the models where the "priming effect" measure is limited to only events of the opposite scale in the preceding time period represents a potential scale effect and the alternate model where all events are included (regardless of scale) in constructing the measure represents a temporal effect.

The sidebar associated with Figure 6.20 lists the important predictors, their associated odds ratios, and marginal effects for the selected model (heavy, solid line) at the micro-scale and macro-scale. For the micro-scale model, there was one unexpected finding in that the estimated market value measure carried a negative sign, which is counterintuitive at first glance. However, if cost minimization is a priority for land developers operating under competitive conditions, then perhaps targeting land parcels that are less expensive (or undervalued) makes sense. This is one potential reading of this finding.

At the macro-scale, the positive effect associated with the distance to completed I-485 access points is also unexpected. One potential interpretation of this finding is that land that is both vacant and inexpensive are more likely to be found on the fringe, which explains the observed relationship. The other unexpected finding at the macro-scale is the negative effect associated with increased land use mix. Again, this result could be related to the trend towards greenfield development along the urban fringe where land use is likely to be more homogeneous.



Macro-Scale Model, One Mile	Odds Ratio	Marginal Effect
Estimated land value in 2001	1.10	0.0026
Parcel aggregation indicator	2.00	0.0259
Demolitions within quarter mile	1.19	0.0048
Land use mix (entropy measure)	0.22	-0.0405
Distance to I-485 (when complete)	1.07	0.0018
Infrastructure availability proxy	1.01	0.0004
Non-residential neighborhood	0.10	-0.0280
Nearby events (all) in prior period	1.13	0.0034
Micro-Scale Model, One-Half Mile	**Odds Ratio**	**Marginal Effect**
Estimated land value in 2001	0.85	-0.0017
Parcel aggregation indicator	2.27	0.0136
Prop. vacant land (block group)	2.58	0.0106
Pct. college graduates (block group)	1.01	0.0001
Demolitions within quarter mile	1.11	0.0012
Nearby events (all) in prior period	1.22	0.0022

Figure 6.20: Overview Of Hazard Model Results.

CHAPTER 7: DISCUSSION AND CONCLUSIONS

7.1 Summary of the Research

This study examines the factors that explain the timing and location of land parcel subdivision events and also explores the temporal and spatial relationships among these events using a survival analysis approach. Theory and findings from prior studies were used to select independent variables and derive associated measures to test two primary hypotheses. The first is that despite the trend towards decentralization and polycentricity, accessibility remains the chief predictors, not only of land value, but also of development activity. The empirical findings of the present study support this assertion, in part. Access to destinations, defined as employment centers, retail nodes, and highways is valued by both households and developers even if the context for understanding and measuring those relationships has shifted. The present study acknowledges this reality by including potential (gravity) variables alongside conventional proximity measures.

The second hypothesis holds that scale effects exist that equal or exceed the temporal "priming effect" when studying the relationship between land parcel subdivision events over time. The hypothesized "priming effect" simply argues that proximity to land parcel subdivision events that occurred in the previous time period increases the probability of observing an event for a given observation in the current time period. This can be conceived as a spillover effect or contagion process as new development drives up land prices or reflect other factors within the immediate area that favor development. In light of what has been documented regarding developer behavior (i.e., risk aversion, favoring proven markets), this temporal "priming effect" is quite plausible. Further, I hypothesize that larger parcels exert a greater "priming effect" on subsequent events than smaller parcels, hence the scale effect. Intuitively, this proposition makes sense, but the results of the hazard models presented in the previous chapter provide some empirical support. Although the scale effect models never fit the data better than the all events model alternatives, the difference in model fit was least for the micro-scale (dependent variable) models, which lends support to the original hypothesis that the "priming effect" is greater for large subdivision events than for smaller subdivision events.

A related line of inquiry involves assessing the spatial extent of the hypothesized "priming effect." A basic sensitivity analysis was performed by varying the distance threshold used to derive the "priming effect" measure and the hazard models were re-estimated. Thresholds of one-tenth mile, one-quarter mile, one-half mile, and one mile were used and the effect (sensitivity) was evaluated using the log-likelihood of each model. The results of this sensitivity analysis indicated that one mile for macro-scale parcels and one-half mile for micro-scale parcels offered the best performance (i.e., maximized the likelihood function for specifications considered). It should be noted that these findings hold for the current study area and study period and should not be generalized to other regions without further research and corroboration.

The study harnessed a series of Python scripts to conduct a parcel change analysis using tax data shapefiles obtained from local sources. This allowed for the documentation of land parcel subdivision activity between 2001 and 2008 and also served as the foundation for the spatial point pattern and hazard model components of the analysis. The technical hurdles involved in conducting a parcel change analysis have been addressed and the door is open for using this approach to study other phenomena of interest to planning practitioners and researchers.

Spatial point pattern analysis techniques were applied to the results of the parcel change analysis as a means of detecting departures from randomness and exploring spatial patterns in the data. The present study is one of relatively few examples of land use applications of nearest neighbor and *K* statistics within the planning literature. This exploratory analysis indicated clustering among land parcel subdivision events over time and across scales. However, the distance at which clustering was detectable tended to fluctuate from year-to-year and by scale, insights that were considered when conducting the hazard model sensitivity analysis described above. A difference of *K*-functions analysis was conducted to determine if the observed macro-scale and micro-scale events were significantly different in terms of spatial pattern, given the variation in intensity across the study area. The conclusion was that the macro-scale events were no more or less clustered than their counterparts at the micro-scale. Finally, basic kernel estimation techniques were employed to produced smoothed maps of the intensity of events at both scales. These maps represent an effective and efficient way to visualize the distribution of land subdivision activity within the study area.

A limited survey of land developers operating in the study area was also conducted. The purpose of the survey was to collect information about the site selection and land acquisition processes (and to a lesser extent, the regulatory climate in local jurisdictions), to inform model specification, and to provide context for the results of the statistical analyses. A total of twelve land developers responded and the survey results were used to identify independent variables for the hedonic and hazard models, as well as to provide a clearer picture of the industry and market conditions in Mecklenburg County. The survey echoed the importance of accessibility and land prices found in prior studies and also reflected the impact of high profile mixed use projects on changing the perceptions of the local development community.

The estimated market value of the land parcels in the sample is a key predictor within the hazard model, but in order to derive this measure a separate hedonic regression analysis was undertaken. An OLS model was estimated for macro-scale and micro-scale parcels based on sales data for vacant land parcels in Mecklenburg County using a series of measures from theory, the literature, and the survey responses. Physical characteristics, accessibility measures, and zoning designations were the most important predictor of sales price at both scales and have a direct relationship with both the costs and expected returns of developing a given site. The residuals of each model were tested for the presence of spatial autocorrelation using a empirically-driven procedure suggested by Dray *et al*., (2006) to select the spatial weights matrix. The OLS estimates were eventually deemed acceptable and these parameters were used to estimate (predict) the value of the land parcels in the hazard model samples. These predicted values can also be conceived as a key component of the overall profitability of developing at a given site (Landis, 1995).

The hazard models were based on a sample (attempted population) of land parcels identified as vacant at the start of the study period and the dependent variable was the probability of observing an event at each of the time periods, given that an event had not previously occurred. Along with the estimated market value, the “priming effect” measure was the other independent variable of greatest interest. Depending on the specification, this measure represented the hypothesized temporal "priming effect" (all events regardless of scale) or a scale effect (only events of the opposite scale). Parallel regression models were estimated at the macro-scale and micro-scale as a means of strengthening the research design and the results of the analyses indicated that the temporal effect is consistently stronger than the scale effect at the macro-scale. However, at the micro-scale, the influence of macro-scale events is practically equivalent to that of a measure based on all events in the vicinity in the previous time period. This is corroborating evidence for the initial hypothesis that large, residential subdivision events exert a greater "priming effect" on subsequent land subdivision activity. Key predictors of parcel subdivision events at both scales were also identified, but perhaps most importantly, this dissertation demonstrates the value of conducting land use research at a disaggregate level and of the embracing a spatial perspective.

7.2 Theoretical Implications

The main theoretical contribution of this dissertation lies in its implications for traditional conceptions of urban systems and land use decisions. In particular, the tenets of the land economics approach are lessening in importance as a framework for understanding land use and urban form. The trend towards decentralization and the rise of polycentric urban form has received much of the blame for this decline, but as the present study demonstrates, rather than jettisoning these conventions, what may be warranted instead is a re-interpretation. This involves developing new methods for identifying employment subcenters rather than operating from the assumption of a single exogenously determined central business district. This also requires revisiting our understanding of spatial relationships to move beyond simple linear distance calculations towards more comprehensive and robust representations of spatial effects. Finally, this reconciliation involves cultivating an appreciation for scale and temporal effects when studying complex systems and phenomena like residential development. This is the logic behind modeling the temporal and spatial relationships between land parcel subdivision events and incorporating independent variables that capture employment and shopping potential, amenities, the built-environment, and the potential impacts of jurisdictional fragmentation. This dissertation takes basic and preliminary steps in this direction, but further research is needed to expand our understanding of the spatial and temporal relationships at work within the land development system.

A second theoretical contribution relates to the assertion by Irwin and Bockstael (2002) that the attraction of open space and seclusion may contribute to a repellant effect between large residential subdivisions. Across all distance thresholds, the parameter estimate for the "priming effect" measure in the macro-scale hazard models carries a positive sign. Even at the shortest distance examined (one-tenth mile), the estimated effect is positive (albeit insignificant). Although it is possible that a repellant effect exists, the present study provides no empirical support. Instead, the opposite conclusion is reached: that proximity to past land subdivision events increases the odds of observing events at subsequent time periods. Again, further research should be conducted to either corroborate or dispute this finding.

7.3 Policy and Practice Implications

The present study has several implications for planning policy and practice. First, the hazard model analyses suggest that land development projects are less sensitive to policy factors such as zoning designation and tax rates. This finding makes sense at the macro-scale, given that larger parcels are typically capable of supporting larger projects with longer time horizons and more significant financial and technical resources. The implication is that perhaps filing a rezoning petition is less onerous for firms with greater resources and experience and when the expected return from a completed project is enough to offset increased time and monetary costs. There is also prior research that suggests an endogenous relationship between land use and zoning designation (Wallace, 1988; McMillen and McDonald, 1991). The influence of growth moratoria (Bento *et al*., 2007) is also reflected in the results of both the parcel change analysis and hazard models (though not significant in the final models). However, if the effectiveness of land use controls as tools for influencing the location and timing of residential development is in doubt, perhaps this is an argument for more innovative (and integrated) approaches to growth management. Greater regional coordination and incentive-based development management policies are examples of strategies that could potentially make sense as Mecklenburg County continues to grow.

The impact of Charlotte's Outerbelt (I-485) is clearly evident at both scales based on the results of the hazard models and the survey responses. Proximity to the completed I-485 was one of the consistent predictors of land parcel subdivision events regardless of scale or distance threshold of the "priming effect" measure. The highway has been planned since the 1970s and construction began in 1988 with numerous delays and challenges peppering the ensuing two decades (Whitacre, 2002). The models include two measures of proximity to I-485, one based on those segments that were open in 2001 and other on the entire, completed loop. The explanatory power of proximity to the completed I-485 far exceeds that of a similar measure of proximity to those segments of the highway that were operational at the beginning of the study period. As early as the late 1990s, land prices in many areas were doubling and tripling as developers attempted to anticipate where future growth would occur (Monk *et al*., 1997). This suggests that land markets are quick to react to planned infrastructure investments of this magnitude and hints at speculation and strategic behavior on the part of land owners. Survey respondents also repeatedly mentioned the importance of "visibility" and of locations that were one or two turns of the freeway as key considerations in the site selection process. This recognition and anecdotal evidence of the impact of the local light rail system on growth patterns suggest a need for further research on the linkages between transportation infrastructure investments and development outcomes.

The frequency at which development moratoria and adequate public facilities ordinances were adopted during the study period stands as a testament to the rate and extent of growth in Mecklenburg County and its surrounding areas. The spillover of development into the relatively rural Union County to the southeast and Iredell County to the north has posed significant challenges for these communities. As Charlotte's strong economy continues to attract and stimulate business, outlying areas can expect increased pressure on existing infrastructure and services from residential development, but will likely see little of the revenue-generating commercial and industrial uses. The adoption and implementation of appropriate policies to manage these impacts will be even more critical in the future as the growth trend can be expected to continue.

Sustained population growth[38] has meant correspondingly high rates of land development, which in turn, has far-reaching implications for the environment. In fact, land

[38] County population increased by 26.5% between 1980 and 1990 and by 36% between 1990 and 2000.

development has outpaced population growth in the county, evidenced by acres of developed land per capita values of 0.14, 0.22, and 0.23 in 1985, 1996, and 2006 respectively (Mecklenburg County, 2008). The environmental impacts of low-density, auto-dependent, homogenous, dispersed patterns of development are widely documented and include: hydrology (Arnold and Gibbons, 1996), open space (Geoghegan, 2002; Irwin, 2002; Kline, 2006), air quality (Stone Jr., 2008), and energy consumption (Ewing and Rong, 2008). Several authors, including Ewing *et al*. (2008), suggest that compact urban form and investment in transit to offset increases in vehicle miles traveled are part of the solution to many of these concerns.

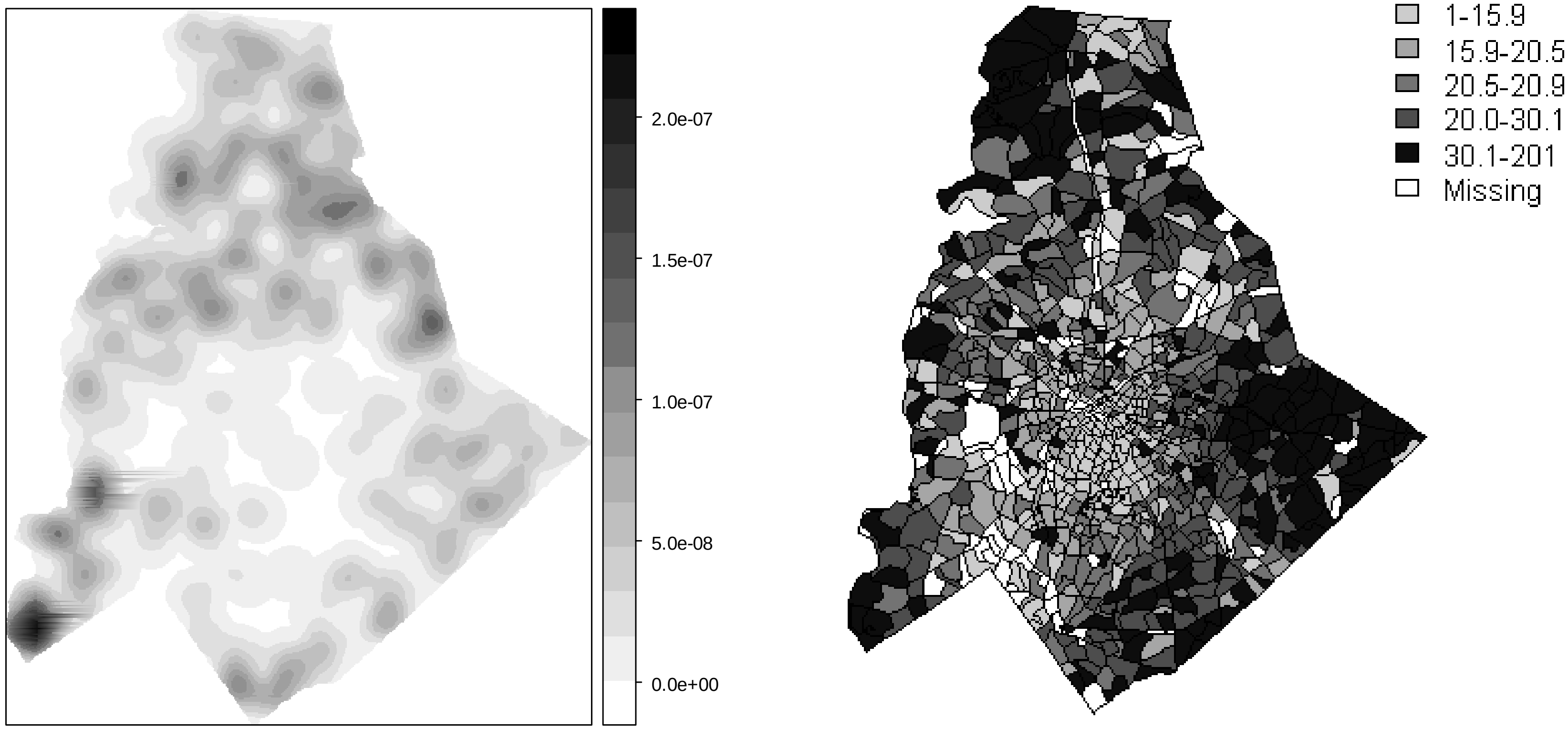
However, debate continues surrounding the connection between urban form, travel behavior, and energy consumption. Although intuitively, one might anticipate that increasing density leads to a reduction in vehicle miles traveled, this relationship only holds if destinations or activity centers are located nearby (i.e., trips are shorter). Also, if energy consumption is the variable of interest, travel distance may not be the most appropriate measure (travel time with respect to congestion). A study published by Newman and Kenworthy (1989) asserted that increasing density would lead to reductions in transportation energy consumption. This assertion has been disputed by a number of authors (Kockelman, 1997; Mindali *et al*., 2004) and corroborated by the findings of others (Cervero and Kockelman, 1997; Brownstone and Golob, 2009). One potential explanation for the ambiguity is the inherent complexity of the relationship between urban form and travel behavior as well as the sensitivity of results to the modeling framework adopted (Boarnet and Crane, 2001). Ewing and Rong (2008) argue that low density patterns of development may also increase residential energy consumption by virtue of losses through transmission lines (longer distances spanned), larger heated areas (home size) on average, and increased local temperatures (heat island effect).

Understanding the linkages between land use patterns, travel behavior, and air quality is an example of how planning practice and research can better respond to these challenges. In Mecklenburg County, the biggest threat to air quality is ozone, which is attributable to emissions from industrial and mobile sources (Mecklenburg County, 2008). Current estimates suggest that roughly one-third of carbon dioxide emissions in the United States, which also has obvious implications for global climate change (Ewing *et al*., 2008). Table 7.1 lists several measures that help to illustrate the implications of the observed land development patterns in Mecklenburg County. For each measure, the mean value for the cases (parcels that experienced an event) and controls (parcels that did not experience an event) are presented along with the results of a two-sample *t*-test assuming non-equal variance. The implications of each of the selected measures are summarized in the right-most column.

At the macro-scale, parcels that were subdivided were larger, further from the I-485 freeway, had lower employment and shopping potential, exhibited less mixing of land cover, and were more highly valued than their counterparts that did not experience an event (on average). One implication is that residents of these subdivisions may be expected to travel further to access employment and shopping opportunities, which could in turn exacerbate air quality issues (NOx, VOCs) and contribute to global climate change (CO_2).

Table 7.1: Comparison Of Means For Cases And Controls.

Measure	Cases	Controls	Reject	Trend for Observed Events
Macro-Scale Land Parcels: 544 Cases, 1442 Controls				
Original parcel size	37.8726	30.4191	YES	Larger parcels favored
Miles to Uptown Charlotte	10.9048	10.7652	NO	
Miles to I-485	2.5147	2.2116	YES	Beltway proximity less important
Employment potential	0.1095	0.1145	YES	Employment proximity less important
Shopping potential	0.1021	0.1083	YES	Retail proximity less important
Land use mix (entropy)	0.3400	0.3570	YES	More homogeneous land uses
Proportion vacant land	0.4467	0.4359	NO	
Proportion non-urban land	0.5481	0.5415	NO	
Est. market value	$613,675.77	$511,823.44	YES	More valuable (costly to purchase)
Moratorium duration	0.2492	0.2836	NO	
Micro-Scale Land Parcels: 497 Cases, 3620 Controls				
Original parcel size	4.8102	4.4022	YES	Larger parcels favored
Miles to Uptown Charlotte	10.3142	9.5738	YES	Less central parcels favored
Miles to I-485	2.9691	2.4925	YES	Beltway proximity less important
Employment potential	0.1194	0.1323	YES	Employment proximity less important
Shopping potential	0.1133	0.1231	YES	Retail proximity less important
Land use mix (entropy)	0.4230	0.4320	NO	
Proportion vacant land	0.4158	0.3845	YES	More vacant land
Proportion non-urban land	0.4624	0.4340	YES	More non-urban land
Est. market value	$132,737.53	$150,354.48	YES	Less valuable (costly to purchase)
Moratorium duration	0.2473	0.1911	YES	Longer moratorium designation



Estimated Intensity of Macro-Scale Events **Mean Travel Time to Work (CTPP 2000)**

Figure 7.1ntensity Of Macro-Scale Events And Travel Time To Work (Minutes).

the kernel estimated intensity of observed macro-scale events alongside the mean travel time to work by traffic analysis zone from the 2000 Census Transportation Planning Package. Comparing the panels of Figure 7.1 reveals some correlation between areas of high subdivision activity and elevated travel times.

As shown in Table 7.1, micro-scale events on average were larger, less centralized, further from the I-485 freeway, had lower employment and shopping potential, and were more highly valued than their counterparts that did not experience an event. Again, the trend towards fringe development is apparent with similar implications for environmental outcomes. One interesting finding here is that the observed events were under development moratoria for a longer period on average, than non-event parcels at the micro-scale. Perhaps this suggests a greater dampening effect at the micro-scale once the restrictions have been lifted.

The dissertation research also has implications for the subdivision review process. In most cases, the impacts of a proposed project are assessed in terms of whether improvements to existing streets or storm drainage infrastructure will be needed as a result of subdivision. However, if the effects of a large project on subsequent development patterns can extend as far as one or two miles (as suggested by the hazard models), then clearly this should be reflected in a broadening of the scope of the impact assessment. Similarly, detection of a significant "priming effect" at the micro-scale (as well as the macro-scale) suggests that the distinction between major and minor subdivisions may warrant re-evaluation.

7.4 Limitations of the Study

This study has several limitations that should be considered when evaluating its findings. First, the entire research design is predicated on changes in the boundaries of land parcels (tax lots) as an indicator of land development. Although this linkage is intuitively appealing, the reality is that subdivision of land parcels does not necessarily lead to construction and occupancy. Next, the study defines an event as a land parcel being split into two or more successor parcels where at least one-half of these are under residential use at the end of the study period. As a result, non-residential land development is excluded from the analysis and mixed use developments with a low proportion of residential lots could also be omitted. Also, given the lag time typically associated with bringing development projects to market, it is possible that candidate events in the latter time periods of the study could be omitted because the use of the successor parcels was not observed by the end of the study period. Stated differently, perhaps more candidate events in the latter time periods would have met the residential use criterion for successor parcels if the observation window was extended further into the future.

In terms of the modeling approach, the study only explicitly accounts for locational and site-specific factors. Although the research is placed within the larger context of land developer behavior and includes a limited survey, it does little to address land owner behavior. Collecting information from land owners would allow for a more realistic and comprehensive model of the land development process, perhaps in a follow-up study. Following the Capozza and Helsley (1989) and Bockstael (1996), development of a vacant land parcel could be modeled as interactions between utility-maximizing actors. Land owners would consider the net present value of expected future revenue streams under current and alternate uses less the costs of development, and informed by other unobserved considerations and preferences. In its present form, this study does not represent the potential richness of land owner behavior. The study also does not allow for land parcels to experience multiple subdivision events, a constraint that may be less tenable for large tracts. However, to appropriately treat this phenomenon a multiepisode or recurring events model would have been estimated, which would have greatly increased the complexity and time required to conduct the sensitivity analysis (i.e., spatial extent of the "priming effect"). It is also possible that the independence assumption is violated in that the probability of observing an event at a given location may be somehow linked to the outcome at other locations. Spatial autocorrelation is an example of a scenario where this might occur. Unfortunately, there is currently no established (formalized) statistic for testing the residuals of a logistic regression model for the presence of spatial autocorrelation (Griffith, 2004). Permutation tests of the deviance residuals could be conducted, but this assumes that the observations are exchangeable (constant risk) and it is unclear what the proper reference distribution would be for such a test (Besag and Newell, 1991; Goovaerts and Jacquez, 2005).

Vacant land parcels are the focus of the dissertation research and as such, the contribution of redevelopment projects, particularly in and around Uptown Charlotte, is not captured. Further, the study is limited to Mecklenburg County, although the effects of rapid growth are clearly manifest across a wider area. The potential influence of edge effects is not explored and expanding the study area to include neighboring counties would likely have improved the validity and generalizability of the research. The spatial point pattern analysis uses edge-corrected versions of the *K*-function and *L*-function, but edge effects are not explicitly accounted for in the regression models. Given that the intensity of land subdivision was found to be higher along the fringe, it is possible that not accounting for edge effects could introduce bias.

The research focuses primarily on spatial relationships and scale effects, but does not spend nearly as much time examining temporal effects. An implicit assumption of the modeling approach is that the hypothesized “priming effect” is manifested within the subsequent one year period. This assumption is ultimately driven by the realities of data collection and availability limitations, but one could imagine conducting a sensitivity analysis analogous to that performed to assess the spatial extent of the priming effect where the temporal lag is varied and the changes in the regression parameters are evaluated. However, given that there is evidence of a “priming effect” using the one-year time lag, it is reasonable to believe that the current model underestimates its true magnitude. If the temporal lag were longer and more accurately reflected the cumulative effects of nearby subdivision events, one might expect the magnitude of this signal to increase.

7.5 Future Research

The long-term effectiveness of the adequate public facilities ordinances (APFOs) adopted by Davidson and Huntersville and also by neighboring counties is one particularly promising area for future research. Inclusion of an independent variable indicating the presence of an APFO in the hazard models was considered, but given that Huntersville adopted its measure in 2007, there was not enough time nor other jurisdictions with APFOs in place (only Davidson) within the county to make it feasible. A follow-up study that draws upon a longer time-series and compares development in these two jurisdictions with Cornelius and the towns in the southern portion of the county could provide some interesting insights into the impacts of these measures on residential development patterns. Another approach would be to employ an interrupted time-series to study the effect of adopting APFOs on the rate of land parcel subdivision, permit issuance, and construction activity.

Another promising line of inquiry for future research involves expanding our understanding of developer behavior. The existing literature on this topic is dated and relies too heavily on the abstractions of neoclassical economics. Recent developments in organizational learning theory and evolutionary economics, both of which trace their origins in part to *A Behavioral Theory of the Firm*, are particularly encouraging (Argote and Greve, 2007). Survey work and qualitative research are particularly well-suited to filling these gaps in the literature. To some extent, land developers are taste-makers and their decisions frame and influence subsequent residential development patterns (and in some cases infrastructure provision) in a critical manner. Therefore, one of the keys to understanding what drives development patterns and the emergence of urban form is understanding how developers choose sites for their projects and the temporal and spatial linkages between current and future growth. A more detailed examination of the character of observed subdivision events in terms of their linkages to environmental outcomes is a logical extension and a candidate for a follow-up study.

Finally, the present study focuses primarily on the supply side of the land use and residential development equation. While this approach was adopted due to limited time and resources, future research will ideally take a more holistic approach to exploring and understanding urban growth and urban systems and include demand-side considerations. As rapidly growing areas like Mecklenburg County continue to grapple with growth-related challenges, guidance on which policies and instruments to pursue becomes a critical question. Urban models, properly situated within a grounded and collaborative planning process can potentially play a major role in the shaping policy responses. This dissertation will serve as a springboard for developing an agent-based model of residential development that will be calibrated using historical data and used to simulate and evaluate the impacts of growth management policies in Mecklenburg County. Agent-based models represent a promising new tool for researching the interactions of large numbers of distinct actors within a complex and multidimensional framework (Moretti, 2002). This modeling approach is well-suited to examining the effects of policy instruments on the land development process and allows for the testing of existing theory in a way that cannot be accomplished using conventional research methods.

APPENDIX A

The following tables provide descriptive statistics for the independent variables used in each of the hedonic and hazard regression models.

Table A.1: Descriptive Statistics For Hedonic Model: Macro-Scale.

Measure	Mean	Std. Dev.	Range	Proportion Zero
Physical Characteristics				
Water body frontage	–	–	0, 1	0.90
Stream frontage	–	–	0, 1	0.25
Slope	2.37	1.37	0.09, 6.45	–
Poor soils	–	–	0, 1	0.11
Wetlands	–	–	0, 1	0.96
Forest cover	0.81	0.24	0, 1	–
Parcel size	3.10	0.59	2.30, 4.91	–
Accessibility				
Employment potential	0.11	0.03	0.06, 0.21	–
Shopping potential	0.11	0.06	0.05, 0.44	–
Distance to freeway ramp	0.57	0.94	-1.94, 2.28	–
Policy Context				
School district	–	–	0, 1	0.57
Tax rate	0.91	0.20	0.73, 1.19	–
Unincorporated	–	–	0, 1	0.65
Zoning	–	–	0, 1	0.38
Demographics				
Population density	1.35	1.30	0.10, 6.51	–
Income (thousands)	10.09	0.34	9.07, 10.93	–

Table A.2: Descriptive Statistics For Hedonic Model: Micro-Scale.

Measure	Mean	Std. Dev.	Range	Proportion Zero
Physical Characteristics				
Water body frontage	–	–	0, 1	0.94
Stream frontage	–	–	0, 1	0.62
Slope	1.46	1.37	0.01, 5.52	–
Poor soils	–	–	0, 1	0.29
Wetlands	–	–	0, 1	0.96
Forest cover	0.63	0.39	0, 1	–
Parcel size	1.41	0.46	0.69, 2.28	–
Accessibility				
Employment potential	0.13	0.05	0.05, 0.41	–
Shopping potential	0.12	0.10	0.04, 1.24	–
Distance to freeway ramp	0.29	1.10	-3.09, 2.23	–
Policy Context				
School district	–	–	0, 1	0.61
Tax rate	1.00	0.21	0.73, 1.19	–
Unincorporated	–	–	0, 1	0.73
Zoning	–	–	0, 1	0.47
Demographics				
Population density	1.71	1.91	0.19, 17.17	–
Income (thousands)	25.92	13.03	8.48, 125.80	–

Table A.3: Descriptive Statistics For Hazard Model: Macro-Scale.

Measure	Mean	Std. Dev.	Range
Land Market Considerations			
Estimated land value in 2001	13.18	1.11	9.58, 17.31
Parcel aggregation indicator	—	—	0, 1
Proportion vacant land in block group	0.4389	0.1300	0.0174, 0.7793
Demographics and Neighborhood Character			
Percent college graduates in block group	43.04	17.99	0, 93.20
Number of demolitions within quarter mile	0.13	0.68	0, 13.00
Land use mix (entropy measure)	0.35	0.13	0.0031, 0.77
Built environment typology class	—	—	0, 1
Proportion non-urban uses within quarter mile	0.5434	0.2309	0, 0.9921
Accessibility			
Logged distance to I-485 (finished by 2001)	1.33	1.04	-3.09, 2.64
Distance to I-485 (when complete)	2.29	2.09	0, 9.13
Logged distance to nearest downtown	1.38	0.62	-1.51, 2.35
Policy Factors			
Infrastructure availability proxy	11.5	9.08	0, 78.02
Tax rate	9.97	0.20	0.73, 1.39
Non-residential neighborhood	—	—	0, 1
Rezoning duration (average number of days)	128.20	32.13	90, 365
Moratorium in place (proportion of year)	0.04	0.17	0, 0.91
"Priming Effect" Measures			
Nearby micro events in prior period: one-tenth mile	—	—	0, 1
Nearby micro events in prior period: one-quarter mile	—	—	0, 11
Nearby micro events in prior period: one-half mile	—	—	0, 13
Nearby micro events in prior period: one mile	—	—	0, 18

Nearby all events in prior period: one-tenth mile	–	–	0, 3
Nearby all events in prior period: one-quarter mile	–	–	0, 12
Nearby all events in prior period: one-half mile	–	–	0, 14
Nearby all events in prior period: one mile	–	–	0, 14

Table A.4: Descriptive Statistics For Hazard Model: Micro-Scale.

Measure	Mean	Std. Dev.	Range
Land Market Considerations			
Estimated land value in 2001	11.91	0.91	9.56, 15.35
Parcel aggregation indicator	—	—	0, 1
Proportion vacant land in block group	0.3883	0.1559	0.0084, 0.7793
Demographics and Neighborhood Character			
Percent college graduates in block group	41.38	18.69	0, 86.10
Number of demolitions within quarter mile	0.31	1.06	0, 16
Land use mix (entropy measure)	0.43	0.13	0, 0.80
Built environment typology class	—	—	0, 1
Proportion non-urban uses within quarter mile	0.4375	0.2257	0, 1
Accessibility			
Logged distance to I-485 (finished by 2001)	1.37	1.01	-3.62, 2.65
Distance to I-485 (when complete)	2.55	2.13	0, 9.16
Logged distance to nearest downtown	1.35	0.63	-2.82, 2.32
Policy Factors			
Infrastructure availability proxy	14.16	9.06	0, 82.55
Tax rate	1.05	0.21	0.73, 1.39
Non-residential neighborhood	—	—	0, 1
Rezoning duration (average number of days)	125.6	30.33	90, 365
Moratorium in place (proportion of year)	0.03	0.14	0, 0.91
"Priming Effect" Measures			
Nearby macro events in prior period: one-tenth mile	—	—	0, 2
Nearby macro events in prior period: one-quarter mile	—	—	0, 3
Nearby macro events in prior period: one-half mile	—	—	0, 4
Nearby macro events in prior period: one mile	—	—	0,

Nearby all events in prior period: one-tenth mile	–	–	0, 5
Nearby all events in prior period: one-quarter mile	–	–	0, 14
Nearby all events in prior period: one-half mile	–	–	0, 16
Nearby all events in prior period: one mile	–	–	0, 19

APPENDIX B

The questions included in the online survey of land developers are presented here. Because responding to each question was completely voluntary, not all respondents provided an answer to each question.

1. How would you characterize your firm?

______ Limited Liability Company
______ Partnership
______ Real Estate Investment Trust
______ Proprietorship
______ Corporation
______ Other

2. How large is your firm in terms of employees?

______ Less than 5
______ 5 to 24
______ 25 to 99
______ 100 to 299
______ 300 to 499
______ 500 or more

3. Please select one of the following that best characterizes your typical project (five acres or more).

______ Single-family residential
______ Multi-family residential
______ Urban village
______ Infill
______ Downtown redevelopment
______ Non-residential uses account for at least 30% of project cost

4. Are there particular price ranges (per housing unit or lot) in which you prefer to work?

______ Yes
______ No

5. What are these price ranges and why?

6. Is the Charlotte metropolitan area your primary market?

______ Yes
______ No

7. Approximately how many projects have you completed in Mecklenburg County over the past decade?

	Residential		Total
______	0	______	0
______	1 to 5	______	1 to 5
______	5 to 10	______	5 to 10
______	More than 10	______	More than 10

8. How many units do you build in a typical year?

9. On average, what is the size of your residential projects in terms of units and acreage?

10. On average, how many projects do you complete in a year?

______ 0
______ 1 to 5
______ 5 to 10
______ More than 10

11. Please identify a residential project in Mecklenburg County that you consider successful and briefly describe why you chose it.

12. Which factors or considerations are most important in your site selection process?

13. Do you typically target vacant parcels?

14. How do you typically learn about the availability of vacant or developable land?

15. How far ahead do you option or purchase vacant land?

16. How common is it for you to aggregate many smaller parcels for residential projects?

17. Is there a minimum size (acreage) that you look for in a vacant land parcel for one of your residential projects?

18. Do you typically buy properly zoned land or prefer to rezone?

19. When evaluating a candidate site, what is a reasonable radius or distance within which to assess things like access to shopping, highway accessibility, schools, parks, and existing residential development (e.g., quarter-mile, half-mile, etc)?

20. What is your strategy with regard to developing in new locations versus allowing others to prove the market and then following?

APPENDIX C

Alternate specifications of the effect of time in the hazard models were considered and the results are briefly presented here. The general model that includes the main effect of time (binary indicator for each time period) is necessarily the best-fitting model. However, in the interest of parsimony, several alternate specifications of the effect of time were considered including a single constant (intercept) that constrains the logit hazard (dependent variable) to remain identical across all time periods (Singer and Willett, 2003: 411) and several polynomial approximations. The order of the polynomial controls the number of inflection points and by extension, the ability of the approximation to capture fluctuations in the observed hazard rate. The linear approximation is constructed by including an intercept term (a vector of ones) as well as a second term, which the time period minus a centering constant *c*, as given below:

$$\text{logit}\, h(t_j) = \alpha_0 One + \alpha_1 (TIME_j - c) \qquad [25]$$

In the present case, the centering constant used is 1, which has the effect of making the estimated alpha parameters represent logit hazard in the initial time period. For the higher order polynomial approximations, an additional parameter is added that is the second independent variable in [25] raised to the corresponding power. Table C.1 shows the deviance and AIC values associated with each of these alternate model specifications as well as the change in deviance as compared with the prior (nested) model and main effect of time model (general specification). Shown in parentheses in columns four and five are the degrees of freedom associated with a chi-square test of the change in deviance.

Table C.1: Comparison of Alternate Representations of Time, Micro-Scale.

Time Representation	Parameters	Deviance	Prior Model	Main Model	AIC
Constant	1	3635.556	–	105.823 (5)	3637.556
Linear	2	3623.528	12.027 (1)	93.796 (4)	3627.528
Quadratic	3	3570.824	52.704 (1)	41.091 (3)	3576.824
Cubic	4	3555.513	15.310 (1)	25.780 (2)	3563.513
Fourth Order	5	3549.071	6.441 (1)	19.339 (1)	3559.071
Main Effect of Time	6	3529.732	–	–	3541.732

Table C.2: Comparison of Alternate Representations of Time, Macro-Scale.

Time Representation	Parameters	Deviance	Prior Model	Main Model	AIC
Constant	1	3077.309	–	86.835 (5)	3079.309
Linear	2	3045.984	31.324 (1)	55.510 (4)	3049.984
Quadratic	3	3036.744	9.240 (1)	46.269 (3)	3042.744
Cubic	4	3025.740	11.003 (1)	35.266 (2)	3033.740
Fourth Order	5	3019.642	6.098 (1)	29.167 (1)	3029.642
Main Effect of Time	6	2990.474	–	–	3002.474

As shown in Table C.1 and Table C.2, none of the alternate model specifications rejects the null hypothesis that the prior (or main effect of time model) are a better[39] fit for the data. The single-constant model is necessarily the worst-fitting of the specifications considered. The greatest gains in terms of deviance (analogous to RSS in OLS) reduction occur with the quadratic specification at the micro-scale and the linear specification at the macro-scale. However, in each case the more general specification performs best (main effect of time). Given that there are only six time periods and that the number of observations is large in both models, the initial model specification, that includes the main effect of time was retained.

[39] Differences in deviance were compared to critical values in a standard chi-square table for the specified degrees of freedom at the 0.05 alpha level.

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