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FACTORS AFFECTING RURAL-URBAN LAND CONVERSION: AN EMPIRICAL ANALYSIS OF THE TUCSON METROPOLITAN AREA, 1975/76-1980

by

Shirley L. Porterfield

A Thesis Submitted to the Faculty of the

DEPARTMENT OF AGRICULTURAL ECONOMICS

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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Professor of Agricultural Economics

Nov. 7, 1984
Date

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ABSTRACT

In recent years concern has grown regarding the adequacy of open space, much of which is in agricultural use, in and around urban areas. Development of this land is essentially irreversible, creating public controversy over the long-run effects of rural to urban land conversion and prompting government intervention in the regional land market. Theory indicates that undeveloped land in close proximity to an urbanized area is more likely to be converted to urban use than land further from the rural-urban fringe. Awareness of the impact of locational factors influencing the conversion of land from low to high intensity uses may improve the efficiency of the land use planning process. Variables thought to be influential in the land development process are high intensity physical land use, residential zoning, minority population, housing value, and accessibility to employment opportunities. Data are analyzed using a resource allocation model with the goal of maximization of net benefits to society over a given time horizon. The study examines the Tucson, Arizona, Metropolitan Area (TMA) over the period 1975/76-1980. Results of the empirical study suggest that land use goals will be achieved only if

decision-makers account for locational conversion pressures when implementing land use guidance techniques such as zoning or taxation.

CHAPTER 1

INTRODUCTION

The nature of urban growth has in recent years become a controversial issue. Improved urban transportation corridors, increased incomes, and a movement toward decentralization of urban economic activity have all contributed to a sprawling, less densely populated urban area. New construction tends to occur at the edge of the urban area or the rural-urban fringe, drawing people away from the central city. As the urban area expands conversion pressures on rural vacant or agricultural land contiguous to the developed area increase. Increasing growth of U.S. agricultural exports, decreasing marginal productivity of cropland, and amenity factors such as loss of open space and of the rural lifestyle have prompted inquiry into the dynamics of the supply of rural land in the United States, particularly that in agricultural use. In a summary of the National Agricultural Lands Study [1981], conversion during the 1970's was estimated at three million acres peryear, approximately one million acres per year from the cropland base.

A. The Agricultural Land Conversion Controversy

Historically metropolitan areas within the U.S. appear to have their beginnings in some form of natural resource use: mining, forestry, fishing, or agriculture. Location of agricultural activity would naturally occur where soil types were best, providing the highest return to factors of production. Once beyond the autarkic stage market centers developed, taking advantage of scale and agglomeration economies. It is not surprising that "16.7 percent of the nation's land that is in SMSA counties contains 20.2 percent of the land in Soil Capability Classes I and II (defined as prime farmland), and while 17.6 percent of the nation's land is classified as belonging to Classes I and II, 21.3 percent of the acreage in SMSA counties is so classified" [Vining, et.al., 1977]. Dillman and Cousins [1982] found that urban development was distinctly selective of prime agricultural land in their study of one North Carolina SMSA. Site preparation of nonprime agricultural land was estimated to be 75 to 125% higher than the cost of an ideal site. The agricultural use value foregone by building on prime land was less than 7% of this additional cost.

Controversy has developed concerning both the rate of agricultural land conversion and the adequacy of the remaining stock of arable land. The pessimistic view espoused by the National Agricultural Lands Study [1981] appears to have garnered the most public attention although Fischel [1982] estimates "that the data referred to by the NALS overstate the 'loss' of rural land by a factor of at least two, and probably much more." Berry [1978] suggests that indirect effects of urbanization such as the shift of political power from farmers to nonfarmers and the damage to crops from air pollution and suburban dwellers are in many areas more significant in reducing agricultural production than the actual conversion of agricultural land. These effects may result in the idling of farm land for a period of time rather than immediate urban development. Crosson [1982] estimates that the pressures exerted by rising export demand and factor prices may, in the future, be much more significant than those of urbanization.

The controversy surrounding the conversion of low intensity land uses (such as agricultural or recreational) to high intensity uses (such as residential or commercial) is based on the concept of irreversibility. Most urban land uses are either physically, institutionally, or economically irreversible, generally structures erected to last over an indefinite time period. As an urban area grows, opportunities to change existing land uses are lost. Irreversibility of urban land uses and externalities generated by declining agricultural acreage (amenity loss, farm operation cost increases) affect society as a whole thus are considered justification for government intervention. Fisher [1982] disagrees.

> Because unrestricted development imposes losses on farmers does not mean that restrictions on development (which preserve farmers' wealth at the expense of future homeowners) represent a gain in efficiency; the externality is reciprocal. Defining the farmland conversion issue as a problem in externalities generated by certain development patterns places certain rights (to farm, to breathe clean air) above other rights (to build homes on cheap development sites for example).

Several legislative measures have been taken at the state government level in an attempt to slow the loss of farmland to nonagricultural uses. Agricultural zoning, use-value and development taxation have been employed with mixed results. Fisher [1982] attributes these types of protectionist legislation to dissatisfaction with the spacial pattern of urbanization rather than agricultural production concerns. Vogel and Hahn [1972] conclude that noncommercial agriculture may provide more benefit in terms of aesthetic value to urban dwellers than commercial agriculture which is often accompanied by air, water, and noise pollution.

B. Objectives of the Study

The primary objective of this research is to identify qualitative factors (independent variables) which influence land conversion. Awareness of these factors may inprove the efficiency of the urban and regional land use planning process. Secondary objectives are (a) to verify results of a similar study by Willis [1982], (b) to document land use changes which occurred in the Tucson Metropolitan Area (TMA) during the 1975/76-1980 period, and (c) to examine policy implications relevant to the findings of this research.

In keeping with these objectives, chapter 2 begins with a discussion of traditional urban land use theory. A review of the simple von Thunen model forms the framework for an examination of residential location theory. An analysis of the impact of changes in the assumptions of the model is followed by a review of empirical studies using variables thought significant in the urban development process.

Theory presented in chapter 2 is expanded in chapter 3 to include the influence of location on land conversion. The focus of the model is narrowed to the rural-urban fringe. Variables hypothesized to influence land conversion and data collection methods used in this study are described in chapter 4. Trends in the Tucson Metropolitan Area over the study period are documented. Statistical results of the empirical study are presented in chapter 5, including an explanation of the statistical model used. Land preservation techniques and policy implications drawn from the results are discussed. Chapter 6 summarizes research findings and suggests direction for further study.

CHAPTER 2

EMPIRICAL STUDIES AND THEORY OF LAND CONVERSION AT THE RURAL-URBAN FRINGE

Agricultural land in close proximity to urbanized areas is thought to face greater conversion pressure than land farther from the urban fringe. A clearer understanding of the conversion process may be gained through the examination of economic forces behind urbanization. Decisions made by both land developers and residential homeowners affect the structure and subsequent growth of the urban area.

This chapter focuses on factors influencing the conversion of rural land, much of which is agricultural, to urban uses. The topic is introduced in a review of traditional land use theory, specifically the theory of residential location. Locational factors thought to influence land conversion are presented in the second section.

A. Traditional Land Use Theory

1. Concepts of Land

a. Natural Resource. As a natural resource, land has two major characteristics. It provides space which is finite and unchanged over time and it provides an apparently infinite flow of services which is variable over time and controlled by man. Land services are the tangible and intangible net benefits derived from a given land use, e.g. agricultural or residential. Much like the benefits derived from solar energy or water resources, land services are available at a fairly constant rate over time. However, unlike those of solar energy, service flows of land may be irreversibly transformed. Choices of society in one period may affect the range of land service flows available in subsequent periods. The change may not be a loss, but rather an alteration of the nature of the land service flow. The relevant economic decision becomes one of optimal intertemporal allocation of land between competing uses [McInerney, 1976].

b. Real Property. Ownership of real property essentially means control of a bundle of rights to use land at specific locations. Shafer [1977] cites four factors which separate real estate from other economic commodities: (1) fixed location, the most important factor in real property value, (2) long life of structural additions, (3) large monetary expenditure generally requiring third party financing, and (4) long-term decisions, e.g. returns over a long investment period.

2. Real Estate Market

a. Supply. Though the overall supply of land is limited, variable amounts are available for use by any one individual. Barlowe [1978] distinguishes between the physical and economic supply of land. The physical supply of land or physical existence of land resources acts as a constraint on the economic supply which "concerns only that portion of the physical supply that man uses." Shafer [1977] further disaggregates the economic or real estate supply into short and long term. The supply of real property or the services derived from real property is highly inelastic in the short run (Figure 2.1a). New construction is costly and time consuming. In the long run however, real property supply is much more elastic, often overreacting to shifts in demand. High sunken costs of construction (site preparation and architectural fees for example) generally encourage the completion of development projects even if demand has already been met. This results in a stair-step long run supply curve with alternate periods of construction and inactivity (Figure 2.1b).

b. Demand. Barlowe [1978] defines consumer demand not as the unsatisfied desires of consumers, but as the willingness and ability of people to buy (effective demand). Over its relevant range, demand for real estate services is more elastic than supply as consumers are able to more rapidly adjust to changing land and capital prices (Figure 2.2). Consumer demand is fairly inelastic at very high and very low real estate prices. At very high prices only a small number of wealthy persons are able to enter the market, investing a smaller proportion of financial resources than the middle or lower income person. At very low prices the demand for real estate is effectively satisfied with only a few very poor persons left in the market [Shafer, 1977].

Long run urban demand for undeveloped land is derived from the demand for improved lots which in turn is derived from the consumer demand for residential or other urban land services. Assuming that the supply of nonland inputs used in land development is relatively elastic, the elasticity of demand for real estate increases with movement from undeveloped suburban land to urban housing [Clawson, 1971].

c. The Urban Land Market.[1] Differences in the value of land services to individuals form the basis of the real estate market [Shafer, 1977]. The market for urban land tends to be disaggregated and disorganized.

1. The real estate market, particularly for housing, is unique in that the turnover rate of parcels is slow (generally years rather than hours or days) and there is very little information available to the public concerning market transactions [Clawson, 1971].

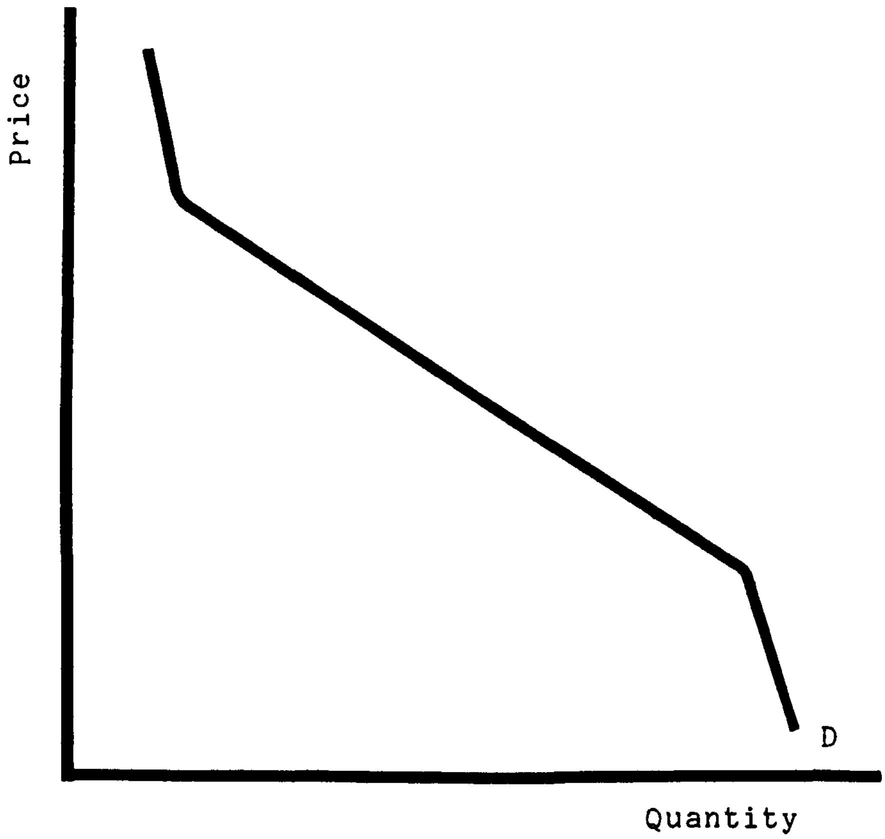

Figure 2.2. Demand for Real Estate Services.

(Source: Shafer, 1977.)

Land development typically occurs in two stages, thus two general land markets exist. In the first, landowners, e.g. farmers, supply land to developers who modify the land, most often through construction. In the second, developers sell to final consumers, e.g. homeowners or commercial enterprises. In actuality there may be many land markets.

d. Market Efficiency. Under the competitive market system, land use decisions are made by the highest bidder. This system may not result in an efficient long run land use mix due to the myopic view of the developer/landowner. Developers and business people tend more toward a goal of profit maximization while households maximize satisfaction or utility in choosing an optimal location. These goals do not necessarily correspond to the public goal of social welfare maximization. Social efficiency (maximization of net social benefits) may be reached in the real estate market in the short run. However, the irreversible nature of real estate development may prevent attainment of a long run efficient and/or equitable solution. Analysis of the effects of development pressures on the long run land use mix may increase market and social efficiency.

B. Urban Location Theory

Development pressure is generally greatest on land closest to the urban area. The structural and socio-demographic changes associated with urban development appear to place pressure on vacant urban and rural-urban fringe land to convert to high intensity uses.

1. Simple von Thunen Model

Location is the basic, underlying determinant of the price of land. Services available from a given parcel of land vary with spacial setting, in particular with distance from a point of maximum overall accessibility or center of economic activity [Richardson, 1979]. The simplified urban location theory of von Thunen[2] assumes this point to be the Central Business District (CBD). Urban land use patterns, modeled as concentric rings by von Thunen, are formed by the opposing forces of transportation costs and the availability of space. Near the CBD transportation, commuting, and communication costs are minimized. Movement away from the CBD increases the availability of undeveloped land, providing greater privacy and increased space for production needs.

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2. Conversation with David L. Barkley, University of Arizona, Department of Agricultural Economics, 1982.

a. Assumptions.

1. competitive market system, i.e. land goes to highest bidder or the most profitable user
2. single market center, the CBD, i.e. all goods are sold and all residential purchases are made at the CBD
3. ubiquitous land fertility/quality
4. no substitution of inputs, i.e. the production function is fixed
5. inputs are ubiquitous
6. uniform transportation network
7. transportation costs are linear, i.e. constant per ton-mile regardless of product shipped

b. Urban Land Allocation. In the simple von Thunen model land in the urban area is allocated according to its use value or its profit per acre. In simplest terms, profit is total revenue minus total cost. Stated in terms of the von Thunen model:

$$\pi/\text{acre} = PA - W - tdA - R(d)$$

where P = price of good sold in CBD (constant at all quantities)

W = nonland costs of production (per acre)

A = output/acre (in tons)

t = transportation costs (in $/ton-mile)

R(d) = maximum rent a given activity would pay to locate d miles from the CBD

d = distance

Setting this equation equal to zero (so that economic profit per acre equals zero) defines what von Thunen termed the Bid Rent equation, or the maximum rent a given activity would be willing to pay to locate dmiles from the CBD. Given values of P, W, A, and t, distance becomes the only decision variable within a given activity. A, the output/acre, varies for each activity, thus each will have its own bid rent curve and its own optimal location in the urban spacial structure. Land use activities with a high value (profit or utility) per unit of land (0a in Figure 2.3) will locate closer to the urban center. Locations farther from the CBD will be allocated to uses with a lower value per land unit (ab and bc in Figure 2.3). Each use is allocated only that amount of land for which it is willing to bid the highest rent. As shown, increasing distance from the CBD results in increasing overall transportation costs and decreasing bid rent for each activity.

An aerial view of the simplified model shows a system of concentric rings surrounding the urban area. Realistically, land uses within the urban area are mixed,

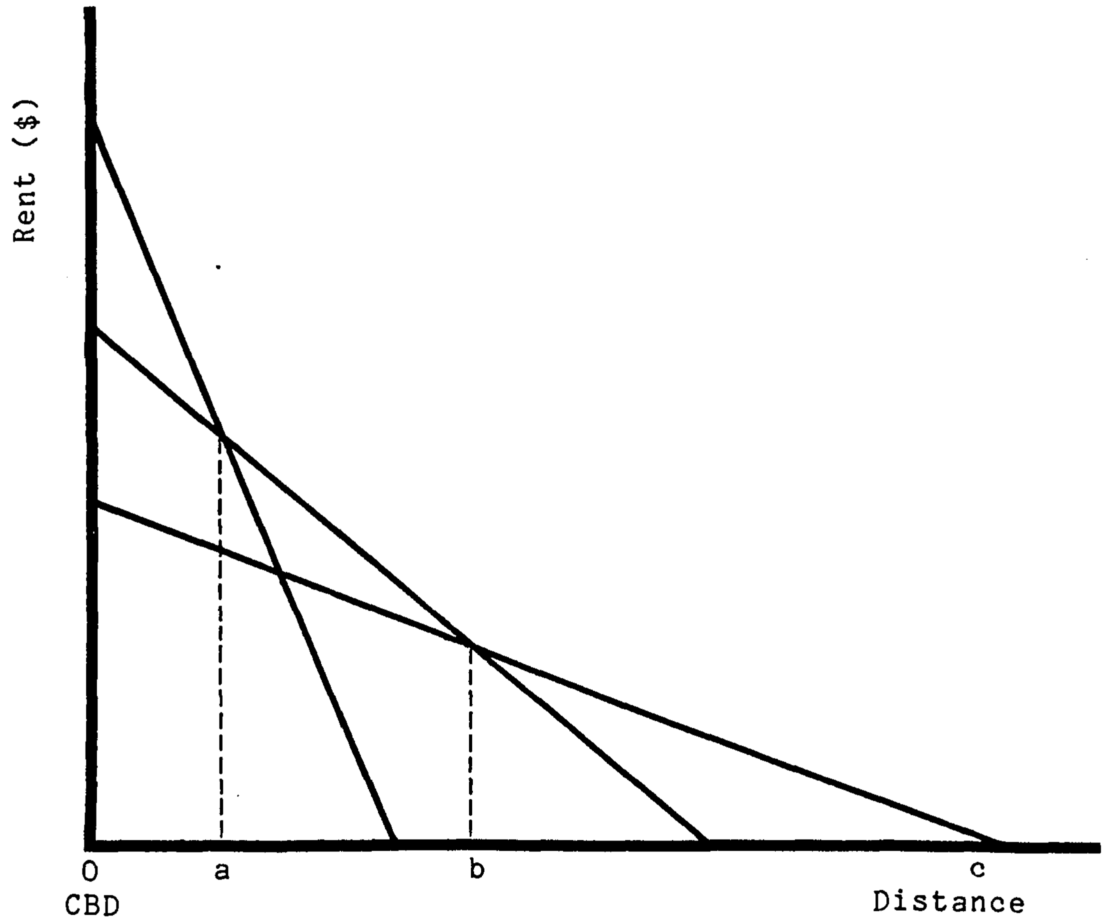

Figure 2.3. Bid Rent Curves of Various Land Uses.
(Source: Barkley, 1982.)

arranged around several (perhaps minor) centers of economic activity.

2. Residential Location Theory

The land allocation process also functions within a given land use ring such as residential. Housing is the largest single urban land user [Muth, 1975]. As an urban area grows, the demand for additional housing may be met by expansion or division of existing housing or construction of new housing. Construction logically takes place at the urban-rural fringe where the supply of undeveloped land is greatest. Land conversion is therefore closely related to choice of residential location.

Residential housing patterns may be illustrated by urban density gradients (Figure 2.4). Population density (persons per square mile) is low at the CBD where most activity is economic in nature. Just beyond the CBD it increases sharply and then falls off at an exponential rate with movement away from the city center [Bish and Nourse, 1975].

$$D_x = D_o e^{-\gamma x}$$

where D_o = population density at the CBD

e = exponential factor

x = distance from the CBD

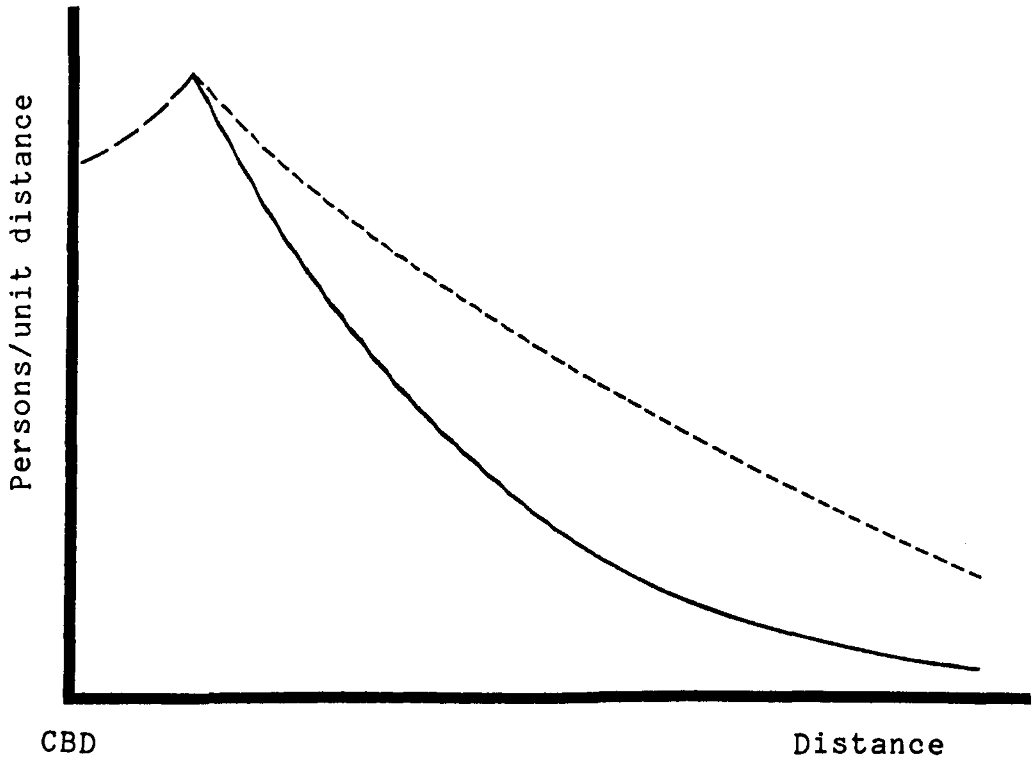

Figure 2.4. Urban Population Density in Relation to the Urban Center (CBD).

(Source: Bish and Nourse, 1975.)

γ = density gradient (the percent decrease in population density as x increases)

The urban density gradient can be used to predict the percentage of the population residing at a given distance from the CBD. It is based on three assumptions:

1. individuals desire to locate near the CBD
2. individuals (consumers) desire to maximize utility
3. contractors (producers) desire to maximize profits

Two further assumptions are made in analyzing the behavior of consumers and producers.

4. one CBD
5. all sites within the urban area are equally desirable for residential location

a. <u>Consumer Behavior.</u>[3] Consumers maximize satisfaction or utility subject to a budget constraint by

---

3. Consumers may be spacially segregated within the urban area by income level through a process known as filtering. Filtering is defined as the "changing of occupancy as the housing that is occupied by one income group becomes available to the next lower income group as a result of decline in [real] market price" [Edel, 1972]. Simply stated it is the process by which new homes constructed at the fringe of the urban area are purchased by the wealthy and middle classes while older homes located closer to the CBD filter down to the poor. Larger homes near the CBD are converted to multi-family dwellings in order to maximize rent payments. Maintenance generally declines to a level supportable by rents earned by the building.

choosing between units of "housing" and "other goods." In order to maintain an equal level of utility at all points in the urban area, homeowners will demand more land and/or larger houses as distance from the CBD increases. Increased transportation costs with movement from the city center effectively decrease the consumer's budget. The given utility level may be maintained either by decreasing the price per unit of housing or by providing more units of housing and/or land at the same price. Thus as distance from the CBD increases, the slope of the consumer budget constraint becomes flatter reflecting a relatively larger housing purchase.

b. Producer Behavior. Producers maximize profit by optimally combining land and nonland inputs in the production of residential housing. The marginal cost to the developer of supplying land services increases with distance from an urban center. Land prices are lower, but may be outweighed by increased construction costs, including transportation of labor and materials and proximity of public service connections. Holding the price of other development inputs constant, the decrease in land price with movement from the CBD provides an incentive for the developer to use relatively more land when building at the urban fringe.

Population density decreases with increasing distance from the CBD as consumers demand more housing at a given price. Construction of a given size tends to take place on progressively larger parcels of land.

3. Changes In The Model Over Time

a. Income Change. Rising urban incomes lead to increased demand for urban housing. Prices per unit of housing rise resulting in a denser occupancy of the inelastic housing stock in the short run. Marginal transportation costs increase reflecting the higher value placed on time. Housing prices tend to increase more rapidly at the urban perifery due to new residential construction. In the long run there is less variation in housing prices and population density between the CBD and outlying areas. Variation of the intensity of residential land use declines. As the rent received from residential land use increases, conversion pressure on urban-rural fringe land grows. Bid rent curves for residential housing retain their slope but are shifted outward reflecting the larger household budget at each income level (dashed lines in Figure 2.5).

b. Population Change. Population growth has much the same effect as rising urban incomes. Growth occurs more rapidly in the outer part of the urbanized area where

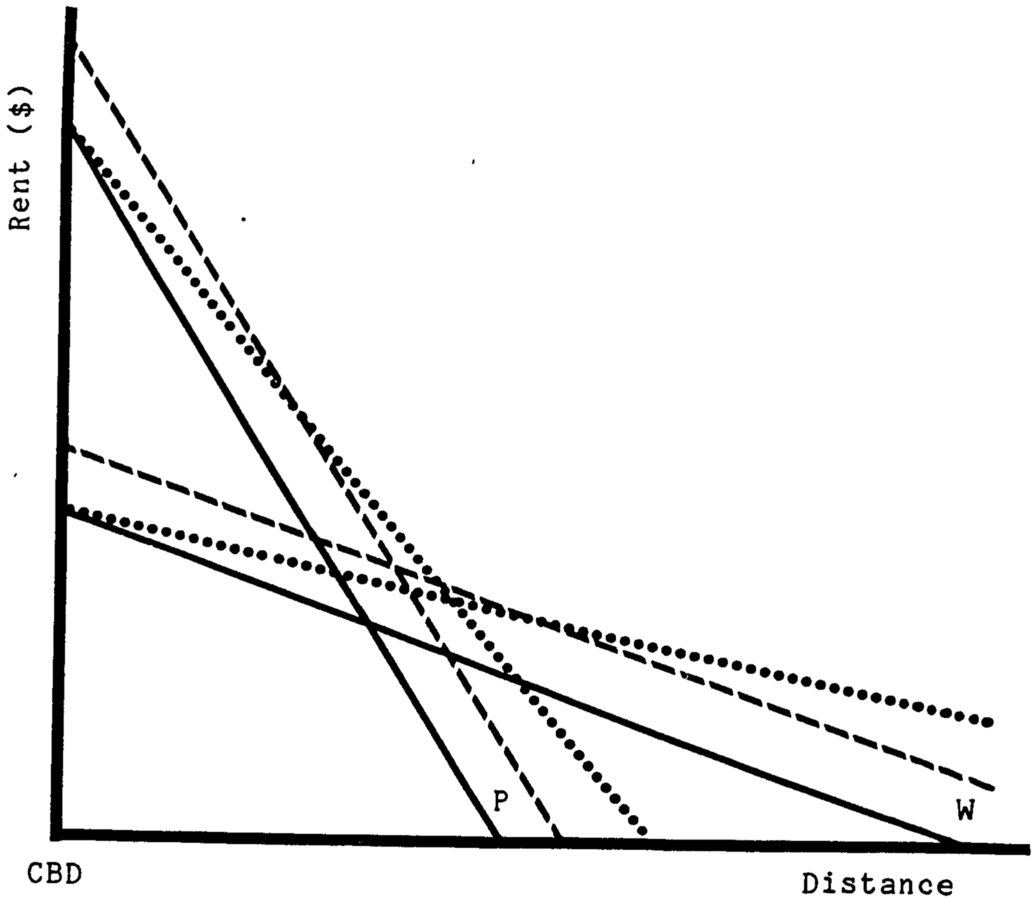

Figure 2.5. The Effect of Changes in the Model.

the large supply of undeveloped land allows a greater rate of expansion of the housing stock. Population density declines more slowly with distance from the CBD as the urban area expands (dotted line in Figure 2.4).

c. Transportation Change. Transportation improvements promote urban decentralization. Muth [1975] describes two changes resulting from the increase of automobile transportation:

(1) suburbanization of residences causing sales potential of suburban businesses to rise, and

(2) reduced cost of circumferential v. that of radial movement in urban transportation (i.e. decreased relative cost of private v. public transportation).

City form changes as the urbanized area spreads along transportation corridors. Housing prices are higher near these corridors reflecting increased proximity (particularly in terms of time) to the central city. Transportation improvements increase conversion pressure on undeveloped land which previously was undesirable due to high commuting costs. As with increases in income and population, cost per unit of housing and population density decline less rapidly when moving away from the CBD. Bid rent curves flatten along transportation corridors reflecting the lower transportation costs (dotted lines in Figure 2.5).

C. Identification of Factors Influencing Rural Land Conversion

1. Physical Factors

Surrounding Land Use. As indicated earlier, proximity to urbanization is thought to influence rural land use. Lee [1979] modeled land use change in Urbandale, Iowa, a Des Moines suburb, over four time periods between 1950 and 1974. The study area was divided into 302 20-acre cells and analyzed using sequential aerial photography. Six possible explanations were postulated for scattered and dispersed development: (1) physical characteristics of parcels, (2) regulatory measures, (3) personal characteristics of landowners, (4) availability of public services, (5) site accessibility, and (6) developer initiative. Ordinary least squares regression was used to test the hypothesis. The most important variable in predicting land conversion was the change in development during the preceeding period in cells contiguous to a given cell. This change in surrounding development was significant and positively correlated with the percentage increase in urbanization in both agricultural and partially urbanized cells.

A similar study by Willis [1982] analyzed the effects of the surrounding land use mix on conversion of land from low to high intensity uses in the Tucson, Arizona metropolitan area (TMA) over three time periods between 1967 and 1976. The TMA was divided into 373 square mile (640 acre) cells. Land use trends were documented through comparison of land use maps generated from aerial photographs. Linear probability analysis (probit) was used to test the relationship between conversion of low intensity land uses (dependent) and proximity of high intensity land uses (independent). For each time period cells were classified as high or low growth areas depending on the magnitude of converted acreage. The upper one-third of cells showing land conversion were given a dependent variable value of 1 while the lower two-thirds were given a dependent variable value of 0. The proportion of land in residential use surrounding a given cell at the beginning of the study period was found to be positively related to land conversion within the cell during the period. Both linear and quadratic equations were significant. Land area in other uses were regressed against conversion, but none were found to be significant throughout all three time periods.

2. Socio-demographic Factors

a. Land Value. The price of undeveloped land to some degree influences the demand for development within a given area. Data approximating land value per unit is not always readily available to the researcher and may not in all cases be the best indicator of development demand. Housing value is often used as a proxy for land value when reliable data on the latter is unavailable. Holding structural or nonlocational characteristics constant becomes a problem with the use of this proxy [Smith, 1978].

b. Race. Racial composition of a given area is thought to influence both residential and commercial/industrial location. Cao [1980] used minority as a percentage of total neighborhood population as a proxy for socio-economic composition in his analysis of residential property values in Tucson, Arizona. Using ordinary least squares, a negative correlation between percent minority and the value of single family homes in a given census tract was found. Krumm [1980], using two-stage least squares, found a similar correlation between the selling prices of 452 Chicago residences and the percentage of Black inhabitants.

Granfield [1974] used race as one of the explanatory variables in a study of the demand for residential sites in Buffalo, New York and Milwaukee, Wisconsin. Modeled as a household specific, dummy variable, race showed negative correlation with location of residence in terms of linear distance from the Central

Business District (CBD). It was concluded, ceteris paribus, that nonwhite households were constrained to live closer to the CBD than their white counterparts.

Assuming that developers are profit oriented, if the majority of development at the urban-rural fringe is for residential purposes and areas with a high proportion of minority residents are also characterized by low housing values then it may be hypothesized that a high minority population will be negatively correlated with urban fringe land conversion. Alternatively, the generally low political power held by minority groups may lead to greater development in areas of high minority concentration due to inability to affect institutional land use decisions. The latter effect may prevail particularly if the planned development is commercial or industrial rather than residential.

3. Employment Accessibility

Barlowe [1978] defines accessibility as the position of a parcel of land with respect to markets and transportation facilities relative to other land parcels. Cost of transportation and communication are involved as well as time-distance considerations. Proximity to employment, shopping, recreational and other opportunities are thought to be influential in the land development process. If residential location theory such as that postulated by Alonso [1960] is assumed, accessibility to the point of economic activity or the CBD becomes important. The existence of urban sub-centers may result in an estimate of accessibility to major centers of employment, shopping centers, or thoroughfares, reached by automobile or some mode of public transportation. Accessibility may be measured in terms of distance or travel time.

Multiple urban centers exist "whenever the marginal costs associated with the optimal monocentric form are larger than the marginal costs of allowing the city to expand" [Greene, 1980]. The locational decisions of firms are hypothesized to depend upon the location of transportation nodes and the size of agglomeration economies. Greene, in an analysis of five SMSAs over the 1960 to 1970 period, found a consistent trend of decreasing spacial concentration of population and employment.

Lee [1979] incorporates both travel time and distance into her model of rural-urban conversion. Travel time is measured in minutes from a given cell to downtown Des Moines while distance is measured in miles from a cell to the nearest interstate access road. She concludes that of the two accessibility variables, travel time is the most significant. The coefficients of both measures generally indicate a positive correlation between accessibility and urban land use change.

Granfield [1974] included distance to the CBD as a factor in the residential location decision of the household. A high correlation ($R^2 = 0.9$) was discovered between distance and time, rendering them equally reliable. Total sector employment and an index of sector accessibility (low numbers correspond to low accessibility) were included as factors in the determination of the supply of urban housing. Location to one's workplace did not appear to be a critical determinant in the demand for residential sites. It was however, concluded to be influential in the choice of dwelling type supplied. As accessibility increased, the supply of single family homes decreased while the supply of duplexes and multi-family housing increased. As sector employment rose, the supply of housing rose, except in areas where sector zoning allowed for the location of firms engaged in manufacturing.

Greenwood [1980] suggests that suburban growth may be due to increased housing supply and improved neighborhood amenities rather than increased employment opportunities. Three-stage least squares was used to analyze data for 62 U.S. SMSAs for the years 1960 and

1970, focusing on the locational interdependencies of housing, employment, and the urban labor force.

Cao [1980] uses two accessibility measures in his study of residential property values: road distance to place of work and proximity to local employment. Both are weighted by employment opportunities at the census tract level. These measures are derived from the assumption of a nonmonocentric structure within the city of Tucson, Arizona. The results suggest, ceteris paribus, that as distance to place of work increases, property value decreases, and as proximity to local employment increases, property values increase.

Most empirical studies conclude that land development is closely related to residential site desirability and residential property values. Close proximity to employment as a desirable factor in residential location is expected to be positively correlated with conversion of low intensity land. The strength of this relationship may decrease with rising income levels [Alonso, 1960] or transportation improvements. Increasing urban decentralization and the rise of urban subcenters may also lessen the importance of employment/shopping accessibility.

4. Institutional Factors

Zoning. Zoning is generally implemented to promote separation of incompatible uses, i.e. uses which impose external costs on the surrounding area. As such, zoning only indirectly controls external costs associated with, for example, water, air, or noise pollution. Lee [1979], using annexation data as a proxy, concluded that zoning was insignificant in the process of land conversion.

5. Summary

Several factors are thought to influence the conversion of land from rural to urban uses. High intensity land use surrounding a vacant parcel generally increases development pressure on the parcel. A high percentage of minorities in the population tends to decrease development pressure. Population increases logically have a positive impact on conversion. Accessibility to employment opportunities appears to positively influence residential location though transportation costs may be outweighed by positive benefits created by living away from employment centers. Zoning, a common land use planning tool, is thought to have little influence on land conversion.

CHAPTER 3

A CONTAGION THEORY OF LAND USE CONVERSION

Traditional land use theory models the land use mix surrounding an area of economic activity. Its focus is generally limited to the urbanized area and often it fails to account for the influence of existing infrastructure on further development. The assumed goal is typically profit maximization.

Land use may also be viewed from the goal of social welfare maximization, equating social benefits and costs at the margin rather than producer revenues and costs. Narrowing the focus to the rural-urban fringe, it can be shown how locational factors affect the conversion of land from low to high intensity uses.

Cory and Willis [1983] hypothesize that urban development is contagious in nature; undeveloped land in close proximity to an urbanized area is more likely to be developed than land farther from the urban fringe. Incorporation of this concept into traditional land allocation theory results in a modified optimal land use mix over a given time horizon. Contagion effects on land conversion in an urban fringe area of fixed size are first modeled in a static time frame and then in a two-period analysis, emphasizing dynamic implications.

A. Static Analysis

Efficient use of the urban fringe acreage requires the maximization of net benefits derived from various land uses over time. In this analysis the goal is maximization of net benefits derived from the allocation of urban fringe acreage among various land uses. For expository simplicity, high intensity land uses have been consolidated as "residential" and low intensity uses designated "agricultural".

$$(1) \quad \text{Max } NB_L = NB(L_R) + NB(L_A)$$

$$\text{s.t. } L_R + L_A = L$$

$$L_R , L_A \geq 0$$

where NB_L = net benefits generated by total land in the urban fringe area

NB_R = net benefits generated by land in residential use

NB_A = net benefits generated by land in agricultural use

L = total land area of the urban fringe

L_R = amount of land in residential use

L_A = amount of land in agricultural use

Based on the assumption of only two land uses: $L_A = L - L_R$

As suggested by traditional theory, marginal benefits derived from a given land use decrease as the supply of land devoted to that use increases. Thus marginal net benefits of agricultural (MNB_A) and residential (MNB_R) uses are decreasing functions of the acreage allotted to each use. Necessary conditions for a pareto-optimal. solution require that net benefits derived from each land use be equated on the margin. Assuming an interior solution with a single global maxima:

$$(2) \quad MNB_R(L_R) = MNB_A(L - L_R)$$

where MNB_R = marginal net benefits generated by land in residential uses

MNB_A = marginal net benefits generated by land in agricultural uses

1. The Effect of Contagion Externalities

As land surrounding a given tract is converted from low to high intensity uses, net benefits of conversion for the tract increase due to increased proximity to employment and commercial activities as well as lower public service provision costs. Thus net benefits are a function of location; changing over time as the urban area expands.

If contagion externalities are disregarded, marginal net benefits of conversion (MNB_R) are simply the distance between marginal benefits (MB_0) and marginal costs (MC_0) as shown in Figure 3.1. Marginal benefits and costs are assumed constant for each unit of land converted, resulting in a linear, downward sloping marginal net benefit curve. For example, if OL_1 acres of land are converted, marginal net benefits are simply the difference between MB_0 and MC_0 over that distance. Exclusion of contagion effects in essence assumes an instantaneous rate of conversion.

Assuming that conversion proceeds a few acres at a time, the derivation of marginal net benefits is altered. Contagion externalities in effect increase the marginal benefits from conversion of land proximate to the urbanized area. The increase in marginal net benefits causes an increase in demand for land at the urban fringe. Demand for fringe acreage in turn affects the adjacent acreage, creating larger marginal external demand impacts for land close to the urbanized area than for land further away. Marginal costs of conversion are assumed to remain constant for each unit of distance from the urbanized area. The reality of this assumption becomes an empirical issue depending, among other things, on excess public service and transportation capacity. In Figure 3.1 if OL_1

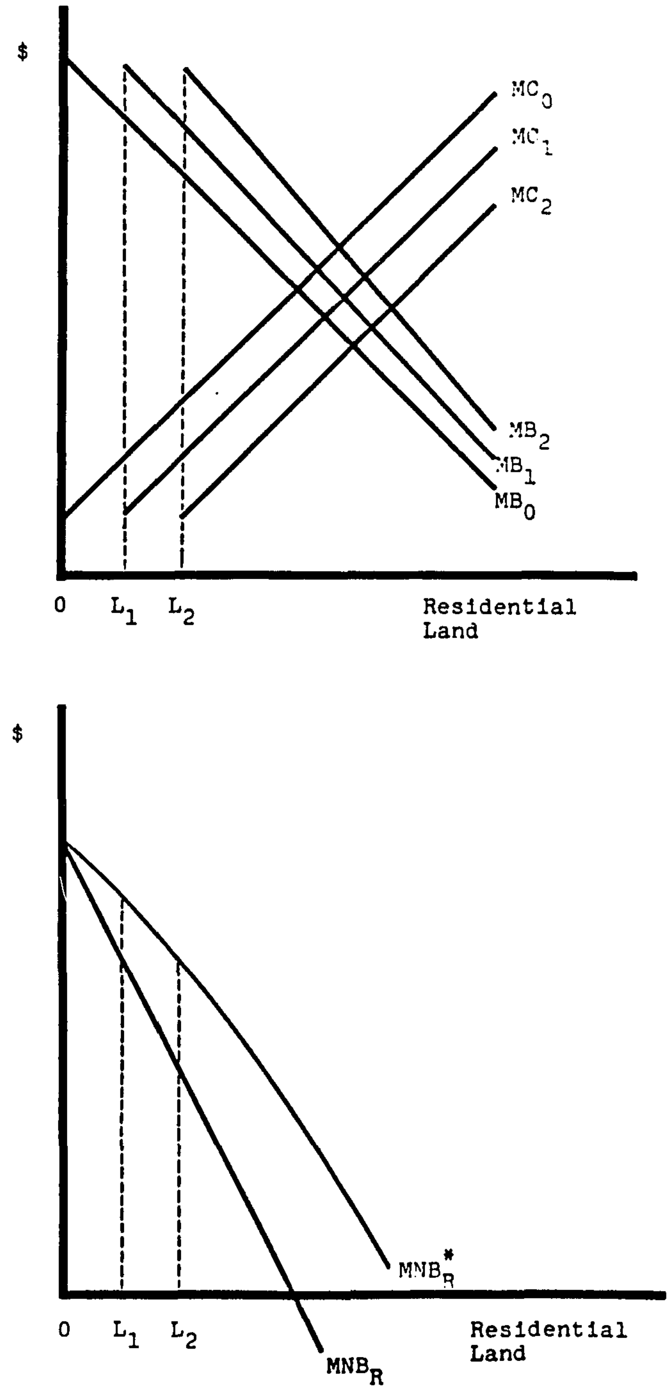

Figure 3.1. Derivation of MNB_R with Contagion Externalities.

(Source: Cory and Willis, 1983.)

acres of land are converted MNB_R^* is measured by the difference between MC_1 and MB_1. Conversion of L_1L_2 acres of land causes a shift to MC_2 and MB_2, illustrating the added benefits as proximity to the urbanized area increases. Rewriting (2) to include contagion effects:

$$(3) \quad MNB_R^*(L_i) = MNB_R(L_i) + MEB(L_i), \; i = 1,\ldots,L$$

$$(4) \quad MEB(L_i) = \sum_{j=1}^{i} [\, \delta jMB_R(L_i) + \delta jMC_R(L_i)]$$

where $\delta jMB_R(L_i) = MB_R^{\,j}(L_i) - MB_R^{\,j-1}(L_i)$

$\delta jMC_R(L_i) = MC_R^{\,j-1}(L_i) - MC_R^{\,j}(L_i)$

i = units of land (e.g. acres)

j = marginal units of i (e.g. square feet)

Thus marginal contagion external benefits (MEB) for each acre converted are simply the summation of the change in marginal benefits occuring as each unit of land from the first to the ith is converted plus the corresponding change in marginal costs of conversion. As defined, marginal benefits are assumed to decrease and marginal costs to increase with each additional unit of land converted.

Figure 3.2 illustrates the pareto-optimal land use mix for the static analysis. Land is measured along the horizontal axis with residential use increasing with

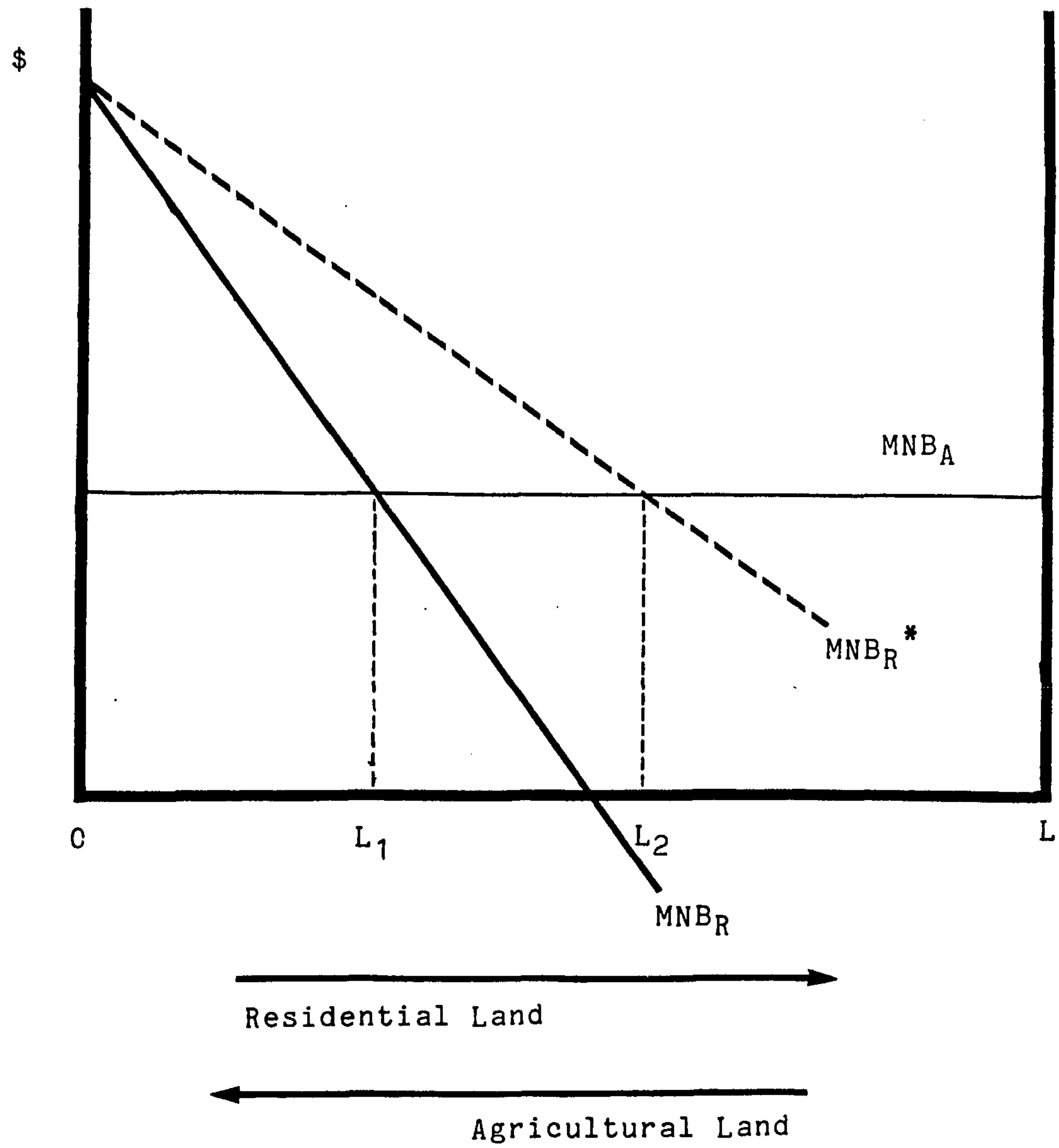

Figure 3.2. Policy Implications of Contagion Externalities.

(Source: Cory and Willis, 1983.)

movement to the right and agricultural use increasing with movement to the left. Net benefits of residential use are maximized at L_2, implying a maximization of net benefits of agricultural use at the same point. It is assumed that agricultural land has no speculative value. MNB_A is assumed constant for graphical simplicity.

2. Policy Implications

Left to itself, the competitive market system will allocate land uses by equating marginal net benefits of residential land plus marginal contagion external benefits with the marginal net benefits generated by land in agricultural use.

If contagion effects are not considered, policymakers will expect conversion to occur up to the point where $MNB_R = MNB_A$, dividing the fringe area into OL_1 acres of residential use and LL_1 acres of agricultural use. The competitive market, sensitive to contagion effects, will expand residential use to L_2. Failure to account for contagion effects leads to an underestimation of the amount of agricultural land which will be converted.

B. Two Period Analysis

Optimal intertemporal land use necessarily implies consideration of the irreversibility of high intensity land uses. Dynamic concepts are illustrated by viewing the land use mix over two periods, now (t_0) and the future (t_1). The pareto-optimal land use mix is derived by maximizing net benefits of each land use over the two periods.

$$(6) \quad \text{Max } NB_L = NB_R{}^0(L_R{}^0) + NB_R{}^1(L_R{}^1) + NB_A{}^0(L_A{}^0) + NB_A{}^1(L_A{}^1)$$

$$\text{s.t. } L_R{}^t + L_A{}^t = L$$

$$L_R{}^t, L_A{}^t \geq 0$$

The irreversibility constraint may by met by inspection in the two period analysis. The amount of land in agricultural use in the first period should be greater than or equal to the amount of land in agricultural use in the second period. Differentiation of the lagrange equation with respect to each land use defines the decision rule.

$$MNB_R{}^0 + MNB_R{}^1 - \lambda = 0 \quad \text{or} \quad MNB_R{}^0 + MNB_R{}^1 = \lambda$$

$$MNB_A{}^0 + MNB_A{}^1 - \lambda = 0 \quad \text{or} \quad MNB_A{}^0 + MNB_A{}^1 = \lambda$$

$$(7) \quad MNB_R{}^0 - MNB_A{}^0 = MNB_A{}^1 - MNB_R{}^1$$

where λ = the shadow price or additional marginal net benefit which would be gained if L were increased by one acre.

In Figure 3.3 optimal intertemporal allocation occurs at L^* or where the difference between marginal net benefits of land in residential and agricultural uses in the present (ab) is equal to the difference between marginal net benefits of the two uses in the future (cd). λ is the height of the line ab = cd, measuring the gain which would be realized if another acre of land were available for either residential or agricultural use.

The introduction of time alters the land allocation process because of the irreversible nature of high intensity land uses. If changes in land use were costless they could be made each period depending upon which land use was most valuable to society. L_0 acres of land could be used for residential purposes in t_0 then L_0L_1 acres converted back to agricultural use during the second period (t_1). Constraints on this type of change imply the existence of opportunity or user costs.

1. User Costs

Howe [1979] defines user costs as those costs incurred equal to the present value of foregone land use for each unit of land converted. In other words, each land use or service flow of land will yield some amount of new benefits (positive or negative) over a given time horizon. If one service flow is disrupted and replaced by another, e.g. agricultural land is converted to

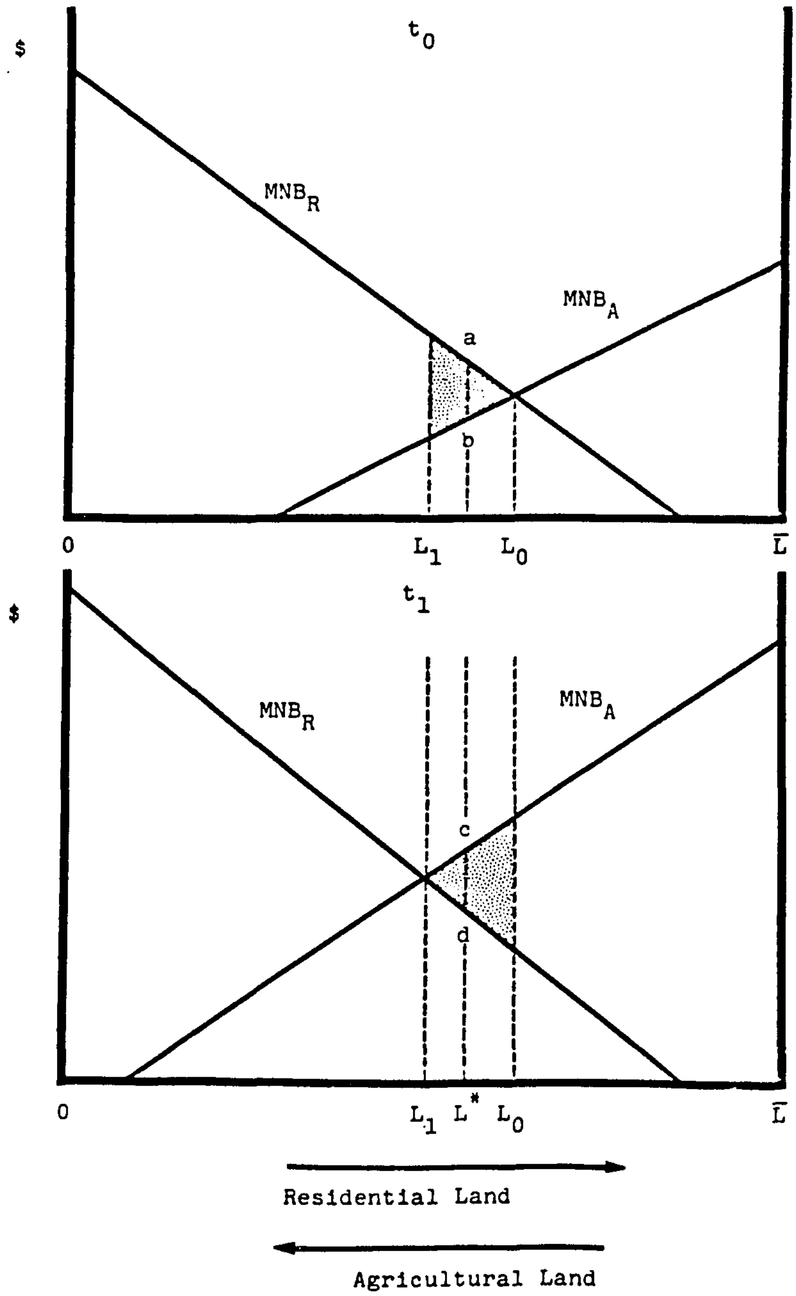

Figure 3.3. Optimal Intertemporal Land Use Mix.

residential, net benefits from the disrupted flow over the remainder of the time horizon are lost. This is the user cost. Net benefits gained are those from the new service flow. If net benefits generated by the new land use are less than the user cost, net benefits to society over time are decreased by changing the land use.

User costs will be incurred if the marginal net benefits generated by land in agricultural use (MNB_A) rise relative to marginal net benefits generated by land in residential use over the two period time horizon (Figure 3.3). Given MNB_R and MNB_A in t_0, net benefits to society will be maximized in the present period with OL_1 acres of residential land and LL_1 acres of agricultural land. However, in the second period land in agricultural use is valued higher than in the previous period and benefits to agriculture have risen relatively more than benefits to residential land. Optimal land allocation in t_1 is OL_0 acres of residential and LL_0 acres of agricultural. If the allocation of the first period is followed, a user cost is incurred equal to the shaded triangle in t_1. If residential land use were stopped at OL_0, there would be a foregone benefit which could have been realized during the first period. Optimal intertemporal allocation occurs where foregone benefits in t_0(ab) equal user costs in t_1 (cd).

2. The Effect of Contagion Externalities

As in the static analysis, net benefits of conversion for the tract increase due to increased proximity to the urbanized area. Maintaining the assumptions of the static analysis, conversion during t_0 provides benefits over both periods. Development provides net benefits during the first period; increased proximity to development provides net benefits during the second, even if no conversion takes place during the second period. Marginal net benefits of conversion in t_1 are therefore a function of the amount of development occurring during both periods. Rewriting (6) to include contagion effects:

$$(8)\quad \text{Max } NB_L = NB_R^0(L_R^0) + NB_R^1(L_R^0, L_R^1)$$

$$+ NB_A^0(L_A^0) + NB_A^1(L_A^1)$$

$$\text{s.t } L_R^t + L_A^t = L$$

$$L_R^t,\ L_A^t \geq 0$$

The resulting decision rule reflects the impact of contagion externalities.

$$MNB_R^0 + MNB_R^1 + MNB_R^1(L_R^0) - \lambda = 0$$

$$MNB_A^0 + MNB_A^1 - \lambda = 0$$

$$(9)\ MNB_R{}^0 - MNB_A{}^0 = MNB_R{}^1 - MNB_A{}^1 + MNB_R{}^1(L_R{}^0)$$

3. Policy Implications

Given an agricultural land preservation goal, a decision must be made concerning land use conversion over time. Figure 3.4 illustrates the effect of contagion externalities on the optimal intertemporal land use mix. If contagion externalities are ignored, planners will expect optimal urban expansion to occur at L^* (as in Figure 3.3). Inclusion of contagion effects in the decisionmaking process will result in a higher estimate of $MNB_R{}^1$ and an increase in high intensity development in both time periods. Optimal intertemporal allocation of land to high intensity uses occurs at L', where foregone benefits incurred in t_0 (a'b') equal the user costs incurred in t_1 (c'd'). Consideration of contagion externalities results in a higher rate of conversion (decreasing over time), reaching the allowable level of development sooner than would the conversion path followed if contagion externalities were ignored. Failure to recognize locational factors affecting land use may needlessly restrict urban expansion, forcing urban residents to bear unnecessary costs.

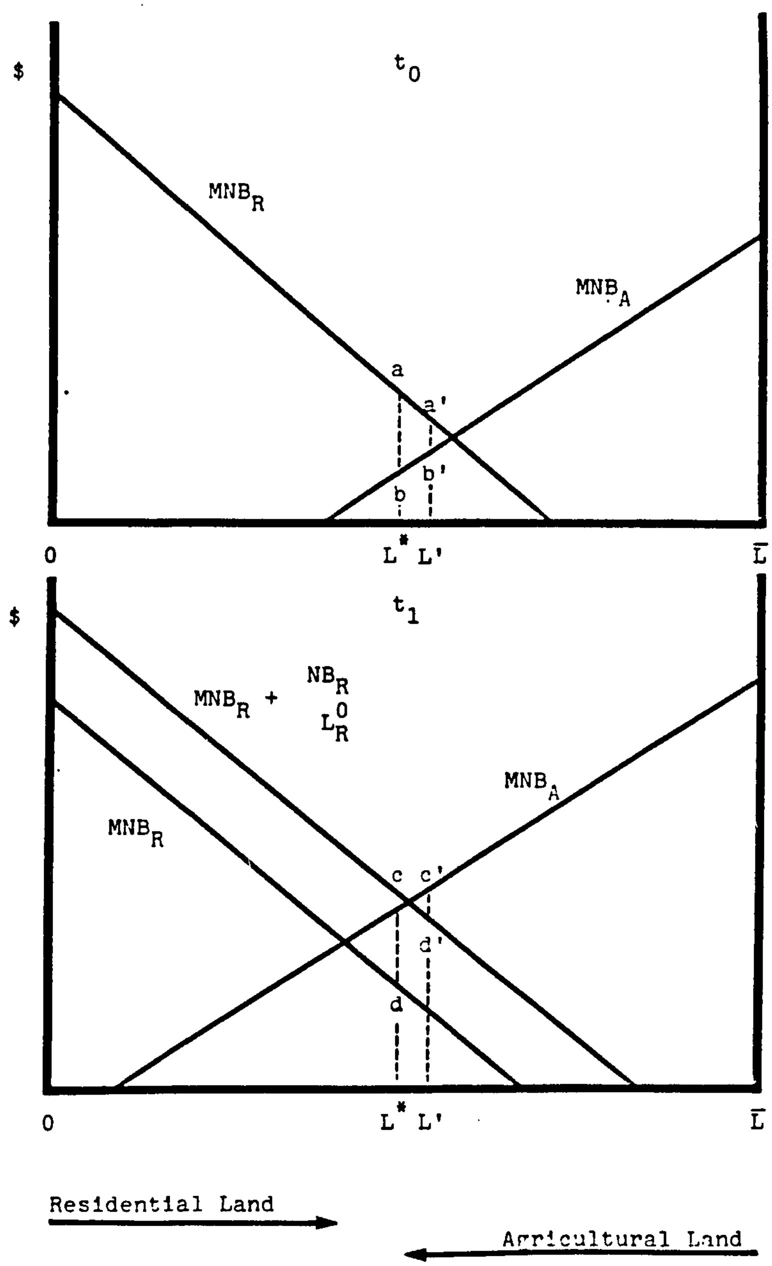

Figure 3.4. The Effect of Contagion Externalities on the Optimal Intertemporal Land Use Mix.

3. Conclusion

Economic theory suggests that conversion to high intensity use is more likely for low intensity land in close proximity to an urbanized area. It appears that a disproportionate amount of the land threatened is prime agricultural land. The optimal rate of development will not be achieved if contagion externalities are not taken into consideration.

CHAPTER 4

DATA MEASUREMENT AND CONVERSION TRENDS IN THE TMA: 1975/76-1980

A. Study Area

Like most other Southwestern cities, Tucson has been characterized by rapid growth and an almost continuous expansion of the urbanized area. Choice of a study area was based on growth in conjunction with the availability of reliable land use data.

The Tucson Metropolitan Area (TMA) as defined by the City of Tucson Planning Department constitutes the study area. The area is divided into 90 census tracts included in the 1980 census of population and housing. It stretches to Oro Valley at its northern end and includes Davis-Monthan Air Force Base in the south, covering 181,845 acres or approximately 284 square miles. East and west boundaries respectively are Saguaro National Monument East and Camino de Oeste. Figure 4.1 illustrates the study area.

B. Data Collection

Data were gathered at the census tract level. "Tracts were generally designed to be relatively uniform

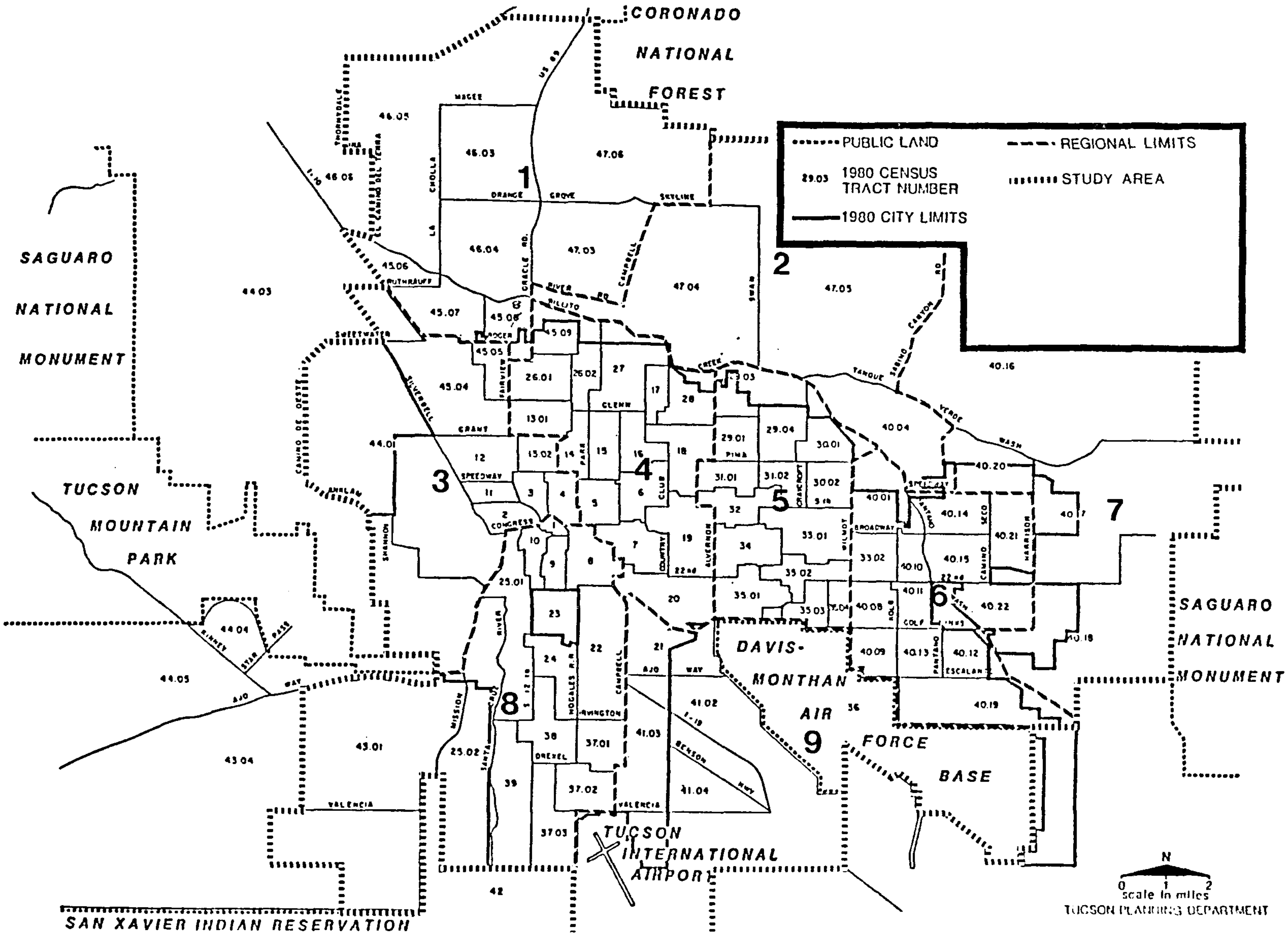

Figure 4.1. Tucson Metropolitan Area by Census Tract.

with respect to population characteristics, economic status, and living conditions. Tract boundaries are established with the intention of being maintained over a long time so that comparisons may be made from census to census" [U.S. Bureau of the Census, 1970]. This level of statistical reporting is used by both the U.S. Bureau of the Census and the City of Tucson Planning Department, greatly facilitating data collection. Primary census tract level data collected by these agencies involved more sophisticated measurement and statistical techniques than those available to the individual researcher, increasing confidence in data reliability.

With the exception of Davis-Monthan Air Force Base, tracts in excess of 5,000 acres were divided into two or more split tracts, providing a more accurate reflection of land use trends. Division lines were determined by city or urban boundaries, or by major streets.

1. Physical Data

Physical land use data were gathered from acreage estimates and land use maps available from the City of Tucson Planning Department. Aerial photos and ground surveys provided the basis for these estimates. High intensity land uses documented in 1976 and 1980 surveys were combined to form these seven generalized land use categories:

Residential -- acreage devoted to suburban ranch, single family, multiple family, or mobile home uses

Commercial -- retail and service establishments, private clubs, nursery schools, office complexes, and shopping centers

Industrial -- both structural and nonstructural including industrial and manufacturing firms, industrial parks, outdoor storage, salvage operations, and construction yards

Institutional -- hospitals, churches, public and private schools, multipurpose centers, dormitory style housing, government owned buildings and storage yards, landfills, and military property

Transportation, Communication, and Utilities (TCU) -- utility administration buildings and infrastructure, radio and television stations, railroad rights of way, sewage treatment plants, irrigation ponds, pay parking lots, airports

Streets, Medians, and Alleys (Streets) -- excludes private access roads servicing only one residence

Drainageways, Washes, and Riverbeds (Drainage) -- waterways, flood-prone areas, ponds not used for irrigation

The High Intensity variable is a summation of the categories listed above. High intensity land uses are assumed to be either physically or economically irreversible. Low intensity land uses such as vacant, recreational, or agricultural are not documented, but can be derived by subtracting high intensity uses from total acreage.

a. Whole Tracts. Physical land use data in acres were reported at the census tract level by the City of Tucson Planning Department. Both 1976 and 1980 data were available at this level.

b. Split Tracts. Acreage devoted to various land uses was reported at the census block level in 1980. Census blocks are small sections of census tracts, generally bounded by streets, roads, railroad tracks, streams, or other features [U.S. Bureau of the Census, 1970].

Land use data for 1976 at the census block level was unavailable. Split tract acerage was estimated by the planimeter method, using a grid screen and counting the number of full and partial cells. Each grid or cell was equal to 10 acres on the 1976 land use map. Three measurements were made for each land use in each split tract. Since total acres in each land use for each whole census tract were known from reported data, average measurements were used as proportional rather than absolute estimates of acreages. Average acres in each land use were summed across the split portions of each census tract. The percent acreage in each land use in each split tract was calculated as follows:

$$\text{Percent Acreage}_{ij} = \frac{\text{Average Acreage}_{ij}}{\sum_{j=1}^{k} \text{Average Acreage}_{ij}}$$

where i = land use

j = split portions of a single census tract

This percentage was multiplied by total acreage in land use i for the entire census tract, giving an estimate of the number of acres in split portion j being used for land use i.

$$\text{Acres}_{ij} = (\text{Percent Acreage}_{ij})(\text{Total Acres}_{i})$$

Five of the census tracts on the fringe of the TMA are quite large (>20,000 acres), extending to the borders of Pima County. These tracts were split with only the urbanized portions included in the study area. Acres in each 1976 land use category were estimated by comparing 1976 and 1980 land use maps. Changes in land use were measured using the planimeter method and subracted from existing 1980 land use data.

Land use was also documented for 1973-1976, the period preceeding that under study. 1973 land use data was collected by square miles rather than census tracts, making reliable comparisons virtually impossible. Land use maps summarizing the 1973 and 1976 Tucson Planning Department studies were compared. Changes in high intensity land use were measured by the planimeter method and subtracted from high intensity acreage in 1976. The scale of the 1973 map was too large to reliably measure changes in any individual land use.

c. Physical Data Reliability. 1976 and 1980 land use data are not necessarily comparable due to different measurement techniques and changes in land use category definitions. In 1976, residential land outside of the city limits designated as suburban ranch was measured along property rather than use lines. In 1980 the designation only included single houses or mobile homes actually involving four or more acres in residential use. No land within the city limits was designated as suburban ranch in 1980. As a result of this change, residential acreage in 1976 may be overstated. An attempt was made to correct for this by multiplying the number of dwellings in 1975 by the average number of acres/dwelling in 1980 for tracts outside the city limits. Both adjusted and unadjusted residential acreages were tested in the model.[1]

Total acres in each tract differ from 1976 to 1980. All 1976 land use acreages were converted to 1980 base.[2]

$$\text{Adjusted Acres}_{ij76} = \frac{\text{Acres}_{ij76}}{\text{Total Acres}_{i76}} \text{ Total Acres}_{i80}$$

where $i = 1, \ldots, 108$ whole and split census tracts

j = land use

In 1976 school playing fields were defined as parks and included in that land use category. In 1980 the playing fields were considered part of the schools and added to the institutional category. This definitional difference was adjusted by comparing 1976 and 1980 land use maps. Parcels of land adjacent to schools, yet categorized as parks in 1976 were measured by the planimeter method and added to the institutional sector.

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1. Unadjusted residential acreage was found to provide the best estimate in the regression model.

2. City planners consider 1980 figures for total acres to be more accurate.

2. Socio-demographic Data

Socio-demographic variables are proportion of the population considered ethnic minorities and house value. Data were gathered from U.S. census reports for 1970 and 1980 and from the City of Tucson Planning Department for 1975. It is assumed that socio-economic data collected in 1975 is fairly compatible with physical data collected in 1976.

Data for minorities was available at the census block level for all three years. Hispanic, Black, and American Indian populations were summed to form the minority variable. Other ethnic groups were too small to be significant.

House value, the median value of single family housing as reported by owners, was gathered at the census tract level for each of the three years. Without access to every observation reported, it was impossible to measure separate median house values for each split portion of a census tract. Where a tract split along city boundaries, house values do vary as recorded by the census bureau.

3. Employment Accessibility

Accessibility to employment involves two separate measurements; distance between the geographic center of each whole or split census tract and percent employment within each tract. Unlike most older urban areas, the TMA has no dominant employment center or central business district (CBD). Cao [1981] developed a measure which essentially assumes the existence of an employment center in each census tract. The measure weights the distance between tracts by the percent employment in each tract.

$$A_i = \sum_{j=1}^{108} d_{ij} \frac{e_j}{E} \quad , i = 1,\ldots,108$$

where d_{ij} = distance from tract i (origin) to tract j (destination)

e_j = employment in tract j

E = total TMA employment

Greene [1980] designates "zones of concentration" rather than assuming each tract is an employment center. He defines a zone of concentration as "any zone [census tract] containing more than twice the employment it would have had if all zones contained equal levels of employment." Eleven census tracts were designated as zones of concentration, based on 1975/76 estimated employment. All other tracts were considered to provide no employment opportunities.

Distances between tracts were measured with a digitizer. Measurements were made from a 1982 street map of the TMA as a scale of 1:42500. Employment data was available from Pima Association of Governments, Transportation Planning Department for the years 1973, and 1980. Data for 1975/76 was linearly estimated. Data were gathered by Transportation Analysis Zones (TAZs) rather than census tracts. Conversion from TAZs to census tracts was accomplished by comparing TAZ and land use maps, estimating the proportion of employment in each census tract when TAZ and census tract boundaries diverged.

4. Institutional Data

Zoning. Zoning data was gathered from city of Tucson zoning plats and recorded information on zoning changes. Acreage in each zoning category in 1973 was available for the city of Tucson in 1970 census tracts. This information was used for those tracts within the city whose boundaries were unchanged from 1970 to 1980. Zoning information concerning tracts which were changed or not included in the 1973 city of Tucson study was estimated from current zoning plats. Acreages and dates of zoning changes occuring subsequent to 1973 were noted on the plats. General land uses (e.g. residential, commercial, industrial) were measured with a digitizer. The average of three measurements was recorded as the acreage in each general zoning category in each full or partial census tract. Acreage was estimated for each year between 1973 and 1980.

5. Conversion

The change in high intensity acreage (HIGH) occuring during the study period was measured as a percent of developable acreage at the beginning of the period. Developable acreage is simply total acres (TOTAL) within a tract less acres already in a high intensity use. This measure was used rather than total acreage as it is thought to more accurately reflect land use changes. Conversion of a few acres of land may be a small proportion of the total land area in a tract, yet a large proportion of the land within the tract which is available to be developed.

$$\% \ HIGH_{76-80} = \frac{HIGH_{80} - HIGH_{76}}{TOTAL_{80} - HIGH_{76}}$$

C. Trends

1. Tucson Metropolitan Area

The Tucson Metropolitan Area as defined earlier consists of a total of 181,845 acres. High intensity land uses covered 51.8% of the area in 1980. One-quarter of the area was being used for residential purposes, 2.8% for commercial, 1.2% for industrial, 8.3% for institutional, 2.1% for TCU, 9.0% for streets, and 2.7% for drainage purposes. With the exception of institutional, all categories increased during the study period. The slight decline in land devoted to institutional use may be due to category definition changes or the transfer of use to other sectors. 6552 acres or 7.0% of the developable land area in 1976 was converted to high intensity use between 1976 and 1980, an average of 1638 acres per year. Most development occurred in the northern fringe or foothills area and in the central metropolitan area. Approximately 50% of the developed acres lie north of the Rillito River.

Population within the TMA grew at an average of 4.0% per year from 1970 to 1980. In comparison, average annual population increase for the nation during the same period was 1.2%, and for Arizona, 5.3%. Population in the TMA grew faster (4.8% per year) during the first half of the decade than the last (2.1% per year). Population density rose from 1.8 to 2.5 persons per acre. The proportion of minorities increased slightly from 25% of total 1975 population to 27% in 1980.

Employment in the TMA rose from 131,921 workers employed in 1973 (approximately 35.4% of the population), to 166,364 in 1980 (36.4% of the population).

2. Regional Trends

In order to more clearly illustrate development trends within the TMA, nine regions have been defined based on (1) percent conversion of developable land from low to high intensity uses, and (2) neighborhood characteristics. Figure 4.1 illustrates converted census tracts and regional divisions. The major portion of developable land converted during the study period lies within regions 1, 2, 4, 5, and 6, roughly the northeastern half of the city.

a. High Development Regions. Region 4 (Table 4.1), West-central Tucson, includes areas surrounding the University of Arizona and El Con Mall. This region showed the largest proportion of developable land converted at 18.1%. Actual acreage converted was 427.8, ranking seventh out of the nine regions. Residential acreage increased slightly, from 47.1% to 48.6% of the region. A dramatic decrease in industrial acreage and corresponding increase in TCU acreage appears to be due to a definitional rather than actual land use change. Industrial use decreased 175 acres while TCU use increased by 184 acres. In 1980, region 4 housed 86,850 persons, 19% of total TMA population. Population increase in the region was slight, approximately 0.75% per year over the ten year period from 1970 to 1980. Population density was

TABLE 4.1. Physical and Socio-demographic Trends: Region 4, 1975/76-1980

PHYSICAL Total Acres = 12623.6

	Residential		Commercial		Industrial		Institutional		TCU		Streets & Drainage	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
1975/76	5944.1	47.1	939.4	7.4	344.1	2.7	733.6	5.8	132.1	1.0	2169.1	17.2
1980	6129.4	48.6	1074.3	8.5	168.8	1.3	821.5	6.5	316.0	2.5	2180.2	17.3
Net Change 1975/76-1980	185.3	3.1	134.9	14.4	-175.3	-50.9	87.9	12.0	183.9	139.2	11.1	0.5

SOCIO-DEMOGRAPHIC

	High Intensity		Developable		Population		Minorities		Employment*		Population
	acres	%	acres	%	#	%	#	%	#	%	Density
1975/76	10262.4	81.3	2361.2	18.7	82901	20.5	14397	17.4	38519	26.4	6.6
1980	10690.2	84.7	1933.4	15.3	86850	18.5	16488	19.0	41220	24.7	6.9
Net Change 1975/76-1980	427.8	4.2	-427.8	-18.1	3949	4.8	2091	14.5	2701	7.0	0.3
Net Change /Year 1975/76-1980	-	-	-	-	790	1.0	418	2.9	540	1.4	-

* Linear estimate

the highest in the TMA, increasing from 6.6 to 6.9 persons per acre over the study period. Growth rate of the minority population was 3.9%, over five times that of the regional population as a whole. Minorities rose from 14.7% of the population in 1970 to 19% in 1980.

Region 1 (Table 4.2) covers the northwestern corner of the TMA, in close proximity to the Catalina Mountains. Most development in this area is fairly new. Of 15,232 developable acres in region 1 in 1976, 17.0% or 2591 acres were converted. This was the highest number of acres developed within a single region, accounting for 40% of the total acres developed within the TMA between 1976 and 1980. Residential acreage increased by 1567 acres or 6.1% of the total land area in the region. Increases occurred in all high intensity land use categories.

Population density within region 1 increased slightly over the study period, from 1.3 persons per acre in 1976 to 1.5 persons per acre in 1980. Average annual population increase during the preceeding period (1970-80) was 9.4%, well above the average TMA rate of 4.0%. Minority percentage remained fairly constant, increasing by only 0.5% during the decade. In 1980, 11.0% of the population of region 1 were classified as minorities.

b. Intermediate Development Regions. Region 5 (Table 4.3) is bounded by the Rillito River to the north

TABLE 4.2. Physical and Socio-demographic Trends: Region 1, 1975/76-1980

PHYSICAL Total Acres = 25905.5

	Residential		Commercial		Industrial		Institutional		TCU		Streets & Drainage	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
1975/76	7829.6	30.2	279.0	1.1	90.4	0.4	256.0	1.0	25.4	0.1	1221.7	4.7
1980	9396.2	36.3	389.4	1.5	101.6	0.4	319.2	1.2	57.7	0.2	2028.8	7.8
Net Change 1975/76-1980	1566.6	20.0	110.4	39.6	11.2	12.4	63.2	24.7	32.3	127.0	807.1	66.1

SOCIO-DEMOGRAPHIC

	High Intensity		Developable		Population		Minorities		Employment*		Population Density
	acres	%	acres	%	#	%	#	%	#	%	
1975/76	10673.5	41.2	15232.0	58.8	33743	8.4	2727	8.0	4210	2.9	1.3
1980	13264.3	51.2	12641.2	48.8	51273	11.0	4385	11.0	6131	3.7	1.5
Net Change 1975/76-1980	2590.8	24.3	-2590.8	-17.0	17530	52.0	1658	60.8	1921	45.6	0.2
Net Change /Year 1975/76-1980	-	-	-	-	3506	10.4	332	12.2	384	9.1	-

* Linear estimate

TABLE 4.3. Physical and Socio-demographic Trends: Region 5, 1975/76-1980

PHYSICAL Total Acres = 9935.6

	Residential		Commercial		Industrial		Institutional		TCU		Streets & Drainage	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
1975/76	4763.3	47.9	880.8	8.9	9.1	0.09	414.7	4.2	25.0	0.3	1948.7	19.6
1980	4958.4	49.9	1001.5	10.1	9.9	0.1	444.6	4.5	24.0	0.2	1784.9	18.0
Net Change 1975/76-1980	195.1	4.1	120.7	13.7	0.8	8.8	29.9	7.2	-1.0	4.0	-163.8	-8.4

SOCIO-DEMOGRAPHIC

	High Intensity		Developable		Population		Minorities		Employment*		Population Density
	acres	%	acres	%	#	%	#	%	#	%	
1975/76	8041.6	80.9	1894.0	19.1	62049	15.4	7866	12.7	18541	12.7	6.2
1980	8223.3	82.8	1712.3	17.2	65668	14.0	9421	14.7	24533	14.7	6.6
Net Change 1975/76-1980	181.7	2.3	-181.7	-9.6	3619	5.8	1555	19.8	5992	32.3	0.4
Net Change /Year 1975/76-1980	-	-	-	-	724	1.2	311	4.0	1198	6.5	-

* Linear estimate

and Davis-Monthan Air Force Base to the south. It includes Park Mall and the Tucson Medical Center. Like region 4, region 5 shows a fairly high percentage of developable land converted (9.6%) and a small number of acres converted (182). It is the smallest of the regions, consisting of only 9935 acres. Approximately half of the land within the region is devoted to residential uses. Residential, commercial, and institutional uses increased somewhat; industrial and TCU acreages remained fairly constant. Acreage in streets decreased, due either to conversion to other uses to measurement technique changes. High intensity acres increased 2.0% during the study period, from 81% in 1970 to 83% in 1980.

Population in region 5 decreased from 1970 to 1975 then increased from 1975 to 1980. Average annual population growth rate for the decade was 0.2% per year. Population density was 6.6 persons per acre in 1980, slightly lower than that of region 4. Percentage minority increased from 12.1% in 1970 to 14.7% in 1980.

Pantano Wash cuts through the center of region 6 (Table 4.4). The area contains two golf courses and several smaller parks. 8.7% of the developable land in region 6 was converted to high intensity use between 1976 and 1980. High intensity acreage increased by 542 acres, accounting for 60% of the region in 1980. Acreage devoted

TABLE 4.4. Physical and Socio-demographic Trends: Region 6, 1975/76-1980

PHYSICAL Total Acres = 14201.7

	Residential acres	Residential %	Commercial acres	Commercial %	Industrial acres	Industrial %	Institutional acres	Institutional %	TCU acres	TCU %	Streets & Drainage acres	Streets & Drainage %
1975/76	4552.1	32.1	376.7	2.7	8.5	0.06	592.2	4.2	66.0	0.5	2385.7	16.8
1980	4880.2	34.4	611.4	4.3	30.8	0.2	641.3	4.5	42.0	0.3	2317.5	16.3
Net Change 1975/76-1980	328.1	7.2	234.7	62.3	22.3	262.4	49.1	8.3	-24.0	-36.4	-68.2	-2.9

SOCIO-DEMOGRAPHIC

	High Intensity acres	High Intensity %	Developable acres	Developable %	Population #	Population %	Minorities #	Minorities %	Employment* #	Employment* %	Population Density
1975/76	7891.2	56.2	6220.5	43.8	66482	16.5	7408	11.1	9813	6.7	4.7
1980	8523.2	60.0	5678.5	40.0	70756	15.1	8181	11.6	11120	6.7	5.0
Net Change 1975/76-1980	542.0	6.8	-542.0	-8.7	4274	6.4	773	10.4	1307	13.3	0.3
Net Change /Year 1975/76-1980	-	-	-	-	855	1.3	155	2.1	261	2.7	-

* Linear estimate

to streets and TCU decreased while all other land use categories increased. 34% of the region is in residential use.

The population of region 6 grew rapidly (10.1% per year) between 1970 and 1975, slowing to 1.3% per year between 1975 and 1980. The combined average growth rate for the decade was 6.0% per year, above the average TMA rate. Average growth rate of the minority population was somewhat higher at 8.5% per year.

Region 2 (Table 4.5) is located in the foothills of the Catalina Mountains, bounded by Coronado National Forest on its northern edge. Though region 2 ranked fifth in proportion of developable land converted at 7.7%, actual acreage converted was 1099, the second highest in the TMA. Changes in land devoted to high intensity uses was mixed. Acreage used for residential, industrial, institutional, and streets purposes increased. Commercial and TCU acres decreased.

Population in this fringe area increased by an average of 14% per year between 1970 and 1980, 11.8% per year during the 1975 to 1980 study period. Minority percentage remained fairly constant throughout the decade at approximately 6.0%.

Region 3 (Table 4.6) includes older neighborhoods west and north of the downtown area as well as newer

TABLE 4.5. Physical and Socio-demographic Trends: Region 2, 1975/76-1980

PHYSICAL   Total Acres = 20569.1

	Residential acres	Residential %	Commercial acres	Commercial %	Industrial acres	Industrial %	Institutional acres	Institutional %	TCU acres	TCU %	Streets & Drainage acres	Streets & Drainage %
1975/76	4520.5	22.0	291.6	1.4	0	0	68.4	0.3	7.9	0.04	1489.5	7.2
1980	5187.3	25.2	248.2	1.2	2.5	0.01	83.3	0.4	4.8	0.02	1950.3	9.5
Net Change 1975/76-1980	666.8	14.8	-43.4	-14.9	2.5	-	14.9	21.8	-3.1	-39.2	460.8	30.9

SOCIO-DEMOGRAPHIC

	High Intensity acres	High Intensity %	Developable acres	Developable %	Population #	Population %	Minorities #	Minorities %	Employment* #	Employment* %	Population Density
1975/76	6377.9	31.0	14191.2	69.0	12431	3.1	566	4.6	2347	1.6	0.4
1980	7476.4	36.3	13092.7	63.7	19755	4.2	1181	6.0	3083	1.9	1.0
Net Change 1975/76-1980	1098.5	17.2	-1098.5	-7.7	7324	58.9	615	108.7	736	31.4	0.6
Net Change /Year 1975/76-1980	-	-	-	-	1465	11.8	123	21.7	147	6.3	-

* Linear estimate

TABLE 4.6. Physical and Socio-demographic Trends: Region 3, 1975/76-1980

PHYSICAL	Total Acres = 16569.4											
	Residential		Commercial		Industrial		Institutional		TCU		Streets & Drainage	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
1975/76	2786.1	16.8	410.5	2.5	382.0	2.3	432.0	2.6	170.2	1.0	2084.8	12.6
1980	2912.9	17.6	573.1	3.5	482.2	2.9	460.1	2.8	281.9	1.7	2123.2	12.8
Net Change 1975/76-1980	126.8	4.6	162.6	39.6	100.2	26.2	28.1	6.5	111.7	65.6	567.8	27.2

SOCIO-DEMOGRAPHIC

	High Intensity		Developable		Population		Minorities		Employment*		Population Density
	acres	%	acres	%	#	%	#	%	#	%	
1975/76	6265.6	37.8	10303.8	62.2	33567	8.3	15075	44.9	17220	11.8	2.0
1980	6833.4	41.2	9736.0	58.8	36754	7.8	17871	48.6	18671	11.2	2.2
Net Change 1975/76-1980	567.8	9.1	-567.8	-5.5	3187	9.5	2796	18.5	1451	8.4	0.2
Net Change /Year 1975/76-1980	-	-	-	-	637	1.9	559	3.7	290	1.7	-

* Linear estimate

developments near Tucson Mountain Park. 41.2% of the land area was in high intensity uses in 1980. Residential land accounted for 17.6% of the total regional acreage.

Population increase within the region was lower than growth rate of the TMA, averaging 2.5% per year between 1970 and 1980. Proportion of minorities remained fairly constant throughout the decade at just under 50% of the total population.

c. Low Development Regions. Davis-Monthan Air Force Base and Tucson International Airport dominate region 9 (Table 4.7). Of 29,677 total acres, 61.1% were devoted to high intensity uses in 1980. 484 acres were converted between 1976 and 1980, 4.0% of the acreage available for development at the beginning of the period. Residential acreage accounted for only 3.9% of the total in 1980. Institutional acreage was highest due to the inclusion of land belonging to Davis-Monthan Air Force Base. 38.9% of the total regional area was in the institutional category in 1980. Decreases in residential and institutional acreages appear to reflect changes in land use on the Air Force base. All other land use categories increased during the period.

Population increased at approximately twice the average TMA growth rate. Average annual population increase during the decade from 1970 to 1980 was 8.1%.

TABLE 4.7. Physical and Socio-demographic Trends: Region 9, 1975/76-1980

PHYSICAL Total Acres = 29676.6

	Residential		Commercial		Industrial		Institutional		TCU		Streets & Drainage	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
1975/76	1219.7	4.1	260.3	8.8	503.9	1.7	11874.7	40.0	2584.4	8.7	1213.1	4.1
1980	1143.6	3.9	259.9	8.8	910.2	3.1	11545.0	38.9	2654.1	8.9	1627.4	5.5
Net Change 1975/76-1980	-76.1	-6.2	0.4	0	406.3	80.6	-329.7	-2.8	69.7	2.7	414.3	40.4

SOCIO-DEMOGRAPHIC

	High Intensity acres	%	Developable acres	%	Population #	%	Minorities #	%	Employment* #	%	Population Density
1975/76	17656.1	59.5	12020.5	40.5	21960	5.4	7189	32.7	26300	17.9	0.7
1980	18140.2	61.1	11536.4	38.9	27467	5.9	10082	36.7	29840	17.9	0.9
Net Change 1975/76-1980	484.1	2.7	-484.1	-4.0	5507	25.1	2893	40.2	3540	13.5	0.2
Net Change /Year 1975/76-1980	-	-	-	-	1101	5.0	579	8.0	708	2.7	-

* Linear estimate

Proportion of minorities within the region was fairly high, 32.7% in 1975. Region 9 provided 29,840 jobs in 1980, about 18% of total TMA employment.

The older neighborhoods south of and including the downtown area house the majority of the population of region 8 (Table 4.8). The region also includes the Santa Cruz River area and scattered developments in the southwestern corner of the TMA, both dominated by mobile home residences. Total acres in region 8 devoted to high intensity uses increased by 460 (2.0% of regional land area) between 1976 and 1980, 3.5% of the acreage available for development in 1976. 22.7% of the region was in residential use. All land use categories increased during the study period.

Population living within the region was quite high (78,930 persons in 1980), though the average annual rate of increase (3.5%) was less than that for the TMA as a whole. Minority population was quite large, 63.5% of the total in 1975. This was the largest proportion of minorities in the TMA.

Forming the eastern boundary of the TMA, region 7 (Table 4.9) is characterized by scattered development, primarily parks and single family homes. Region 7 is the second largest region with 28,328 acres. Only 1.1% or 199 of the 18,828 acres available for development were

TABLE 4.8. Physical and Socio-demographic Trends: Region 8, 1975/76-1980

PHYSICAL Total Acres = 24036.3

	Residential		Commercial		Industrial		Institutional		TCU		Streets & Drainage	
	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
1975/76	5341.9	22.2	674.2	2.8	453.1	1.9	598.6	2.5	330.4	1.4	3423.2	14.2
1980	5460.9	22.7	743.2	3.1	499.8	2.1	654.9	2.7	363.1	1.5	3559.5	14.8
Net Change 1976-1980	119.0	2.2	69.0	10.2	46.7	10.3	56.3	9.4	32.7	9.9	136.3	4.0

SOCIO-DEMOGRAPHIC

	High Intensity		Developable		Population		Minorities		Employment*		Population
	acres	%	acres	%	#	%	#	%	#	%	Density
1975/76	10821.4	45.0	13214.9	55.0	69502	17.2	44108	63.5	27972	19.1	2.9
1980	11281.4	46.9	12754.9	53.1	78930	16.9	49531	62.8	29542	17.7	3.3
Net Change 1975/76-1980	460.0	4.3	-460.0	-3.5	9428	13.6	5423	12.3	1570	5.6	0.4
Net Change /Year 1975/76-1980	-	-	-	-	1886	2.7	1085	2.5	314	1.1	-

* Linear estimate

TABLE 4.9. Physical and Socio-demographic Trends: Region 7, 1975/76-1980

PHYSICAL Total Acres = 28246.9

	Residential acres	Residential %	Commercial acres	Commercial %	Industrial acres	Industrial %	Institutional acres	Institutional %	TCU acres	TCU %	Streets & Drainage acres	Streets & Drainage %
1975/76	6200.0	21.9	314.2	1.1	0	0	374.3	1.3	29.9	0.1	2500.1	8.9
1980	6467.1	23.8	157.6	0.6	1.8	0	189.0	0.7	26.6	0.09	2775.3	9.8
Net Change 1975/76-1980	267.1	4.3	-156.6	-49.8	-	-	-185.3	-49.5	-3.3	-11.0	275.2	11.0

SOCIO-DEMOGRAPHIC

	High Intensity acres	High Intensity %	Developable acres	Developable %	Population #	Population %	Minorities #	Minorities %	Employment* #	Employment* %	Population Density
1975/76	9499.3	33.6	18747.6	66.4	20948	5.2	1795	8.6	1188	0.8	0.7
1980	9698.2	34.3	18548.7	65.7	30757	6.6	2602	8.5	2410	1.4	1.1
Net Change 1975/76-1980	198.9	2.1	-198.9	-1.1	9809	46.8	807	45.0	1222	102.9	0.4
Net Change /Year 1975/76-1980	-	-	-	-	1962	9.4	161	9.0	244	20.6	-

* Linear estimate

converted during the study period, the lowest in the TMA. Decreases were seen in three land use categories: commercial, institutional, and TCU. Acreage devoted to residential use and streets increased. Residential use covered 23.8% of the region in 1980. Region 7 has the largest number of drainage acres (1064), 3.8% of its total land area.

Although very little acreage appears to have been developed during the study period, approximately 14.4% of the 1973 developable land area in region 7 was converted between 1973 and 1976, an average conversion rate of 1360 acres per year. This region was especially vulnerable to measurement error with over 50% of the residential acreage in 1976 classified as suburban ranch.

CHAPTER FIVE

RESULTS OF THE EMPIRICAL ANALYSIS

A. Introduction

Over any given period of time a vacant parcel of land may undergo structural change. The percentage of area converted within the parcel may be designated as "high" or "low". Though many intermediate stages may be defined, this dicotomy most accurately reflects data reliability and is simplest to model. Establishment of the relationship between probability of conversion and various physical, socio-demographic, and institutional factors is the purpose of this analysis.

This chapter first looks at the estimation procedure used. Section B describes each of the independent variables and their influence on land conversion during the study period. Two separate models are discussed. The first analyzes observations of physical land uses, socio-demographic characteristics, and employment accessibility for the entire metropolitan area. The second looks only at the influence of residential zoning on land conversion. Table 5.1 presents the statistical results of the empirical study. Section C summarizes the empirical findings, concluding with a discussion of policy implications.

The Model

Choice of a statistical model was based on (1) research goals, (2) compatability with available data, and (3) simplicity. Probit, a model of binary, qualitative choice was chosen.[1] Much of the data used is subject to human error (e.g. measurement of aerial photographs or individual reporting of census information). Data is reliable if compared in a relative rather than absolute sense. Data was tested qualitatively, answering "did the hypothesized variables significantly influence conversion?" rather than "how much influence did the hypothesized variables have on conversion?"

As discussed in chapter 4, the percent change in developable acres during the study period was the dependent variable. It was not known a priori how much change in developable acreage constituted "high" conversion. In order to determine this "critical" value,

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1. Probit was chosen rather than logit because there is no indication that the independent variables are not normally distributed. Amemiya [1981] finds no statistical difference between the two models unless using an extremely large number of observations or data which is obviously concentrated in the tails. For a more detailed explanation of the probit model see Pindyck and Rubinfeld [1981], pp 280-87.

observations were ranked from highest percent change to lowest. The top one-third[2] observations were considered to have undergone "high" conversion during the study period and were given a dependent variable value of 1. All other dependent variables took on a 0 value. The resulting critical value was 0.18, i.e., developable acreage in 33% of the observations had decreased by 18% or more during the study period. Thus, if

$$\begin{matrix} Z_i \geq Z^* \text{ then } Y_i = 1 \\ Z_i < Z^* \text{ then } Y_i = 0 \end{matrix} \quad , \ i = 1,\ldots,108$$

where Z^* = critical value

Z_i = observed percent change in developable acres

Y_i = dependent variable value

B. Factors Affecting Urban Development

1. Contagion Effects

It was hypothesized that vacant urban and rural-urban fringe land is more likely to be converted the closer it is to urban development. Land in high intensity uses both within and surrounding a given tract was found to significantly influence conversion. As the majority of developed land in the TMA is used for residential

2. Data was also regressed at the highest 10, 25, and 50% levels. As in Willis [1982], 33% gave the best fit.

purposes, both residential and high intensity land use categories were analyzed.

a. Internal pressure. The proportion of acreage within each tract devoted to high intensity (denoted PCTHIGH76) and residential (denoted PCTRES76) uses at the beginning of the study period appears to significantly influence land conversion (using a one-tailed test).[3] Land use within the tract is included in equations 1 through 4 of Table 5.1. PCTHIGH76 and PCTRES76 have positive coefficients in all four equations. Both are significant at the 0.01 level in equations 1 and 3 which exclude any measure of accessibility to employment. In equation 2 which includes a measure of employment accessibility in 1976 (denoted ACCESS76), PCTHIGH76 is only significant at the 0.05 level. PCTRES76 remains significant at the 0.01 level in equation 4.

b. External pressure. Equations 5 through 8 include the proportion of land surrounding each tract which was used for high intensity (denoted PCTSURHIGH76) and residential (denoted PCTSURRES76) purposes at the beginning of the study period. The coefficients of PCTSURHIGH76 are positive and significant at the 0.10

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3. A one-tailed test is used because coefficients of these variable are assumed to be one-sided, i.e. either positive or negative as hypothesized.

TABLE 5.1 Alternative Estimates of Factors Affecting Conversion
(Absolute T-Ratios in Parentheses)

Equation Number	1	2	3	4	5	6	7	8	9	10	11
PCTHIGH76	1.3517 (2.37)[a]	1.4890 (1.92)[c]									
PCTRES76			2.4519 (3.18)[a]	2.5559 (2.90)[a]							
PCTMIN75	-3.2414 (3.38)[a]	-3.1985 (3.31)[a]	-3.0643 (3.17)[a]	-3.0620 (3.16)[a]							
PCTHIHOUSVAL75	-1.7305 (2.04)[b]	-1.8100 (2.00)[b]	-2.2964 (2.79)[a]	-2.3282 (2.79)[a]	-3.0161 (3.04)[a]	-2.6494 (2.48)[a]	-3.4323 (3.60)[a]	-3.0038 (2.88)[a]			
PCTSURHIGH76					1.1190 (1.54)[d]	1.0158 (1.38)[d]					
PCTSURRES76							0.7281 (0.65)	0.4657 (0.41)			
PCTSURMIN75					-5.6550 (3.78)[a]	-6.1401 (3.76)[a]	-5.5649 (3.47)[a]	-6.2288 (3.44)[a]			
ACCESS76		0.0231 (0.26)									
ACCESS7376						-0.3870 (0.90)		-0.4345 (1.01)			
ACCESS7376Z				-0.0296 (0.25)							
PCTZONEDRES76									1.3350 (1.52)[d]	7.3837 (1.22)[d]	
PCTZONEDRES76SQ										-4.5709 (1.04)	
PCTZONEDRES7377											6.6556 (1.72)[c]

a. significant at the 0.01 level (one-tailed test)
b. significant at the 0.025 level (one-tailed test)
c. significant at the 0.05 level (one-tailed test)
d. significant at the 0.10 level (one-tailed test)

level in equations 5 and 6. PCTSURRES76 shows the correct sign in equations 7 and 8, but neither coefficient is significant.

c. Conclusion. As hypothesized, the proportion of developed land within a census tract influences the conversion of vacant land within the tract. This finding confirms those of Willis [1982] and Lee [1979], supporting the contagion theory of urban development. The influence of high intensity land uses in surrounding tracts appears to be less significant than that of similar uses within the tract. The proportion of surrounding land in residential uses is insignificant in the land conversion process given the observed sample. Two factors may be responsible for these results.

(1) As discussed in chapter 4, tracts showing the largest acreage conversions are on the fringe of the TMA. These tracts are typically not completely surrounded by other tracts and in fact generally have one or more exposed sides. Surrounding high intensity and residential acreage was only measured in tracts within the TMA, i.e., high intensity acreage outside the study area was ignored. Thus for fringe area tracts, PCTSURHIGH76 and PCTSURRES76 are underestimated.

(2) The TMA consists of 108 census tracts varying in size from 180 to just under 5000 acres. It may be that

land developers simply do not take into consideration the surrounding land use, particularly when developing a parcel in the interior of a large tract. The immediate surroundings may be far more influential in the decisionmaking process.

2. Socio-demographic Factors

Two socio-demographic factors, ethnic origin and housing values, were found to significantly influence land conversion.[4]

a. Minority population. The proportion of the population belonging to a minority ethnic group both within (denoted PCTMIN75) and surrounding (denoted PCTSURMIN75) each census tract was found to negatively influence land conversion. Coefficients of PCTMIN75 in equations 1 through 4 and PCTSURMIN75 in equations 5 through 8 in Table 5.1 were significant at the 0.01 level.

It appears that developers may be (consciously or unconsciously) reluctant to invest in areas of high minority concentration. Most new construction,

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4. Partial multicollinearity exists between the minority and the housing value variables. It does not result in biased estimators though they may be unreliable. Values of the t-statistics for both variables are high indicating that the correlation between the two probably has little impact on the regression model. The model is being used only to test the significance of the hypothesized variables, not for prediction, thus multicollinearity is not considered a problem.

particularly residential, takes place outside of the central city where minorities are concentrated. These areas are typically viewed as more environmentally aesthetic. Houses are larger and, though generally situated on larger parcels of land, may generate more profit per square foot for the developer.

b. Housing value. Median housing value expressed as a percentage of the highest median housing value in the TMA at the beginning of the study period (denoted PCTHIHOUSVAL75) was used as a proxy for land prices. Though this variable may not accurately reflect price per unit of land due to varying house sizes, according to the liklihood ratio test[5] it does belong in equations 1 through 8 in Table 5.1.

The coefficients of PCTHIHOUSVAL75 are negative in all eight equations. They are significant at the 0.025 level in equations 1 and 2 and at the 0.01 level in equations 3 through 8.

The negative influence of housing values on conversion is probably not due to lack of initiative on the part of developers. Expensive homes are purchased by the wealthy who have the political and economic power

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5. See Theil [1971], pp 98-100 for an explanation of the liklihood ratio test.

necessary to maintain the character of their neighborhoods and surrounding areas.

3. Employment Accessibility

Most studies have found that accessibility to employment opportunities exerts a positive influence on the choice of residential location. Steinnes [1977] argues that causality between intraurban residential and employment location runs the other direction, except in the case of retail trade. Pooled cross-sectional, time-series data for fifteen cities is analyzed in a simultaneous systems model. Results suggest that people follow retail trade to the suburbs and in turn are followed by manufacturing and service industries. Results of the present study do not appear to validate either hypothesis.

Accessibility was measured for all tracts at the beginning of the study period (denoted ACCESS76) and for the change over the period preceeding that studied (denoted ACCESS7376). The zones method proposed by Greene [1980] was also used to look at the change in accessibility over the preceeding period (denoted ACCESS7376Z).

Signs of the coefficients of the three accessibility measures are ambiguous. Smaller values of ACCESS76 denote greater employment accessibility thus the sign of the coefficient should be negative if accessibility is a factor in the choice of a construction site. As shown in equation 2 in Table 5.1, the sign of the coefficient is positive and insignificant, indicating that employment accessibility does not influence locational decisions. Coefficients of ACCESS7376 and ACCESS7376Z should also be negative if employment accessibility is important (1976 measure should be smaller than 1973 denoting greater accessibility, thus the change over the period should be negative). In equations 4, 6, and 8 in Table 5.1 the coefficients are the correct sign but are insignificant.

It appears that accessibility to employment is not an important factor in the land conversion process. It may be that travel time rather than distance should be used to measure accessibility. Many converted areas are quite far in terms of miles from large employment centers but are close to the freeway or to major transportation corridors. In addition, Tucson has a large senior citizen population to whom accessibility to employment would be of little or no importance. The environmental amenities of the foothills region may outweigh the disutility associated with a long drive to work. It is possible that the existence of a potential labor force within a given tract may draw employers to the area rather than employment opportunities drawing residents. Causation in this direction is generally thought to occur between regions rather than within a given region.

4. Zoning

Zoning data was available only for tracts within the Tucson city limits. In order to study the influence of zoning on conversion the sample size was reduced to fit existing information. Data was aggregated by useage groups: single family, multiple family, commercial, industrial, and rural. Single and multiple family groups were combined into a residential variable. Since the majority of land in Tucson is zoned residential, only the residential variable was considered.

Equations 9 through 11 in Table 5.1 show the results of the reduced sample. The coefficient of the proportion of each tract zoned residential at the beginning of the study period (denoted PCTZONEDRES76) is positive and significant at the 0.10 level (equation 9). A quadratic relationship between PCTZONEDRES76 and conversion was also hypothesized to analyze the relative desirability of mixed land uses (e.g. residential and commercial) within a given tract. Signs of the coefficients in equation 10 indicate that residential zoning may initially have a positive influence on conversion though as more of the tract becomes zoned residential the influence may become negative. It appears that a mixture of land uses is viewed more favorably by residents than if the entire tract is devoted to residential use. The coefficient of the squared term (denoted PCTZONEDRES76SQ) is not significant.

Several hypotheses were tested to allow estimation of the time lag between residential zoning changes and actual changes in developable acreage. It appears that it takes approximately four years for zoning changes to influence land conversion. The percent change in acreage zoned for residential uses between 1973 and 1977 (denoted PCTZONEDRES7377) has a positive and significant (at the 0.05 level) coefficient.

Even with a reduced sample size it may be concluded that residential zoning positively influences land conversion. Most development within the city limits is infill, involving small parcels of land. It is likely that the hypothesized relationship is much stronger in the county portion of the TMA where more rezoning, involving larger tracts of land, occurs. City data suggest that zoning may be more influential in the land conversion process than is commonly thought.

C. Summary and Policy Implications

Several factors have been found influential in the conversion of land from low to high intensity uses. Physical land use, specifically the proportion of high intensity and residential acreage within a given tract, has a significant, positive influence on land conversion. Coefficients of surrounding high intensity and residential acreage are also positive. The surrounding residential coefficient is not significant, possibly because of bias (underestimation) in the data. Physical land use results confirm the contagion theory of Cory and Willis [1983].

Socio-demographic variables were found to have a negative influence on land conversion. All coefficients were significant. The proportion of the population considered members of an ethnic minority, both within and surrounding a given tract, may only indirectly influence new construction. It may be that developers do not consciously avoid areas with a large proportion of minorities. The availability of environmentally aesthetic land in larger parcels at the rural-urban fringe may draw developers, particularly of residential housing, away from the inner city where minorities are concentrated. Conversely, expensive residential developments tend to discourage further new construction possibly due to the political and economic power held by the wealthy.

Accessibility to employment appears to have little effect on the location of new construction. Signs of the coefficients of the accessibility variable are ambiguous and none are significant. Tucsonans, particularly those who are retired, may value residential location attributes other than proximity to employment. If accessibility is important, it may be in terms of time rather than distance traveled. It is possible that causation runs in the other direction. Residential location could influence the location of employment opportunities.

Coefficients of the zoning variables show the correct sign though not all are significant. If the sample size were increased to include all areas within the TMA it is probable that the influence of residential zoning on land conversion would be much stronger. There appears to be a time lag of four years before zoning changes affect land development.

Policy Implications

Comprehensive community planning requires public decisionmakers to view land use changes from the standpoint of both developers and area residents. If preservation of existing land uses is considered socially desirable, goals may be achieved through some form of land use control. Typically control is attempted through zoning or taxation, either of developers (development) or vacant land owners (use-value).

If the contagion effects of physical land use are not considered in the policymaking process, marginal net benefits of land conversion will be misspecified. Open space preservation goals will be under or overachieved. For example, suppose that public decisionmakers have determined that a preservation goal of LL_0 acres of open space or agricultural land (Figure 5.1) will result in maximization of net social benefits.[6] This goal may be reached through zoning, some form of taxation or, though highly unlikely, through direct purchase of the land to be preserved.

Zoning may be costly to implement and enforce, particularly if zoning changes occur frequently. Zoning may promote exclusion of certain ethnic or income groups resulting in an inequitable distribution of the benefits and costs associated with its use [Ervin, et.al, 1977]. As indicated by the results of the empirical analysis, rezoning is particularly prevalent in the TMA. In Figure 5.1, given the estimate of MNB_R, L_0L_1 acres of land will be zoned for open space or agricultural use only, the rest preserved by interaction within the competitive land

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6. Example drawn from Cory and Willis [1983].

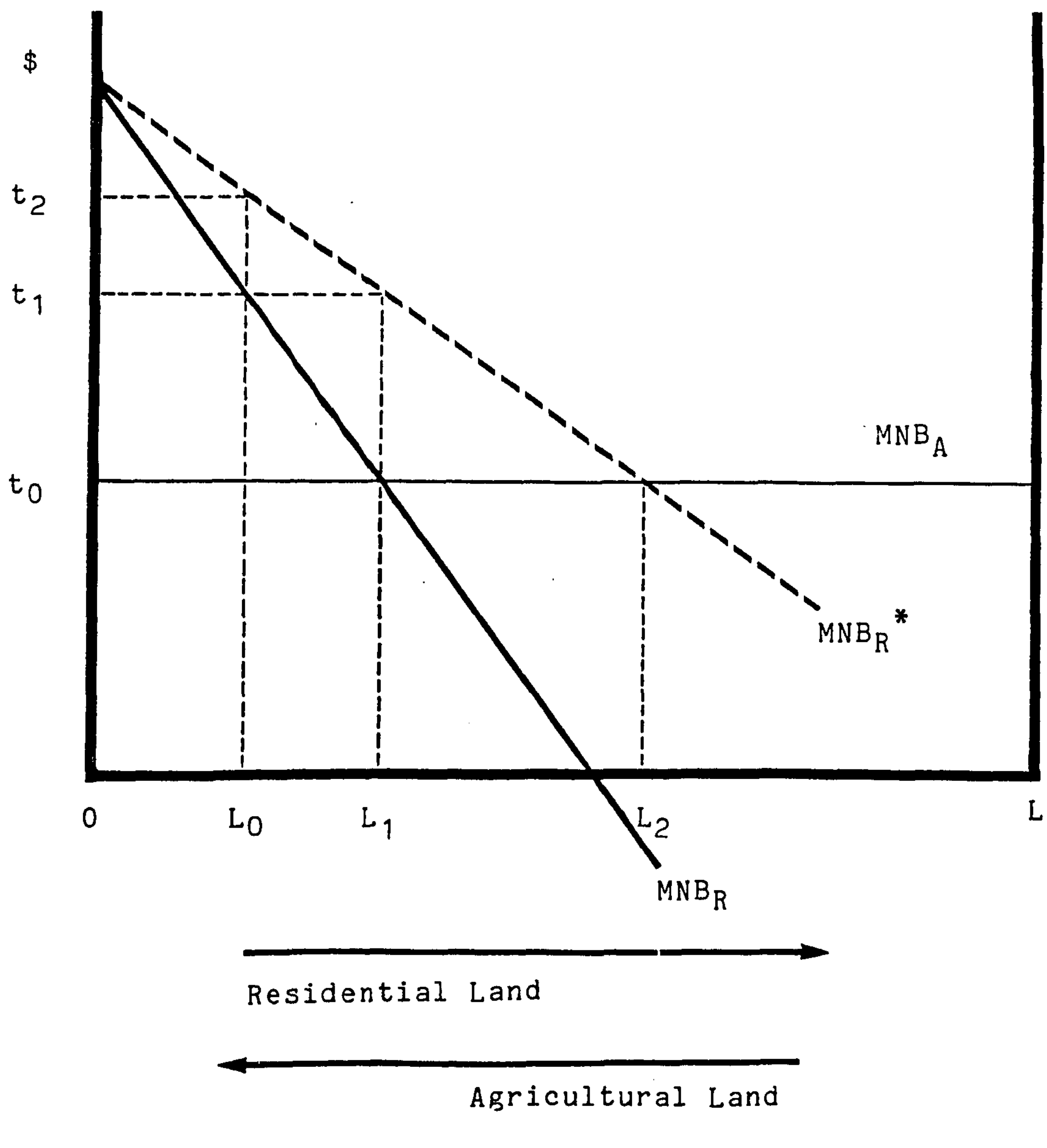

Figure 5.1. Policy Implications of Contagion Externalities: Zoning and Taxation.

(Source: Cory and Willis, 1983.)

market. Contagion externalities will cause leapfrog development to occur due to the misspecification of the size of the marginal net benefits of conversion. L_0L_1 will be preserved and L_1L_2 converted to residential or other high intensity use.

Zoning, if strictly enforced, is a potentially strong land use planning tool. Nonconforming uses abound in the TMA, mostly due to frequent annexation of county land into the city. Though zoning in the annexed parcel is changed, existing uses are allowed to remain. In addition, most requested zoning changes are granted. The result is a zoning ordinance with little power or significance. More accurate record keeping, particularly the number of acres in each zoning category in each census tract or alternative method of division may help decisionmakers guide the growth process.

Taxation will also fail to reach the preservation goal if contagion effects are not considered. Following MNB_R, developers paying an additional tax of t_0t_1 will stop conversion at L_0. However, since developers are actually receiving benefits along MNB_R^*, conversion will continue out to L_1. Similarly, if open space land owners are granted preferential assessment amounting to t_0t_1, LL_1 acres of land will be held in open space or agricultural use. Taxes would have to be set at t_0t_2 in order to achieve the preservation goal. The difference between the two tax levels is the marginal external benefit associated with contagion externalities.

Preservation goals in the current period will not be reached if contagion effects on low intensity land use conversion are not considered. User costs may be incurred in future periods or benefits of conversion in the present period may be foregone.

Employment accessibility, at least in the TMA, appears to have little influence on the location of new development. However, the urban infrastructure as a whole probably has a great deal of influence on land conversion. Availability of adequate water and sewer capacity may be the most effective land use planning tool in the TMA at the present time. By requiring large scale developers to provide streets and bear some portion of other urban infrastructure costs, public planners may be better able to guide growth, particularly as it moves away from the central city into more remote areas.

CHAPTER 6

CONCLUSION

In recent years concern has grown over the adequacy of open space in and around urban areas. Land at the rural-urban fringe seems particularly vulnerable to high intensity development. A disproportionate amount of the land surrounding urban areas is in agricultural uses, presumably a result of our agrarian heritage. Much controversy exists among politicians, economists, agriculturalists, and others over the long run effects of the conversion of land from agricultural to urban uses. Controversy exists primarily because of the irreversible nature of urban development. Government intervention appears justified to both control the direction of urban growth and to determine an efficient long run land use mix.

Cory and Willis [1983] hypothesize that urban development is contagious in nature, i.e., that rural areas contiguous to an urbanized area are more likely to be converted than undeveloped land farther from the rural-urban fringe. They contend that unless the added benefits of close proximity to the urban area are included in decisions made by public planners, open space or agricultural preservation goals will not be achieved.

The Tucson, Arizona, Metropolitan Area (TMA) during the period 1975/76-1980 was chosen for the empirical study. Data were gathered at the 1980 census tract level with the exception of very large tracts. Tracts in excess of 5000 acres were divided into two or more areas of approximately equal size. Data for divided tracts were gathered at the census block level. Total number of tracts observed was 108.

The dependent variable, conversion, was measured as the percent change in developable acreage during the study period. Developable acreage is the number of acres of land available to be developed, excluding geographically unsuitable areas (e.g., drainage areas or extremely steep slopes).

Several factors were hypothesized to be influential in the land conversion process. The proportion of land in high intensity and residential use, both within and surrounding a given tract of land, was expected to positively impact the conversion of undeveloped land within the tract. No definite a priori determination could be made concerning the impact of the racial minorities on the location of new high intensity development. Likewise, the influence of housing value (used as a proxy for land value) and accessibility to employment on land conversion were a priori indeterminant. Zoning appeared to be insignificant in the process of land conversion.

The influence of hypothesized factors on conversion was tested using probit, a model of binary, qualitative choice. Choice of a statistical model was based on (1) research goals, (2) compatibility with available data, and (3) simplicity. The primary objective of this study was to identify factors influencing the conversion of land from low to high intensity uses. Given the reliability of data based on measurement of aerial photographs and information reported by individual residents of the TMA, the change in developable acreage in each tract during the study period can be measured with confidence only in a relative sense. Though many intermediate stages may be defined, the "low" conversion, "high" conversion or 0,1 dichotomy is simplest to model.

Observations were ranked ordinally by estimated percent change in developable acreage during the study period. Coefficients of independent variables were most significant when the top one-third of dependent variable observations were considered to have undergone "high" conversion assigning them a dependent variable value of 1. All other dependent variables took on a 0 value.

Physical land use results confirm the contagion theory of Cory and Willis [1983]. High intensity land use within and surrounding a given tract was found to have a significant, positive influence on land conversion. The impact of residential acreage was also positive, though the surrounding residential coefficient was insignificant. Preservation techniques such as zoning or use-value or development taxation are ineffective if contagion effects on low intensity land use conversion are not taken into consideration.

Racial composition, both within and surrounding a given tract, and housing values exerted a significant, negative influence on urban development.

Statistical results concerning accessibility to employment were ambiguous, indicating little influence on the location of new development. Results may have been different if accessibility had been measured in terms of time rather than distance.

Lack of complete data forced a reduction in sample size in order to look at the impact of residential zoning on land conversion. Observations were constrained to the city limits of Tucson. Though most major zoning changes take place outside of the city limits, results of the smaller sample show a significant, positive relationship between residential zoning and new development. There appears to be a time lag of four years between residential zoning changes and the start of new construction.

It is probable that many other factors are influential in the conversion process. Land development, particularly for commercial or industrial use, may be affected by intraurban/regional property tax assessment levels. The availability of urban infrastructure is important to the location of new development and one of the benefits associated with contagious land conversion. The question of causation between residential location and the location of employment opportunities warrants further investigation. Residential location choice may depend on a variety of additional factors such as school availability and quality and the desirability of the surrounding natural environment. Additional study including these and other factors may increase the efficiency of the public decisionmaking process and contribute toward an optimal long-run land use mix.

APPENDIX A

DESCRIPTION OF INDEPENDENT VARIABLES

PCTHIGH76 -- the proportion of total acreage in a given tract devoted to high intensity uses (residential, commercial, industrial, institutional, streets and medians, drainage areas and washes) in 1976

PCTRES76 -- the proportion of total acreage in a given tract devoted to residential use in 1976

PCTSURHIGH76 -- the proportion of total acreage devoted to high intensity uses in 1976 in all tracts contiguous to a given tract

PCTSURRES76 -- the proportion of total acreage devoted to residential use in 1976 in all tracts contiguous to a given tract

PCTMIN75 -- the proportion of the population in a given tract reported as members of an ethnic minority (the summation of Black, Hispanic, and Indian) in the 1975 special census

PCTSURMIN75 -- the proportion of the population reported as members of an ethnic minority in the 1975 special census in all tracts contiguous to a given tract

PCTHIHOUSVAL75 -- median, owner-occupied, single family housing value in a given tract as reported in the 1975 special census, expressed as a percentage of the highest median value reported in the TMA

ACCESS76 -- a measure of employment accessibility developed by Cao [1980]

$$A_i = \sum_{j=1}^{108} d_{ij} \frac{e_j}{E} \qquad ,i = 1,\ldots,108$$

where A_i = accessibility of tract i to employment opportunities (a smaller value denotes greater accessibility)

d_{ij} = road distance between the geographical centers of tracts i and j

E = total TMA employment in 1976

e_j = number of persons employed in tract j in 1976

ACCESS7376 -- the change in accessibility (A_i) over the period 1973 to 1976. The variable is negative if accessibility increases.

ACCESS7376Z -- a combination of measures developed by Cao [1980] and Greene [1980] used to identify minor urban employment centers. Only tracts containing a level of employment equal to or greater than the average level of employment over all census tracts in the TMA are considered to contain positive levels of employment.

Thus if

$$e_j \geq \frac{E}{108}, \text{ then } e_j = \text{number of persons employed in tract } j$$

$$e_j < \frac{E}{108}, \text{ then } e_j = 0$$

PCTZONEDRES76 -- the proportion of total acreage zoned residential in a given tract within the Tucson city limits in 1976

PCTZONEDRES76SQ -- the square of PCTZONEDRES76

PCTZONEDRES7377 -- the percent change in acres zoned residential in each tract between 1973 and 1977, i.e. the proportion of total acreage zoned residential in a given tract within the Tucson city limits in 1977 minus that of 1973

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