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Analyzing urban decentralization*

The case of Houston

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Decentralization in the Houston region is analyzed in this paper by the estimation of population density functions. The study is novel in that it uses actual land utilized for residential activity at different locations rather than using total land area. Also we analyze population density by regressing lot size of individual homes on their distance from the CBD. The development of Houston is also analyzed with reference to competing theories of urban development and explanations of decentralization.

1. Introduction

This paper analyzes urban development in the Houston region, emphasizing the decentralization over time of residential activity and employment. Descriptive information on trends in suburbanization is presented for a number of years. Also, we follow Mills (1972) in estimating an exponential residential density function for a number of census years.

This study introduces an essential empirical innovation for analyzing population density: It uses the *actual* land utilized for residential activity at different locations rather than following the conventional approach of using *total* land area. First we use an approach originally developed by Barton Smith for Chicago which uses micro information on single family homes lot sizes to estimate density. We regress the lot size of individual homes on their distance from the CBD. This information, along with information on the number of single-family units and multi-family units at various locations allows us to estimate the amount of land *actually* used for residential houses at different locations (for different census tracts). These estimates for Houston

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imply that the proportion of land used for housing decreases sharply with distance from the CBD, and that the amount of vacant land or undeveloped land increases significantly with distance from central locations. Even at locations eight miles from the CBD more than 50 percent of the land is undeveloped even though much of current development in Houston is occurring at distances of 25–30 miles away from the CBD.

Also we have utilized estimates of actual land used by census tract in 1980 for residential use and other activities, developed by the City of Houston Planning Department. These data confirm the large amount of vacant land in Houston, evidence of the city's leapfrog pattern of development. We utilize the land use data to estimate, for one point in time, the actual density gradient by regressing population per unit of residential land in a census tract on the distance of the location from the CBD.

These estimates confirm the result, based on individual housing units that density per unit of residential land is quite uniform, and that in some sections of the Metropolitan Area density actually increased with distance from the CBD. This suggests that for newer, sprawling cities with large amounts of vacant land, declining exponential density fuctions may be a statistical artifact. Lower suburban densities may reflect the existence of vacant land rather than the consumption of more land per houshold.

The micro data, and the land use data for Houston allow us to evaluate competing models of urban development. The standard urban model analyzed by Mills (1967) and Muth (1969) emphasizes long-run equilibrium in city structure and assumes malleability or reconstruction of a city's form. In contrast, work by Harrison and Kain (1974) and Anas (1978) stresses the durability of cities and the importance of various historical layers, or portions, of a city's development. Our work on Houston is generally supportive of the durability model. Also, we are able to present some evidence on the importance of neighborhood effects, and the 'flight from blight' explanation of the decentralization of urban areas.

The next section of the paper presents a brief review of the standard urban model and subsequent modifications and extension of this model. Section 3 develops the more systematic work on density gradients and presents some descriptive information on Houston. Section 4 discusses the Houston evidence with reference to competing theories of urban development and explanations of decentralization.

2. Models of urban structure

The monocentric model of urban spatial development was developed by Alonso (1964), Mills (1967) and Muth (1969). In this model, all employment is concentrated at the CBD and locational choice is modeled solely on the basis of access to the employment center. Commuting costs can be avoided by living at central locations. Rents are high and tall, expensive residential buildings are built close to the city center. Households living at central locations will consume small quantities of housing and spend little on commuting, while households which commute longer distances will consume more housing and land, which are cheaper at more distant locations from the CBD. Under certain simplifying assumptions this model implies that population density declines exponentially with distance from the center.

The model is a long-run equilibrium model, and capital (structures) is malleable. Changes in equilibrium urban structure, resulting from population growth, changes in real income, or in commuting costs occur quickly. For example, if population grows rapidly, the density of inner city neighborhoods will increase and the city will also expand on the suburban fringe. In this model the city always expands outwards, and as capital is malleable there is no vacant land in developed areas. The history of past development is ignored.

Harrison and Kain (1974), in an empirical paper, propose an alternative to the standard model with malleable capital. They emphasize the durability of capital and postulate that urban structure should be explained as the aggregation of past patterns of development rather than as an equilibrium adjustment to current conditions. Homes and lot sizes do not change significantly from the time when particular areas of the city were developed.

The observed negative density gradient is a mere historical artifact reflecting faster population growth, lower real incomes and higher commuter costs, resulting in the higher density of older cities developed earlier. Although, Boston and Houston are different because of differences in the timing of their development. The current suburban development of both cities appears to be very similar.

Cooke and Hamilton (1984) develop a simulation model based on the durable capital model. They assume myopic foresight and that development in each decade reflects the real income of that period. In applying the model to Baltimore and Houston and in comparing the predicted results with actual development they found evidence of leapfrogging and scattered development even prior to the widespread use of the automobile. Also, they found that a significant proportion of the housing close to the CBD in both cities is relatively new, contrary to the predictions of their model. This might be evidence of the demolition of fully depreciated housing, or might also be evidence of 'filling in' on vacant land.

Anas (1978) has presented the most complete, formal analysis of the model with durable capital and myopic foresight. On his formulation only the market conditions within each period of development determine the character (density) of that period's development. There is no foresight to the development process and the character of the existing housing stock is determined by past trends in market parameters.

Anas presents a number of results contrasting the welfare and size of a short-run non-malleable city with those of a malleable static city. The most striking proposition is that with durability and myopic foresight density *may* increase with distance from the center as population grows. Although this result appears to hold under a wide range of values of real income and commuting cost it depends on slowly growing nominal incomes and constant commuting costs. In this model the price of land currently developed depends on its opportunity cost in agriculture. The density of new development will depend on the real incomes of those that settle in the new development. Real income equals y_i real income exclusive of commuting cost in period i-r_i is the per unit cost of travel in period i and d_i is the distance from the city center to the zone of current development. Real income net of commuting cost is $y_i - k_i d_i$. The result that density increases with distance from the city center depends on falling real income inclusive of commuting costs. This will *not* occur if y_i increases over time or if k_i falls over time to offset longer commuting distance as the city expands. The prediction that densities will increase with distance seems unlikely – though as we shall see there is some evidence of this occurrence in Houston.

Wheaton (1982, 1983) has developed an interesting compromise between the durable capital model of Anas, and the long-run malleable Mills–Muth model of urban structure. He notes that older houses and other buildings located at the city center can be redeveloped. As the city grows outwards, central land values increase and it becomes profitable to redevelop central locations. Wheaton demonstrates the very plausible proposition that redevelopment will take place in central locations and that the redevelopment will increase the density of the existing land use. This model implies that density will decline with distance from the city center. The process of redevelopment is a realistic version of the long-run equilibrium model. The assumption of malleability should not be taken too literally as increases in density are not carried out by adding to the height of existing buildings but through the redevelopment of land or by building on vacant land. As Mills and Muth have noted in the empirical implementation of their models, the adjustment of urban structure to changing conditions takes place only with a long adjustment lag.

In a companion article to his piece of redevelopment, Wheaton (1982a, b) has substituted the assumption of perfect foresight for myopic foresight. This assumption generates vacant land for speculative purposes. It will become profitable to withhold some centrally located land in order to develop it at higher density in the future. This consideration provides an efficiency basis for leapfrog development. Wheaton demonstrates that under some conditions it will be profitable to develop the city from the outside, inward towards the center. Initial suburban development implies higher commuting costs and lower land rents in the initial stages of development, which are weighed against the higher density and rents and lower overall commuting made possible by withholding from development centrally located land.

The standard static urban model and the extensions and modifications of the model are all based on non-social and non-institutional factors such as transportion costs, changes in transportation technology, and changes in real income and housing demand. Decentralization of residential activity and the location of various income groups within Metropolitan areas are analyzed in terms of historical changes in commuting costs, income induced changes in housing demand, and whether the income elasticity of demand for housing exceeds the income induced elasticity of commuting costs.

One elaboration of the monocentric model is the interaction between employment and residential decentralization. White (1976) notes that as a large portion of the population becomes suburbanized, firms will follow to provide services and to take advantage of lower suburban wage and land costs. Similarly, as large employers become suburbanized their employees will follow them.

A very different set of explanations of suburbanization and decrease in urban densities emphasize neighborhood amenities, fiscal and public service considerations. 'The escape from blight' explanations of suburbanizations argue that high crime rates and concentrations of poor in the central city induce middle class residents to move to the suburbs. The rich isolate themselves from the poor to avoid the deterioration in their tax base that social/economic integration brings. Also, if low income minority groups are concentrated in older housing in the central city and central city schools have large enrollments of minorities, the white middle class will suburbanize much more rapidly than would be predicted by considerations of demand for the newest housing and the availablity of cheap land. A precise quantitative analysis of the relative importance of different cause explanations remains elusive. In the study of one city, Houston, we present some evidence on the importance of neighborhoods and the 'flight from blight' explanations of suburbanization.

3. Density gradients and the decentralization of Houston

Houston is a new, low-density city heavily oriented towards automobile transportation. Half of the city's residential and commercial real estate has been built since 1960. Two-thirds of all office space was built after 1960 and remarkably, one-half of all office space was built during the 1980s. Employment is distributed within a relatively large number of activity centers. Commuting distances are long with work trips of 25–30 miles not uncommon. Nonetheless, despite its spread-out character and the lack of pedestrian traffic, there is a definite centrality to the city.

The urbanized area of Houston lies on a flat featureless plain, covering more than 900 square miles. In contrast to most of the larger cities in the country, the city of Houston is not entrapped by suburban jurisdictions, but instead dominates the metropolitan area. Through annexation, the city has grown to encompass 590 square miles. Houston's population has increased exclusively through annexation. Since 1940 the city's population increased by four times to 1.6 million, but the population of the city's 1940 boundaries has remained essentially unchanged at 375,000. The older, central core of the city within the Inner-Loop (Interstate 610) is 100 square miles, twice the area of Boston.

Population decentralization in Houston has been occurring for some time. Employment is more centralized than population. Excluding the CBD, the ratio of population to employment inside the Loop is approximately one; the ratio in the suburbs is closer to five. More recently, however, employment has been decentralizing. The CBD's share of total employment has declined steadily over the last two decades and now constitutes less than 11 percent of total metropolitan employment. Most of the recent growth in metropolitan employment has occurred outside the Loop. Between 1970 and 1985, total inner-city employment grew by only 92,000 jobs, whereas 671,000 new jobs (87 percent of the total) were created outside the inner-city. During the 1980s, all of the growth in population occurred in areas 20–30 miles from the CBD. Much of the new construction occurred in 'master-planned communities'. There has been little population-altering residential redevelopment in the inner-city. Since 1960 the Inner-Loop population had fallen slowly, but steadily, from 535,000 to 442,000.

Houston is not a symmetrical city. In general, the east side of Houston consists of industry and blue-collar residential communities. The more affluent neighborhoods and the institutions serving them have primarily developed in the western and northern portions of the metropolitan area.

The average population density in Houston today is a very low 3,000 people per square mile. The densest areas of the city are less dense than the average density of many of the large, older cities in the United States. Mills (1972) estimated exponential density functions for the years 1948, 1953, 1958 and 1963 using two data points. Mills' basic results were confirmed by OLS estimations of the same exponential functions using individual census tract data for census years, including an update for 1980. Table 1 displays both sets of the density function parameters and fig. 1. illustrates the implied change in density patterns between 1950 and 1980.

For all years the intercept term indicates that the overall densities in Houston are quite low. Albuquerque, Phoenix, and San Diego were the only cities with lower initial densities in the Mills study.

The slope coefficient is also low, but not as low as Houston's reputation might suggest. The 1948 slope coefficient of 0.37 is actually higher than Boston's or Philadelphia's.

Table 1

Houston metropolitan area density gradients.

	Mills' two-point estimate[a]	Census-tract estimate[b]
1948	−0.37	–
1950	–	−0.28
1953	−0.28	–
1958	−0.24	–
1960	–	−0.23
1963	−0.21	–
1980	–	−0.15

[a]Mills (1972, table 11).

[b]1950 log (density) = 3.13 − 0.283 * distance, $R^2 = 0.766$, No. of observations = 107.
(18.2)

1960 log (density) = 3.14 − 0.232 * distance, $R^2 = 0.808$, No. of observations = 107.
(20.1)

1980 log (density) = 2.83 − 0.148 * distance, $R^2 = 0.474$, No. of observations = 474.
(16.2)

t-statistics given below estimated coefficients.

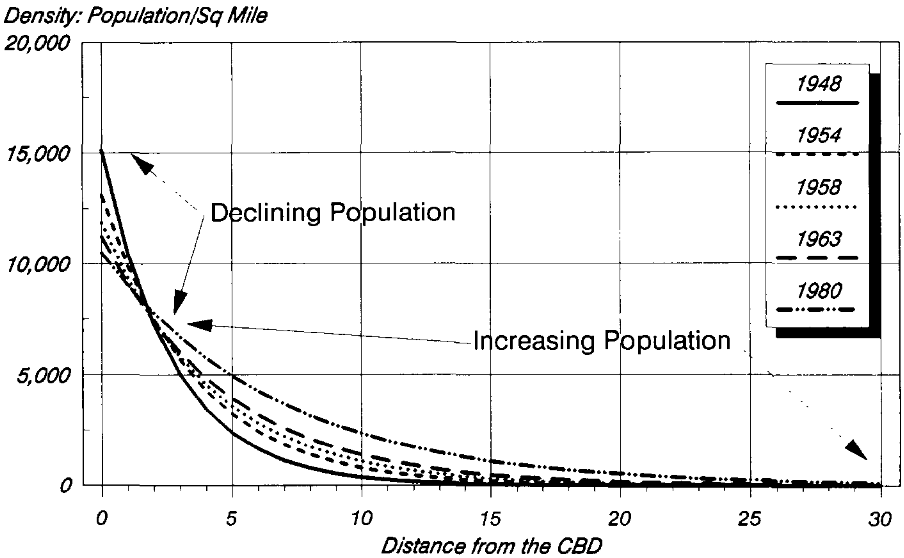

Fig. 1

By 1963, Houston's slope coefficient of 0.21 suggested a further flattening of the density function and, hence, greater decentralization. In that year, San Diego had a lower slope coefficient, but surprisingly, Boston's was identical to Houston's. Between 1948 and 1963 the intercept fell 36 percent and the

Table 2
Micro densities for single-family homes, Houston, Texas.

	Pre-1950s	1950s	1960s	1970s	1980
Micro land use					
Average lot size (in square feet)	8,804	9,482	10,214	9,673	9,083
Average home size (in square feet)	1,913	1,564	1,914	2,018	2,341
Home/lot size ratio	0.2173	0.1649	0.1874	0.2086	0.2578
Microdensity gradient					
Without SQFT	−0.01929	−0.01716	−0.01939	−0.03310	−0.02619
With SQFT	−0.00581	−0.01822	−0.01899	−0.03082	−0.02151

slope coefficient fell 43 percent. This was not atypical, however. Many cities experienced declines in overall density of as much as 50 percent. The average decline in the slope coefficients for Mills' eighteen cities was 35 percent.

The decentralization and declining density trend in Houston continued through 1980. By 1980 the intercept had fallen to 10,000 people per square mile and the slope coefficient had fallen to 0.15, a 15 percent per mile change in density.

Fig. 1 reveals the fact that the decentralization in Houston involved both the absolute decline in 'inner-city' population and the in-fill of existing 'suburban' areas. Despite the fact that the suburban area of Houston had extended beyond mile eight in 1948, growth in population continues in that location throughout the contemporary period as development proceeded to fill in vacant or agricultural land. In 1948, the outermost bounds of the city were mile 14. By 1963, these bounds had extended to mile 22 and by 1980 to mile 30.

Despite the fact that aggregate population density between mile 29 and 30 is quite small the housing being developed at mile 30 is being built at essentially the same density as is housing at mile 20. In fact, housing in the distant master-planned communities is generally built on smaller lots than similar housing in closer-in tract developments. The reason why overall or aggregate density of land at mile 30 is so small is that so little of the land there has been developed. We have pursued two approaches to analyze the effects of vacant land on estimated aggregate density.

Our first approach is to use micro information on individual single family homes built at different time periods in different locations. The results of this analysis are reported in table 2.

This table shows that the average lot size for housing has changed little over time. The fall in lot size between the 1960s and 1970s can be attributed to the more rapid rate of population growth during the latter period, as would be predicted by Anas (1978). The continuing decline of lot size in the depressed 1980s is a bit of a puzzle but reflects in part the rapid rate of construction in the early 1980s.

In table 2 we also report the 'density gradient' based on the regression reported in table A.1 in the appendix. These results indicate that the typical lot size declines slightly with distance between two and three percent per mile and that implied decline population density on land developed as single family housing is only a fraction of the decline in the aggregate density function.

These results suggest that the elasticity of demand of land for single family housing is quite small. It should be noted that the price (rent) gradient for housing was quite small until the 1980s and the houses built close in the 1980s were on lots laid out much earlier. So the results are not consistent with the Mills/Muth model, but the micro results also indicate that the Harrison and Kain (1974) historical perspective may be very relevant for current density patterns.

Interestingly, distance to the CBD by itself explains very little of the variation in micro density levels. However, when square feet of living area of the newly constructed homes is included as a second explanatory variable, the R^2 of the estimating equations increases from 0.02–0.15 to 0.16–0.45. This reaffirms the importance of the income level of the initial inhabitants of new housing in determining density patterns as suggested by Cooke and Hamilton (1984) and Anas (1978).

A more direct way of determining the significance of vacant land on developed land density relative to densities calculated on the basis of overall land area is to use information on actual land use. One advantage of this approach is that it accounts for multi-family housing. Fortunately, the Planning Department of the City of Houston calculated actual land use by census tract for 1980. These data indicate that the percent of land that is vacant (not used for 'urban purposes' ... residential, commercial, industrial, institutional, etc. ranges from 4 percent in inner-city tracts to 99 percent at the very edge of the metropolitan area.

In table A.2 we report the regression of gross population density by census tract calculated as population divided by total land area and net population density calculated as population divided by either occupied land area or residential land area. Table 3 provides a summary of the density gradients with respect to distance from the CBD. Also, this table indicates that the percent of land occupied declines by 9 percent per mile. The density of occupied land declines by 5.8 percent per mile. Together they account for 14.8 percent per mile decline in the aggregate density estimate. This means that 60 percent of the decline in the gross density with respective to distance to the CBD is attributable to declining rates of land utilization. When residential occupancy of land is analyzed, more than 65 percent of the

Table 3

Gross vs. net density gradients; 1980 census tract estimates.

	Slope coefficient
Total land area vs. occupied land area	
Net density	−0.058
% occupied	−0.090
Gross density	−0.148
Total land area vs. occupied residential land area	
Net density	−0.050
% occupied	−0.098
Gross density	−0.148

decline in aggregate population density is attributable to declining land utilization.

The estimated land utilization gradients indicate that while 94 percent of all land is utilized within the first mile ring at mile 10, 40 percent is utilized and at mile 20 only 15 percent is utilized. At distances beyond mile 20 the rate is extremely small. Yet large master-planned suburban communities are this distance and beyond. Interestingly in these distant communities such as Kingwood and Woodlands the lots for single family homes are smaller than in most other suburban locations with similar housing.

4. Discussion of Houston's development pattern

Conventional measures of the aggregate density gradient indicate that Houston has been decentralizing over time. Recently released census figures for 1990 indicate that decentralization continued, possibly accelerated, during the 1980s. Between 1980 and 1990 the population of the city of Houston and the core county, Harris, grew at 2.2 and 17.0 percent, respectively. In contrast the populations of the two principal suburban counties grew by 60 percent.

Another principle conclusion of our analysis is that the density gradient for population on developed residential land is quite flat, with a decline of density of about 5 percent per mile in 1980. Leapfrogging and the existence of large amounts of vacant land are also characteristic of Houston's development.

A number of the explanations of the small density gradient also explain leapfrogging. One of these is Houston's transportation system which is consistent with the models posed by Anas and Moses (1979) and Yinger

(1989). There are seven major freeways converging upon the CBD and there are three major circular roads, *the Inner Loop*, averaging approximately 5 miles from the CBD; *Beltway 8*, which is 10–12 miles from the CBD; and *Route 1960/Highway 6*, which has been improved to form a continuous six-lane arc around two-thirds of the metropolitan area at a distance of between 20 to 25 miles from the CBD. The intersection of circular and radial highways has promoted concentrations of employment and retail activity.

In many ways Houston is reminiscent of Steen's (1986) description of 19th Century Philadelphia. In his article on Spaced Street railroads, Steen notes that a non-ubiquitous transportation system results in a complicated distribution of population density. Housing, retailing and other businesses cluster along high speed transportation corridors. Spread-out, leapfrog, 'spider-like' development is promoted. In Houston's case, the development of freeways increased density along the freeways and decreased density in suburban locations away from the freeways. Land considerably distant from freeways or circular roads that provide access to the freeways tends to remain vacant, while land close to the freeways, but 10–15 miles further out, is developed.

The road system has an important impact on the pattern of employment decentralization. Of the total 156 million square feet increase in office space during the two-decade period between 1969 and 1989, 117 million square feet (75 percent of the total) were built in clearly defined office employment centers at or near the intersections of major freeways or thoroughfares. Work accessibility along the freeway network improved *relative* to accessibility between freeways. By 1989 more than 30 percent of office space was in suburban locations, employment decentralization further encouraged residential decentralization and also augmented the forces leading to 'finger development'. More than other cities, Houston's freeways are critical to its transportation needs – 3 percent of lane miles accommodate 40 percent of automobile trips. Leapfrog development can also be explained by the heterogeneity of land. Some Houston area land is riddled with mini faults; some is covered with waning oil and gas fields; some have poor drainage characteristics; and some have relatively poor access via ancillary roads. Developers have turned to the best wooded land to develop, even if it entails greater distances from the CBD.

Another important explanation of decentralization and leapfrog development is the financing of development. A large part of Houston is unincorporated and development in the city's extra-territorial jurisdiction if financed by developer created municipal utility districts (MUDs). There are more than 500 MUDs in the Houston area and the size of a MUD's service area depends on the size of the developer's land holdings. The difficulty of assembling large tracts of land close in explains the success of the master-planned communities located 25–30 miles from the CBD, because all of these have involved the purchase of large unique parcels of land. A single land developer can take advantage of economies of scale in infrastructure development and finance. Also in these communities it is easier to create neighborhood amenities, produce a coordinated plan with enhanced visual amenities for the area, and protect residential subdivision with high restricted deed restrictions.

The historical dominance of single family homes in Houston is another explanation of its low density. Interestingly, the ratio of single family to multi-family housing is only modestly correlated with distance in Houston. A majority of the city's 450,000 multi-family units were constructed outside the Inner-Loop during the booming 1970s to house the rapidly growing labor force. Much of the in-fill of closer-in suburban land (mile 7 to mile 17) during the 1970s and 1980s was multi-family. One of the most dense census tracts is found seven miles to the west of the CBD in a tract dominated by apartments built in the 1970s.

The higher, residential densities in areas developed during the most rapid period of growth is consistent with the durable non-malleable models of Anas and the historical emphasis of Harrison and Kain. In general the Houston experience is supportive of the work of these writers.

During the 1970s the influx of affluent households to Houston should have increased lot sizes but rising land prices and infrastructure cost caused lot size to fall. With the recessions of the 1980s land originally laid out (but not developed) as 40 feet frontage has been converted to 70 feet frontage. Most residential neighborhoods within the inner city, especially those in the affluent west side have maintained their initial character and density. High income neighborhoods, characterized by large homes on large lots, and protection by deed restrictions have remained unchanged from the 1920s. The rapid change of Houston has not resulted in a transformation of existing neighborhoods, but in the development of new housing, on vacant land on the fringes of the city.

The standard urban model and the work of Wheaton predict redevelopment and an increase in residential densities as the city grows and commuting distances increase. The Houston boom led to the redevelopment of some low density residential areas in the inner city as high density office and commercial areas. But there has been very little residential redevelopment. This is in part due to the collapse of oil prices as in the early 1980s about 5,000 units in expensive highrise condominium building were constructed in the inner city.

The only other significant gentrification has occurred in central neighborhoods close to the rapidly growing medical center. Here, some areas in independent jurisdictions with zoning, and in neighborhoods with deed restrictions, smaller houses have been demolished or replaced with expensive houses for affluent professionals. In these neighborhoods relatively modest lots often command a price of $225,000 – five to six times higher than lots in comparable suburban neighborhoods.

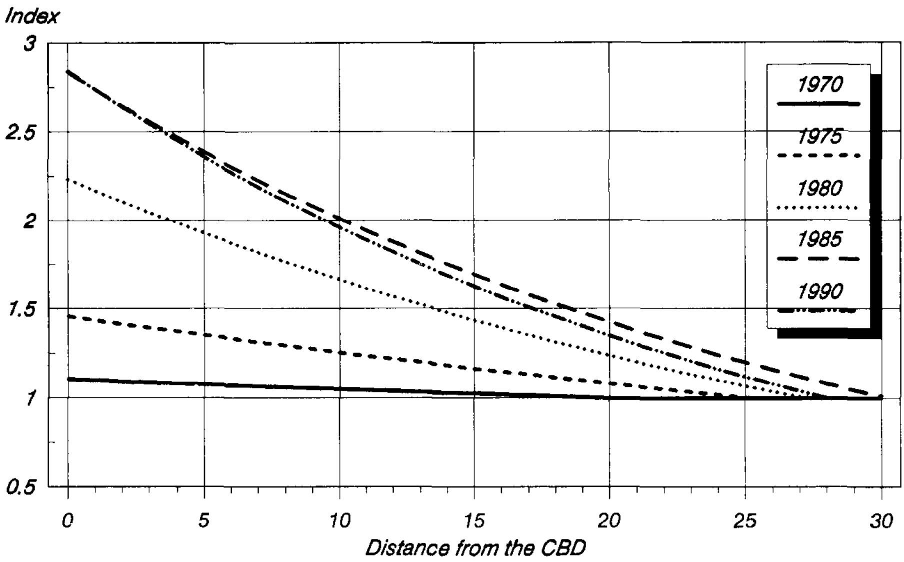

Fig. 2

It was the rapidly escalating forces in these secure, exclusive neighborhoods that led to the sharp rise in the gradient of housing prices in the 1970s and 1980s. This rapid use of centrally located housing is explained by the growth in the city, and congested freeways.

But there is tension or even an inconsistency between rapidly rising housing prices in some parts of the inner city and the decline of the overall inner city population. The decline of the poorer neighborhoods and the abandonment of old small, wooden frame housing in the inner city during the 1980s is easily explained by the filtering model developed by Cooke and Hamilton, and many others. Following the downturn in the Houston economy a large amount of new, high quality housing became available in the western sections of the city. Apartment rents fell sharply to half of previous levels, and lower income residents moved out of the inner city to suburban areas.

But the decline and the lack of redevelopment during the booming 1970s can be explained not only by neighborhood effects but also by the availability of large tracts of suburban land and the expanded, uncongested freeway systems in the early 1970s. One neighborhood effect is the lack of zoning in Houston. In many inner city neighborhoods non-conforming land use impinges on residential areas. These non-conformities complicate any contemplated residential redevelopment even if land use regulation were now introduced. Also, many of the declining neighborhoods have poor social infrastructure, narrow poorly maintained streets, lack of storm sewers, and antiquated water supply. Redevelopment would have required a substantial injection of public funds.

The classic problem of redevelopment is to rebuilt a large enough area so that the affluent household who can afford the new house feel secure with respect to the social and economic status of their neighbors. The very high land prices in the 'exclusive' or 'secure' inner city neighborhoods confirm the importance of this factor.

The possible redevelopment of the inner city and the explanation of decentralization is complicated by the possible influence of racial and ethnic prejudice. During the 1960s the tolerance of middle class whites for racial integration of neighborhood was slight and areas tipped very quickly. During the 1970s and especially the 1980s, blacks and the rapidly growing Hispanic population moved into the outlying areas and suburban school districts bordering on the centrally located Houston Independent School District have been integrated. A few small, semi-rural school districts remain more than 90 percent Anglo. Several others including those containing a number of planned communities have minority enrollments of less than 20 percent. These school districts are 20 to 30 miles from the CBD and if the demand for racial and ethnic exclusivity is a significant factor in the rapid development of these areas the vacant land between these communities and the CBD will not be developed.

Some rapidly growing suburban districts are integrated at the school district level though neighborhood segregation results in segregated primary schools, and even segregated high schools.

Fiscal factors, often cited as one factor leading to the formation of homogeneous high-income suburbs are not a significant explanation of decentralization of Houston. During the last decade the city of Houston has chosen to annex little of its extra-territorial jurisdiction but because of its substantial industrial tax base its taxes are not higher than suburban jurisdictions. There is considerable variation of taxes among municipal utility districts and some of the smaller districts developed in the late 1970s. But even the larger more efficient master-planned communities have tax rates in excess of the central city.

However, there appears to be some value living in a more decentralized environment. Suburban residents seem to prefer inefficient volunteer fire departments or independent security patrols than to be serviced by the monolithic Houston fire and police department.

5. Concluding remarks

We have reviewed various models of urban structure and have documented the decentralization of residential activity in Houston. The evidence on lot size by location, and the density gradients estimated with land area actually used for housing provide stong evidence that residential densities are, and have been quite uniform throughout the Houston area for some time. The significnce of vacant land suggests that declines in aggregate density over time are explained by the abandonment of inner city housing as well as suburban development rather than by an increase in the amount of land per occupied housing unit.

The historical development of Houston is generally supportive of the durable, non-malleable model developed by Harrison and Kain, though the Houston evidence is consistent with certain predictions of the standard monocentric model such as the increase in the price gradient with city size. Also with the great abundance of land in Houston and the relatively fast travel times (except in the late 1970s and early 1980s) it is not surprising that suburban development dominated an increase in the residential density of the inner city.

Houston's spread out development, leapfrogging over large tracts of vacant land, to locations 25–30 miles from CBD is consistent with the view that suburbanization is due in part to a flight from higher crime rates in the inner city. Suburbanization increases the distance between high and low income neighborhoods. Also, the heavy reliance on automobile travel reinforces the infrequent interaction between different socio-economic groups. The systematic piece of evidence we have on the importance of neighborhood effects is the co-existence of very high prices in some inner city neighborhoods and the decline and abandonment of areas close by.

Appendix

Table A.1

Estimated micro density functions.[a]

Pre-1950s

$$\text{Log (density)} = -8.79 - 0.0193 * \text{DIST} \qquad R^2 = 0.11$$
(293.6) (7.7)

$$\text{Log (density)} = -8.54 - 0.0058 * \text{DIST} - 0.20 * \text{SQFT} \qquad R^2 = 0.23$$
(212.2) (2.0) (8.4)

1950s

$$\text{Log (density)} = -8.92 - 0.017 * \text{DIST} \qquad R^2 = 0.02$$
(138.3) (2.5)

$$\text{Log (density)} = -8.47 - 0.018 * \text{DIST} - 0.28 * \text{SQFT} \qquad R^2 = 0.16$$
(96.7) (2.9) (7.1)

1960s

$$\text{Log (density)} = -8.88 - 0.019 * \text{DIST} \qquad R^2 = 0.05$$
(152.9) (4.6)

$$\text{Log (density)} = -8.44 - 0.019 * \text{DIST} - 0.23 * \text{SQFT} \qquad R^2 = 0.19$$
(109.2) (4.9) (7.9)

1970s

$$\text{Log (density)} = -8.44 - 0.033 * \text{DIST} \qquad R^2 = 0.15$$
(177.6) (13.6)

$$\text{Log (density)} = -7.90 - 0.031 * \text{DIST} - 0.28 * \text{SQFT} \qquad R^2 = 0.29$$
(137.8) (13.8) (14.2)

1980s

$$\text{Log (density)} = -8.49 - 0.026 * \text{DIST} \qquad R^2 = 0.13$$
(282.8) (18.0)

$$\text{Log (density)} = -7.9 - 0.021 * \text{DIST} - 0.29 * \text{SQFT} \qquad R^2 = 0.45$$
(274.9) (18.6) (36.6)

[a] t-statistics given below estimated coefficients.

Table A.2

1980 estimated density functions.

Gross density

$$\text{Log (density)} = 2.82 - 0.148 * \text{DIST} \qquad R^2 = 0.416$$
(2.8) (17.5)

Net density

Occupied land

$$\text{Log (density)} = 2.52 - 0.058 * \text{DIST} \qquad R^2 = 0.178$$

$$\text{Log (\% occupied)} = 0.308 - 0.0903 * \text{DIST} \qquad R^2 = 0.545$$
(0.66) (24.3)

Residential land

$$\text{Log (density)} = 3.12 - 0.0498 * \text{DIST} \qquad R^2 = 0.263$$
(6.59)(12.9)

$$\text{Log (\% occupied)} = -0.292 - 0.0985 * \text{DIST} \qquad R^2 = 0.267$$
(0.312)(13.1)

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