UNDERSTANDING THE BOSTON REAL ESTATE MARKET: A SYSTEM DYNAMICS APPROACH

by

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Submitted to the Sloan School of Management
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ABSTRACT

Median housing prices in the city of Boston have risen over six-fold in the twenty years since 1970. To explain the rapid rise in housing costs, this paper explores the fundamental economic factors behind the Boston residential real estate market. The events of the past two decades are put into perspective, by exploring the trends in population growth and the rate of household formation, the growth of the regional economy, the change in interest rates, the rise in household incomes, and the supply of housing.

Through the use of computer simulation, a system dynamics model is presented which explains the pricing behavior exhibited by the Boston housing market. The simulation closely models the change in real estate prices observed over the past twenty years, explaining roughly 90 percent of the price variation in the Boston market. The model is further used to simulate the supply and demand in the real estate market for the next decade, to show that even under aggressive economic assumptions, there will need to be a "correction" in housing prices before demand catches up with supply. The correction in prices will range from 5 to 20 percent depending on the direction in which the regional economy heads.

Thesis Supervisor: John D. Sterman

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ACKNOWLEDGEMENTS

A number of people were influential in encouraging me to develop a computer simulation of the Boston housing market. Foremost, I would like to thank my thesis advisor, John Sterman, for introducing me to the field of system dynamics through his model of the growth and decline of People Express Airways. After watching his demonstration of how a complex situation could be modeled on a personal computer, I was prompted to enroll in his course on system dynamics in the Spring of 1988. Though his insights and guidance, I was able to apply the methodology of system dynamics to the real estate industry.

I would also like to thank Alexander Ganz and Rolf Goetze at the Research Department of the Boston Redevelopment Authority. The research which they have conducted has proven invaluable in my understanding of the Boston housing market.

I would like to thank Karl Case, visiting scholar at the Federal Reserve Bank of Boston, for discussing the econometric model of the Boston housing market which he created. His research has helped me to formulate several segments of my model.

David Kirk, Director of the Boston Financial Consulting Group, Inc., deserves special mention for sharing with me his recent study of the Cambridge and Boston condominium market.

My thanks are also due to Lesley Cummin for the time she took to review my final draft before printing.

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INTRODUCTION

The 1980's have proven to be a turbulent decade for the Boston real estate market. Since 1980, the regional economy recovered from a deep recession generating job and income growth among the fastest in the nation; an economic resurgence dubbed the "Massachusetts Miracle". A remarkable boom in housing prices has accompanied the miracle. Between 1983 and mid-1987 housing prices in the Boston region have more than doubled. An often-cited report by the National Association of Realtors showed the median sales price of existing single family homes in the Boston metropolitan area rose 38 percent in 1985 alone.[1] In the second quarter of 1985 alone the median sales price in Boston rose from $108,600 to $131,000, an increase of more than 20 percent. The monthly mortgage payment needed to service this purchase also rose from $920 to $1,112.[2] Rapidly rising home prices have created an "affordability crisis" for the first-time home buyer.

The effects of the affordability crisis seem to be spilling over into the labor market. There is increasing concern that the rising cost of housing is limiting the region's businesses from attracting employees -- at all income levels -- from other regions where housing costs are much lower. A recent report by the Boston Redevelopment Authority makes a strong case that the shortage of affordable housing is the number one barrier to bringing workers into the Boston area.[3] The boom in the real estate market, spurred by the resurgence of the region's

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[1] Karl E. Case, "The Market for Single-Family Homes in the Boston Area," New England Economic Review, Federal Reserve Bank of Boston, May / June 1986: pp. 38-39.

[2] Assumes 20 percent down, fixed-rate, 30-year mortgage, no points at 12.4%, (the average mortgage interest rate in 1985).

[3] Rebecca Stevens,."The Housing Crisis and New England's Economy: State and Local Initiatives to Offset the Federal Retreat," Boston Redevelopment Authority, October, 1988: pp. 4-8

economy, may thus prove to be the the economy's downfall. The shortage of affordable housing may crimp New England's labor supply and regional competitiveness for years to come. Frank Morris, the chairman of the Federal Reserve Bank of Boston -- who in 1975 predicted the region's economic resurgence -- predicted in June 1988 a decade of significantly slower employment growth in the region (a rate of half the national rate). "To maintain past levels of growth would require a large in-migration of workers to the region which," Morris said, "is precluded by the region's high housing costs."[4]

Amidst rising concern about housing affordability, however, another seemingly contradictory crisis is unfolding. Regional banks, particularly savings and loan institutions, are experiencing increasing problems with their real estate loan portfolios. In several segments of the housing market, particularly suburban condominium projects, housing demand has fallen off significantly. The softening market places many development projects in jeopardy and is sending a ripple of panic through the regional banking system.[5] Why are development projects failing if we are in the midst of a housing shortage?

In the most comprehensive explanation to date of what has taken place, Karl Case, visiting scholar with the Federal Reserve Bank of Boston, has attempted to explain the boom in the real estate market through a structural econometric model of housing supply and demand.[6] In 1986, Case was only able to explain roughly 40 percent of the rapid rise in area real estate prices. As an alternate explanation, Case suggests that the Boston market is locked into an expectational spiral, much as the Amsterdam Stock Exchange had been during the 1630's tulip

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[4] David Warsh, "Decade of Slow Growth Seen for Massachusetts Economy," Boston Globe, June 23, 1988.

[5] "Real Estate Market in New England States Hits Slump: Banks are Feeling the Pinch," The Wall Street Journal, July 12, 1989.

[6] Karl E. Case, "The Market for Single-Family Homes in the Boston Area," New England Economic Review, Federal Reserve Bank of Boston, May / June 1986: pp. 38-48.

bulb mania.[7] In such a spiral, rising prices feed expectations of future price increases, leading to increased speculative demand and still higher prices -- a positive feedback loop of self - fulfilling expectations. Ultimately, however, all such speculative bubbles burst as prices outstrip the earning potential of the underlying investment and the incomes of potential buyers.[8]

In the Fall of 1988, Case suggested that real estate prices may have already peaked in the Boston area and the real estate market is heading into a "post-boom" period.[9] As prices soften, savings and loan institutions who lent to marginal borrowers on the assumption that rising prices would cover their exposure,are experiencing rising defaults and foreclosures, a phenomenon all too familiar to lenders in Texas and Colorado.

In order to make sense of the conflicting perceptions and explanations behind the Boston real estate market, I have developed my own economic model of the market. The model is in the form of a computer simulation which employs the conceptual framework and methodology of "System Dynamics," developed by Jay W. Forrester in the 1960's at the Sloan School of Management at the Massachusetts Institute of Technology. Using the model, I will explain the economic factors behind the the rapid boom and subsequent leveling off of housing prices in the 1980's. The model can be used as a forecasting tool to understand the market under varying assumptions regarding interest rates and other macroeconomic variables. It may also be used to understand the implications of various public policies aimed at alleviating the region's affordability crisis.

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[7] Fernand Braudel, The Wheels of Commerce -- Civilization & Capitalism, 15th-18th Century (Volume II), Harper & Row , 1986: p. 101.

[8] Charles Kindleberger, Manias, Panics, and Crashes, Basic Books, NY, 1978.

[9] Karl E. Case and Robert J. Shiller, "The Behavior of Home Buyers in Boom and Post-Boom Markets, The New England Economic Review, The Federal Reserve Bank of Boston, Nov / Dec 1988: 29-46.

CHAPTER 1

OVERVIEW OF THE BOSTON REAL ESTATE MARKET.

Before presenting the model of the Boston Housing Market, it is necessary to put the events of the past two decades into perspective. Several aspects of the Boston real estate market were explored in detail. The relevant data fall into three broad categories: recent trends in the demographics of Boston; economic trends in the region; and the housing market itself. To aid in the discussion of the model, the following variables will be explored further:

1) Population Trends. Census data and projections of population trends for the city will be reviewed. Birth rates, death rates, net migration, as well as trends in average household size will be explored in order to estimate the rate of household formation.
2) The Regional Economy. Levels of employment (and unemployment rates) and the rise in wage levels will be discussed to gauge the magnitude of the "Massachusetts Miracle."
3) Interest Rates. Mortgage interest rates for home buyers in the city of Boston will be tracked for the past twenty years.
4) Household Income Census data on household incomes, their distribution, and the rate of labor force participation will be reviewed to understand how many households are able to participate in the housing market.
5) The Housing Market. The size of the housing market, rates of production of new units, as well as the nature and types of units (i.e., subsidized housing units, rental units, owner-occupied, and condominium units) will be explored.
6) Housing Prices.Housing prices in Boston will be discussed at the neighborhood level. Price levels for the following are considered: sales prices of

condominium units; sales prices of existing rental units; and the monthly rents of existing market rental units (rental units are still the predominant form of tenancy in the city of Boston).

GEOGRAPHIC SCOPE OF STUDY

The Boston Redevelopment Authority has divided the city of Boston into sixteen neighborhood planning districts which follow the lines of local convention. I have limited the scope of the study to those neighborhoods most impacted by the recent rise in condominium activity. The study area consists of the most central neighborhoods: East Boston, Charlestown, South Boston, Central (the North End, downtown waterfront, Chinatown), Back Bay / Beacon Hill, the South End, Fenway / Kenmore, and Allston / Brighton. Together these eight neighborhoods comprise roughly half the population and housing stock and nearly 80 percent of the condominium activity. The map in Figure 1.1 shows the study area in relation to the city of Boston.

POPULATION TRENDS AND RATE OF HOUSEHOLD FORMATION

In May of 1987, a state report found Boston's 1985 population to be 601,095, representing an increase of 38,100 from the 1980 population of 562,994, and a reversal of thirty years of decline.[9] Figure 1.2 shows that all of Boston's neighborhoods have shared in this decline and subsequent recovery.

Boston's population had fallen by almost a third from its peak of 801,000 in 1950, to the low-point of 563,000 in 1980, as a result of post-war suburbanization, the loss of more than half of

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[9] The Report of Decennial Census Commission to the Secretary of the Commonwealth of Massachusetts on the Boston Decennial Census of January 1, 1985, Boston, May 1987.

Figure 1.1: Study Area.

the city's manufacturing jobs, and the effect of the deep national recession of the early 1970's on Boston. Unemployment reached 12.5% in 1975, and as the city lost its blue-collar jobs, it also lost blue-collar workers and their families. Compounding these factors were increasing racial strife manifesting itself through the school busing crisis and the subsequent flight of white families to the suburbs.

A confluence of factors are contributing to the population revival. In the 1970-80 decade, while Boston's overall population level was declining, there was a substantial net increase in the young adult population (+ 28,000 for 25 to 34 year olds),particularly in the core neighborhoods of this study. In-migration of young adults continued through the 1980's. The massive outflow of blue-collar workers and their families has ceased with the stabilization of industrial jobs and the improvement of neighborhood housing conditions. In addition, Boston's birth rate has been rising since 1977. Improved life expectancy for all segments of the population has also lead to a declining death rate for Boston's residents. Figure 1.3 shows the net migration, birth and death rates for the core neighborhoods of this study expressed as annual percentages of the total population.

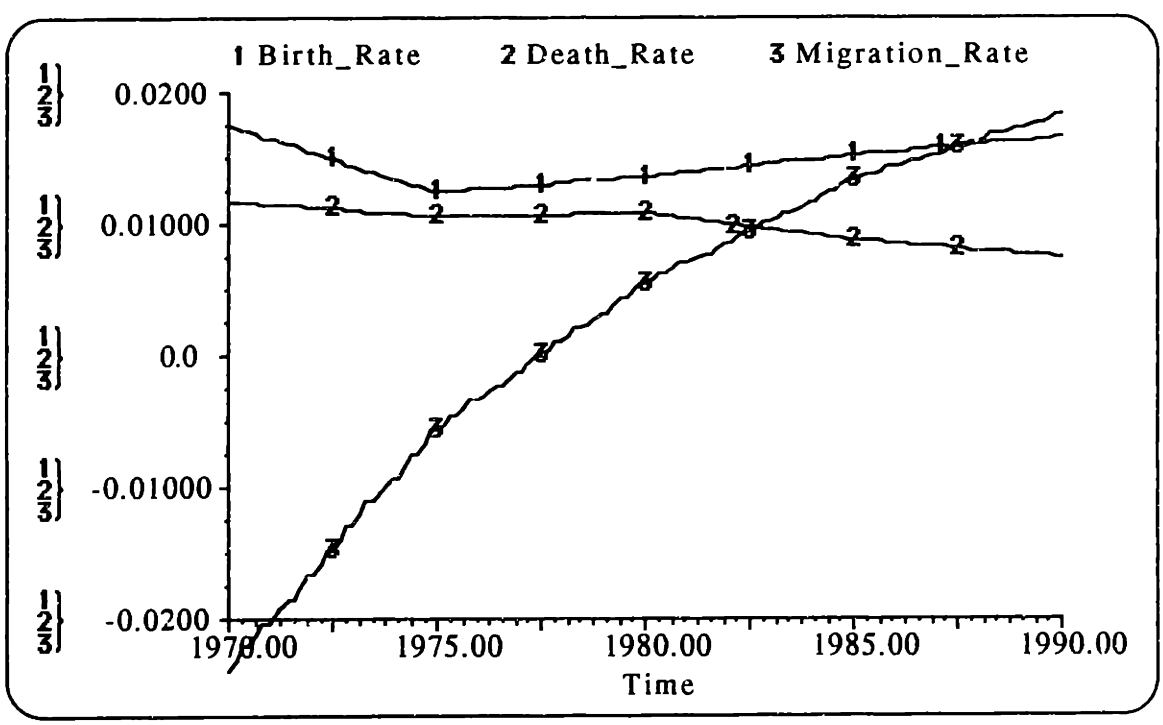
Figure 1.2: Boston Population by Neighborhoods (1950 - 1985).[10]

Neighborhood	1950 Population	1960 Population	1970 Population	1980 Population	1985 Population
1. East Boston	51,152	43,809	38,873	32,178	32,956
2. Charlestown	31,332	21,147	15,353	13,364	13,441
3. South Boston	55,670	43,959	38,488	30,396	30,079
4. Central	38,381	20,681	19,344	21,862	24,924
5. Back Bay / Beacon Hill	28,150	24,939	27,538	30,212	31,552
6.. South End	57,218	35,002	22,680	27,125	25,372
7. Fenway / Kenmore	36,649	32,963	32,965	30,842	36,649
8. Allston / Brighton	67,102	64,207	63,657	65,264	68,413
TOTAL STUDY AREA	365,654	286,624	257,497	248,177	266,635
CITY OF BOSTON	801,000	698,081	641,071	562,994	601,095

10 "Population Projections for Boston," The Boston Redevelopment Authority, 1985.

In addition to a reversal in the decline of Boston's population, average household size has begun to level off after a long period of decline. Average household size fell from 2.73 persons in 1970 to 2.43 persons in 1980, reflecting a national trend of growth in non-family households as rising income and relatively cheap housing made it easier for the young and the old to spin off from the nuclear family. Stability has emerged since 1980, with a 1985 average of 2.40 persons per household. In the core Boston neighborhoods, population per household has also declined (from 2.31 in 1970, to 2.07 in 1980) and began to stabilize (at 2.06 in 1985). These figures reflect the younger, increasingly single, professional people who have returned to the city. Figure 1.4 shows the downward trend on the neighborhood level, while Figure 1.5 shows the total population and the number of households in the study area for the past two decades.

Figure 1.3: Net Migration, Birth, and Death Rates (1970 - 1990)[11]

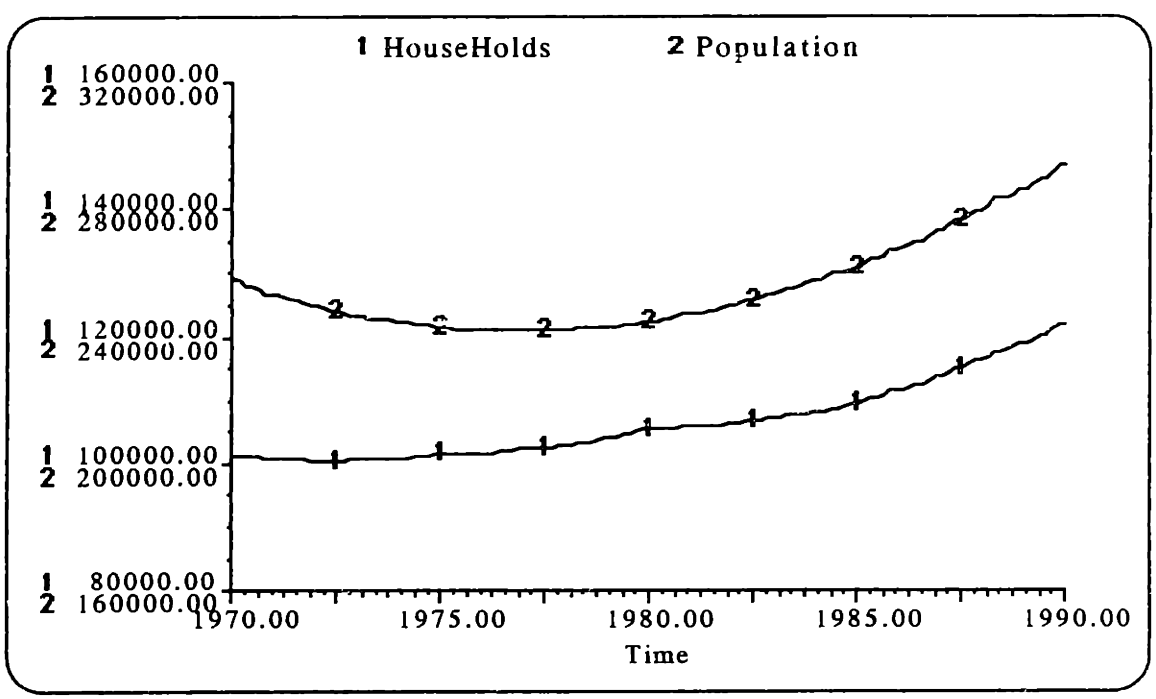


11 Ibid.

Figure 1.4: Population per Household by Neighborhoods (1970 - 1985).

Neighborhood	1970 POP / HH	1980 POP / HH	1985 POP / HH
1. East Boston	3.00	2.45	2.40
2. Charlestown	3.06	2.53	2.30
3. South Boston	2.78	2.39	2.30
4. Central	2.10	1.88	1.90
5. Back Bay / Beacon Hill	1.58	1.51	1.60
6.. South End	2.17	2.16	1.80
7. Fenway / Kenmore	1.68	1.57	2.10
8. Allston / Brighton	2.40	2.19	2.10
TOTAL STUDY AREA	2.31	2.07	2.06
CITY OF BOSTON	2.74	2.43	2.40

Figure 1.5: Population and Households in Study Area (1970-1990)



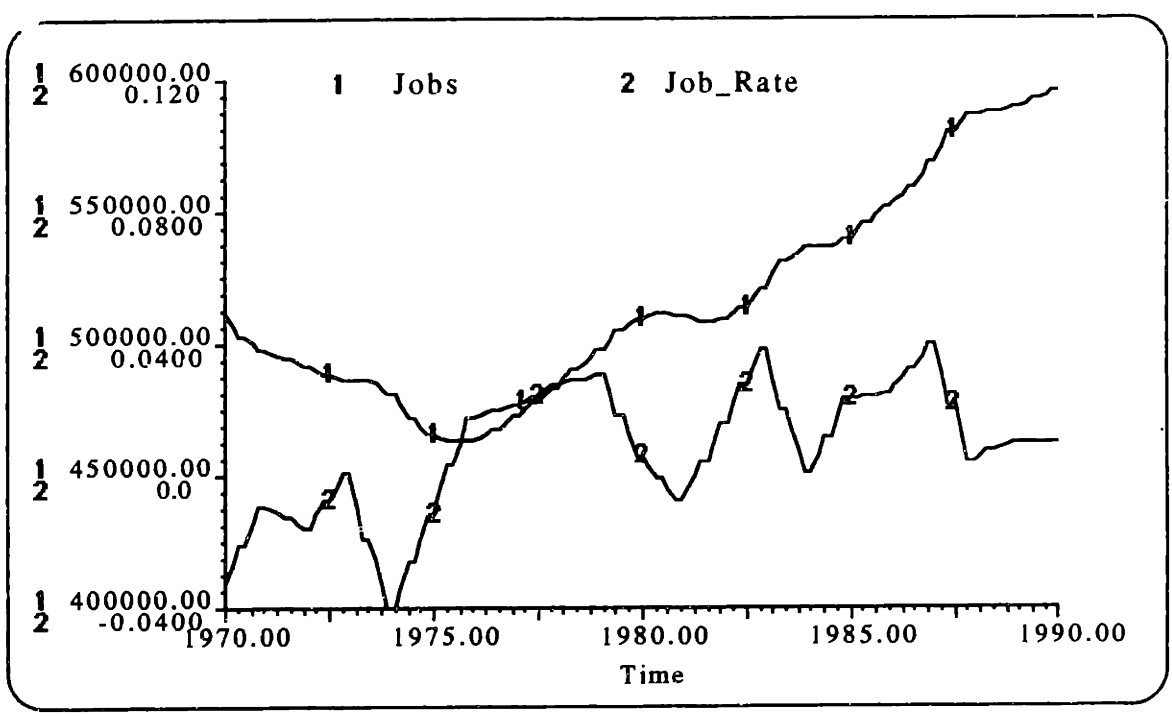
THE REGIONAL ECONOMY

The recent performance of the Boston economy has been extraordinary and prospects for the future still remain strong. Boston's jobs expanded from 458,000 in 1976 to 566,000 in 1988, an annual growth rate of 1.8%. Employment growth from 1983 to 1988 was 54,300,

representing an annual growth rate of 2.1%. Figure 1.6 shows the employment base in Boston as well as the annual rate of change.[12]

These trends reflect Boston's emergence as the pre-eminent service economy and exporter of services among the nation's large cities. In 1984, Boston ranked highest with 57% of its employment in services, finance, and transportation and communication, in comparison with 56% in San Francisco, and 53% in New York City.[13] Boston also led the way as an exporter of services, with a 35% share of services employment dedicated to exports, surpassing the relative size of the services export role in San Francisco and New York City, the runner-up cities. Boston's service activities, dominated by professional and business

Figure 1.6: Boston Employment and Rate of Change (1970-1988)[14]



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12 Alexander Ganz, "The Boston Economy and the Housing Market," Boston Redevelopment Authority, June 1987: p. 1.

13 Ibid: p. 1.

14 Research library of the Commonwealth of Massachusetts, Division of Employment Security.

services, higher education and medicine, money management and communications, serve the needs of the metro area, state, New England region, the nation and the world.

Boston's prosperity mirrors that of the region it serves. The U.S. Bureau of Economic Analysis reported in April 1987 that "In 1986, the largest percentage gains in per capita income were in the high income regions - New England and the Mid Atlantic. In both regions, per capita income has increased faster than the national average in every year since 1980". New England had the highest 1986 growth rate (6.5%) of the nation's eight regions. The Massachusetts rate was 6.9%.[15]

The Boston economy has gained not only in the number of jobs, but also in quality. Since 1982, Boston's per capita income growth has exceeded that of the metro area, state, New England region, and the nation, reflecting the upscale occupations and income of a growing share of its labor force and the quality of the city's jobs. Average annual wage growth in Boston has been higher than that for the metro area and state in each of the last seven years. Wages have increased with the rapid growth in employment in small and medium sized businesses and professional services firms, which have a larger share of professional, managerial and technical workers, in comparison with the slower growth in employment for the large banks and insurance companies. As a result, average annual wage increases for Boston jobs has regularly exceeded the rise in the consumer price index and has helped fuel the rise in both household incomes and the amount of disposable income available for the purchase of housing services. Figure 1.7 summarizes the average annual wage in the city of Boston as well as the annual percentage increase.

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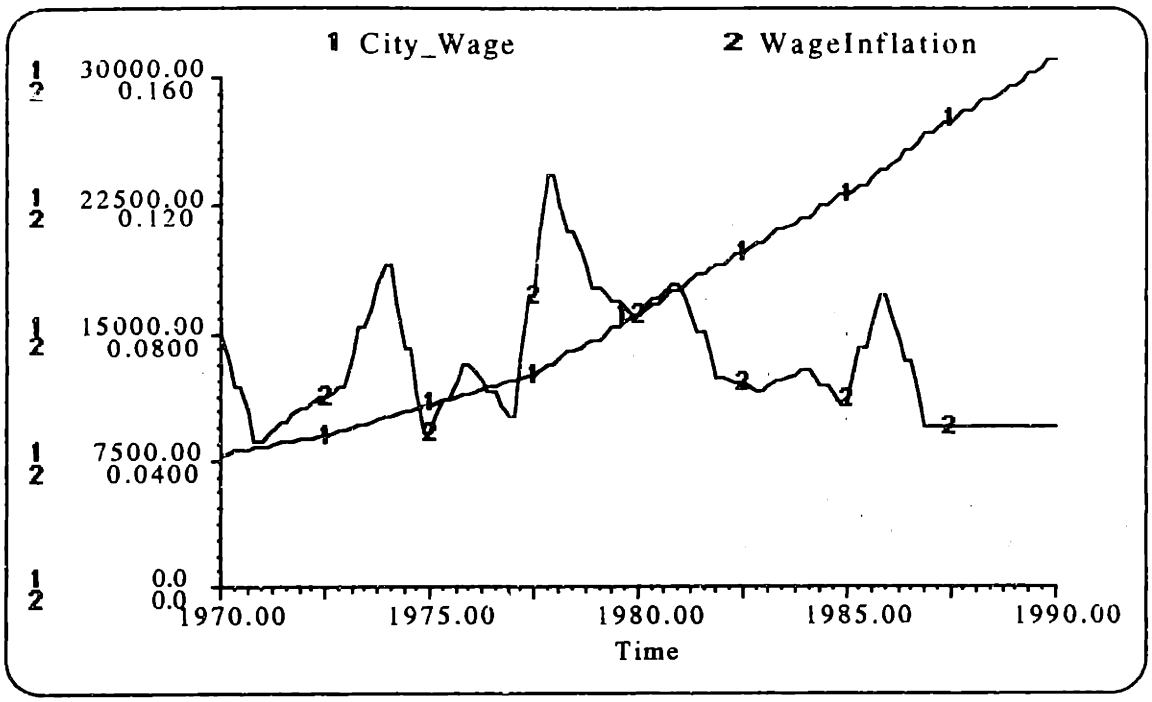
15 Op Cit, A. Ganz: p. 2.

Figure 1.7: Boston Annual Wage and Rate of Change (1970-1988)[16]



While the boom in the Boston economy during the 1980's helps to explain why its real estate market rose dramatically, it is equally important to put the events of recent years into broader perspective. The first oil shock of the 1970's hit the New England economy, and Boston in particular, especially hard. Together with a post-war decline in manufacturing jobs, the unemployment rate peaked at 12.7% in 1975, compared to 8.5 % nationally. The effects of the 1974-75 recession persisted longer than they did nationally, helping to keep the real estate market relatively depressed. The transformation of the Massachusetts economy to a more service - oriented basis helped to insulate the region from the effects of the 1980-82 recession. In fact, the slow-down was less severe than that of the 1970's with the unemployment rate peaking at 9.0% in 1982. compared to 10.8% nationally. Figure 1.8 summarizes these findings.

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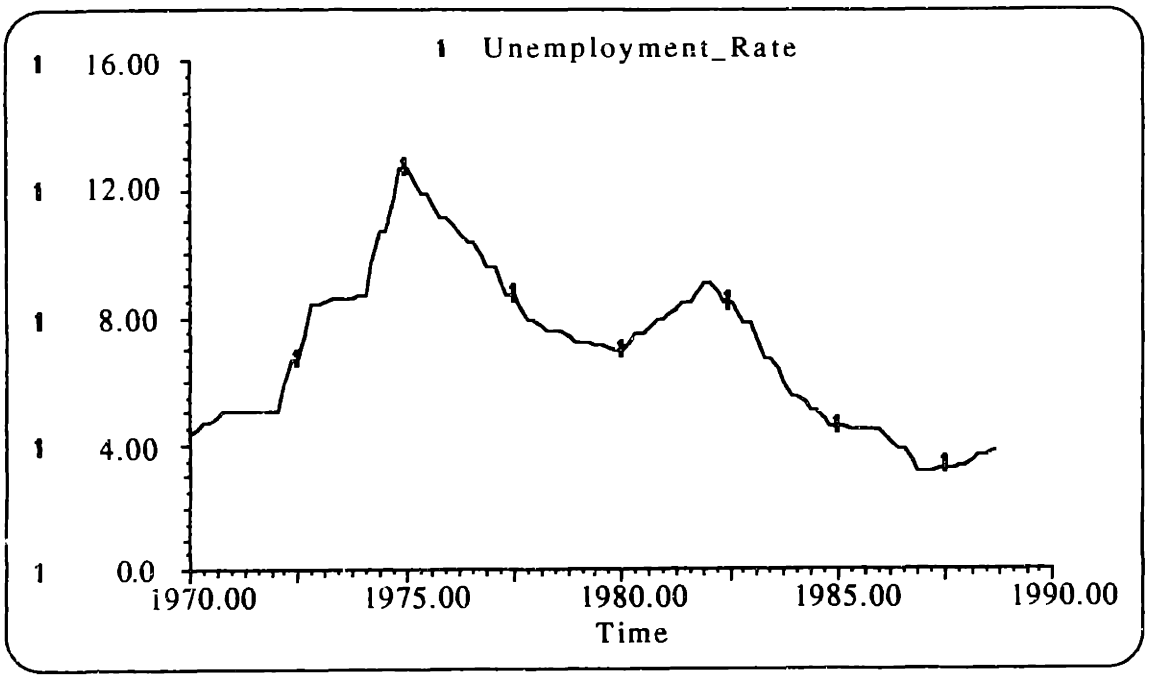
16 Research library of the Commonwealth of Massachusetts, Division of Employment Security.

Figure 1.8: **Boston Unemployment Rate (1970-1988)**



INTEREST RATES

The cost of financing is critical to both housing purchase and real estate development decisions. Interest rates fluctuated widely since 1970 and the deregulation of the financial industry caused a number of financing alternatives to supplement the conventional 30-year fixed-rate home mortgage. Whereas the fixed-rate mortgage comprised over 90 percent of home purchases in 1970, recent estimates by the Federal Home Loan Bank Board indicate that roughly one half of new mortgage originations in the Boston area are done on a floating rate basis.[17] In normal times, with a rising yield curve, these adjustable rate mortgages (ARM's) have offered a lower rate of interest than their fixed-rate counterpart. Lower short-term rates help to lower the initial cost of borrowing allowing more households to qualify for a loan, though possibly creating problems later. Figure 1.9 shows the effect of the growing use of

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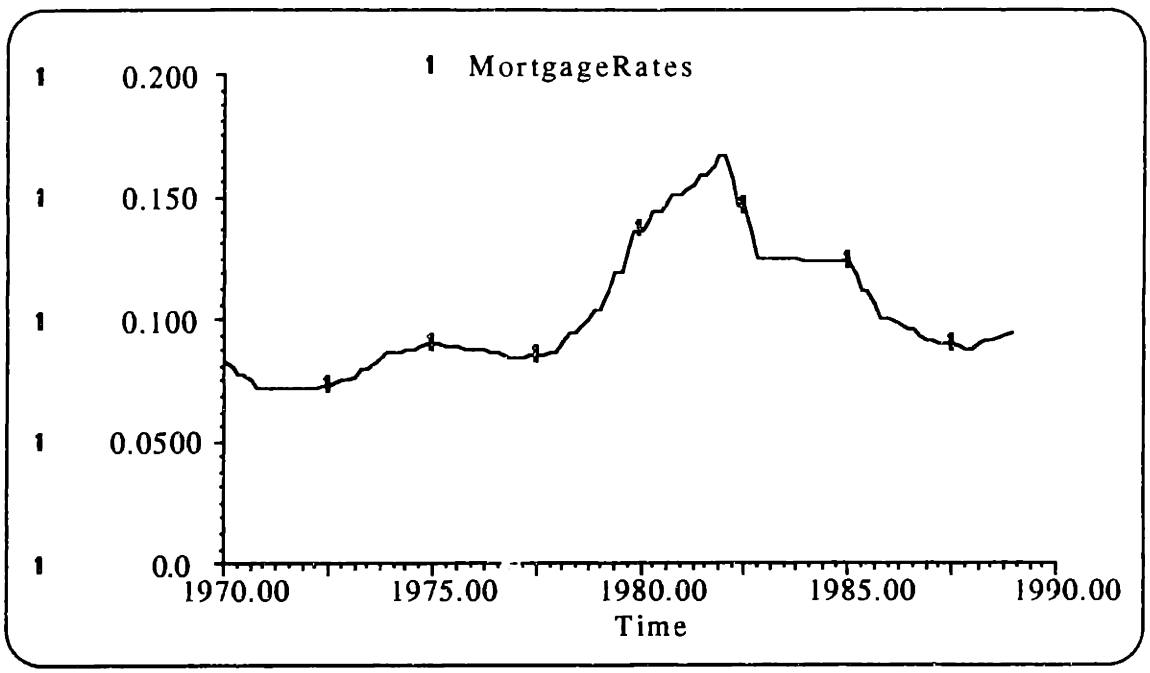
[17] Interview with Karl E. Case, visiting scholar with the Federal Reserve Bank of Boston.

ARM's by plotting the weighted average of the initial interest rate for all mortgages (both fixed and floating) originating in the Boston area.

Figure 1.9: Mortgage Interest Rates for the Boston Region (1970-1988)[18]



HOUSEHOLD INCOMES

One of the most important variables needed to predict the level of real estate prices is a measure of household incomes. The amount of household income available to service mortgage payments, property taxes, and other operating costs will be the primary driver in the real estate market. Even with rampant speculation, housing is still purchased primarily as a person's prime residence and not as an investment. In a recent survey of home buyers in the Boston area, 15.6% purchased a house "strictly for investment purposes"[19] As such, the

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18 Research library of the Federal Home Loan Bank of Boston.

19 Karl E. Case and Robert J. Shiller, "The Behavior of Home Buyers in Boom and Post-Boom Markets," New England Economic Review, Federal Reserve Bank of Boston, Nov. / Dec. 1988: p. 35.

amount of money which financial institutions will lend against a households' income will help establish a ceiling above which real estate prices will be reluctant to pass.

It is important to understand the relationship between household incomes and home prices on the local level. Often affordability indices of real estate are created to correlate the median household income of a region with the median sales price of homes. A problem, however, lies in the aggregation of data. Summarizing household incomes on a national level and comparing with the national median home price conveys very little information. To aggregate local household incomes and home prices in Milwaukee with those of Orange County to establish a national "affordability index" hides much of the richness in the local data.

Likewise, measures comparing Boston SMSA household incomes with regional home prices have their shortcomings. Just as data from Wisconsin should not be combined with that from California, one must be careful from reading too much from "local" Boston SMSA data which aggregates data from Newton together with data from East Boston. Housing markets are an inherently local phenomena, and as such, I have attempted to correlate household income data and housing prices on the neighborhood level.

Unfortunately, the only good data for household income is tabulated every ten years by the U.S. Census Bureau. In addition, in 1985 the city of Boston conducted an extensive survey of more than 2,000 households to supplement the 1980 census data. To estimate household incomes in the off years, however, it was necessary to develop a proxy for household incomes based upon both the 1970 and 1980 census data and the annual city employment and wage data discussed earlier.

It is important to note that even with the extensive reporting provided by both the 1970 and 1980 U.S. Census surveys, the data are not always comparable across years. For instance, in 1970 the census data provides household income in detail only for families, and

not for households of singles or unrelated individuals. In 1970 only 65 percent of households were classified as families.

In 1980, the census data provides income statistics for all households and even provides separate figures for those households which own their own home. Unlike suburban housing markets where a majority of households own their own home, only 28 percent of Boston households owned their own home in 1980. Home-ownership in Boston has since risen to around 35 percent as the expanding condominium market has allowed more households to purchase their own home. It will therefore be important to separate out the average incomes of those households most likely to purchase their own home from the rest of the population.

Figure 1.10: Boston 1980 Household Income Data[20]

Neighborhood	Median HH Income	Owner HH Income	Index	Ownership Percentage
1. East Boston	11,359	15,516	1.36	0.32
2. Charlestown	13,535	22,192	1.64	0.33
3. South Boston	10,548	17,036	1.62	0.27
4. Central	15,314	27,318	1.78	0.10
5. Back Bay / Beacon Hill	17,266	38,405	2.22	0.20
6.. South End	12,178	28,090	2.30	0.16
7. Fenway / Kenmore	8,388	24,999	2.98	0.03
8. Allston / Brighton	12,699	20,856	1.64	0.16
CITY OF BOSTON	13,140	21,209	1.61	0.28

To analyze the 1970 and 1980 census data on the neighborhood level properly, it was first necessary to gather the data on the census tract level and then aggregate along the lines of the BRA designated neighborhoods discussed earlier. In 1980 there were 163 census tracts in the city of Boston which I combined to form summary data for the city's 16 neighborhoods. Figure 1.10 shows some of the summary data for the core neighborhoods encompassed by my study. In particular, I am trying to show the relationship between median income for all

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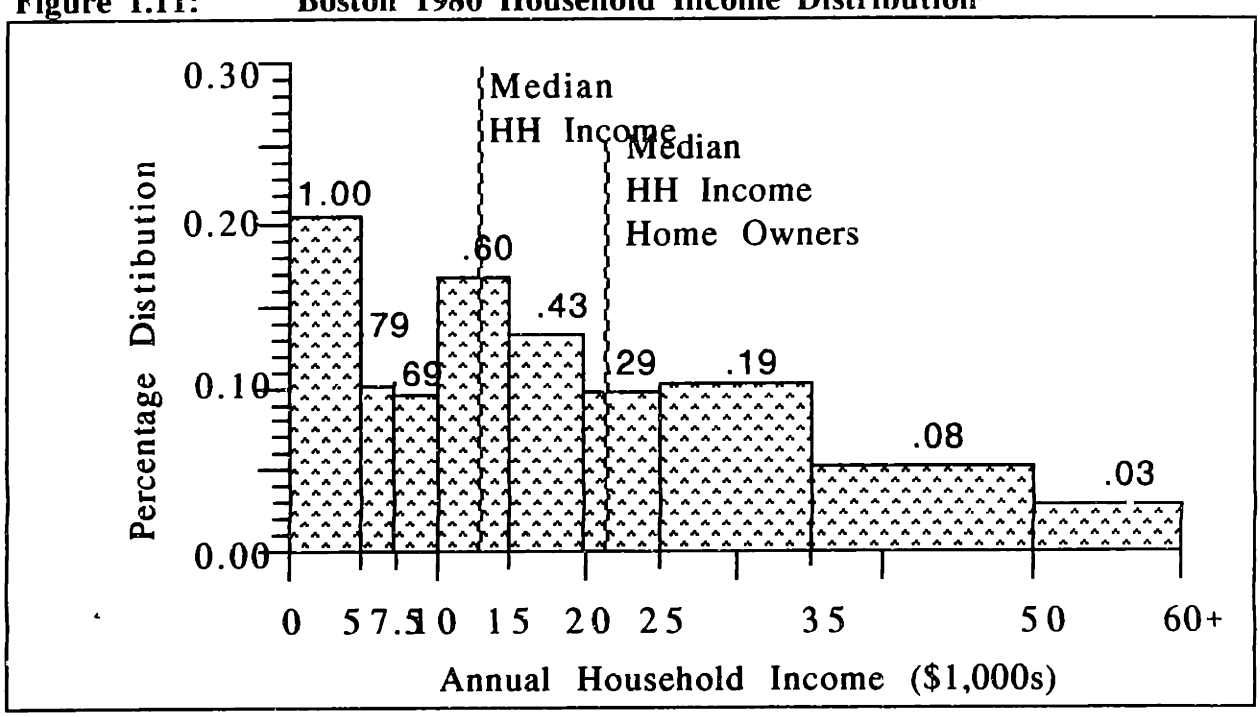
20 Summary of 1980 U.S. Census data.

households (the first column) with the median income of homeowners (the second). Also shown is the ratio between the two (the index) and the percentage of households which own their own home. As can be seen, for the city as a whole, the median income of homeowners is about 60% higher than that of all households. The traditional measure of median household income includes data for single households who tend to rent and for households below the poverty level who are provided housing services through the city's subsidized housing stock.

Figure 1.11: Boston 1980 Household Income Distribution[21]



To understand the income levels of those households most likely to purchase their own homes, it is necessary to look at the distribution of household incomes across different income groups. The 1980 census data provides information about household incomes along 9 income intervals. The histogram in Figure 1.11 shows the distribution of household incomes in the city of Boston. It is important to note that the shape of this income distribution is similar on

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21 Ibid.

both the neighborhood level (although with varying median income levels) and across time, as compared with the 1970 census data.

The cumulative percentage figures appear above each income level,showing the percentage of households with incomes at that level or above. For instance 29% of households earned $20 - 25,000 or above in 1980. The same income interval contains the median income level of homeowners ($21,209) which comprise 28% of the total households. It is the income level of homeowners for which a proxy needs to be developed.

A proxy can be found by looking at the link between the average number of wage-earners per household, the average Boston wage, and median homeowner household income. Figure 1.12 shows the resulting relationship in 1980. By multiplying the average city wage by the number of workers per household (Labor per HH) produces a measure of wage income per household (Imputed HH Income) The ratio of the wage income calculation to the total household income for homeowners produces the Area Index.

The Area Index is a measure of the relative wealth of the various neighborhoods in Boston. A figure greater than 1.00 indicates residents receive higher than average wages, or have sources of income other than wages which might include interest and dividend income, rents and royalties. For neighborhoods with an index less than one, the indication is that the average residents are not able to receive the average city wage for their labor. Figure 1.13 shows that the area index has been increasing for most of the neighborhoods in Boston, an indication that the residents of Boston are making economic progress with respect to their suburban counterparts.

Figure 1.12: 1980 Factors Behind Proxy for Household Income [22]

Neighborhood	Average City Wage	Labor per HH	Imputed HH Income	Owner HH Income	Area Index
1. East Boston	15,827	1.13	17,885	15,516	0.87
2. Charlestown	15,827	1.25	19,874	22,192	1.12
3. South Boston	15,827	1.09	17,251	17,036	0.99
4. Central	15,827	1.30	20,575	27,318	1.33
5. Back Bay / Beacon Hill	15,827	1.24	19,264	38,405	1.96
6.. South End	15,827	1.18	18,676	28,090	1.50
7. Fenway / Kenmore	15,827	1.41	22,316	24,999	1.12
8. Allston / Brighton	15,827	1.31	20,733	20,856	1.01
STUDY AREA	15,827	1.25	19,784	23,987	1.21
CITY OF BOSTON	15,827	1.26	19,942	21,209	1.06

Figure 1.13: Area Index Over Time.[23]

Neighborhood	1970 Area Index	1980 Area Index
1. East Boston	0.92	0.87
2. Charlestown	0.96	1.12
3. South Boston	1.05	0.99
4. Central	0.91	1.33
5. Back Bay / Beacon Hill	1.66	1.96
6.. South End	0.79	1.50
7. Fenway / Kenmore	0.71	1.12
8. Allston / Brighton	0.99	1.01
STUDY AREA	1.02	1.20
CITY OF BOSTON	0.97	1.06

THE HOUSING MARKET.

To understand fully the nature of the housing stock, I turned to the research department of the Boston Redevelopment Agency (the BRA). As mentioned, through their system of classifications, they have divided the City into sixteen neighborhood planning districts which follow the lines of local convention. The BRA classifies the existing housing stock along four broad lines: subsidized housing units, private rental units, owner-occupied one-to-four family

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22 Ibid.

23 Ibid.

units, and condominiums. The BRA also tracks the housing stock by type of structure, either one-to-four family or multi-family rental, subsidized, or condominiums. Figure 1.14 shows a summary of the Boston housing stock by neighborhood in 1980.

In 1988, the BRA completed an extensive study of the changing Boston housing stock since 1970, together with projections to the year 2000. The following provides a summary:[24]

> In 1970, Boston was a city of 232,000 housing units, of which nearly 60 percent were located in one-to-four family strictures. These units were either owner-occupied or private apartments.
>
> By 1980, after a decade of slow but steady growth, Boston's housing stock had grown by a net 8,900 units to 241,200. The distribution of these units by type was much the same as it had been a decade earlier, except that the number of units developed or rehabilitated under subsidy had expanded from three to ten percent of the stock.
>
> Boston's housing market strengthened during the early 1980's and the rate of abandonment declined. By 1985 the city had gained another 8,100 units, at a net growth 80 percent higher than during the 1970's. However, this strong housing market encouraged another type of housing development, condominium conversion: between 1980 and 1985, over 13,000 already existing apartment units were converted into condominiums.
>
> The proportion of assisted housing nearly doubled from 1970 and 1985 from 22,300 units, or 9 percent of the 1970 stock, to 43,300 units, or 17.4 percent of the 1985 stock. Private rental housing declined by a similar amount, 20,000 units, during the same period, from 150,900 units or 65 percent of the 1970 stock, to 130,900 units or 52.5 percent of the 1985 housing stock.
>
> From 1984 to 1986, as Boston's revitalization took hold, housing values rose sharply, at over 30 percent per annum, driving up rents and making the Boston SMSA one of the highest priced regions in the country by 1987. Rising values spurred new housing development, including over 3,500 housing starts in 1986 alone.
>
> In the mid-1980's, market forces and tax reform skewed housing development toward condominium construction, while conversion of the city's rental stock into condominiums accelerated. Between mid-1985 and the end of 1986, over 7,500 apartment units were converted into condominiums, while another 660 units, nearly 20 percent of units constructed in 1986, were newly built as condominiums.

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24 Rolf Goetze and Mary Bourguignon, Boston's Housing Stock: 1970 - 2000, Boston Redevelopment Authority Policy Development and Research Department, January 1988.

Housing affordability has thereby become even more critical as the strong housing market and the loss of so much rental stock raised both the rents and the prices of existing and newly constructed units beyond the reach of more low and moderate income residents.

Due to Federal cutbacks in housing assistance, city and state programs designed to help maintain housing affordability were able to produce 1,060 assisted units in 1986. This was about one-third of the year's new housing stock and amounted to one unit for every four condominium conversions during this same period.

Condominium conversions in the future are expected to affect rental units in one-to-four family apartment buildings, as well as those private, multi-family structures. Meanwhile, the number of traditionally owner-occupied units in single-family homes, duplexes and triple-deckers is expected to remain roughly constant.

The result of these changes in the housing stock can be seen on the neighborhood level as the difference between Figure 1.14 and Figure 1.15. As discussed, I have limited the scope of the study to those neighborhoods of Boston most impacted by the recent rise in condominium activity: East Boston, Charlestown, South Boston, Central (the North End, downtown waterfront, Chinatown), Back Bay / Beacon Hill, South End, Fenway / Kenmore, and Allston / Brighton. Together these 8 neighborhoods comprise roughly half the population and housing stock of the city and nearly 80 percent of the condominium activity.

With data distilled from several BRA studies, I was able to create Figure 1.16, which shows annual changes in the number of rental units in the study area.[25] From a high of

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25 The following Boston Redevelopment Authority reports were used:

Alexander Ganz, "Housing Production in Boston: A Review of Supply, Inventory of Activity, and Issues for the Future," 1985.

Alexander Ganz, "Boston's Housing, 1988: An Informational Report," May 1988.

Alexander Ganz, "Boston Housing Facts and Figures, 1988.

Rolf Goetze, "Recent Condominium Development Patterns, 1986 - 1988," April 1989.

Rolf Goetze, "Boston's Changing Housing Patterns: 1970 to 1985, July 1986.

Rolf Goetze, "Boston's 1985 Housing Stock and Comparisons with 1980, By BRA Planning District," December 1985.

Rolf Goetze, Condominium Development in Boston: 1969 - 1987," August 1988.

86,700 rental units in 1970, the stock fell to a level of 65,000 units by 1987. In all years but 1977 new construction exceeded those units demolished or set aside under rental subsidy programs. The main driver behind the fall in rental units has been the dramatic rise in the rate of conversion of rental units to condominiums, reaching a peak of nearly 4,000 conversions in 1987.

During the same period the number of condominium units produced rose dramatically, from 600 units in 1970, to over 26,000 units in 1987. Figure 1.17 shows that most of the activity has taken place since 1980, with the majority of condominiums being supplied out of the existing rental housing stock. It is interesting to note that roughly 25% of all condominium units supplied are a result of new construction. From 1970 to 1987 the stock of subsidized rental housing doubled from 10,650 units to 21,050 units. At the same time the number of owner-occupied one-to-four family structures remained fairly stable at roughly 17,000 units. Figure 1.18 shows the levels of these various stocks from 1970 to 1990 (With years 1988 - 1990 projected)

Figure 1.14: Boston's 1980 Housing Stock by Neighborhood

Neighborhood	Assisted Housing	Rental Units	Owner-Occupied	Condos	Total Units
1. East Boston	2,100	8,650	3,800	0	14,550
2. Charlestown	1,850	2,600	1,650	0	6,100
3. South Boston	3,300	7,450	3,200	100	14,050
4. Central	1,600	8,650	550	800	11,600
5. Back Bay / Beacon Hill	650	14,400	950	2,400	18,400
6. South End	4,800	7,450	1,300	200	13,750
7. Fenway / Kenmore	1,200	10,900	100	50	12.250
8. Allston / Brighton	2,700	21,300	4,150	350	29,500
STUDY AREA	18,200	81,400	15,700	3,900	119,200
BOSTON TOTAL	40,150	141,550	54,650	4,450	241,100

Rolf Goetze and Mary Bourguignon, "Boston's Housing Stock: 1970 - 2000," January 1988.

Figure 1.15: Boston's 1987 Housing Stock by Neighborhood

Neighborhood	Assisted Housing	Rental Units	Owner-Occupied	Condos	Total Units
1. East Boston	2,150	8,500	4,250	450	15,350
2. Charlestown	1,900	3,150	1,750	1,050	7,850
3. South Boston	3,400	6,650	3,650	950	14,650
4. Central	1,900	6,450	700	4,950	14,000
5. Back Bay / Beacon Hill	750	11,150	900	6,450	19,250
6. South End	5,450	5,200	1,650	2,300	14,600
7. Fenway / Kenmore	1,550	8,400	100	3,100	13,150
8. Allston / Brighton	3,950	15,500	4,300	7,000	30,750
STUDY AREA	21,050	65,000	17,300	26,250	129,600
BOSTON TOTAL	44,750	122,350	58,750	31,500	257,350

Figure 1.16: Annual Change in Rental Units in Study Area

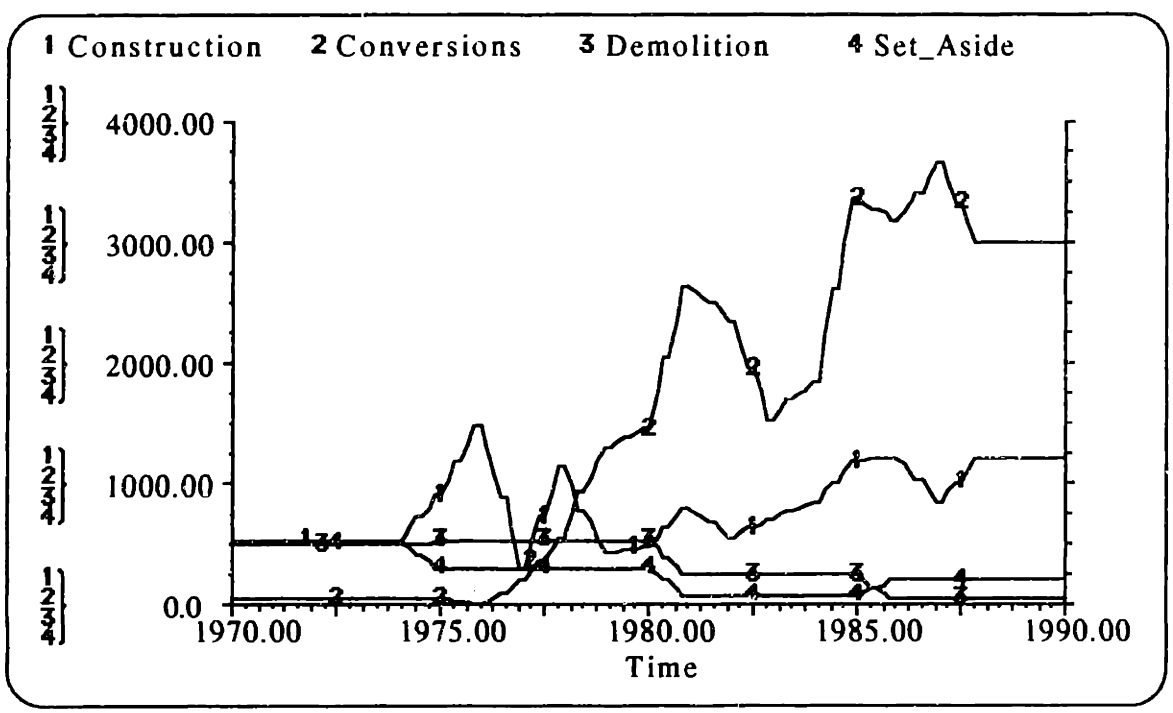


Figure 1.17: Annual Change in Condominium Units in Study Area

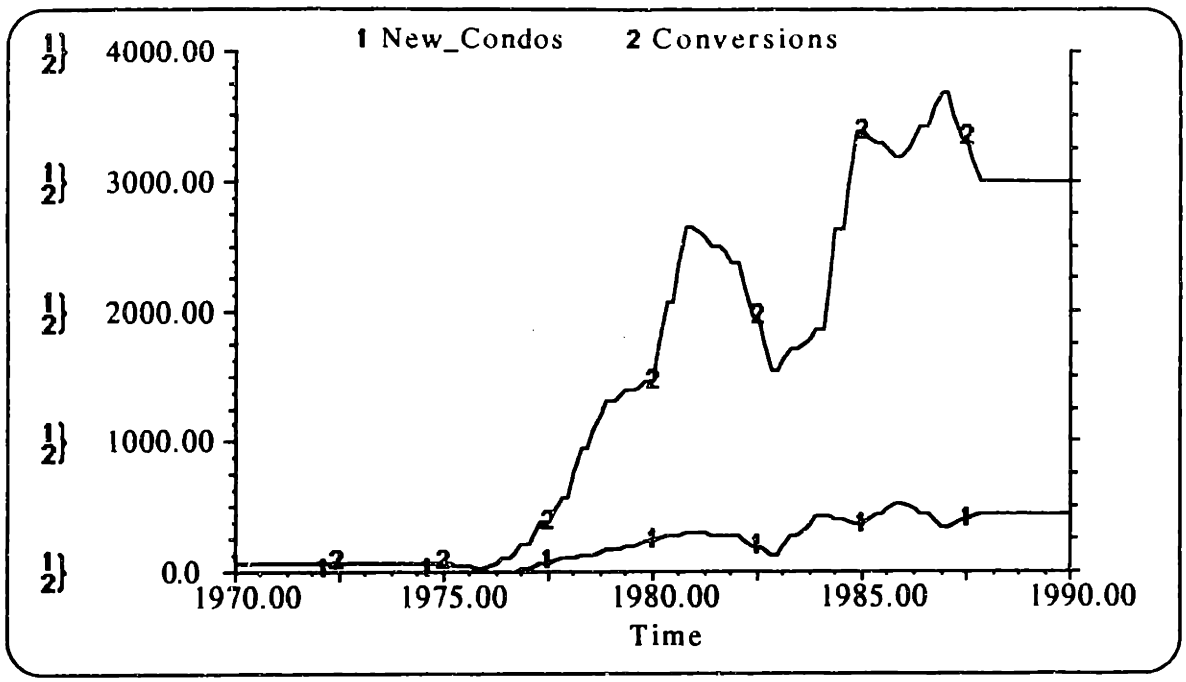
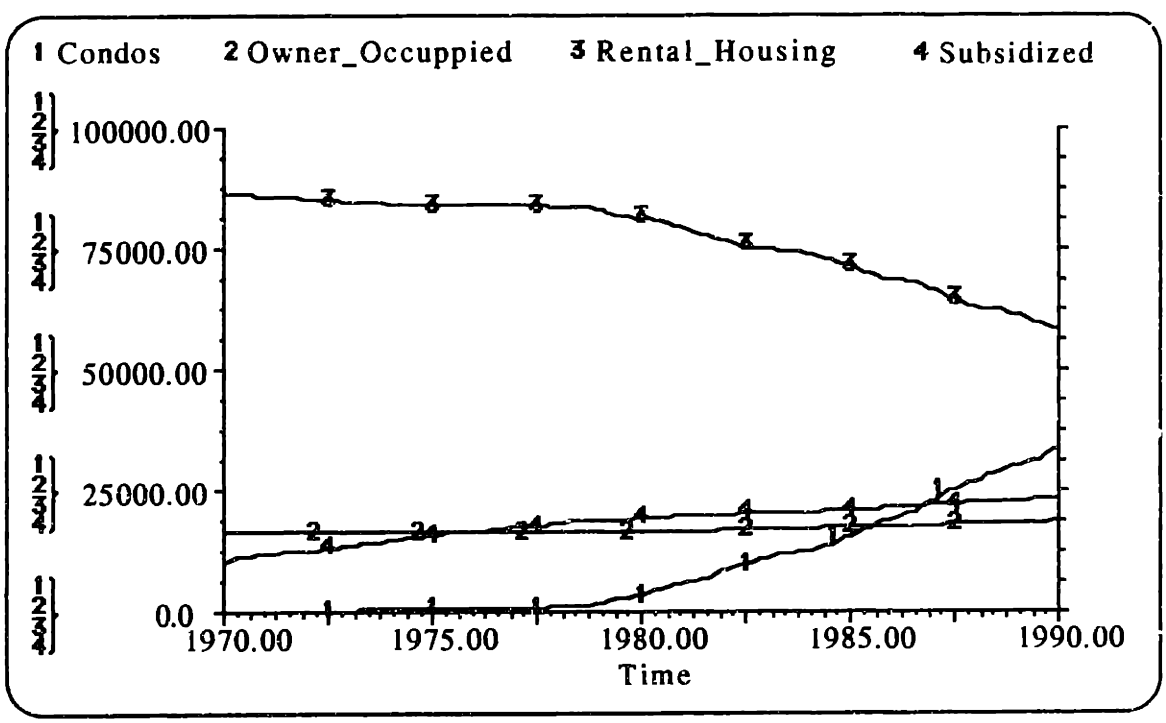


Figure 1.18: Housing Units in Study Area



PRICES IN THE BOSTON HOUSING MARKET

Research on the Boston real estate market is hindered by the lack of an accurate data base of housing prices in the city of Boston. Several sources have attempted to track home prices in recent years, but they fail on several counts. One potential source is the National Association of Realtors which does a good job at tracking single family home prices in the major SMSA's around the country.[26] While these data would be useful for building a model of the suburban housing market, they prove inadequate in the urban neighborhoods of this study where under 10 percent of all housing units can be classified as traditional single family homes.

Another potential source is provided through the reporting of Banker and Tradesman.[27] Banker and Tradesman provides extensive reporting of all real estate transaction by property address. While proving quite good for understanding average values and transaction volumes, the information does not convey enough information about the size of units sold (one, two, three bedroom, etc.) nor the number of units present in multi-family structures. In addition the service is not provided for years prior to 1980.

The Boston Redevelopment Authority has conducted studies from time to time and has tracked the price of a select number of condominium units in Boston from 1980 to 1987. In addition, the BRA has put together a data base of contract rents from both the U.S. Census data and information provided by the Boston Rent Equity Board. Here the price data for units sold is on a per square foot basis and is only based upon a limited sample of transactions since 1980.[28] To get more detailed information I needed to look elsewhere.

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26 National Association of Realtors, Existing Home Sales, Monthly Report.

27 Banker and Tradesman , Condominium Sales Report, 1984 - 1988.

28 Rolf Goetze and Deborah Oriola, "Condominium Development in Boston: 1969 - 1987, Boston Redevelopment Authority, August 1988: pp. 13-24.

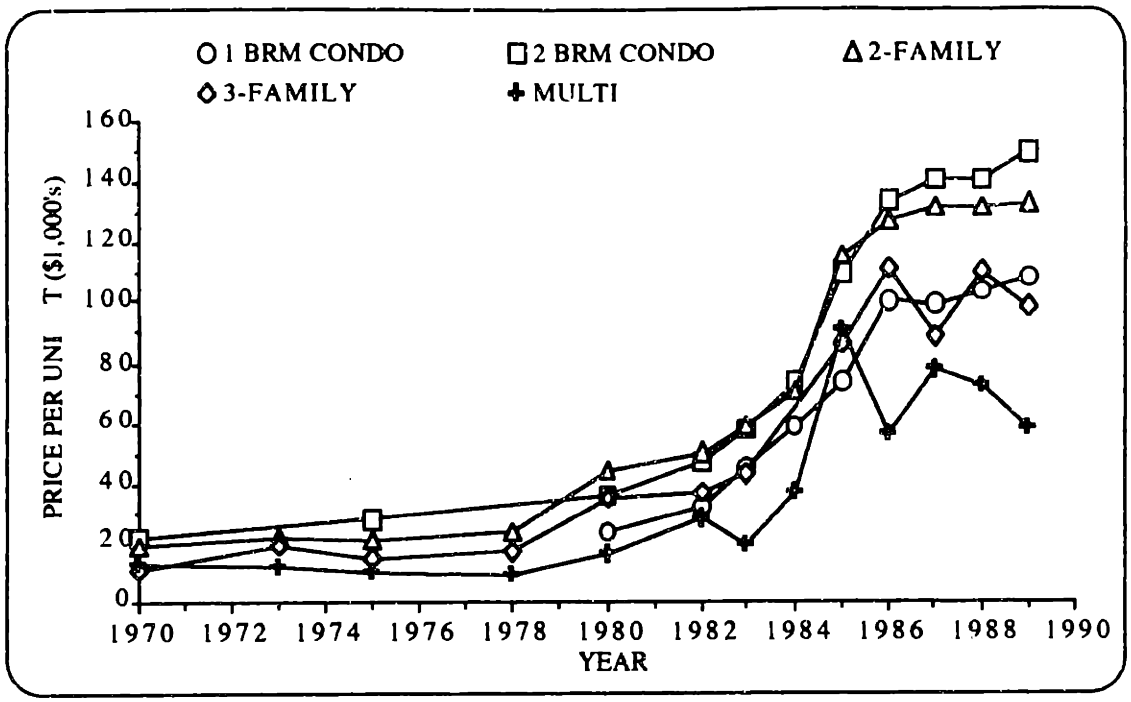
For my analysis I wanted to develop a stable time series of price levels for condominium units, prices of the existing rental units, and for monthly rental rates. I wanted the data to be classified by the number of bedrooms (in the case of condominium prices and monthly rents), by type of structure (i.e.. single, 2-family, 3-family, etc. for the existing housing stock), and by neighborhood over the past two decades. To achieve this I turned to the asking prices quoted in the Boston Globe classified ads.

By looking at over 11,000 observations, I was able to categorize all the real estate listings for condominiums, existing units, and rents occurring on the first Sunday of May for each of the following years: 1970, 1973, 1975, 1978, 1980, 1982, 1983, 1984, 1985, 1986, 1987, 1988, and 1989. I chose the month of May for each year to avoid capturing any seasonal effects of the real estate market as well as to ensure an ample supply of listings, as May is traditionally a strong month for real estate transactions.

While questions may be raised over using asking prices as opposed to actual transaction data, I feel that taken as a time series of data, asking prices yield a stable index of values which holds up well over time. I found that for most categories of real estate, the asking prices for both rents and sales prices were normally distributed around a mean with typical standard deviations in the neighborhood of 20 to 30 percent of the mean. The Appendix provides more detail on the methodology I have used as well as the summary of my actual findings on the neighborhood level.

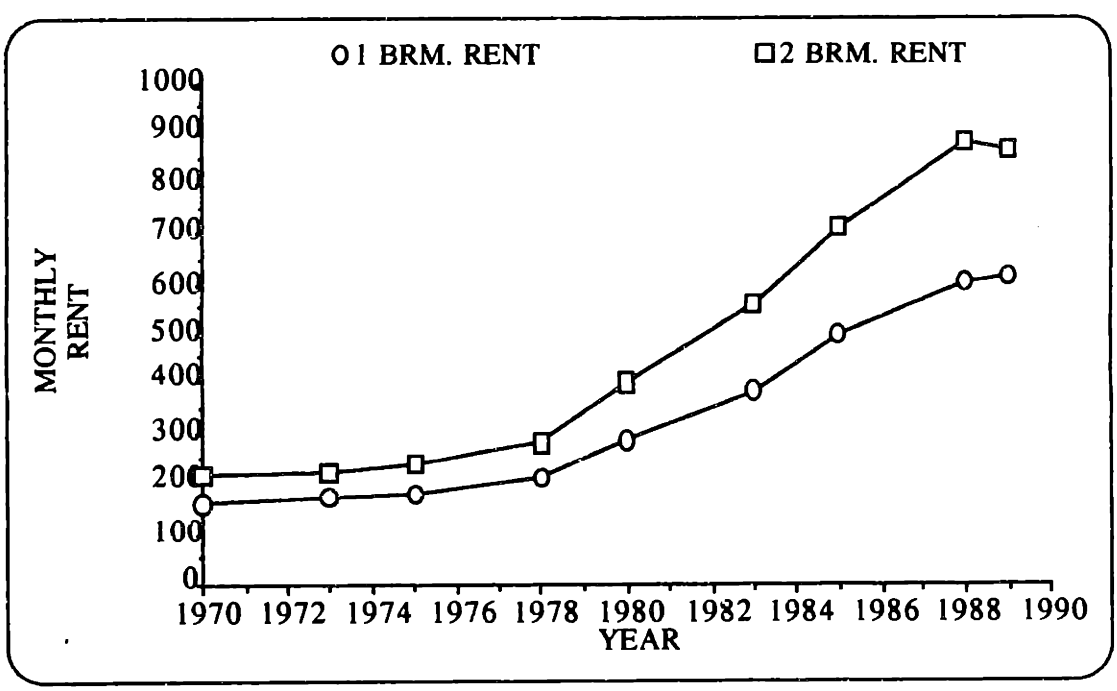
Figure 1.19 shows the results of the analysis for the neighborhood of Allston / Brighton. The graph shows the time series data for asking prices for one and two bedroom condominiums, as well as price data on two-family, three-family, and multi-family housing stock. Values are expressed in thousands of dollars and that the existing rental unit prices are represented on a per unit basis (i.e.: a three-family structure selling for $180,000 will be shown as 60 ($1,000's) per unit.). Charts on the other neighborhoods appear in the appendix.

Figure 1.19: Asking Prices for Real Estate - Allston / Brighton



By applying the same methodology to monthly rents, I was able to create a time series of data for rents for each neighborhood. Figure 1.20 shows the results for Allston / Brighton.

Figure 1.20: Asking Prices for Rents - Allston / Brighton



With an index of prices classified by neighborhood and type and nature of unit, I developed a composite index of housing prices for the entire area under consideration. The composite index was created from a summary list of condo prices by neighborhood weighted by occurrence of each type (i.e. 40% 1 - bedroom, 45% 2 - bedroom, 15% 3 - bedroom) and then weighted by the actual number of units existing in each neighborhood at the time. A composite index was also created for monthly rents and for prices of the existing rental stock. The results, which can be seen in Figure 1.21, show the composite index for prices in the total study area for Condominiums (H_CondoPrice), monthly rents (H_Rent) and for the existing housing stock (H_StockPrice).

Figure 1.21: Composite Index of Housing Prices and Rent (1970 - 1989)

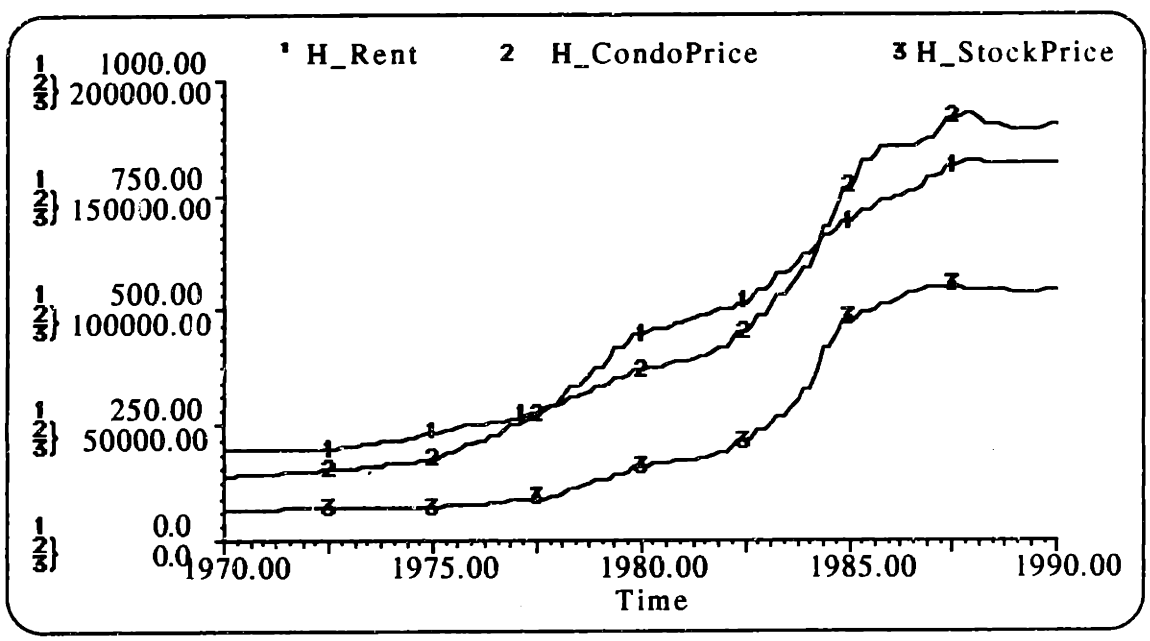


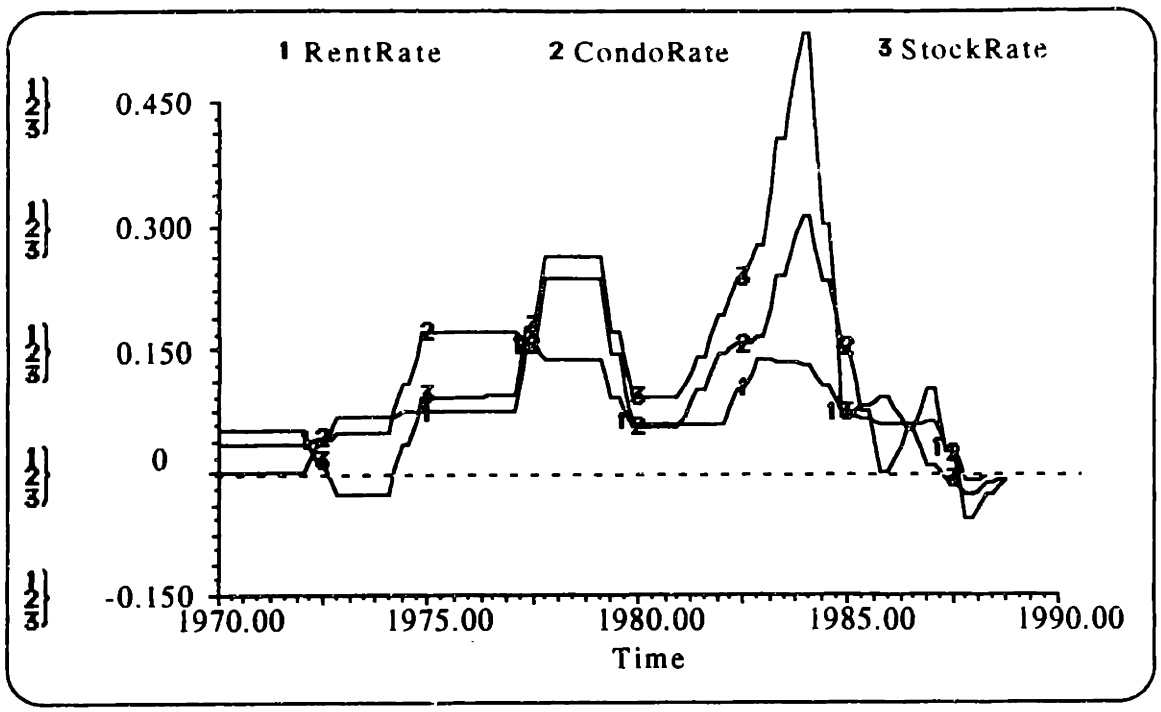
Figure 1.22 shows the price level changes expressed as annual percentage increases (or decreases). It is interesting to compare the data with common perceptions. Through 1975, prices and rents were fairly flat. In fact, prices of rental units actually fell during the 1974-75 recession which hit the Boston area particularly hard. Also, price rises for both rents and condo prices began to increase in the latter 1970's peaking in 1979 at around 25 percent. The

rate of price increase then fell during the recession of 1979-1981 and didn't begin taking off again until 1982 reaching a peak annual rate of increase by 1985 of about 25% for condo prices, a more modest 14% for rents, and over 55% for existing units as the conversion of units to condominiums was under full swing.

In past two years the market has become soft. From my observed data the average asking price for a condominium in the study area has fallen 5 percent from $188,300 in May 1988 to $178,200 in May 1989. The average monthly rent has held steady at $825 and the asking price of existing units has fallen 3 percent form a per unit price of $110,600 in 1988 to $107,600 in 1989.

Note that the margin between asking and selling prices is not constant. During the boom, many selling prices were close to asking prices, and in some cases units sold for <u>more</u> than the asking price. Average times to sell during the boom was short, often only days or hours. When the market softens, time to sell increases and selling prices drop below asking prices. Thus the asking price data underestimate the recent drop in prices.

Figure 1.20: Annual Rate of Change in Price Levels (1970 - 1989)



CHAPTER 2

SYSTEM DYNAMICS AS AN APPROACH TO UNDERSTANDING THE BOSTON REAL ESTATE MARKET

System dynamics is a discipline originating in the theory of engineering-control and information-feedback systems. In the 1960's, Professor Jay Forrester of the Sloan School of Management at the Massachusetts Institute of Technology, adapted the sophisticated modelling and analytical methods of control engineering for use in social and business problems. System dynamics is a methodology developed to identify the essential structure of complex systems and to show that structure produced the system's dynamic behavior. After indentifying the structure of a system, a model is created and run on a digital computer to explore the effects that various changes in parameters or policy would have on the behavior of the system.

The concepts of structure and dynamic behavior apply to all systems that change over time. Such dynamic systems include the processes of engineering systems, biology, social systems, psychology, ecology, and all those where positive - and negative - feedback processes manifest themselves in growth and regulatory action. Soon the concepts of system behavior were applied to the dynamics of urban growth and decay.

The publication of Urban Dynamics by Jay Forrester in 1969 marked a unique point in the analysis of social systems.[29] The book combined Forrester's system dynamics approach with the practical expertise of a committee of urban managers and businessmen, headed by the former mayor of Boston, John F. Collins. Urban Dynamics refuted conventional wisdom that most urban problems were caused by factors beyond the control of the central cities. Using a computer simulation model, Forrester showed that most urban problems arise, instead, from the interactions of processes that occur within the cities themselves. These problems include

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[29] Jay W. Forrester, Urban Dynamics, The M.I.T. Press, 1969: p. 1.

the decline of a city's economic base, the decay of its housing stock, and the out-migration of its young population Forrester's model also identified policies which the cities could follow to exercise some control over the own destinies.[30]

While the field of system dynamics showed great promise in being applicable toward modeling a variety of societal and business situations, there were drawbacks. In the 1960's and 1970's computer models had to run on unwieldy main-frame computers, and were written in undecipherable computer code. Only the most technologically-minded operators could understand and run these models. Unfortunately, this created a gap between the businessmen and women who had intimate knowledge of the systems to be modeled and the technicians needed to run the computers.

The technological barrier fell with the advent of personal microcomputers in the early 1980's. A recent article in The Economist notes that strategic planning, which also grew up along side the computers, had long been relegated to the backroom with the mainframe computer, instead of the boardroom where decisions were being made. The Economist notes that with the spread of desktop microcomputers, executives have a new tool to allow them to marry long term strategic planning with day-to-day decision-making. The first step toward this marriage has been the use of spreadsheet programs such as Lotus 1-2-3 which allowed executives to manipulate numerical data and to make simple, short -term forecasts.[31]

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30 For further readings on urban dynamics refer to the following:

Louis Edward Alfeld, and Alan K. Grahm, Introduction to Urban Dynamics, Wright - Allen Press, Inc., Cambridge, Massachusetts, 1976: pp: xiii.

Nathaniel J.Mass, ed., Readings in Urban Dynamics: Volume 1, Wright - Allen Press, Inc., Cambridge, Massachusetts, 1974.

Walter W.Schroeder, III, Robert E. Sweeney, Louis Edward Alfeld, eds., Readings in Urban Dynamics: Volume 2, Wright - Allen Press, Inc., Cambridge, Massachusetts, 1975

31 "Management Brief: Decisions, Decisions," The Economist, July 22, 1989: pp. 64-65.

The second generation of decision - making tools are currently becoming available. This involves the ability to simulate a firm's activity through the use of system dynamics and decision analysis techniques on a personal computer. Having constructed a computerized model of their business, executives can the "play" with it in varying circumstances, or microworlds, changing strategic assumptions and searching for winning strategies.[32]

I hope to show how these recent trends in decision technology can be applied to the real estate industry which is still currently struggling with first-generation spreadsheet applications. With the help of Professor John Sterman at the System Dynamics Group at the Sloan School of Management, and the user-friendly, system dynamics software application, STELLA[33], I have developed a model of the Boston housing market on a Macintosh[34] SE personal computer. The model explains the pricing behavior exhibited by the Boston real estate market over the past two decades, and I hope to show its value as a learning and forecasting tool in the following chapters.

OVERVIEW OF THE BOSTON HOUSING MODEL

The system dynamics model which I have developed to simulate the Boston housing market is built up of seven components. The design for each component follows from the previous discussion on the overview of the Boston real estate market. The Boston Housing Model includes a component module for each of the following sub-systems:

1) The Population. The population module contains the variables effecting population growth and the rate of household formation. Included here are the

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32 Ibid, pp 65.

33 STELLA is a registered trademark of High Performance Systems, Inc.; Lyme, NH 03768.

34 Macintosh is a registered trademark of Apple Computer, Inc.

factors needed to determine the number of households in the system: birth and death rates, net migration and average household size

2) The Economy. The economic subsystem contains the variables necessary to create a simple model of the local economy. Included here are the factors which effect household income, investment demand and new development: employment growth, the size of the labor force, the unemployment rate, wage inflation, interest rates, and federal tax policy

3) Household Demand. The household demand module contains a model to determine the number of households who can afford to purchase a house under the prevailing conditions. Here, household income will be determined and compared with housing prices and mortgage rates to create a measure of affordability. The affordability measure will be compared against the income distribution curve to see how many households can afford to participate in the housing market.

4) Speculative Demand. A model of speculative demand for investor condominiums will be developed. It is be based upon expected price appreciation, the rental return, mortgage rates and federal tax policy.

5) Prices. The pricing module contains a model for comparing household and speculative demand to the supply of housing to simulate the market level of housing prices. The apartment vacancy rate will be used to formulate the market rent.

6) The Housing Supply. The housing supply segment will model the stock of housing units along four classifications: subsidized units, private rental units, owner - occupied units in one-to-four family structures, and condominiums.

7) Production. The production model will determine the rate of construction of new housing as well as the rate of conversion of existing rental

units to condominiums. Production will depend upon housing prices, the rental return, the cost of capital, and tax policy.

These seven components are all linked to each other to form the feedback loops which determine the behavior of the real estate market. Figure 2.1 shows an overview of how the seven modules interact with each other.

It is important to note the limitations and scope of the model. As discussed earlier, the study only covers the housing market of the eight central Boston neighborhoods. As such, important factors related to the suburban real estate market will not be covered. For example, no account will be made for the relative level of attractiveness between the city and its suburbs to determine an endogenous measure of net migration to Boston. In addition, the model is not intended to simulate the dynamics of the regional economy. Rather, the macroeconomic variables needed in the simulation will be introduced exogenously with a provision to allow the user to input various assumptions for the future.

Figure 2.2 shows conceptually which aspects of the model will be determined endogenously, exogenously, or are beyond its scope. Prices and speculative demand will be endogenously simulated by the model. The level of rental units and condominiums will be determined endogenously, while the level of subsidized and owner-occupied units will be modeled exogenously based upon historic trends. Population trends and economic variables will be exogenous inputs to the simulation. All other aspects not discussed are outside the scope of the study.

Figure 2.1 Overview of the Boston Housing Model

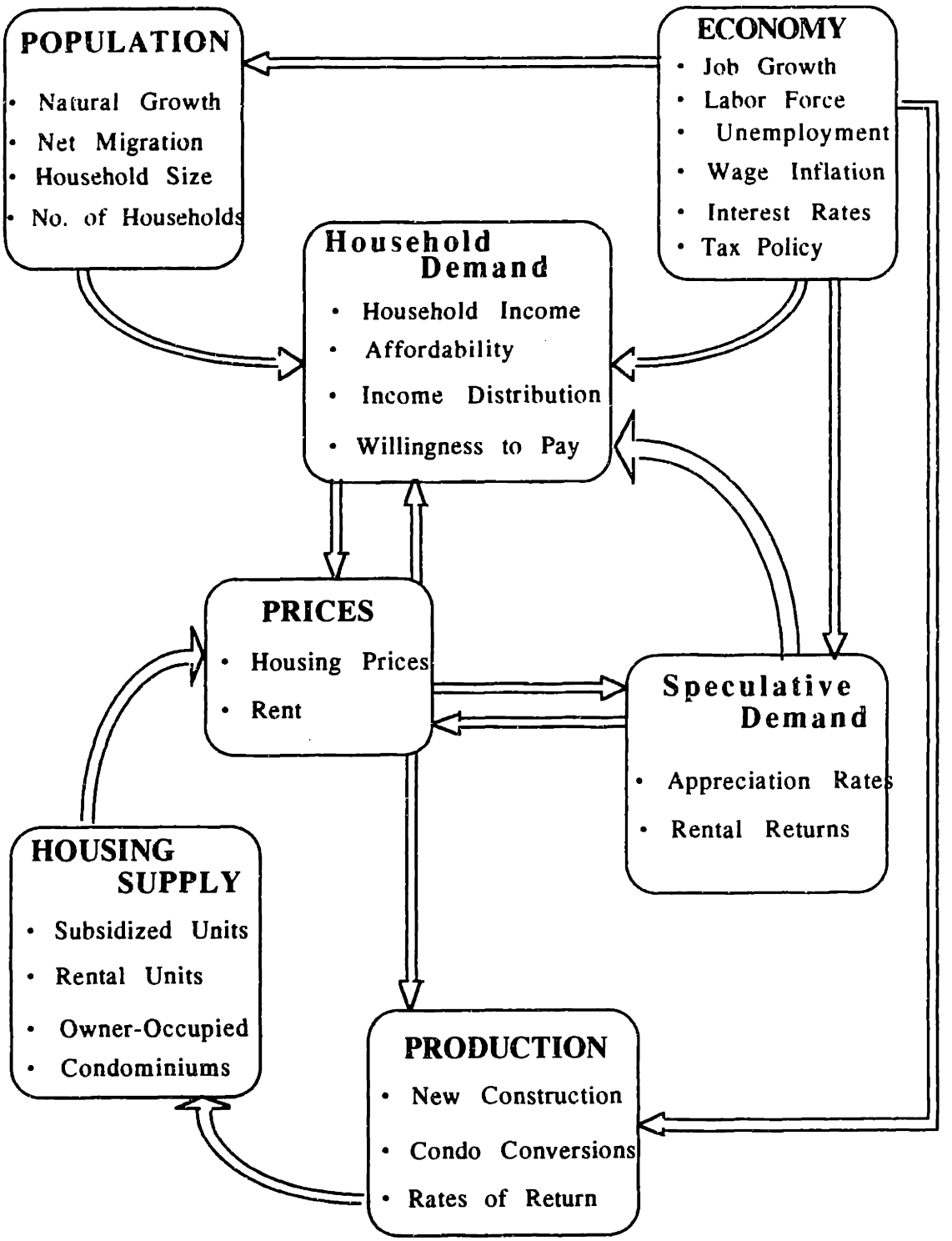
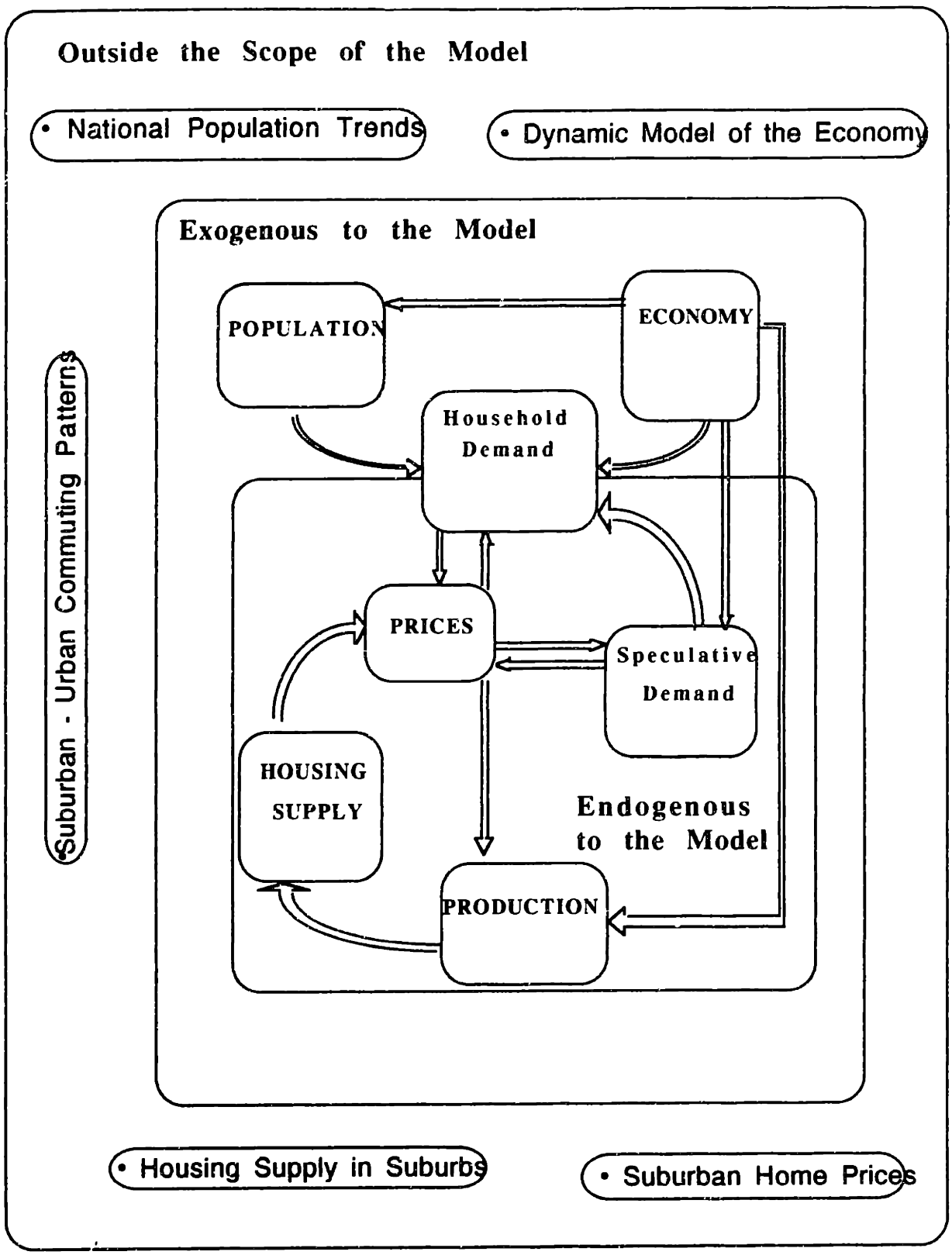


Figure 2.2 Scope of the Boston Housing Model



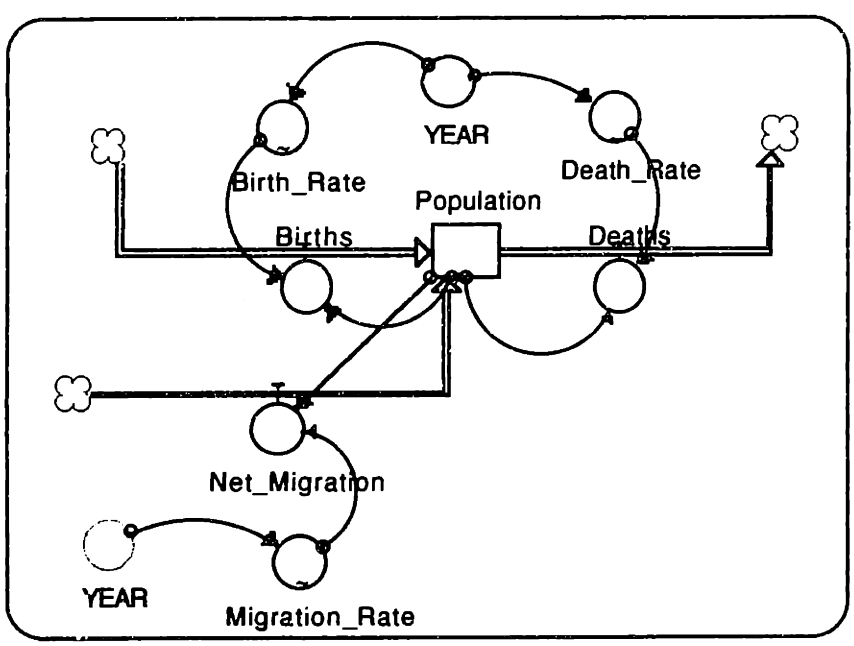
CHAPTER 3

MODEL OF THE BOSTON REAL ESTATE MARKET

POPULATION GROWTH AND HOUSEHOLD FORMATION

The foundation of the Boston Housing Model is structured around the dynamics of the decline and recovery of the population of the city. As explained earlier, the rates of birth, death, and net migration into the study area used in the model are based upon actual rates observed over the past two decades. Figure 3.1 shows the Stella representation of the population "module" of the model.

Figure 3.1: Population Model

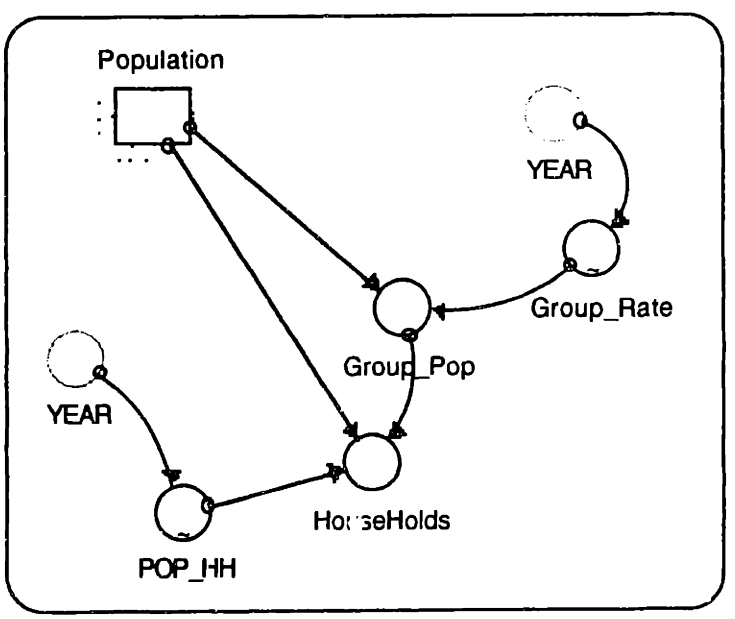


Here we can see that the Population (a stock variable represented by a rectangle), is determined by the cumulative effects of Births, Deaths and Net_Migration. (flow variables represented by "valves" in the plumbing network) into or out of the system. In turn, these flow variables are determined by the product of the actual Population times the fractional rates

of change (represented by the variables: Birth_Rate, Death_Rate, and Migration_Rate). These rates of change are determined by the historic data. These exogenous functions can be recognized by the tilde (~) near the lower portion of the circle representing the rates. The table functions are defined as a function of the input variable pointing to them, in this case the variable YEAR, indicating that the rate is an exogenous variable based upon past history.

Once we have determined the size of the population in our study area, the next step is to predict the number of households. To do so we first need to adjust the population figure to factor out those individuals living in group quarters. The group population includes people primarily living in college dormitories, prisons, and other institutions. They are included in official statistics for population but their living quarters have not been included in the earlier discussion of the housing stock of Boston. Including institutional housing such as college dormitories is beyond the scope of the model.

Figure 3.2: Household Formation



In 1970, 6.2% of the population of Boston was classified as living in group quarters. The figure rose slightly to 8.3% by 1985. For the core neighborhoods of this model, the

group percentage was 9.5% in 1970, 10.2% in 1980, and 13.9% in 1985. The rising figure is due primarily to growth of the campuses of Boston and Northeastern Universities. In fact, in 1985, the group percentage, range from a low of 1.8% in Charlestown to a high of 35% in the Fenway / Kenmore area.[35]

As discussed earlier average household size in Boston's core neighborhoods has fallen from 2.30 persons per household in 1970 to 2.05 in 1980. Household size began to stabilize in the 1980's. As can be seen in Figure 3.2, the ratio POP_HH is represented as an exogenous variable through a table function. The population module thus captures the historic data on population and household formation discussed earlier (see Figure 1.5).

THE ECONOMY

The second major exogenous component of the Boston Housing Model is the regional economy. Since a model of the economy is clearly beyond the scope of this project, I have attempted to reduce the components of the economy to a few very simplified variables. These include: Job_Rate, a measure of job growth to be used as a proxy for real economic growth; the unemployment rate; Labor_HH (workers per household) a proxy for the labor force participation rate; Area_Index, a relative measure of the rising household incomes of Boston residents with respect to the SMSA average; WageInflation, the annual percentage increase in Boston salaries; and MortgageRates, a weighted average of mortgage interest rates in the Boston region.

Figure 3.3 shows the basic model for economic growth. Here the stock variable modeled is the total number of jobs located in the city of Boston. It should be noted that roughly half of all jobs located in the city of Boston are filled by commuters from the suburbs.

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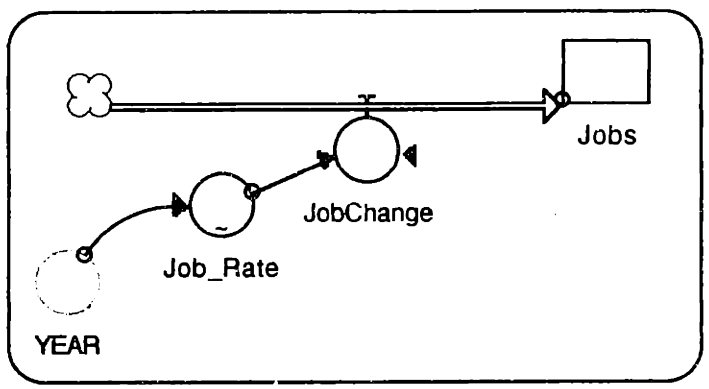
35 "Fenway / Kenmore: Neighborhood Profile 1988," Boston Redevelopment Authority, 1988: pp 2-3.

Conversely, approximately 15% of the employed residents of Boston work outside of the city limits.[36] For now, the rate of economic growth is determined exogenously based upon actual historic results. In subsequent years, we can change the projected rate of growth to test different scenarios. The rate of job growth will in turn affect the rate of net migration into the city, so that the effects of a recession or slow-down can be modeled.

Figure 3.3: Economic Growth



The next stage in the economic model is to determine a measure of household incomes. Figure 3.4 shows how the average annual city wage is modeled through the variable WageInflation. As discussed earlier, a good measure of the household income of the average home-owner can be approximated by the product of the average salary (City_Wage) times the average number of workers per household (Labor_HH). Homeowner income must then be adjusted by the Area_Index which takes into account various factors such as other income sources and the relative affluence of core neighborhood residents compared to their suburban counterparts. The product of these calculations is the median annual household income for home-owners: HH_Income_Owners.

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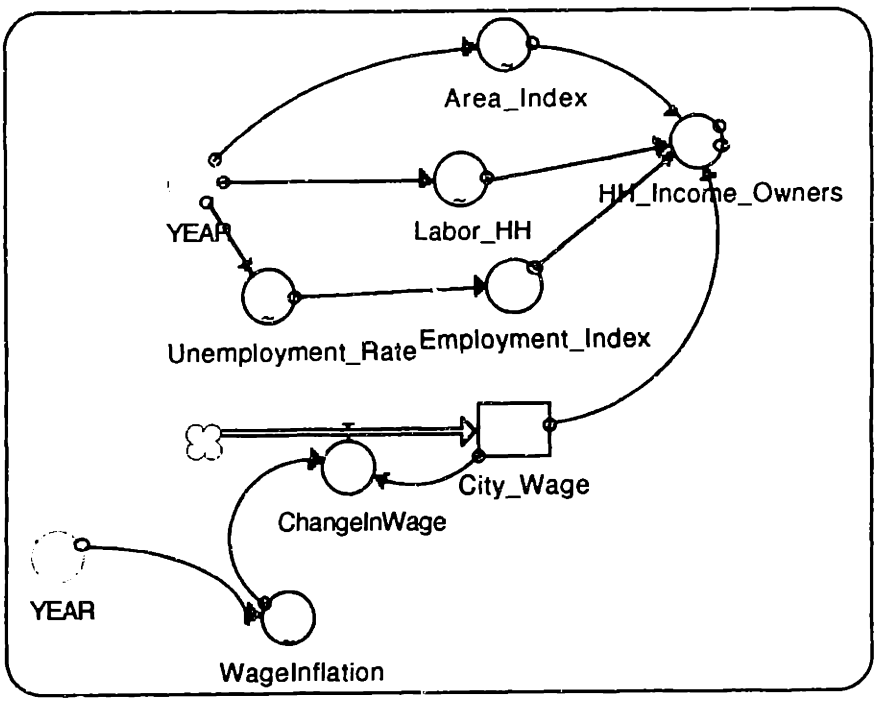
36 "Resident Workers Share of Boston Jobs: From the 1985 Household Survey'" Boston Redevelopment Authority, February 1987: pp 1-12.

Figure 3.4: Household Income

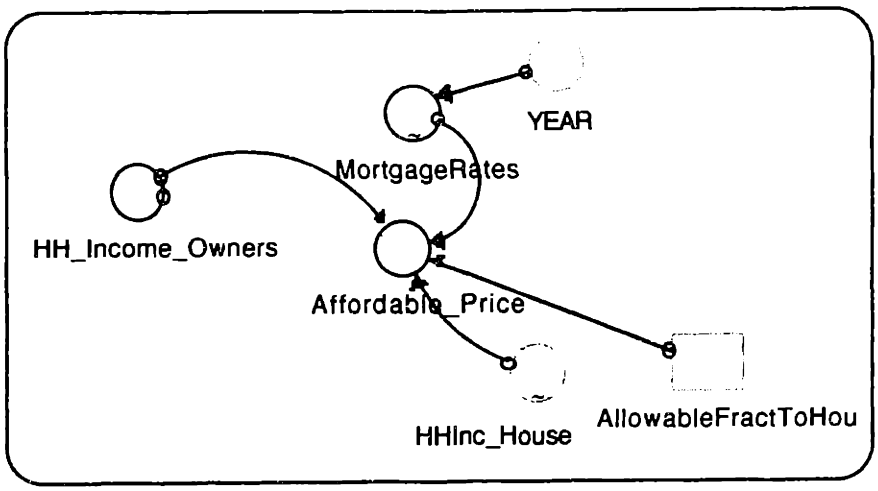


It is now possible to introduce mortgage interest rates to determine the home price which the median household income could support. In Figure 3.6, MortgageRates are introduced as an exogenous variable based upon the historical performance of mortgage originations in the Boston region. To determine the affordable price, a simple financial model is employed to calculate the amount of financing for which a home-owner would qualify, based upon the prevailing mortgage rate and the fraction of household income which can be used to support mortgage payments, HHinc_House. The housing fraction represents a household's mortgage payment as a fraction of total household income, and will be determined endogenously in a further segment of the model.

Historically, the housing fraction has fluctuated between roughly 15% during the early 1970's (during the slack real estate market) to a peak of over 40% during the recent boom of 1986. In addition another variable the fraction of household income financial institutions allow to be used against a mortgage, AllowableFractToHou, will be introduced later. In short, the

maximum fraction of household income against which banks will lend will determine the upper limit of the housing fraction.

Figure 3.6: Affordable Housing Price



The financial subsystem defines the affordable price of a home as that which the median household income could purchase. It is assumed for simplicity that a home is purchased with 90% financing (10% down-payment) and that initial mortgage payments are for interest only. The tax benefits of home ownership are not taken into account, but then again, neither are operating expenses (i.e. real estate taxes, insurance, etc.). It has been assumed that these two effects roughly equal each other. In future versions a more detailed calculation of ownership costs may be substituted. The Affordable_Price will later be used to determine the demand for housing.

In addition to modeling housing prices, the Boston Housing Model includes a simplified approach to determine rent levels. As with home prices, the model begins with a measure of the household income of renters. The median income of all households is used to proxy the average renter's income. Historically the median income for all households has risen from around 54% of the home-owner's median income in 1970 to around 65% today. To account for the difference between homeowner and renter household income, the variable,

Renter_Index, is introduced as an exogenous variable which is used to discount the HH_Income_Owners to determine HH_Income_Renters. The graph of Renter_Index can be seen in figure 3.8.

Figure 3.7: Rent Model

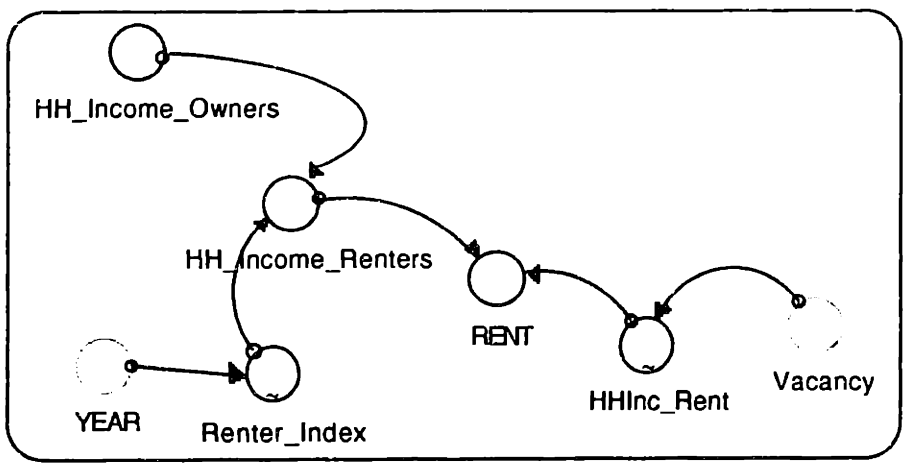
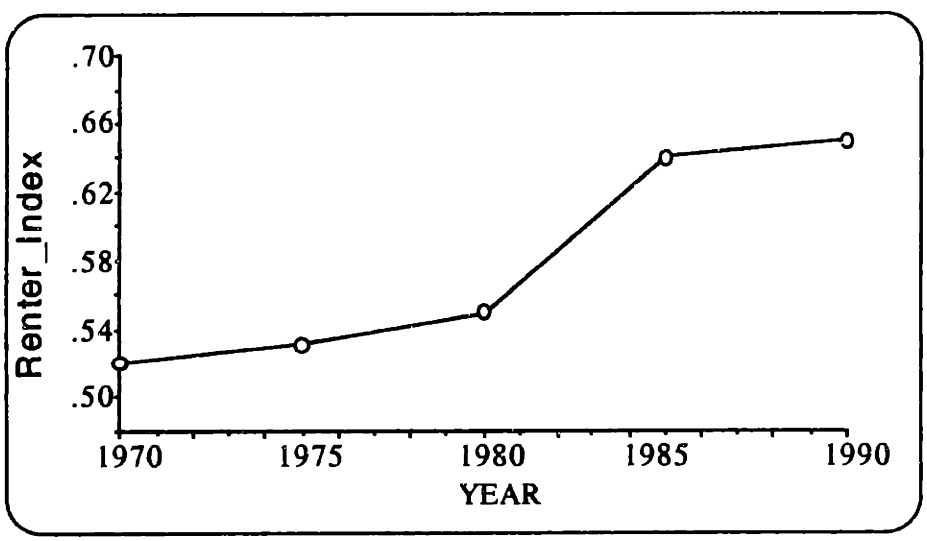


Figure 3.8 Rent_Index



The other determinant of the median rent is a budget term, HHInc_Rent, which is similar in concept to HHInc_House used above. The fraction of household income needed to cover rent payments in Boston has fluctuated from between 30% and 45% of the median income of all households. The same rent fraction is used by the model. With the help of a

Vacancy variable to be introduced later, the budget fraction will vary with the tightness of the housing market (it will range from 45% when vacancy rates are low, and will approach 30% when the market is soft).

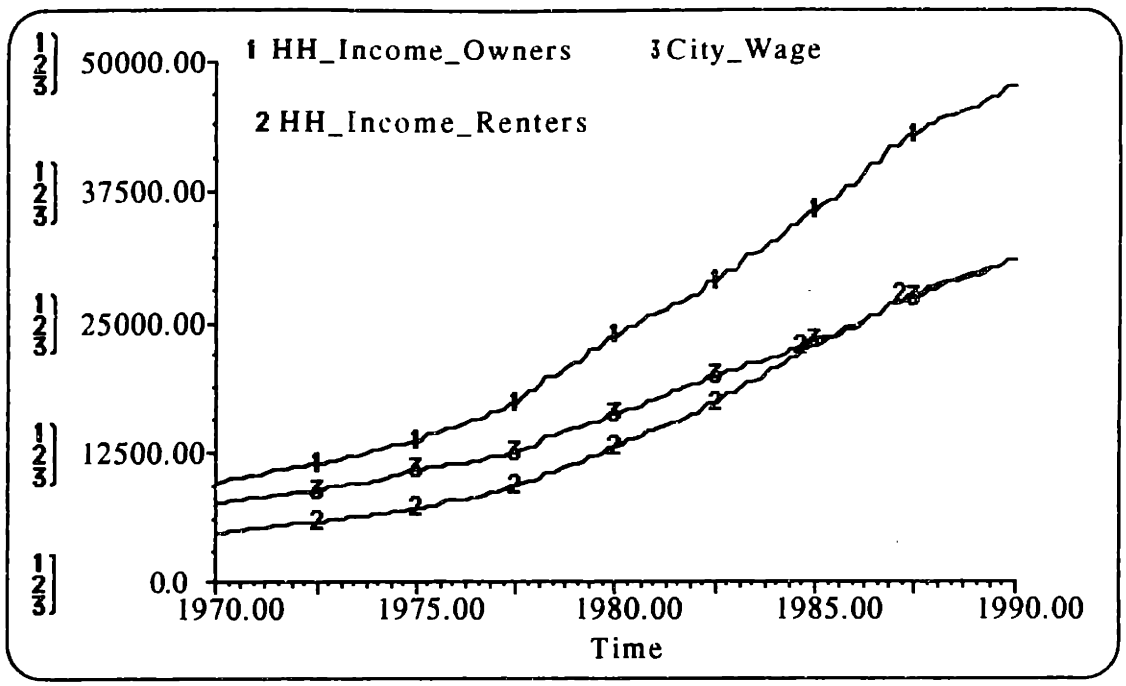
INITIAL TEST OF MODEL AGAINST REALITY

At this stage in the model-building process we are ready to run the demand subsystem to generate household incomes and determine affordable price ranges for both housing prices and market-rate rents in Boston's core neighborhoods.

Figure 3.9 plots the rising household incomes for both homeowners and renters. As can be seen, I have also plotted the average annual wage in Boston as a reference point. Note that the growth in household incomes has exceeded that of wages. The rising household incomes are consistent with three trends throughout the 1980's. The first is a result of more women entering the labor force helping to raise the average number of workers per household. Second, the "Massachusetts Miracle" has lasted through much of the decade, lowering the unemployment rate and allowing more people in the labor force to earn a wage. Third, as more professionals have been attracted back to the core neighborhoods their relative household incomes with respect to the SMSA average has begun to move upward, as shown in the rising Area_Index.

Figure 3.9 shows that as the median city wage approaches $30,000 in 1989, the median income of home-owners is climbing above $45,000. As we will see, the rise in household incomes is the dominant driver behind the residential real estate market.

Figure 3.9: Historic Rise in Household Incomes.



With the projection of household income, we can generate a plot of affordable housing prices if we assume that the average fraction of household income is held constant at 30 percent. We know historically that the fraction of the median household income necessary to purchase a home has fluctuated between roughly 20 and 45 percent, but 30 percent is a good benchmark perceived in the real estate industry to be an affordable figure. Figure 3.10 shows the results of running the model with actual mortgage rates and plots both the benchmark price (Affordable_Price) against the historical measure of condominium prices (H_Condo Price). Note that the 30% affordable benchmark rises in step with actual housing prices and rarely deviates by more than about 35% of the actual observed prices. The second observation is that during the 1970's actual prices are below the affordable threshold, which is to be expected given the declining population and slack real estate market. Conversely, in the 1980's as the real estate market heated up, prices regularly exceed the benchmark.

Figure 3.10: Actual Prices vs. Affordable Benchmark.

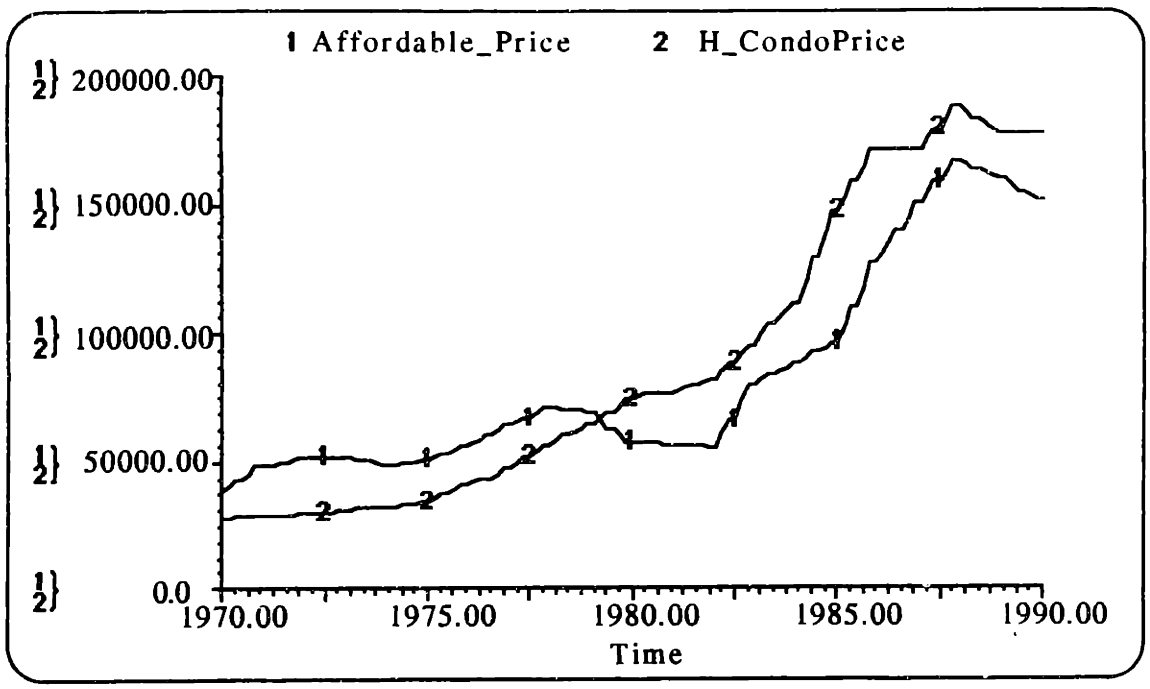
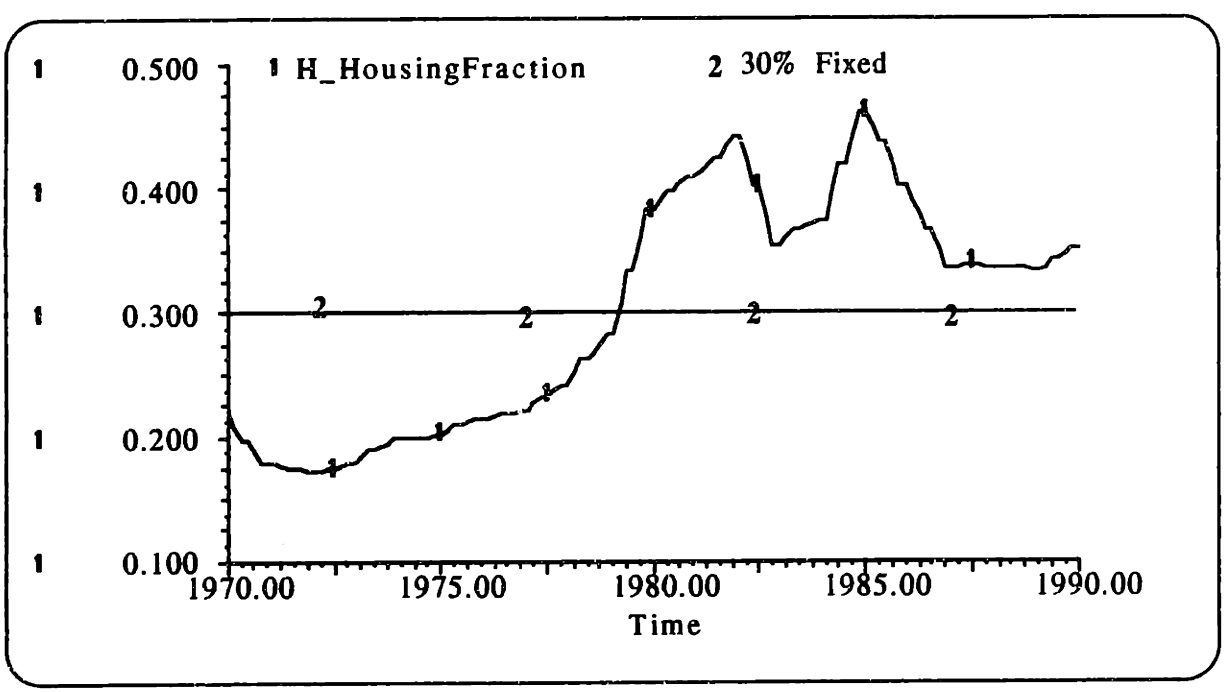


Figure 3.11: Historical Fraction of Median HH Income Required to buy the Average Condominium vs. Benchmark.



Another way of viewing the rising trend in prices is to plot the historical ratio of the fraction of household incomes required to purchase the median condominium unit. Figure 3.11 shows both the historical ratio as well as the reference benchmark of 30 percent. A subsequent supply and demand pricing model will be introduced to help explain the rising household fraction.

Using the same modeling techniques, we can also compare the historical trend in rents with an affordable benchmark. Historically the fraction of median incomes needed to pay for rent has fluctuated between 30 and 45 percent. Using 35 percent as the affordable benchmark, Figure 3.12 compares observed rents (H_Rent) and the benchmark (RENT). Aside from three periods, the early 1970's, 1980-83, and 1988-89, the benchmark closely predicts the historic rent.

By observing the historical relationship between rents and household incomes (H_Rent Fraction) with the 35 percent benchmark we can identify periods of tight and soft rental markets. Once a measure of rental vacancy is introduced these periods will become more easily identified. Figure 3.13 shows the relationship between the historic fraction of household income needed for rent and the benchmark of 35 percent.

Figure 3.12: Observed Rent vs. Benchmark.

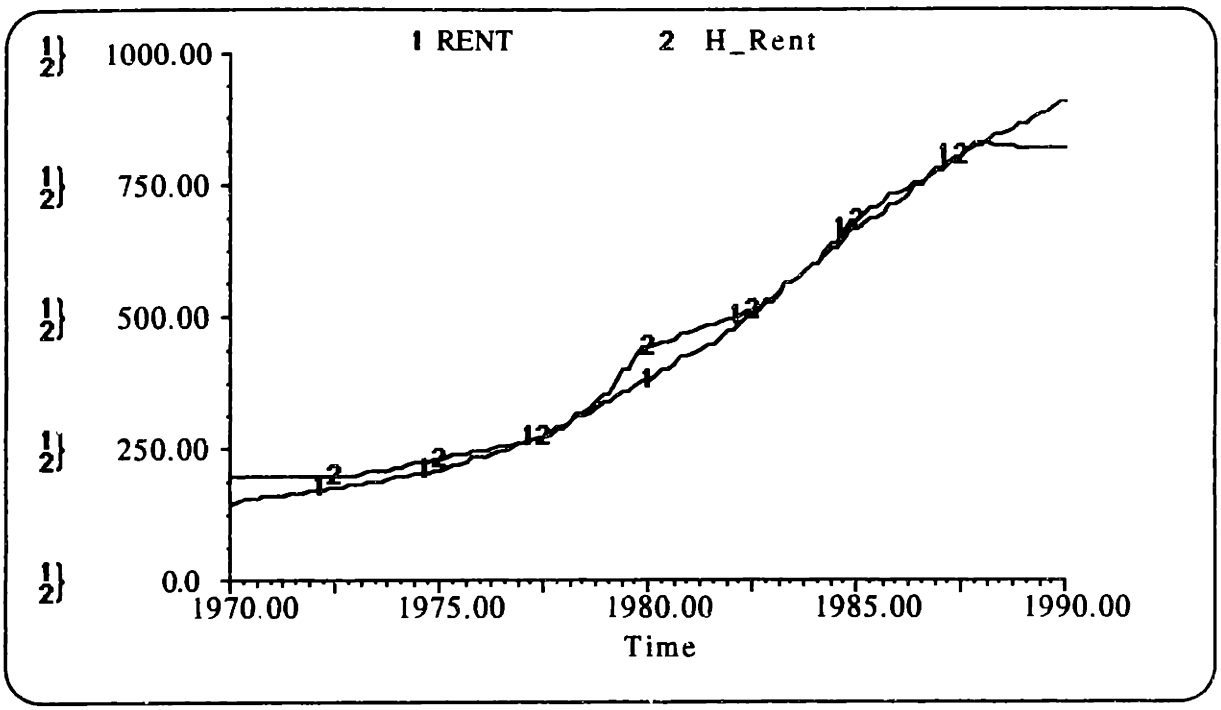
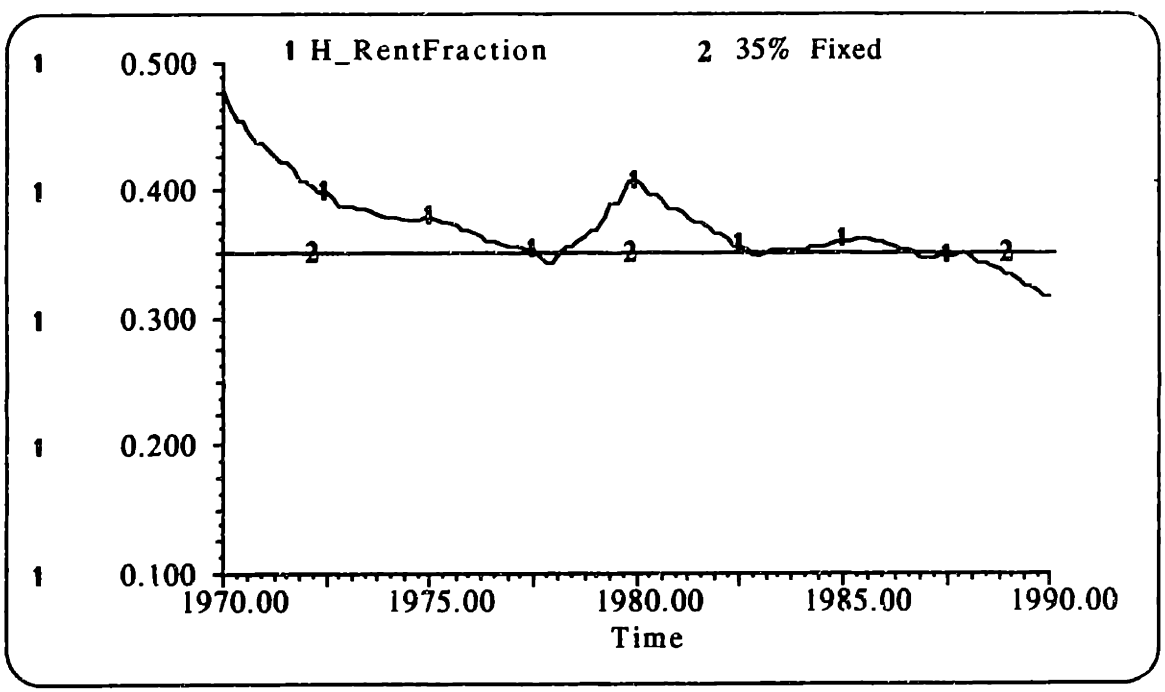


Figure 3.13: Historical Rent Fraction vs. Benchmark.



HOUSING STOCKS AND RATES OF CHANGE

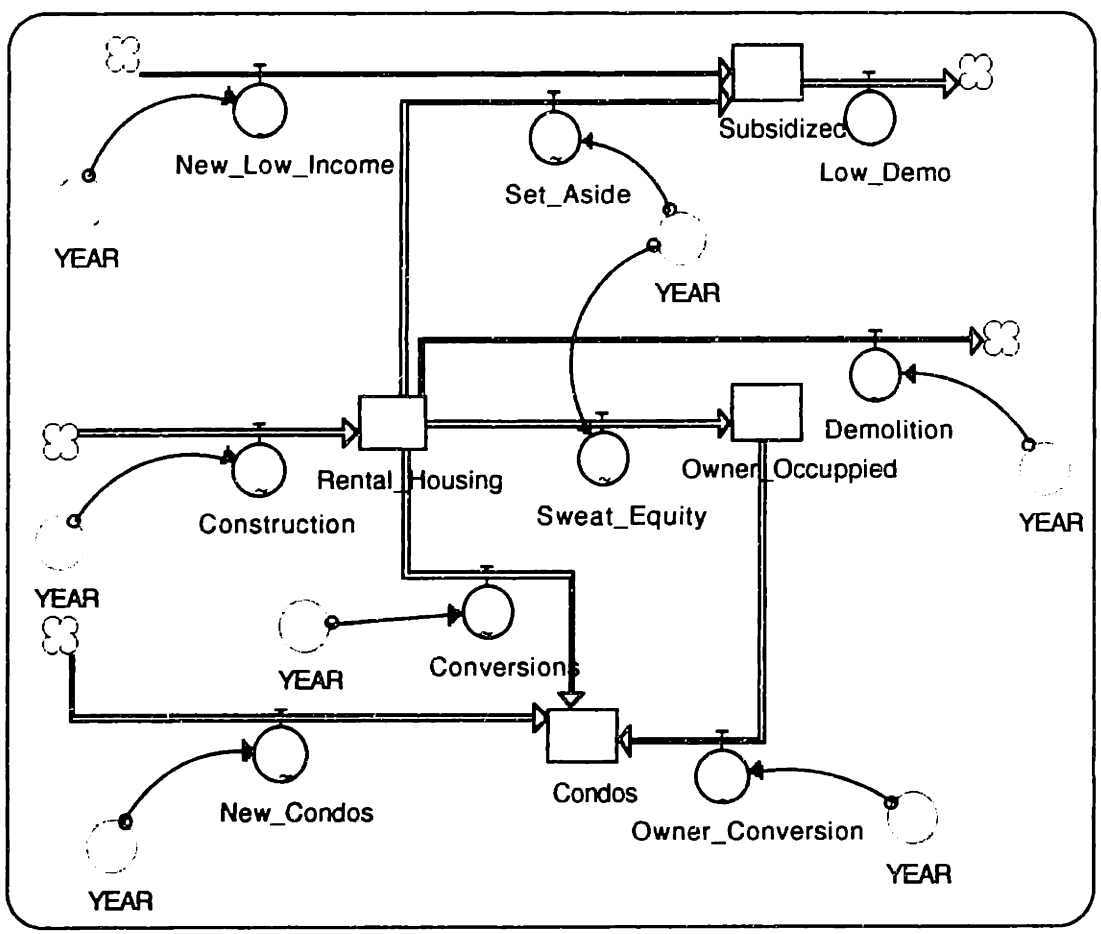
With the discussion of the demographic and economic factors which help in determining household demand for housing complete, supply constraints can be introduced. First, a model will be presented which exogenously calculates the various components of the housing stock in Boston's core neighborhoods based upon historical data. Once established, these levels of housing stocks will be used together with levels of demand from both households and speculative investment to develop a market-clearing model to simulate the mechanics of pricing in the real estate market. In addition, the supply of rental units will be used to determine the rental vacancy rate needed to simulate rental values.

The Boston Housing Model uses the same classification of housing units as the Boston Redevelopment Authority, namely: subsidized units, rental units, owner-occupied units in one-to-four family structures, and condominium units. Figure 3.14 shows the basic supply model. Here subsidized housing units are represented by the stock variable, Subsidized. The stock of units can be increased by new construction (New_Low_Income) and by existing rental units set aside under various rental subsidy programs (Set_Aside). As discussed earlier rates of subsidized housing production have remained fairly stable over the past two decades and are modeled here exogenously based upon actual results and city estimates of the future. The stock of subsidized units is reduced through demolition (Low_Demo). In recent years the level of demolition of subsidized units has been negligible.

The next component of the housing stock to be modeled is the supply of rental units (Rental_Housing). As can be seen, the stock of rental units is increased by new construction (Construction) which includes the major renovation of existing buildings not previously classified as residential. Historically, the rental construction rate has fluctuated between 500 and 1,600 units annually, and is shown as an exogenous variable. The rental stock is reduced in four ways. First, rental units may be set aside under the subsidized programs discussed

above. Second, the stock is reduced through the demolition (Demolition) of existing units. The demolition rate was high during the 1970's, but has been reduced to a trickle as most sub-standard units have been either eliminated or renovated. Third, the supply of rental housing can be reduced when an "urban homesteader" moves into an existing one-to-four family structure and rents out the remaining units, a trend captured with the variable Sweat_Equity. Demolition of owner-occupied and condominium units is ignored.

Figure 3.14: Exogenous Housing Supply Model.



Fourth, the most pronounced reduction of the existing rental stock has been through conversion of rental units to condominium units. As discussed earlier the rate of conversion

has increased exponentially over the past decade reaching nearly 4,000 units annually in 1987. The rate of conversion will be modified later so that it may be determined endogenously.

The next component in the supply of housing units is that of owner-occupied units in one-to-four family structures (Owner_Occuppied). As noted earlier, the stock of owner-occupied units is increased by people purchasing and moving into existing rental structures. The stock is reduced through the conversion of these buildings to condominiums. In recent years, the stock of owner-occupied units has remained fairly stable at around 17,000 units. The rate of Sweat_Equity has kept pace with the rate of conversion to condominium units at around 200 units annually.

The fourth, and most rapidly increasing component in the stock of housing units is the supply of condominiums (Condos). As shown, the stock of condominium units is increased through new construction (New_Condos), through the conversion of existing rental units, and through the conversion of owner-occupied units. New construction is first determined exogenously but will later be modified.

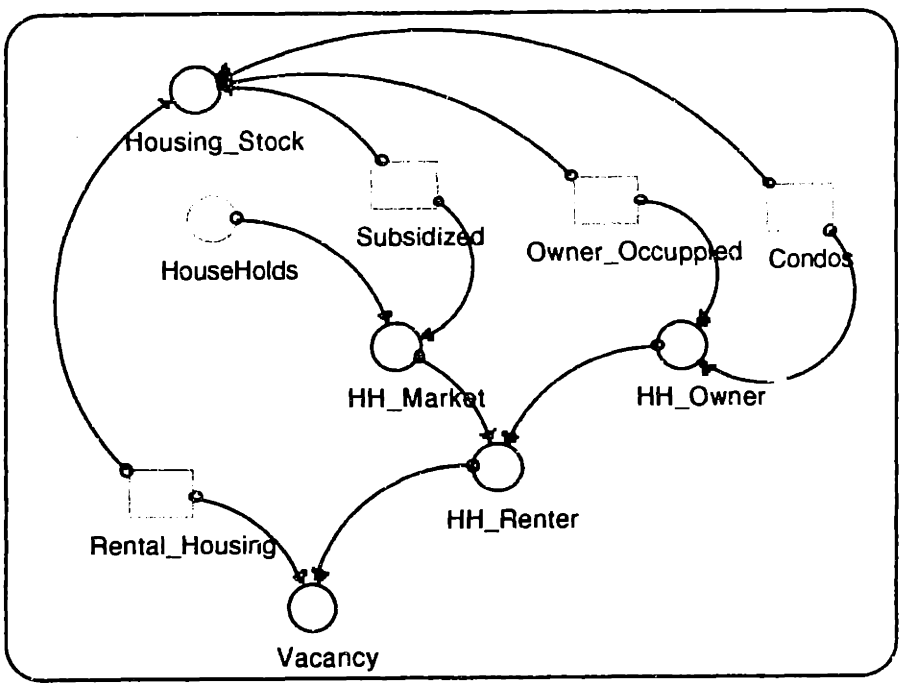
MEASUREMENT OF THE RENTAL VACANCY RATE

By simulating the model we can produce the results discussed earlier in the overview of the Boston housing market. Namely, Figures 1.16, 1.17 and 1.18 can be reproduced to show the annual change in the supply of rental and condominium units as well as the level of all housing units in the study area. Figure 3.15 shows how the four stocks of housing units, together with the total number of households, can be used to determine the vacancy rate of rental units.

The first step is to determine the number of households in the market for housing services. I have defined the number of households in the market as those which are either renting a unit or have purchased a home to live in. The number is represented with the variable

HH_Market. HH_Market is the difference between the total number of households and those who are living in subsidized units. For the model I have assumed only 95 percent of the total subsidized units are habitable. The 5 percent rate of "chronically vacant " housing is from BRA estimates,which take into account boarded-up units and those in units various stages of disrepair.[37]

Figure 3.15: Rental Vacancy Model



Next I have defined the variable, HH_Owner as the total number of households which live in their own unit. The figure includes both owner-occupied units and condominiums. By definition, all the owner-occupied units are habitable. For the condominium units, I have assumed that 95 percent are occupied at any point in time. The difference between HH_Market and HH_Owner, determines the number of households who will have to rent an apartment (HH_Renter).

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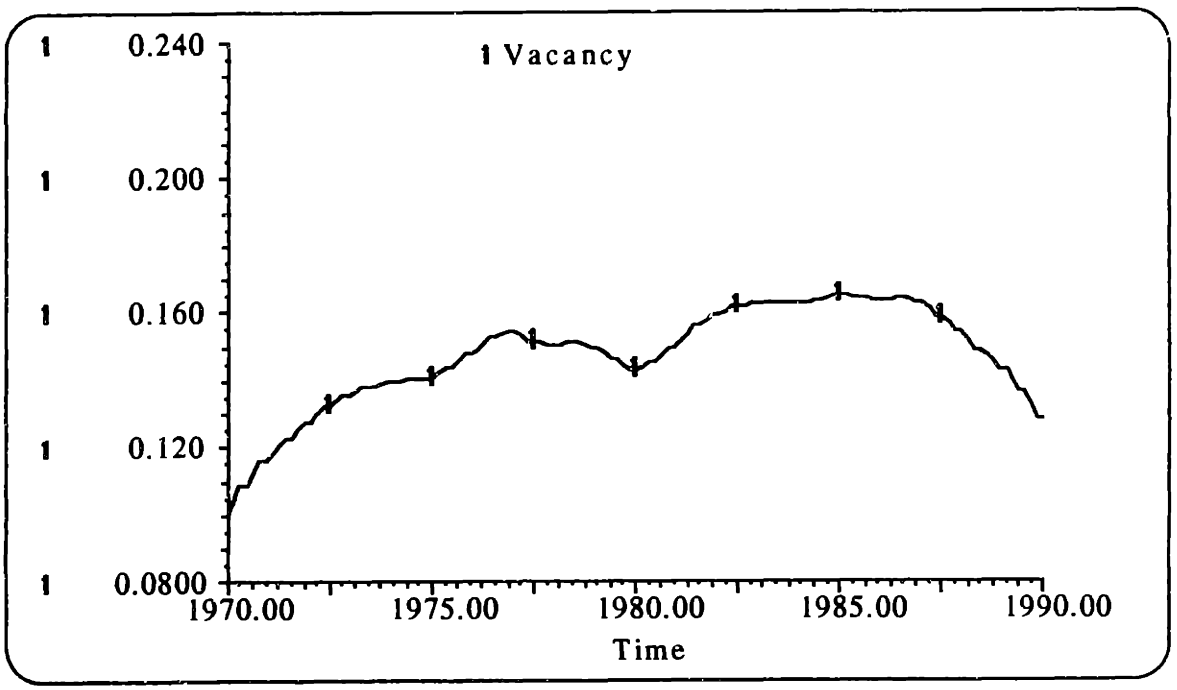
37 "Housing Production in Boston: A Review of Supply, Inventory of Activity, and Issues for the Future," Boston Redevelopment Authority, 1986: p.3.

Comparing the total number of households renting (HH_Renter) to the total number of apartments available (Rental_Housing), determines the rental vacancy rate. The vacancy rate is expressed as a percentage of total units available which remain vacant. Figure 3.16 shows the vacancy rate generated by running the model.

Figure 3.16: Rental Vacancy Rate.



PREDICTED RENTS VERSUS OBSERVED VALUES

With a measure of the rental vacancy rate, the budget variable, HHInc_Rent, can be modified to reflect the status of the rental market. Through the table function, HHInc_Rent shown in Figure 3.17, I have allowed the fraction of household incomes people are willing to commit to rent to vary between 30 and 45 percent. Figure 3.16 shows vacancy rates based upon historical values of supply and demand. It can be observed that there is a structural vacancy rate of around 14 percent. When the vacancy rate falls below this number there is pressure for rents to rise faster than incomes (i.e. an increasing HHnc_Rent ratio) and for the rent increase to slow when the vacancy rate rises. It should also be noted that all rental units,

including abandoned and uninhabitable units, have been included, accounting for the high structural vacancy rate.

With the table function for HHInc_Rent, the rent for an apartment can be modeled endogenously within the system. Figure 1.18 shows the predicted rent (RENT) as compared to the actual observed values (H_Rent). Likewise, Figure 1.19 shows the model generated rental fraction (HHInc_Rent) as compared to the historical value (H_RentFraction).

Figure 1.17 HHInc_Rent vs. Rental Vacancy Rate.

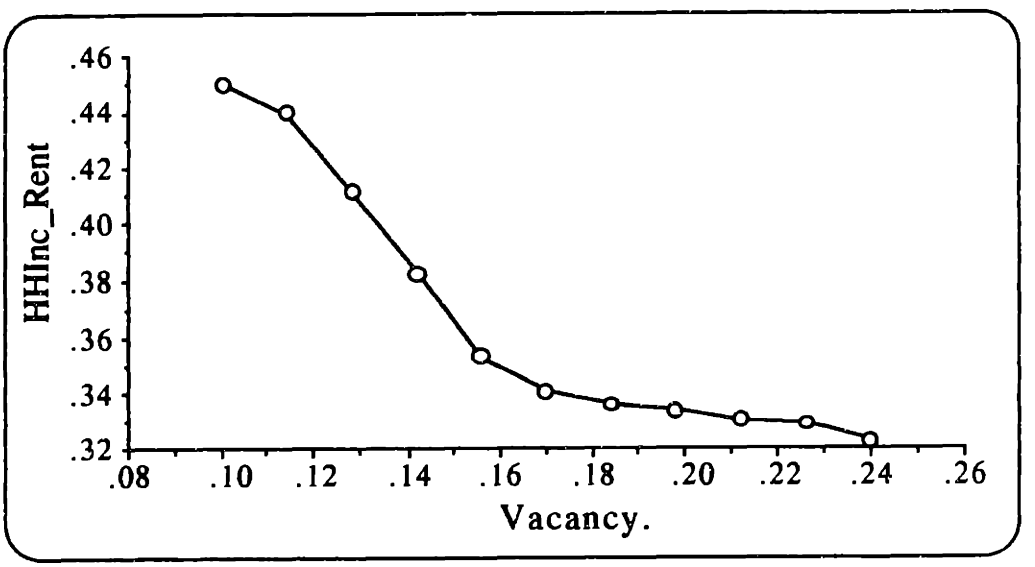


Figure 1.18: Predicted Rent vs. Observed Values.

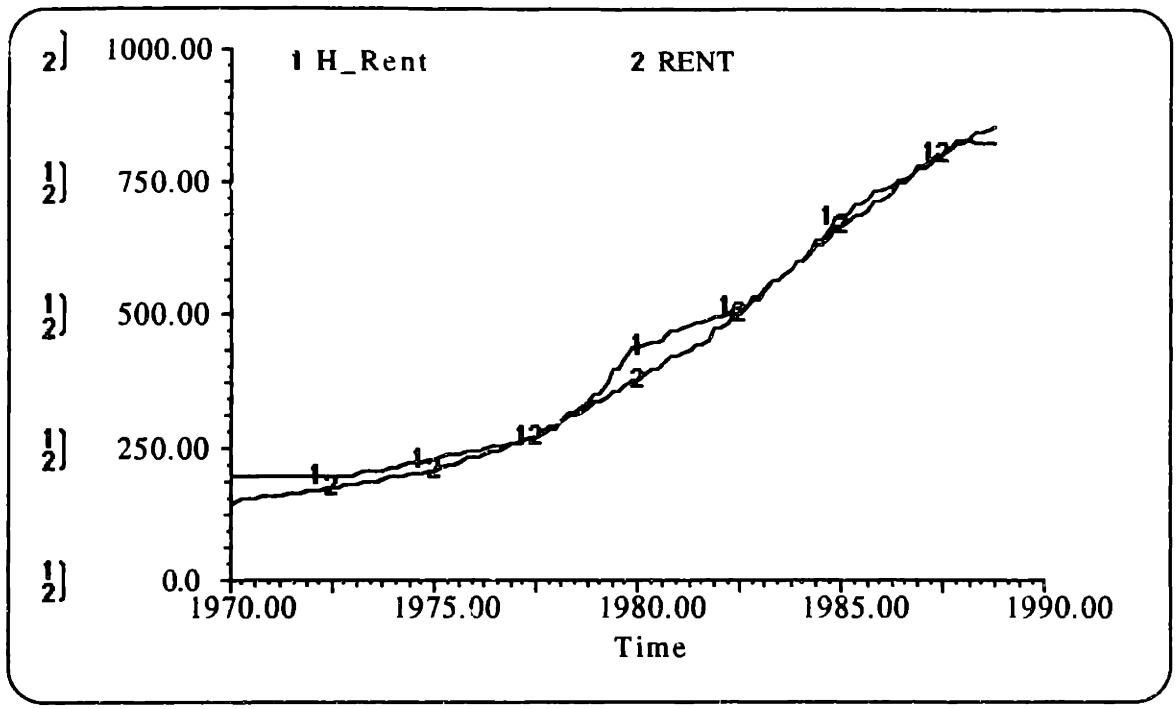
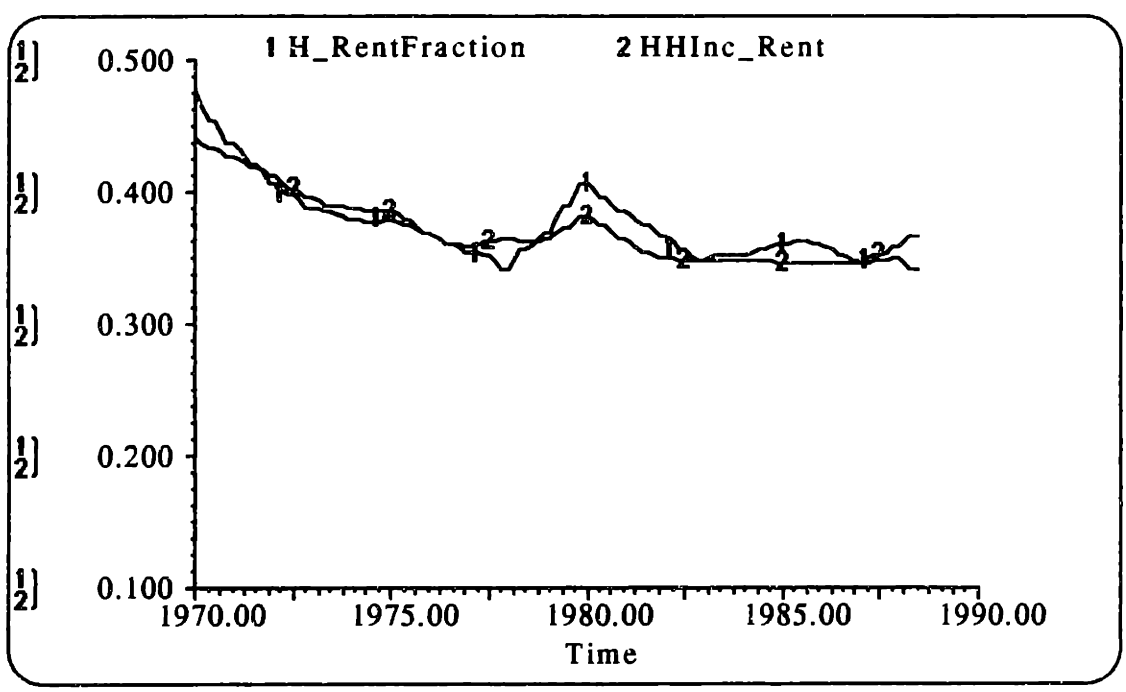


Figure 1.19: Predicted Rent Fraction vs. Actual Values.

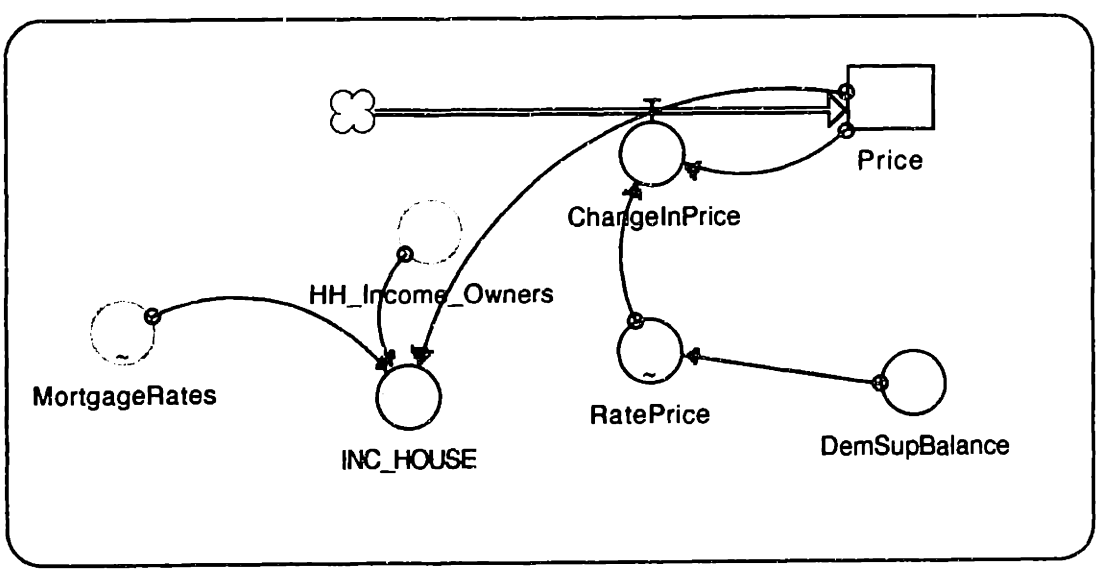


INTRODUCTION OF THE PRICING MODEL

With the Population, the Economy, and the Housing Supply segments of the Boston Housing Model defined, it is time to explain the mechanics behind the pricing model. There are two model components of housing demand. One provides a measure of household demand by estimating the number of households financially capable of purchasing a home. The second establishes a measure of the speculative investment component of housing demand. These two measures can then be compared to the supply of housing to determine the balance between supply and demand and changes in prices.

As can be seen in Figure 3.20, the supply / demand balance, DemSupBalance, will be used to determine the percentage change in housing prices through the use of a table function. When demand is in excess of supply, the pressure will manifest itself in rising prices. Conversely, when the market is soft, prices will have a tendency to fall. As shown, the price of housing, Price, is represented by a stock variable which can be increased (or decreased) by the ChangeInPrice, flow variable. The mechanics of the rate of change will be explained fully once the measures of household and speculative demand are established.

Figure 3.20: Housing Price and Ratio to Median Income.



INC_HOUSE is a measure of the fraction of the median household income of a home-buyer necessary to purchase a home at the prevailing market price. The measure is similar to the Historical Housing Fraction discussed in the previous section . The INC_HOUSE fraction will be used to help model the establishment of credit standards by the financial institutions.

CREDIT STANDARDS FOR HOME BUYERS

As discussed earlier in the section on housing prices, the fraction of household income needed to purchase a home has risen from roughly 20 to 45 percent since 1970. Rising housing prices have outpaced household income despite the increase in wages and workforce participation. Banks responded to the decline in affordability by revising traditional credit standards.

Historically, banks perceived the decision to purchase a home as primarily an exercise in consumption. As such, credit standards limited home mortgage debt service payments to around 25 percent of a purchaser's income. In the past decade, however, the purchase of a home has come to be perceived to have both a consumption and an investment component. As such, lending institutions are perceiving a portion of the decision to buy as including a "forced" savings plan in the equity of the home. Thus, banks have been increasingly willing to raise the credit limits to around 35 percent of a household's income. One area bank has recently announced that it will lend up to 45 percent of a household's income if it can be demonstrated that a similar amount of money had been spent in the last three years for rent.[38]

It should also be noted that in the early 1970's the condominium market was in its early stages and still an unknown quantity for most banks. As such, the predominant form of home-ownership available for residents was to purchase a multi-family structure and occupy a unit.

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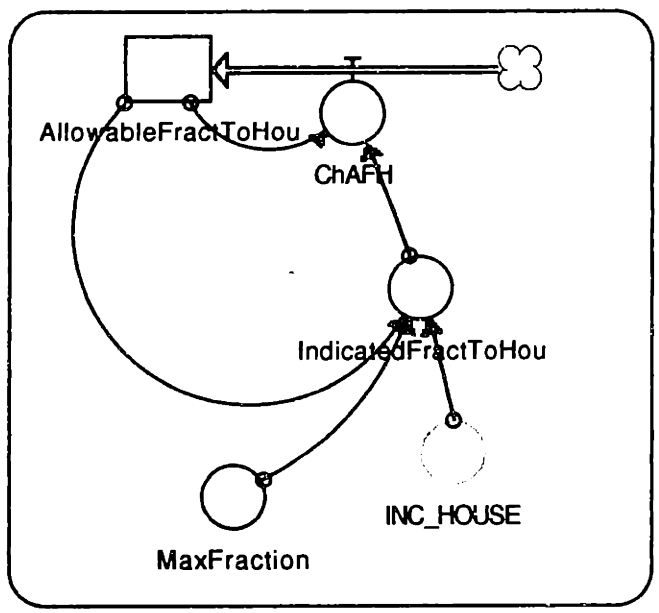
38 "Program Could Widen the Pool of Home Buyers," The Boston Globe, July 24, 1989.

Since all values of housing prices in this study have been adjusted to reflect the per unit cost, the price of a typical triple-decker would be three times the per unit price. Thus the ratio of household income needed to purchase a building becomes higher, partly explaining the lower lending ratios in the 1970's.

Figure 3.21: Establishment of Bank Credit Limits

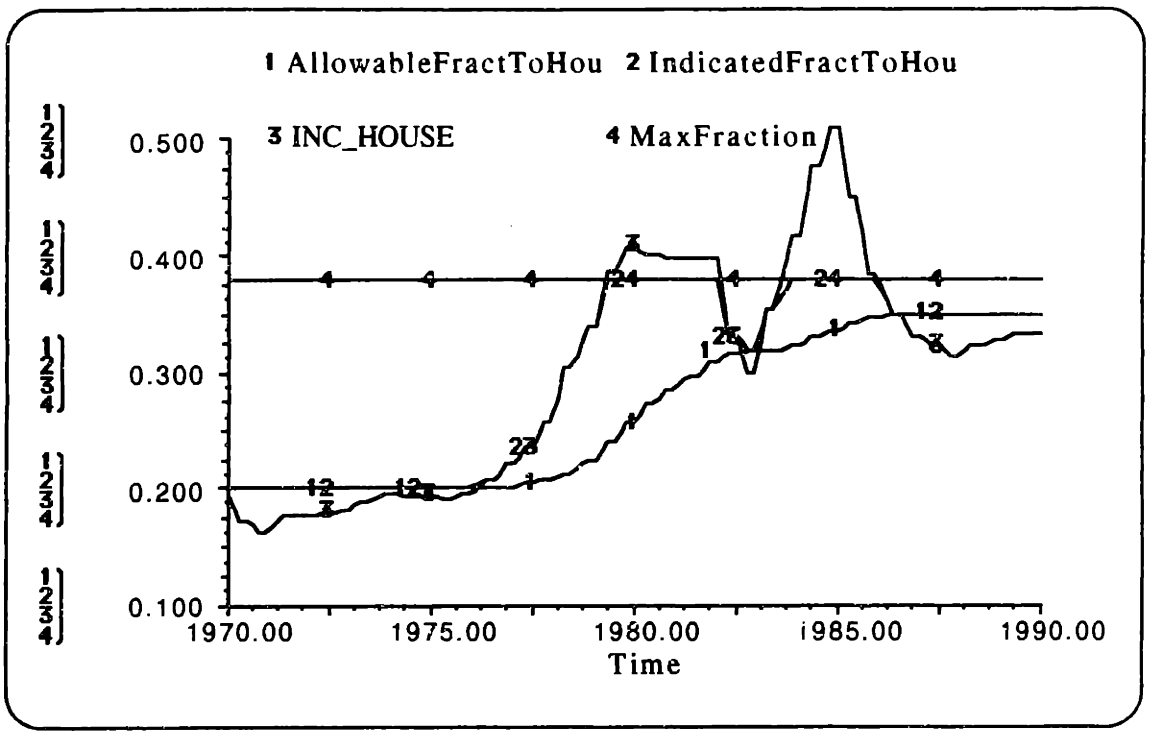


To capture the upward ratcheting of the bank's credit standards, I employ the model shown in Figure 3.21. The diagram shows the credit limit imposed by banks as the stock variable, AllowableFracToHou. The credit limit is modified by the change in the allowable fraction of income to housing, or ChAFH. In essence, allowing the credit limit to adjust over time toward the IndicatedFractToHou, which is the minimum value of either a maximum limit (MaxFraction) or current financial reality, INC_HOUSE. The upward movement of credit standards takes four years to adjust to each new level of INC_HOUSE.

Figure 3.22 plots the simulated credit limit imposed by banks as they respond to the realities of the real estate market. Variable 1, AllowableFracToHou, can be seen lagging in

response to variable 3, INC_HOUSE. Credit limits are bounded by the MaxFraction assumed to be 38 percent.

Figure 3.22: Upward Trend in Bank Credit Standards



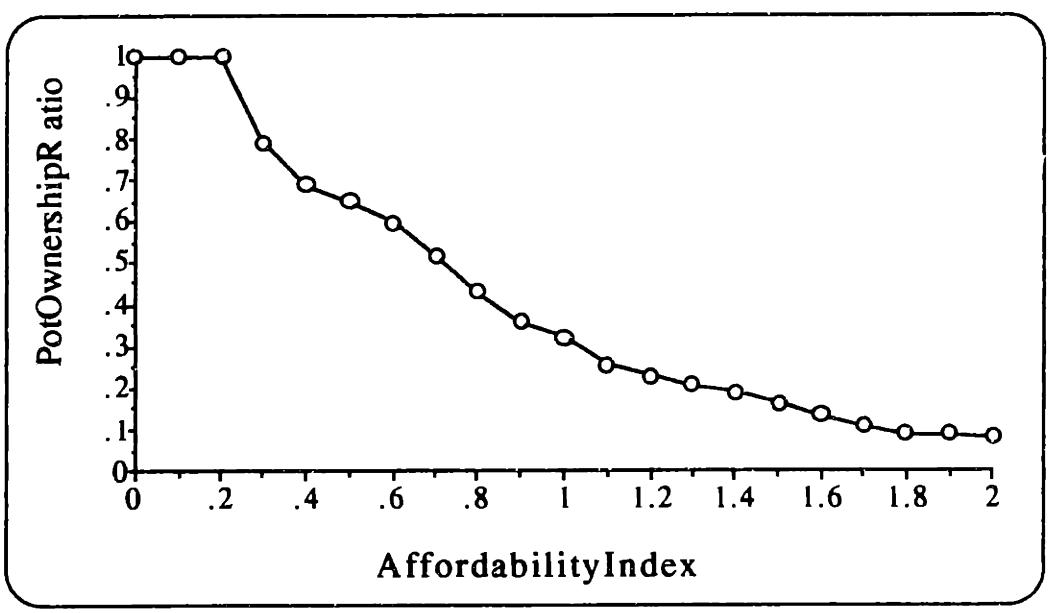
DETERMINATION OF HOUSEHOLD DEMAND

Given credit standards imposed by financial institutions, the affordable price for a home can be established for the median household income and the prevailing mortgage rate. In the previous section, an equation for an affordable price was explained and can be referred to in Figure 3.5. The affordable price will be compared to the actual market price to arrive at an "affordability index". The mechanics of this process can be seen in Figure 3.24.

The AffordabilityIndex is the ratio of the market price (Price) to the Affordable_Price. If greater than one, fewer households qualify for a mortgage. If less than one, more households become eligible. The ratio of affordable to actual prices will be converted into the percentage of households which can purchase a home through the table function,

PotOwnershipRatio. The table function was derived from the income distribution data discussed earlier in this paper. Figure 3.23 details the relationship of this function. When the affordable price equals the market price (i.e. the ratio = 1.00), then 32 percent of households will qualify to purchase the median priced home, consistent with the observation that roughly 32 percent of all households earn at or above the median household income for homeowners. It is also consistent with the fact that in today's market 32 percent of households own their own home.

Figure 3.23: Table of Potential Ownership Ratio.



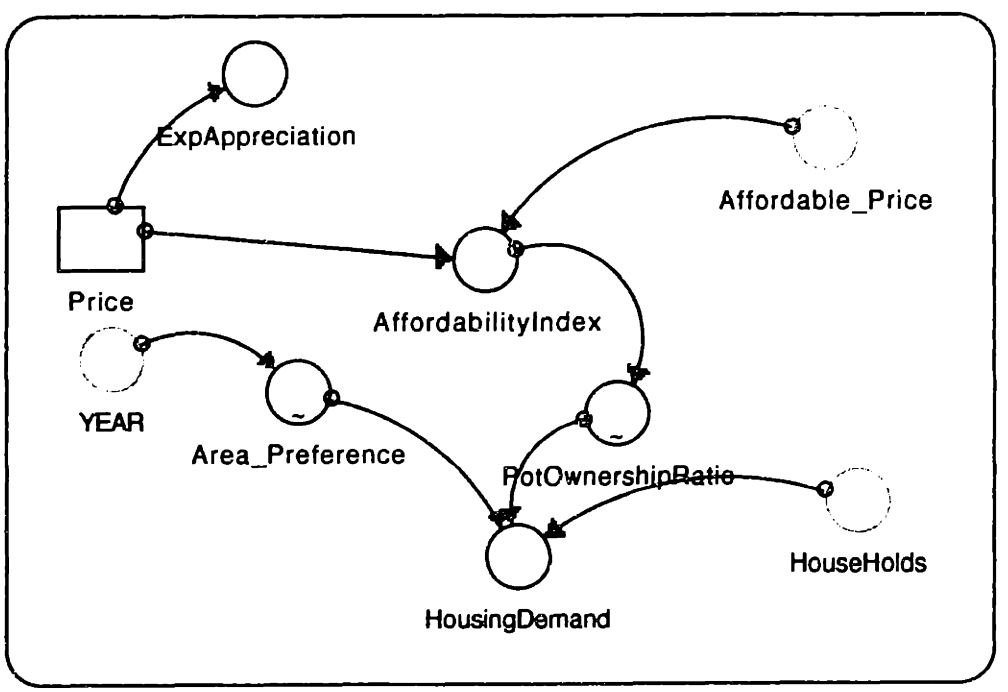
Also, it has been noted that the median income for all households is at roughly 65 percent of the median for home-owners. From an extrapolation of the table (the actual function contains more data pairs), when the affordability index falls to 65 percent, then 50 percent of all households will be able to purchase a home. The function will, therefore, set the parameters for the magnitude of demand created when home prices fall or household incomes rise.

In today's housing climate it is assumed that everyone who can afford to purchase a home will enter the market to do so. A strong desire to own a home in the city has not always

been the case. In the early 1970's there was net migration out of the city due to various social and economic factors. From post-war suburbanization to a declining employment base and a school busing crisis in Boston, there were many reasons, beyond the scope of this model, which dampened the demand to purchase a home in the inner city regardless of one's ability to obtain a mortgage. To model these exogenous factors, I have developed a variable, Area_ Preference, which dampens household demand by 50 percent during the early 1970's. After 1975, when net migration to Boston becomes positive, indicating an increased preference for urban living, the Area_Preference rises, reaching 100 percent by 1980.

The PotOwnersipRatio is then multiplied by the actual number of households and the Area_Preference to gauge the total level of household demand. When combined with a measure for speculative demand, a balance with the supply of housing can be measured.

Figure 3.24: Household Demand.



SPECULATIVE INVESTMENT.

One of the more prominent factors behind the run-up of real estate prices in the 1980's was the speculative demand for condominiums, fueled by federal tax policy and the expectation of rising prices. While speculative demand is recognized as a contributing factor, there is very little documented evidence as to how many condominiums were purchased as an investment. Measuring the number of investors is one area of my study that needs more research. Nonetheless, I have developed a model of speculative demand which allows for up to 30 percent of all condominium sales to be investment related in times of rapidly rising prices. Conversely, the model allows for the sale of these units as prices fall.

Important in the measure of speculative demand will be a measure of the expected rate of appreciation of home prices. The expected rate of appreciation is represented by the variable ExpAppreciation, which calculates the first order exponential average of the past trend in the percentage change in Price with an assumed time constant of two years.

The key to determining the magnitude of investment demand is to develop an after-tax measure of condominium return. Figure 3.25, shows the variable, AfterTaxReturn, which employs the following formula to determine the after-tax return to a condominium investor:

$$E[R_1] = (r_0/P_0)\cdot(1-T_p) + E[(P_1 - P_0)/P_0]\cdot(1-T_{cg}) + (1/D)\cdot(1-T_p) - I_0\cdot(1-T_p)$$

Where:

$E[R_1]$ = The expected after-tax return to investment in year 1

r_0 = the annual rent in year 0

P_0 = the median condominium price in year 0

$E[(P_1 - P_0)/P_0]$ = the expected annual percentage rise in condominium prices

T_p = the marginal personal tax rate

T_{cg} = the marginal capital gains tax rate

D = the depreciable tax life

I_0 = the mortgage interest rate in year 0

The equation breaks down the return to an investor into four components; 1) an after - tax income component from rent, $(r_0/P_0)\cdot(1-T_p)$; 2) an after-tax component of annual appreciation, $E[(P_1 - P_0)/P_0]\cdot(1-T_{cg})$; 3) a measure of the tax benefit of the depreciation write-off, $(1/D)\cdot(1-T_p)$; and 4) an after-tax deduction of debt service, $I_0\cdot(1-T_p)$. Since the equation assumes 100 percent financing, it is the same as determining the after-tax net present value using a hurdle rate equal to the mortgage rate. Therefore, when the return is positive, there is an incentive for investment.

Figure 3.26 shows the expected after-tax return to a condominium investment using the formula and historic price data. The rapid rise in the investment return during the mid-1980's when the real estate market was booming can be seen.

Figure 3.25: After-Tax Return to a Condominium Investment.

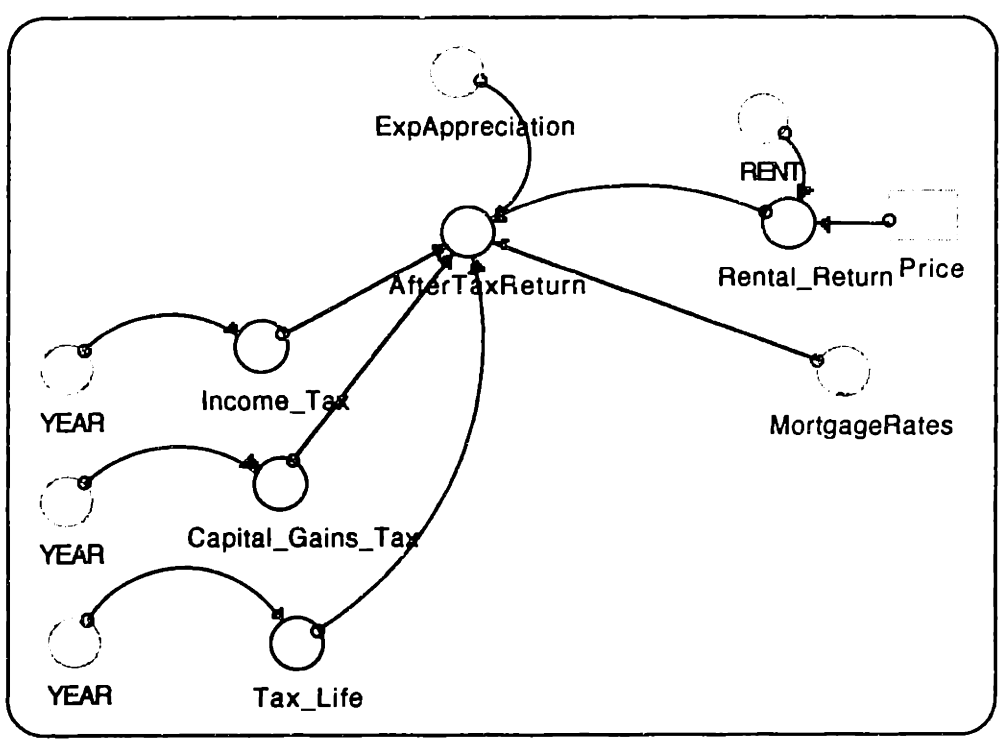
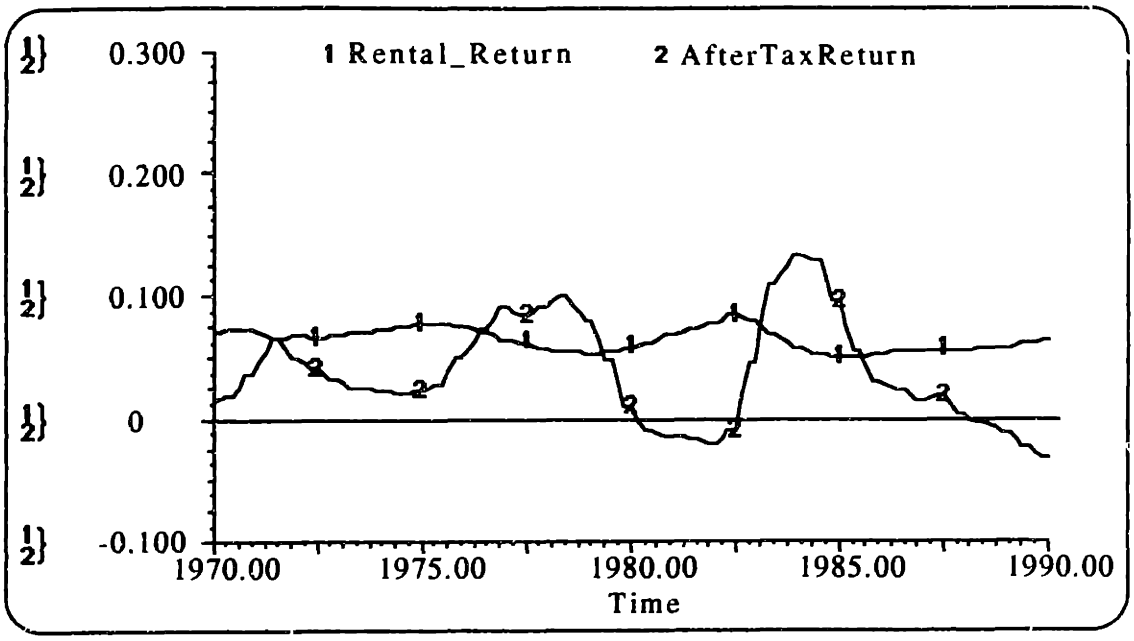


Figure 3.26: Historic After-Tax Return to a Condominium Investment.



INVESTMENT DEMAND

The after-tax condo return needs to be translated to an actual level of demand. From the historical data the after-tax return for investor condos was positive during the 1970's. However, the positive return did not manifest itself into sales of investor units until the end of the decade. It took time for the condominium market to become established, for sufficient volume of production to exist, and for both investors and lenders to become familiar with the concept. I have modeled this learning process through the Learning_Curve variable introduced in Figure 3.27. The Learning_Curve is a table function which dampens demand in early years while the condominium market becomes established. From a value of zero in 1970, this variable rises exponentially to 100 percent by 1980.

By multiplying the Learning_Curve by the after-tax return, the LaggedReturn variable is created which correlates well with expected investor demand. An additional check is added with the use of the Investor_Condos stock variable. Investor_Condos, which will be

explained in the next section, is a cumulative inventory of all investor condos purchased. It allows for a check if the after-tax return becomes negative, since it only allows for a negative value, and thus a sale of investor units, if there is already an existing stock of units to sell.

The LaggedReturn is translated into a level of demand through the InvestorDemand table function which can be seen in figure 3.28. The function defines the percentage of total housing units demanded for investment given different rates of return. The percentage can vary between +20 percent, if the return is high, to - 5 percent, indicating a sell-off of units, if the return becomes negative. The Learning_Curve can be seen in Figure 3.28.

Figure 3.27: Investor Demand.

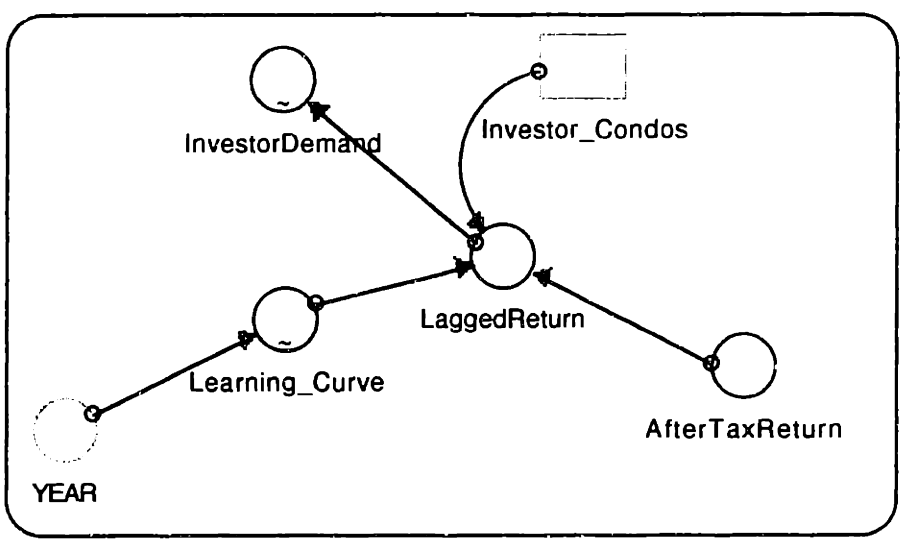


Figure 3.27: Investor Demand.

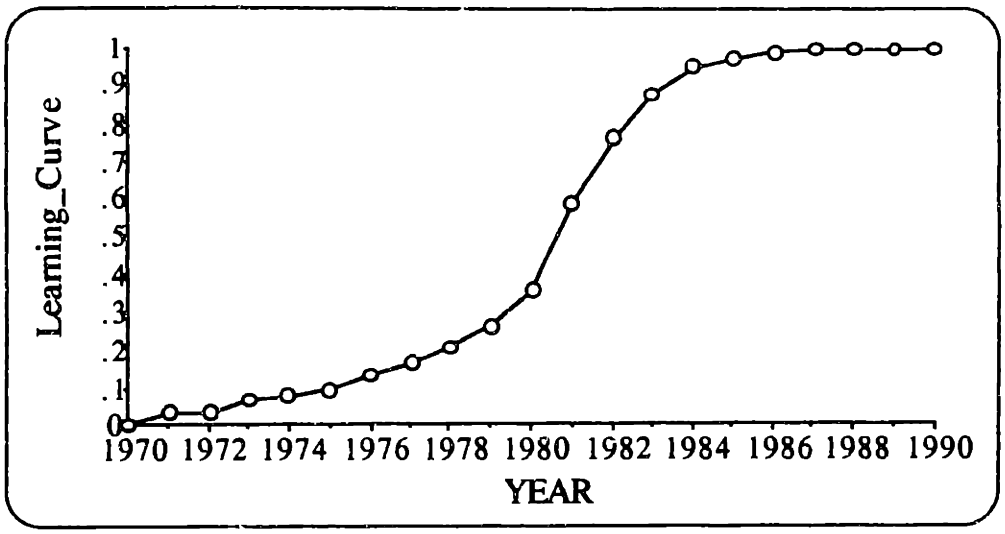
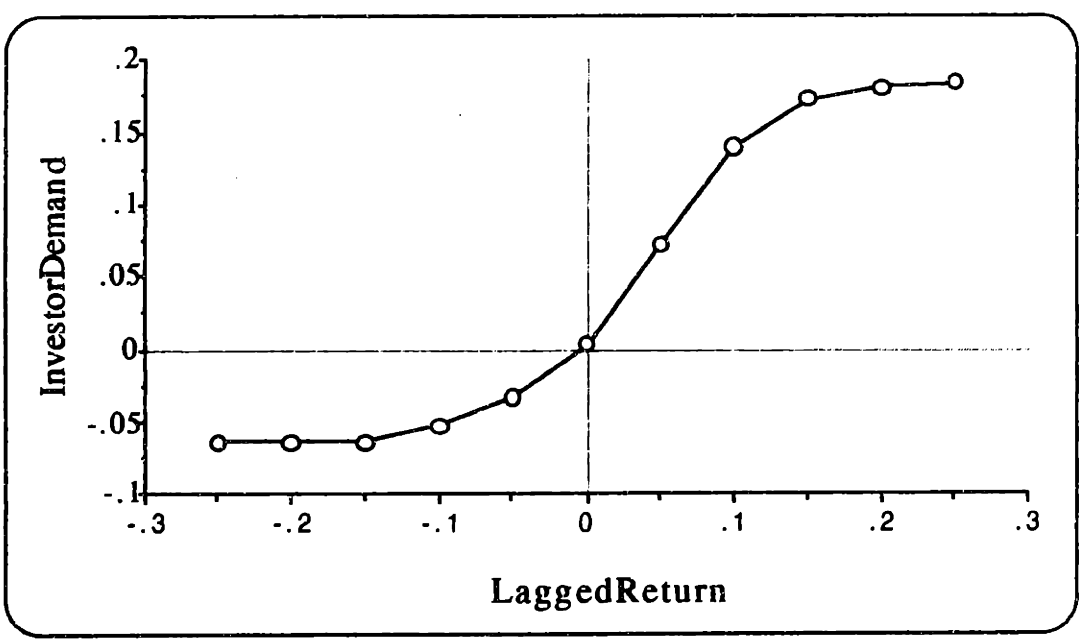


Figure 3.29 Investor Demand Function

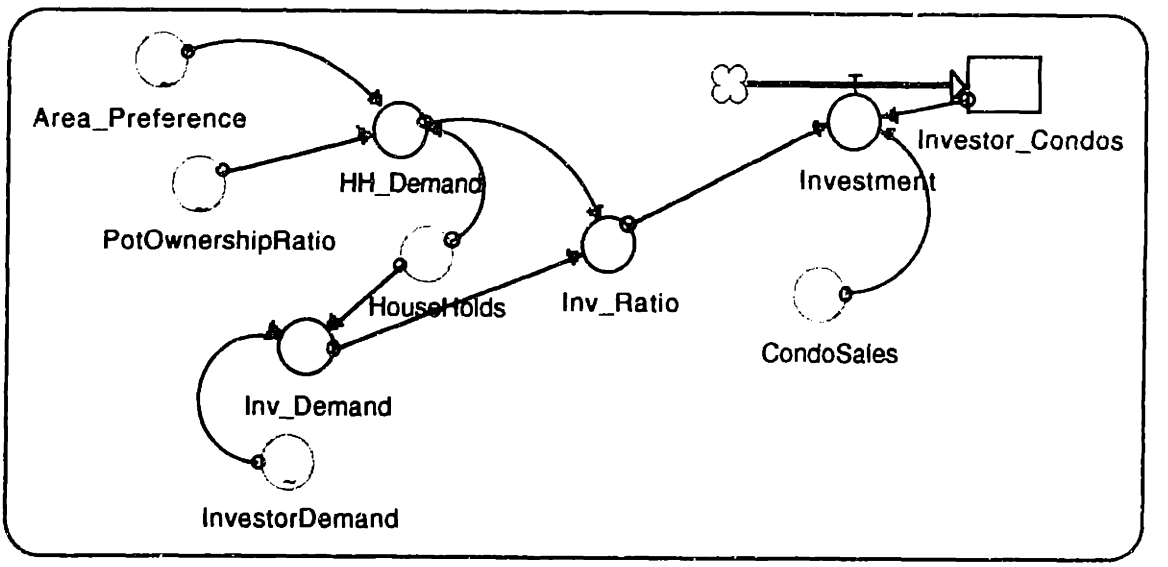


INVENTORY OF INVESTOR CONDOMINIUMS

It is necessary to keep track of the total condominium units purchased for investment. The number of investor units needs to be included in the calculation of rental unit vacancy. The stock will also allow for the existence of negative investor demand to manifest itself through the sale of units held.

To keep track of the total level of investor condominiums, I use the model structure identified in Figure 3.30. Here, both household and investor demand are converted to a common measurement, namely a percentage of total households. The ratio of investor demand to total demand (Inv_Ratio) is then multiplied by the total condominium sales (CondoSales) to determine how many condominium units are purchased annually by investors (Investment). Total condo sales are assumed to equal total production. The stock of investor condos is then used to help establish the level of vacancy for rental units. It is assumed that all of the investor units are offered to the market as rental units.

Figure 3.30: Inventory of Investor Condos.



SUPPLY AND DEMAND

With a measure for both household and speculative demand established, these can be compared to the supply of housing to see whether prices should be rising or falling. In the Boston Housing Model, total demand is represented by the variable, HousingDemand. The total demand is the sum of both household demand and investor demand and is expressed as the number of individuals (households or investors) who have the financial means to purchase a home. On the supply side, it is assumed that every condominium and owner - occupied unit is available for sale. The supply and demand structure can be seen in Figure 3.32.

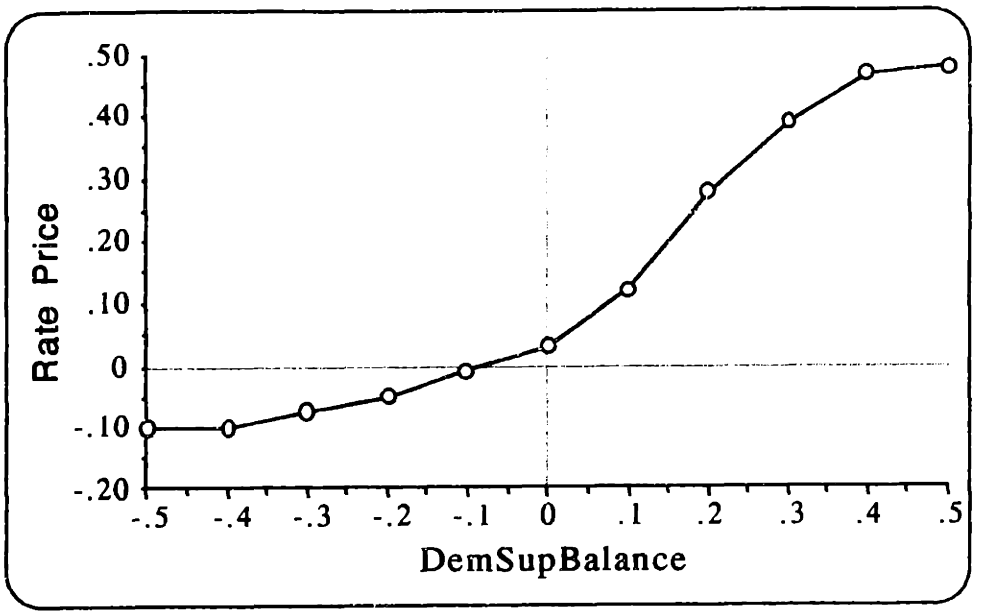
Critical to the model is an approximation of the pricing dynamics which occur as result of supply and demand pressure. Figure 3.31 shows the table function used to determine the annual rate of change in housing prices. It should be noted that all prices used in the model and the historical discussion are expressed in nominal terms. Therefore, if prices hold steady in the model , they are actually falling in real terms (assuming, of course, a positive inflation rate in the economy). The table in Figure 3.31 was derived by trial and error, as a function which both fits the historic data and is grounded in common sense.

As can be seen, when demand exceeds supply, upward pressure is exerted on prices. Prices rise at a nominal 2 percent increase when demand equals supply, and rises at an annual increase of 50 percent, when demand outstrips supply by 50%. The function presents an inelastic supply curve when prices are rising.

When demand is less than supply, however, the pricing function presents an elastic supply curve. When demand is at only 60 percent of supply (i.e. DemSupBalancs = -.40), prices will fall 10 percent annually. This is consistent with the observation that in most real estate markets, save the U.S. oil patch, prices are "sticky" downward. Usually slack demand manifests itself in the form of a lower volume of transactions, rather than lower prices, as

sellers either withdraw their houses from the market or settle for a longer period in which to sell.

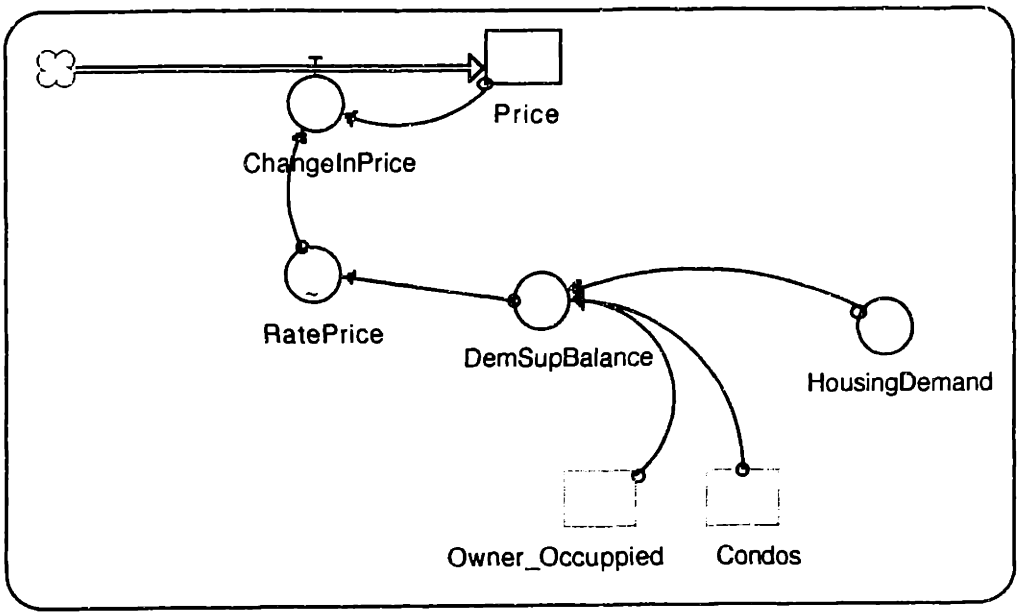
Figure 3.31: Table of Supply and Demand Curve.



One of the drawbacks with the modeling approach I have chosen is the inability to estimate the volume of transactions. Perhaps in a future revision of this work, the supply and demand dynamics might be modeled at the margin. This might be accomplished by modeling the supply as only new condominium produced and a fraction of the existing housing stock. Conversely, demand might be measured as consisting of the new households entering the market (through net migration or new household formation) and a fraction of the existing home-owners who might be contemplating a trade-up to another home.

With the pricing component of the Boston Housing Model in place, it may now be tested to see how well it stacks up against recent history.

Figure 3.32: Pricing Mechanics.



CHAPTER 4

RUNNING THE BOSTON HOUSING MODEL

TIME HORIZON.

For this chapter, the Boston Housing Model will be run to test its ability to predict both housing prices and rents in the core Boston neighborhoods. The model will be run to simulate twenty years (1970 to 1990). The results of the simulation will be compared to the historic time series data for accuracy. It should be noted that the historic price data is current to the year 1989; for the test results, the 1990 historic prices are assumed to be the same as 1989.

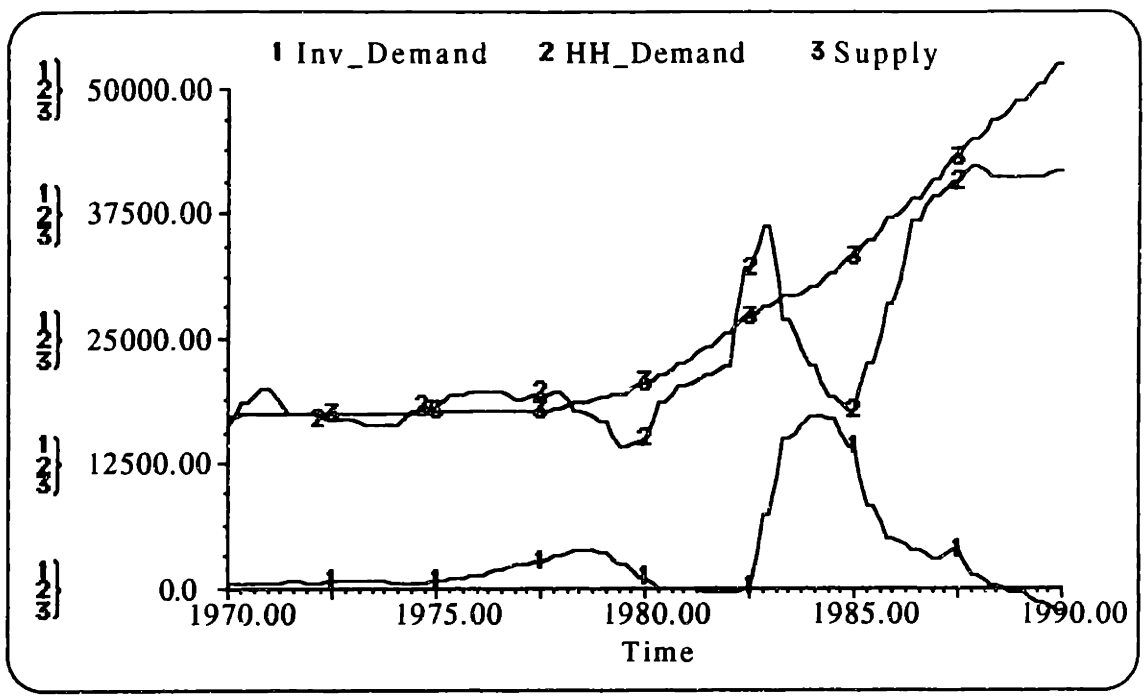
SIMULATION OF SUPPLY AND DEMAND.

Figure 4.1 shows the test results for the model's simulation of investor demand, household demand, and supply. As can be seen, household demand for housing is relatively in line with supply during most of the 1970's. A small drop in demand can be seen during the 1974-75 recession when both unemployment and interest rates were high. By the end of the decade, demand can be seen dropping sharply as a result of the high interest rates accompanying the 1979-82 recession. The demand for investor condos begins to develop during the late 1970's, but as will be shown, the stock of units is not high enough for this to have much of an impact.

By the start of the 1980's, the recession is under full swing. Mortgage rates are well into the double digits, and the unemployment rate is peaking at a round 9 percent. However, demand recovers quickly. The quick recovery is due in part to the fact that the Massachusetts economy was less affected by the recession than the rest of the nation. The Boston economy recovered quickly while working professionals were being attracted back to the city, the labor force participation rate of women was on the rise, and the rate of formation of new households

was increasing. All these factors resulted in an increase in the number of households, as well as a rapid rise in their median income levels.

Figure 4.1: Simulation of Supply and Demand



The model shows that the above factors resulted in a rise in household demand even before interest rates began to fall in 1983. In fact, the above trends were in effect since 1980, so that the response of the real estate market to the first fall in interest rates should have been expected. Mortgage rates fell from an average of 16.7 percent in 1982 to 12.5 percent in 1983. The drop increased household demand from around 22,000 households in 1982 to nearly 37,000 in 1983 (out of total of around 110,000). Fundamental economic factors in the Boston economy were thus sufficient to drive household demand in 1983 and start housing prices into an upward spiral.

Once prices began to rise in 1983, speculative demand began to take off. Fueled by expectations of future price increases based on those just experienced, investor demand quickly rises to account for nearly 40 percent of condominium sales by the end of 1984. Investment

demand, in turn, pushes the price of housing beyond the reach of the median household income and household demand plummets. It is only when interest rates fall for a second time, beginning in 1985, that household demand recovers and continues on the upward trend begun in the early 1980's. With expected rates of price increase never quite realized, together with a change in federal tax policy, the demand for investor condominium units gradually diminishes.

SIMULATED PRICES VERSUS OBSERVED DATA.

Figure 4.2 shows the simulated housing prices of the model (Price) plotted against the actual observed data (H_CondoPrice). As can be seen the fit is quite good. For a closer observation of fit, Figure 4.3 shows the fraction of the median household income needed to purchase a house. Shown are both the model simulation (INC_HOUSE) and the observed data (H_HousingFraction). The graph clearly shows two relative peaks in housing prices during the 1980's. The first run up in prices peaks in 1982 and is the direct result of fundamental housing demand discussed earlier. The second run-up in prices, as reflected in the housing

Figure 4.2: Simulated Housing Prices vs. Observed Data.

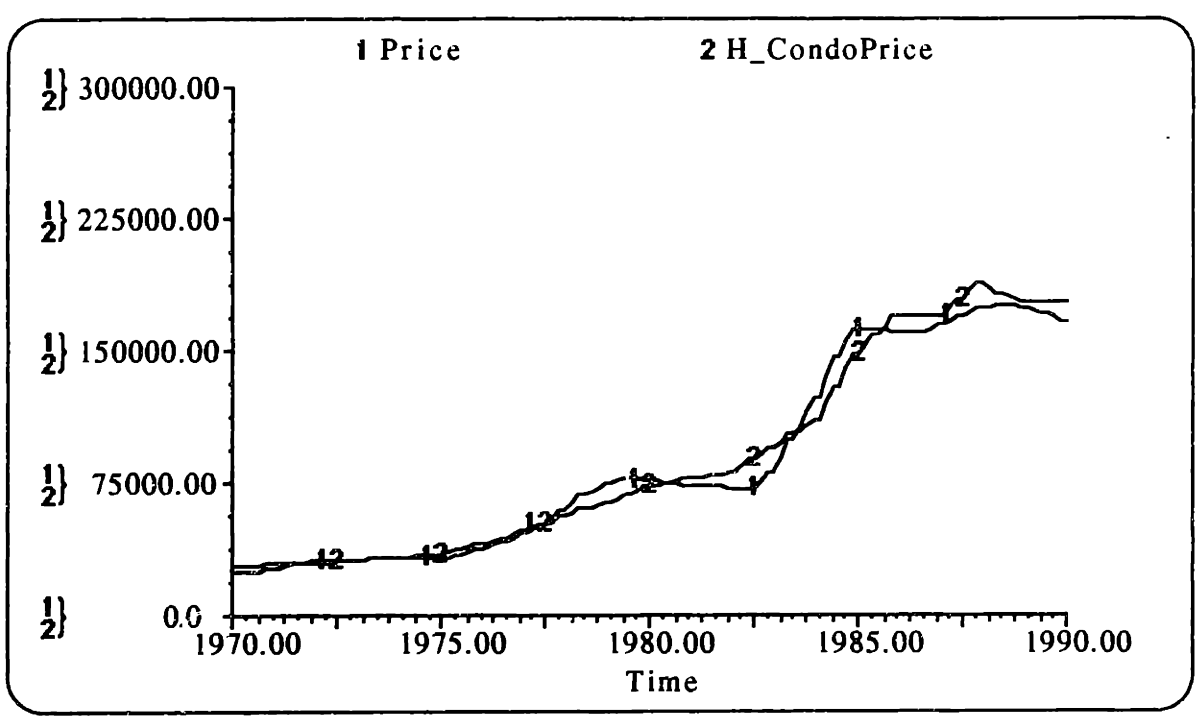
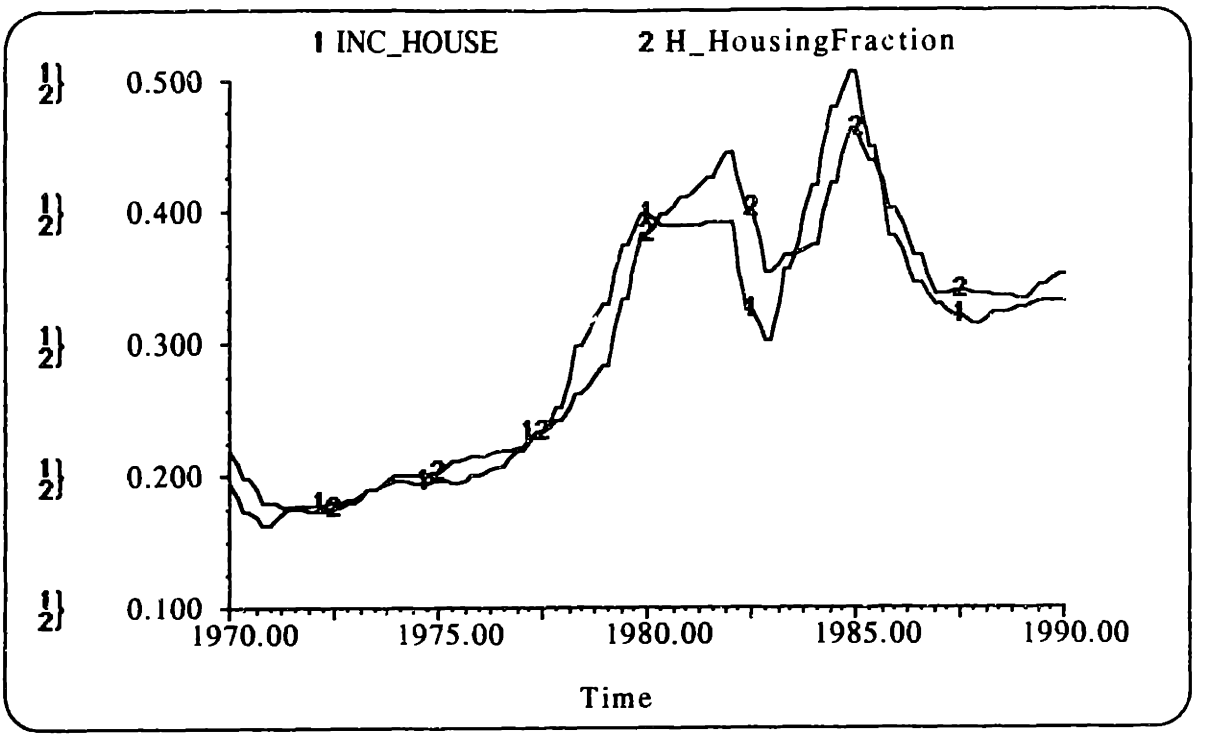


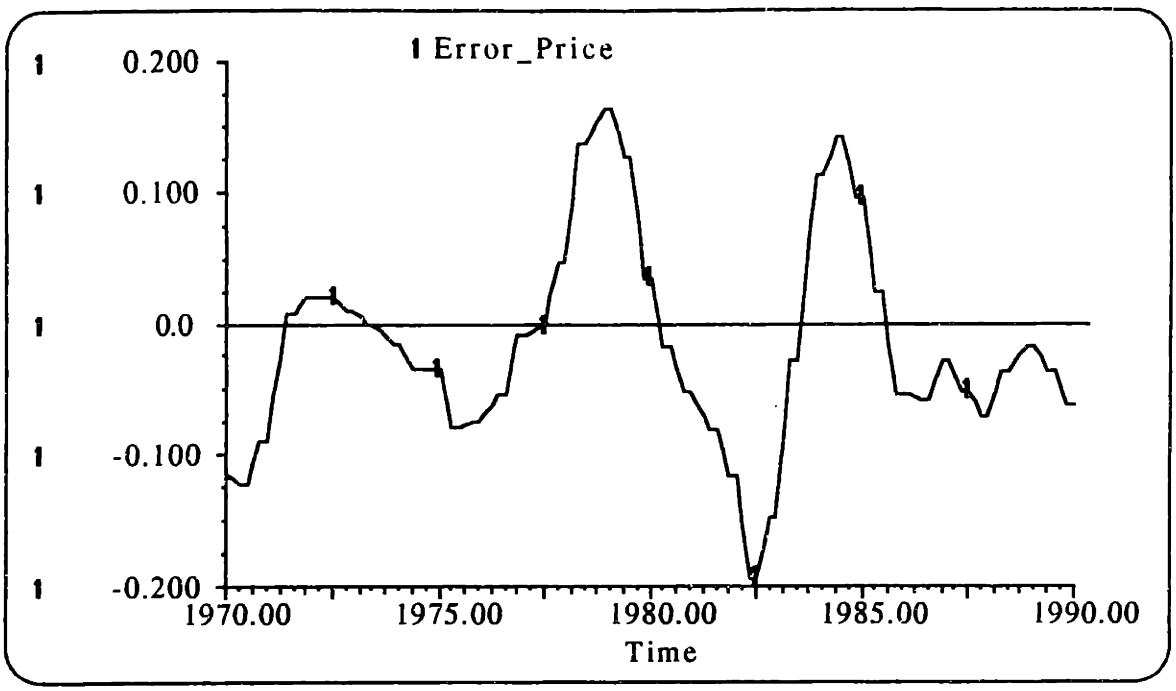
Figure 4.3: Simulated Housing Fraction vs. Observed Data.



fraction, shows a peak occurring in 1985. This time, it is the result of speculative investment, in response to the previous run-up in prices.

To measure the accuracy of the simulation, Figure 4.4 plots the percentage difference between the simulated and the actual price. The simulated housing price lies within 20 percent (plus or minus) of the observed data. In fact, the high peaks in the error measure occur primarily as a result of timing differences between the simulated and actual data, so that for most years the the simulated price falls within 10 percent of the observed value! Another way of interpreting the result is to note that roughly 90 percent of the price variation in the Boston real estate market has been explained by the model.

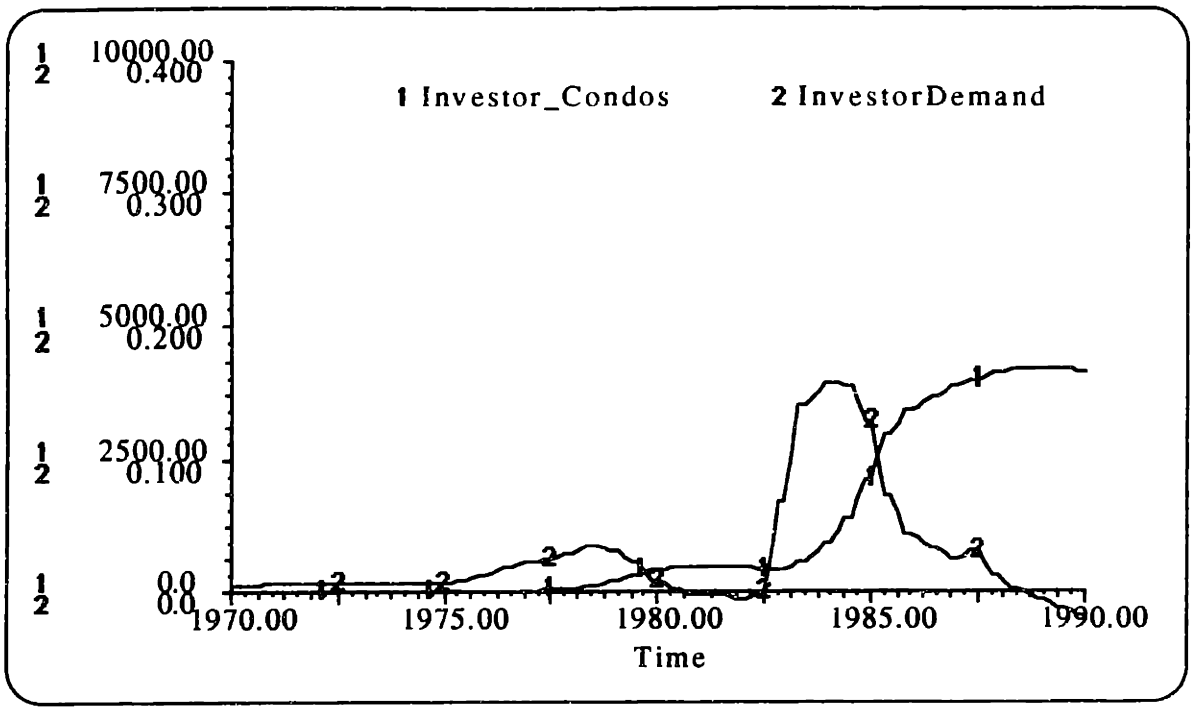
Figure 4.4: Percentage Error in Housing Price Simulation



The accuracy of the model was achieved while simulating both the household and speculative demand. Household demand was derived using fundamental economic data to determine the number of households who could afford to participate in the market. Speculative demand, however, was derived from a series of educated guesses regarding the expected after-tax return associated with the investment in a condominium unit. Were these assumptions realistic?

Figure 4.5 plots the level of investor demand (expressed as a percentage of total households) against the cumulative stock of investor condominium units purchased. The total number of investor condos peaks in 1988 at around 4,000 units when the total supply of condominiums is at over 26,000 units, indicating that roughly 15 percent of all the condominium units today are held by investors. Fifteen percent is not an aggressive assumption, and could probably be verified by further research.

Figure 4.5: Investor Condominiums.



SIMULATION OF RENTS

Figure 4.6 shows the simulated median rent for an apartment (RENT) plotted against the historical observed value (H_Rent). Again it should be noted that the last observation for the time series is in 1989 and the model extends that value to 1990. The simulated rent fits the historical values quite well. Figure 4.7 shows that the error in prediction lies within 15 percent of the actual value. In other words, more than 85 percent of the rise in rents in the Boston market can be attributed to fundamental economic factors, namely rising household incomes and a declining vacancy rate.

Figure 4.6: Simulated Rents vs. Observed Values.

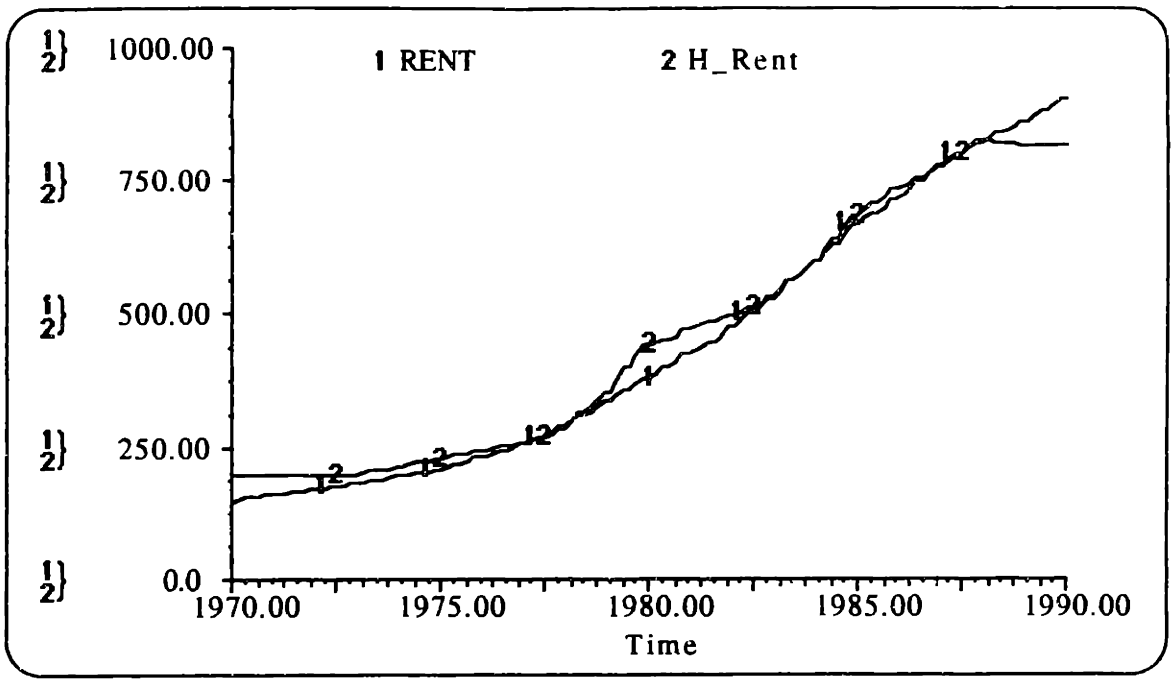
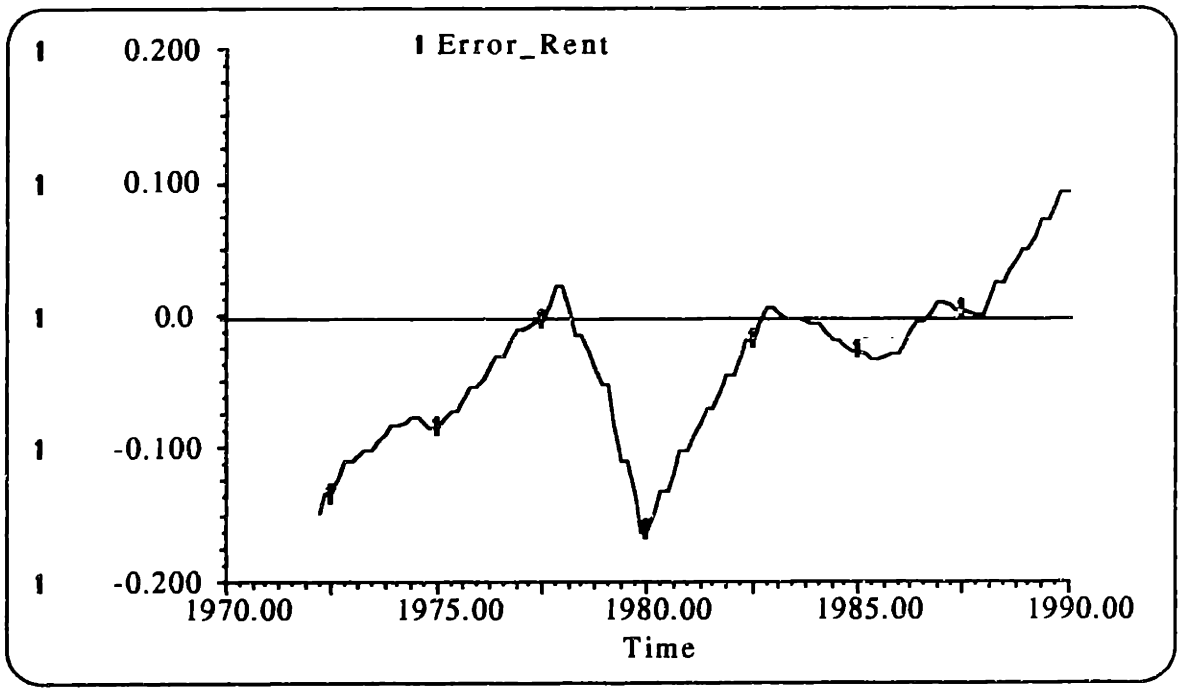


Figure 4.7: Percentage Error in Rent Simulation.



CHAPTER 5

LOOKING TOWARD THE NEXT DECADE

CLOSING THE LOOPS IN THE MODEL.

In the discussion on the overview of the model, it was noted that that two important feedback loops would have to be developed in order to have the model perform as a self-contained system. The first of these loops involves linking the in-migration of residents to the local economy. Migration should only occur as long as there is a net increase in employment to attract new residents to the city.

The second feedback loop involves creating a series of production functions to model the real estate development process. As of the time of this writing, a full model of new construction and condominium conversions has not been established. However, I have created an equation which closely approximates the rental conversion process. Since the conversion of the existing stock of rental units accounts for three-fourths of all new housing units for sale in the study area, this equation will allow the model to be run as a close approximation of what I expect to achieve with a full model of the production process.

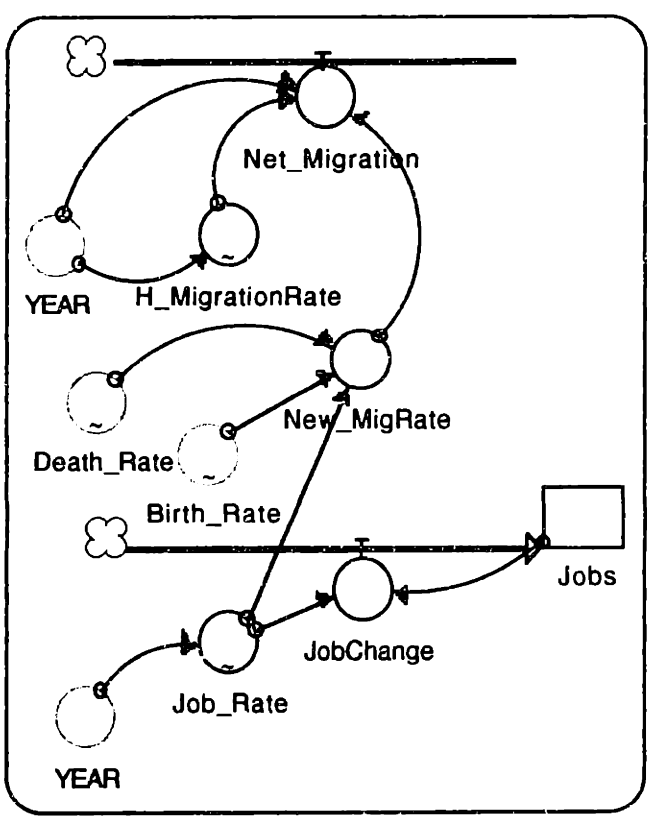
LINKING NET MIGRATION TO EMPLOYMENT OPPORTUNITIES

For the existing version of the Boston Housing Model, net migration into the city was established exogenously, based upon actual data. For projections into the future, however, exogenous assumptions are not appropriate. To expect net migration to continue at the rate of the past five years would be unrealistic. As strong as the local economy has been, the employment base has been growing at roughly 1.8 percent annually. The net migration rate has been approaching 2.0 percent annually. When combined with the natural growth rate (births minus deaths) of 0.9 percent, the population has been growing at a rate of 2.9 percent.

If this rate were to continue, the new residents would quickly face a tougher time looking for work and would thus lose their incentive to migrate.

To avoid the problem in simulating the 1990's, I have modified the model so that after 1989, net migration is set equal to the rate of creation of new jobs, less the natural population growth rate. Since the rate of labor participation in Boston's households has begun to stabilize, any new jobs will have to be filled by either new households (natural growth) or migrants to the area. With the modification I have made, I can ensure that the labor market maintains an even balance, and ensures that an aggressive projection of population will not create an "illusory" demand for housing. Figure 5.1 shows the Stella diagram of this modification.

Figure 5.1 Modification of the Net Migration Rate.

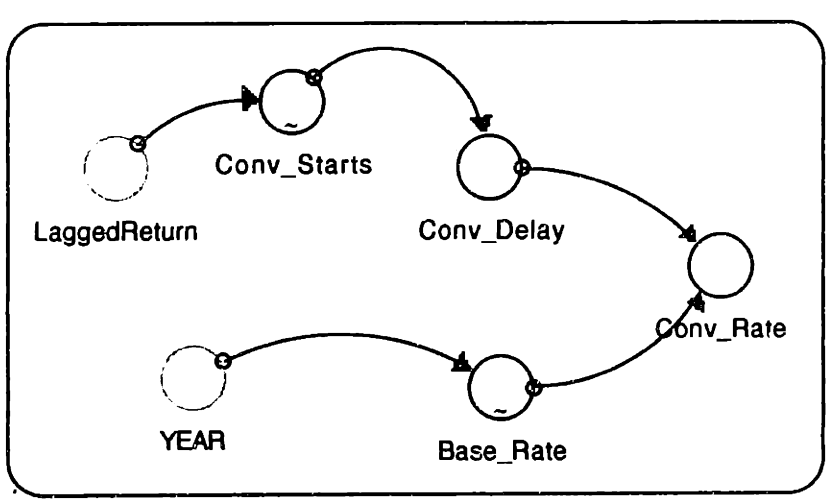


ESTIMATING THE PRODUCTION FUNCTION.

While a full model of new construction of rental units and condominiums has not yet been established, I have developed a series of equations to simulate the rate of conversion of existing rental units into condominiums. As conversion is the predominant form of production of condominium units, it will allow the model to be run as a fair approximation of what I hope to achieve in the future. For the other rates of housing production, the model will use estimated projections from the Boston Redevelopment Authority.

To estimate the rental conversion process, I began with the measure for the return on a condominium investment established in Chapter 3. When return is positive the conversion of rental units to condos will be started. When return is negative the production starts will be curtailed. Figure 5.2 shows the structure of the model. The LaggedReturn variable is the same return to investors discussed earlier. Return is converted to the variable, Conv_Starts, through a table function. The Conv_Starts variable can range between 0 and 4 percent, of total rental units. Conv_Starts result in completed units with an average lag of two years (Conv_Delay). The lag approximates the two year planning and renovation period typical in the conversion of rental units to condominiums.

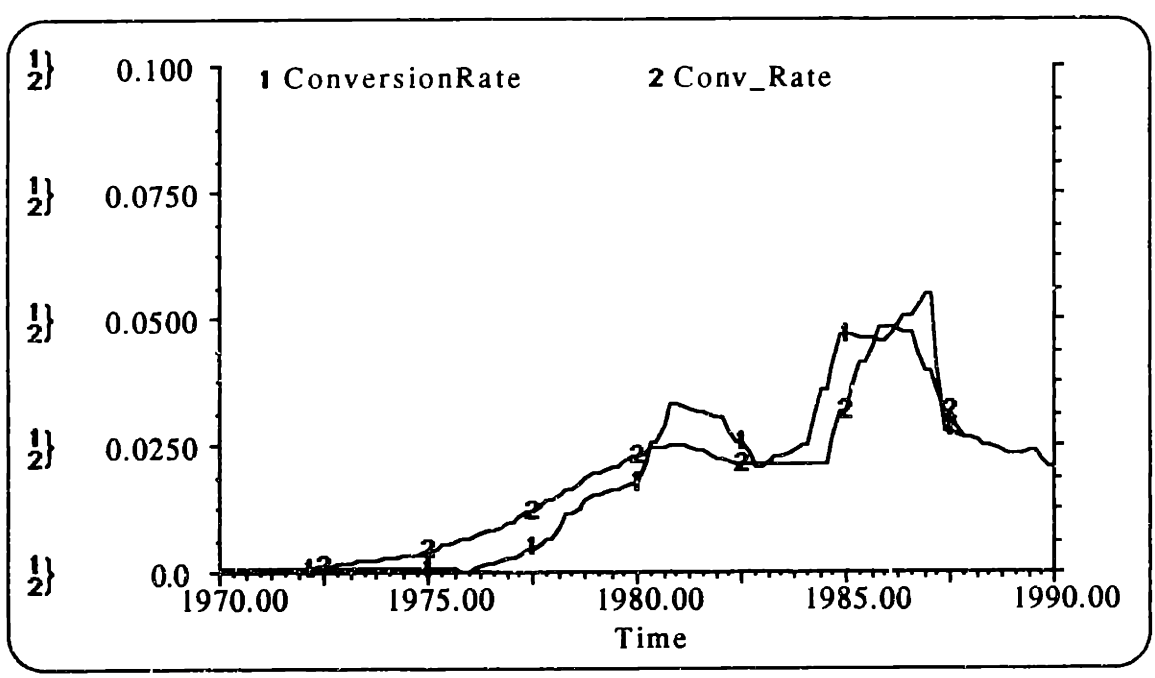
Figure 5.2 Model of the Conversion Rate.



In addition to a variable component which is dependent on economic factors, the estimated measure of conversion activity contains a base rate of activity regardless of the economic environment. This base rate is included to model the inertia inherent in the building industry. As seen from the historical data, conversion activity has not fallen below 1,800 units annually during the 1980's. Despite record interest rates and high unemployment in 1981-82. To model such "inertia" the base rate increases from 0 percent in 1975 to 2 percent by 1985 when it stabilizes. When the base rate is combined with the variable component, a new measure of conversion activity, Conv_Rate, is formed.

Figure 5.3 shows the plot of this new measure (Conv_Rate) against the historical value (Conversion Rate). While the new estimate is a little aggressive in the 1970's, a fairly good fit has been established for the 1980's. The estimate will be used in the model after 1988. Prior to that time, the actual data will still be used.

Figure 5.3 Estimate of the Conversion Rate.



FORECASTING THE FUTURE

To use the Boston Housing Model to simulate supply and demand in the real estate market for the next decade it will be necessary to establish the economic parameters under which the model should be run. Since forecasting the regional economy is clearly beyond the scope of this model, I have included three different scenarios. The first scenario assumes that the regional economy continues to grow at its present rate. The second scenario assumes the the Federal Reserve can engineer a "soft landing" consisting of slow growth and a lowering of interest rates. The third scenario, on the other hand, assumes a mild recession complete with rising interest rates.

CONTINUED GROWTH

The first scenario is a test of continued growth. Real economic growth, as measured by the growth in employment, continues at 2% per year. Accompanying this continued expansion of the economy is a slight rise in mortgage interest rates to 10.5%. The summary of these parameters is shown in figure 5.4.

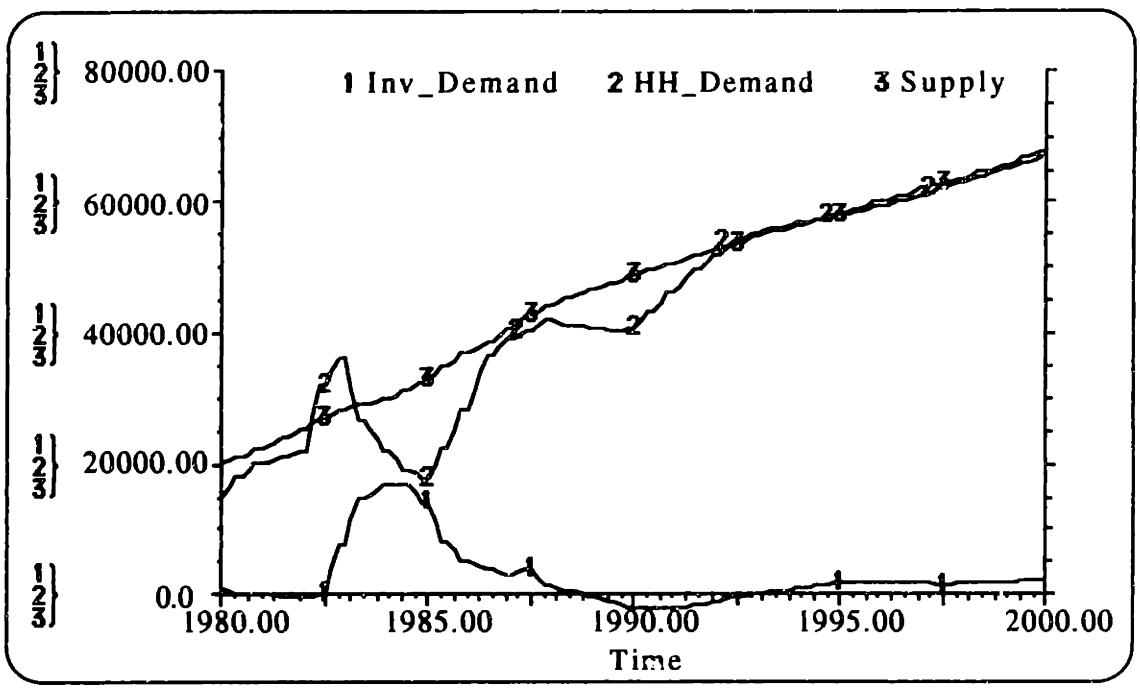
Figure 5.4: Assumptions for Continued Growth.

YEAR	1990	1991	1992	1993	1994-2000
Job Growth	2%	2%	2%	2%	2%
Wage Inflation	5%	5%	5%	5%	5%
Interest Rate	10%	10.5%	10.5%	10.5%	10.5%

The results of running the model out to the year 2000 can first be seen in Figure 5.5. The figure shows the level of both household and investor demand against the total supply. While the supply of housing continues to move upward, household demand falters from 1989 through the end of 1990. The drop is primarily the result of the slight rise in interest rate to 10.5 percent. Concurrently, the demand for investor units disappears and investors begin to

sell some of the units which they currently hold. Both factors lead to a real decline in housing prices. It is not until 1991, when rising wages allows more households to enter the market, that household demand begins to recover.

Figure 5.5: Forecasted Demand Under Continued Growth



The response of supply to lackluster demand can be seen in Figure 5.6. The rate of conversion of rental units subsides to a base level of roughly 2 percent of the outstanding rental stock, or about 1,500 units per year. Conversions pick up a little by 1994, after prices have started to recover.

Figure 5.6: Conversion Rate under Continued Growth

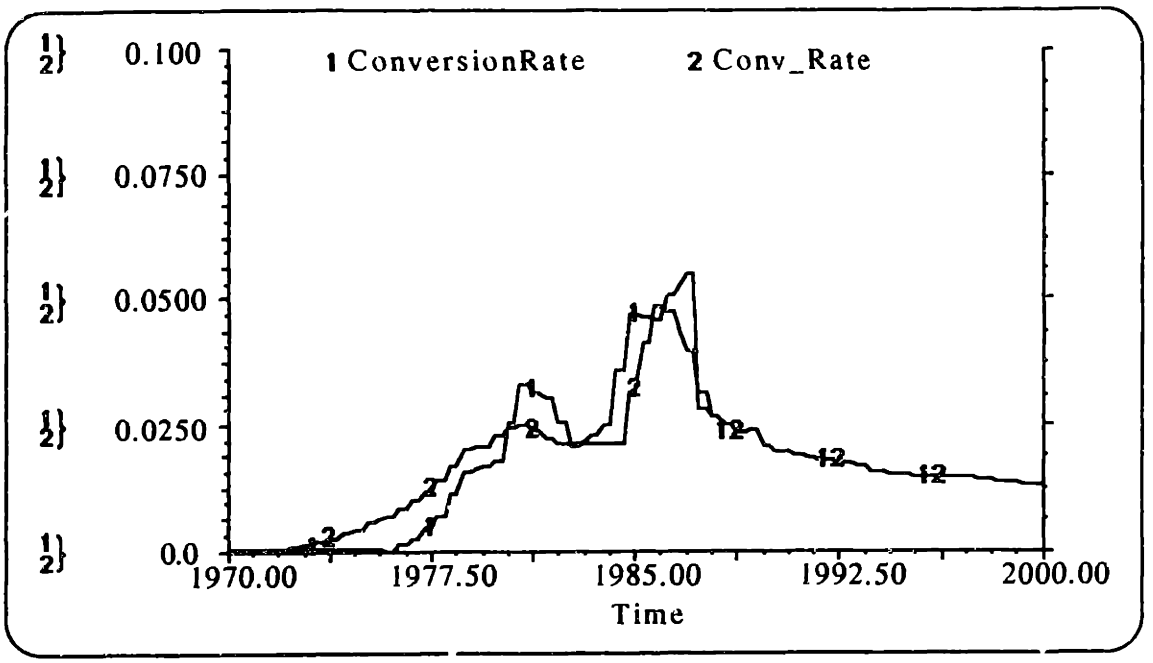


Figure 5.7 plots the forecast for housing prices. It should be noted that the historic values (H_CondoPrice) are shown for 1980 to 1989. After that the 1989 value is shown for use as a reference to the forecast. Here, it can be seen that decline in prices observed in today's market will continue for a couple of years. In fact, the model suggests that prices will fall about 10 percent before they start to recover.

Figure 5.8 shows the annual rate of change for both housing prices and rents. Here prices are shown falling during 1990 and 1991, albeit at a modest rate of 4 percent per year. Rents, on the other hand, continue their steady upward climb. In fact, as the rate of rental conversion subsides, the rental rate continues to match the rate of wage inflation.

It is interesting to note that even after prices begin to recover, they begin to stabilize at a rate of growth slightly below that of wages, around 4 percent annually. This follows the logic of the model. Currently 30 percent of households own their own home. For household

Figure 5.7: Condominium Prices under Continued Growth

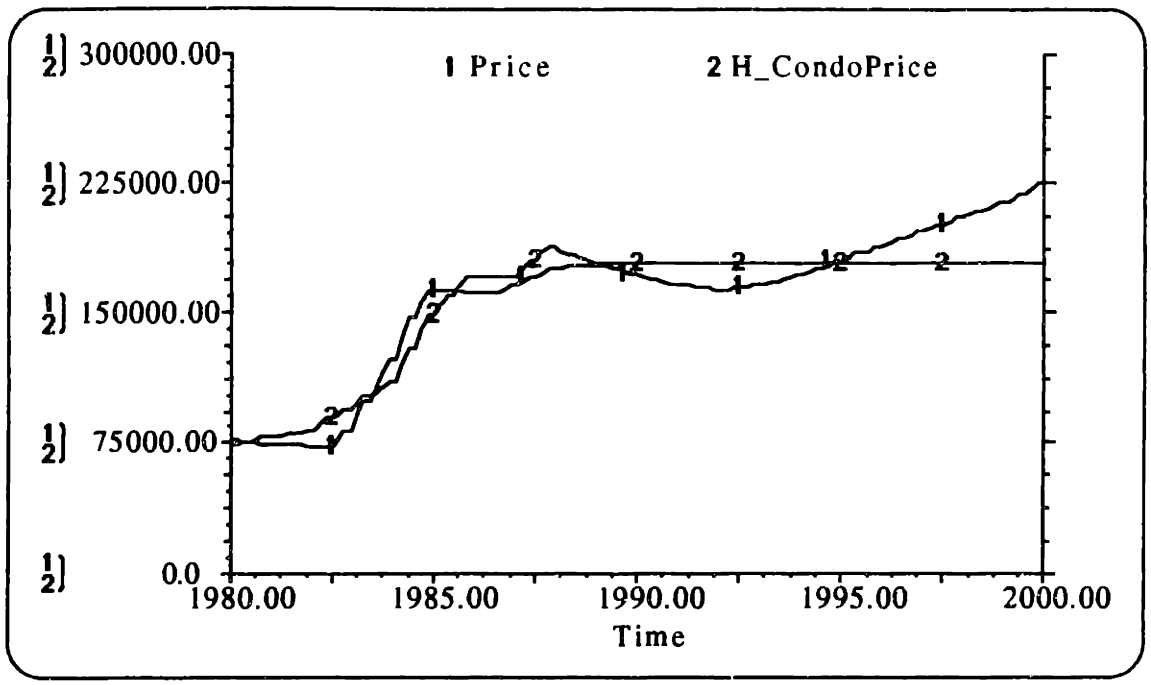
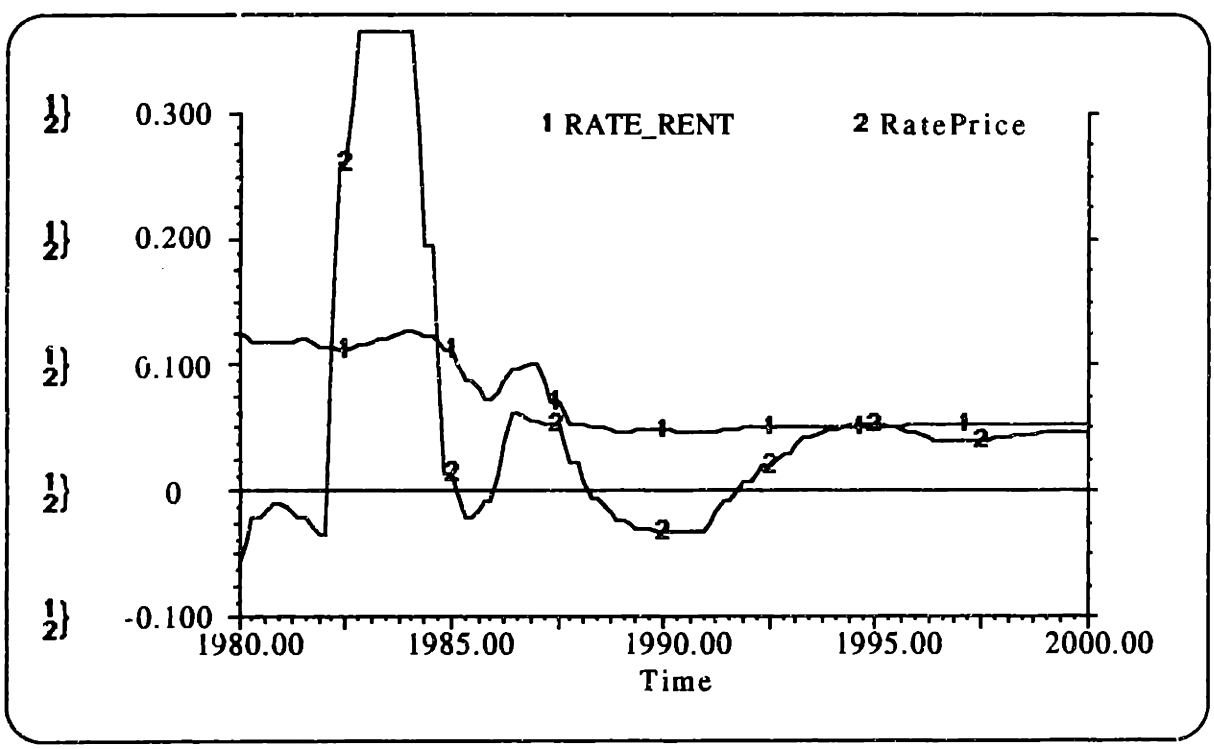


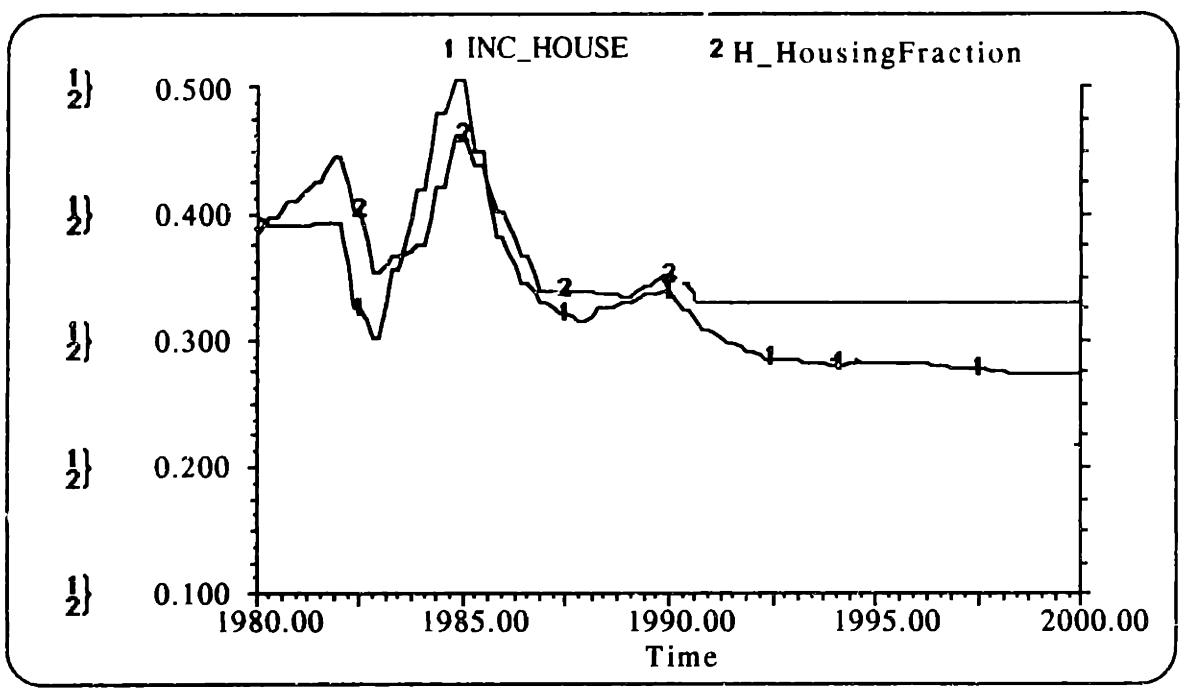
Figure 5.8: Changes in Prices, Rents under Continued Growth



demand to continue growing, more households need to be attracted into the market. Greater household demand will occur when the rate of growth of median home prices is below that of household incomes. In essence, more households will be able to buy, as the average mortgage payment moves down along the income distribution curve.

The ride in affordability can be clearly seen in figure 5.9. Even as prices have begun to recover by 1991, the fraction of median household income needed to purchase a home continues to decline to around 28 percent. The drop is a significant decline from today's level of 35 percent.

Figure 5.9: Housing Fraction under Continued Growth



SOFT LANDING

Under this scenario, the Federal Reserve is successful at engineering a "soft landing", allowing for economic growth to occur at a slow rate, while avoiding a recession. While the Federal deficit starts to come down under the Gramm - Rudman targets, the Fed is able to ease the money supply which helps to lower the interest rates. Figure 5.10 shows that for the scenario, the rate of job growth is held to 1 percent per year. Wage inflation remains the same at 5 percent, and the mortgage interest rates fall to 9 percent.

Figure 5.10: Assumptions for a Soft Landing.

YEAR	1990	1991	1992	1993	1994-2000
Job Growth	1%	1%	1%	1%	1%
Wage Inflation	5%	5%	5%	5%	5%
Interest Rate	9.5%	9.0%	9.0%	9.0%	9.0%

The effects on supply and demand can be seen in Figure 5.11. While the supply of housing continues to increase, household demand holds steady. The strength in household demand is in contrast to the actual decline experienced under continued growth. The increased demand is primarily due to the slight drop in interest rates to 9.0 percent, which leads to a rebound in household demand by 1990. In the soft landing scenario, the demand for investor units also disappears, however, it returns slightly in 1991 in response to the increase in prices.

While Figure 5.12 plots the forecast for housing prices, Figure 5.13 plots the rate of change. It can be seen that prices only fall for 1989 and 1990 at about 2 percent per year. This drop amounts to about a 5 percent "correction" in real prices before the market recovers. In fact, due to the lower interest rates, more households are attracted to the market and the rate of price change approaches 10 percent (twice the rate of wage inflation) before settling in the 4 percent range.

Figure 5.11 **Forecasted Demand in a 'Soft Landing'.**

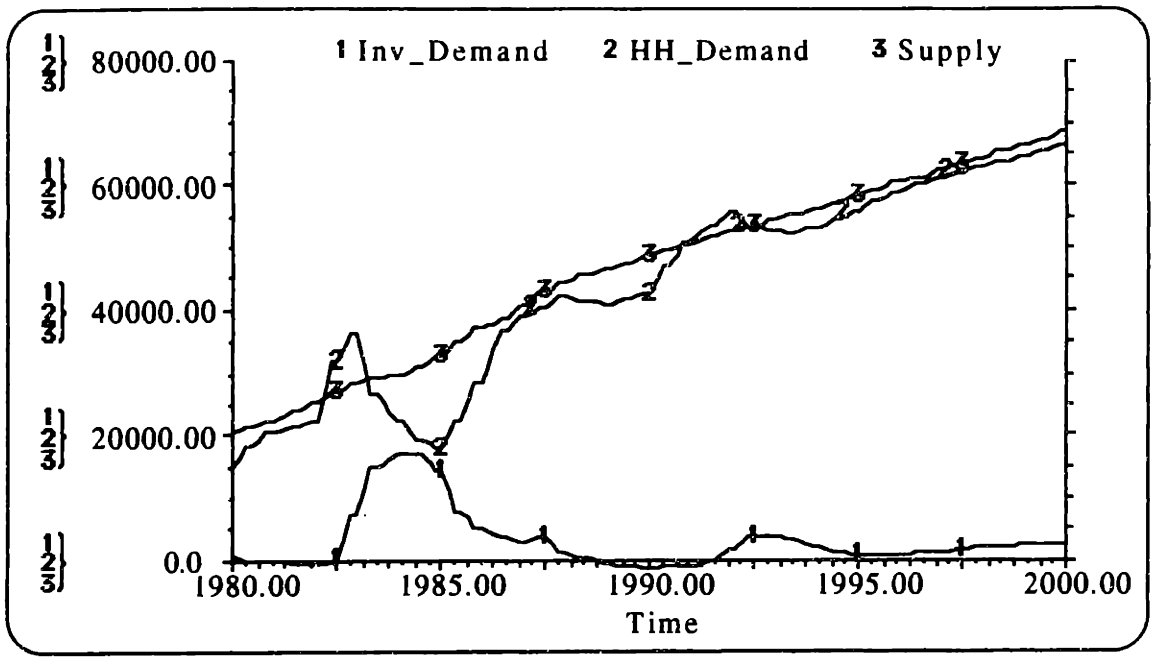


Figure 5.12 **Forecasted Prices in a 'Soft Landing'.**

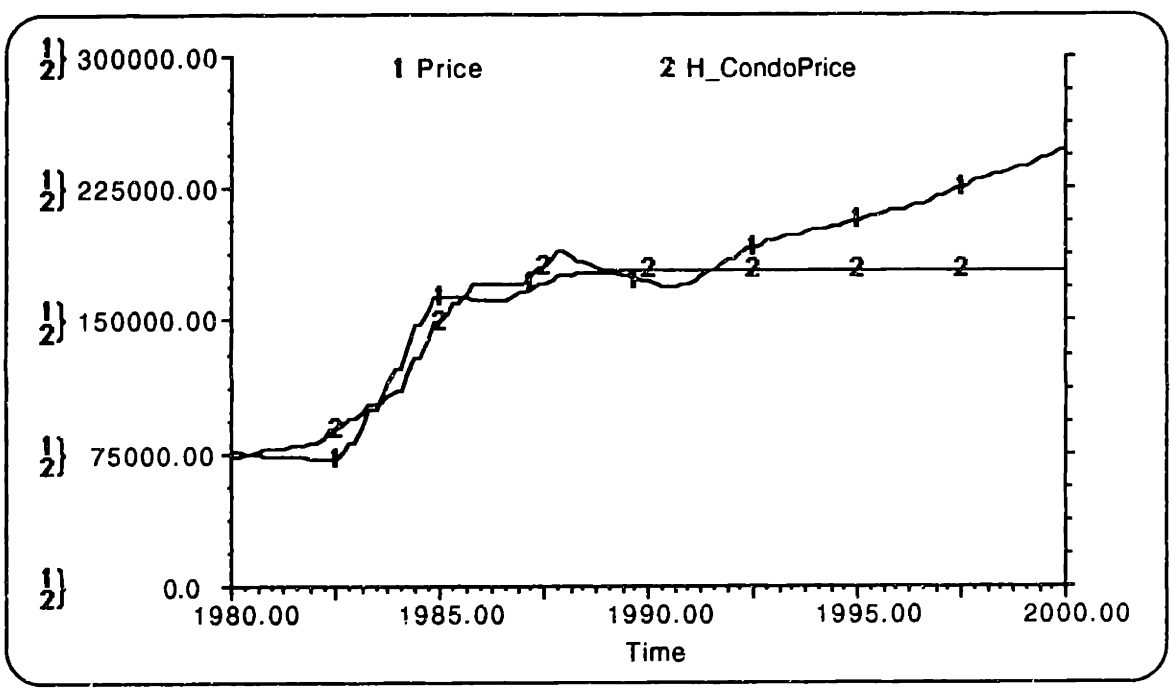
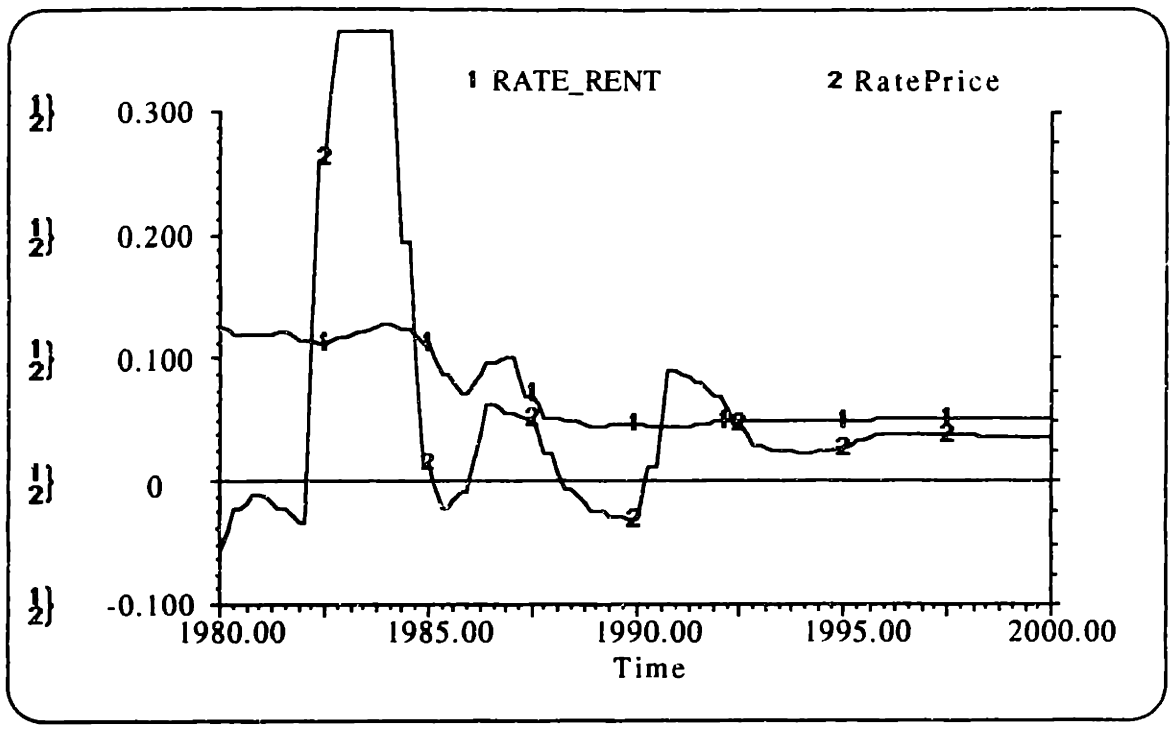


Figure 5.13 Changes in Prices, Rents in a 'Soft Landing'.



MILD RECESSION

For this third scenario, I have introduced a mild recession into the economy. In this case the real growth in the economy is negative as the employment base falls by 1 percent in 1990 and 1991. The drop in employment is followed by a recovery of 2 percent growth in 1992, and stabilized growth, of 1 percent per annum, thereafter. During the recession interest rates rise to 12.5 percent before stabilizing at 10.5 percent. Wage inflation holds steady at 5 percent annually. Figure 5.14 summarizes these assumptions.

Figure 5.14: Assumptions for a Mild Recession.

YEAR	1990	1991	1992	1993	1994-2000
Job Growth	-1%	-1%	2%	1%	1%
Wage Inflation	5%	5%	5%	5%	5%
Interest Rate	11.5%	12.5%	10.5%	10.5%	10.5%

The effects on supply and demand can be seen in Figure 5.15. Again, the supply of housing can be seen rising in the face of a sharp drop in household demand. The recession-induced fall in household demand is further reinforced by a sell-off of investor-held condominium units. These two factors combine to cause housing prices to fall nearly 20 percent, which can be seen in Figure 5.16.

The plot of the rate of change in prices and rents can be seen in Figure 5.17. Prices can be seen to continue their current decline until 1992 when interest rates begin to come down. The rate of decline reaches nearly 8 percent in 1990. Meanwhile, the rental market remains fairly strong with annual rent increases holding at 5 percent per annum. Figure 5.18, which shows the fraction of median household income needed to purchase the median home, will peak for a third time in the 1980's before settling in a more affordable range by the 1990's.

Figure 5.15: Forecasted Demand in a Mild Recession.

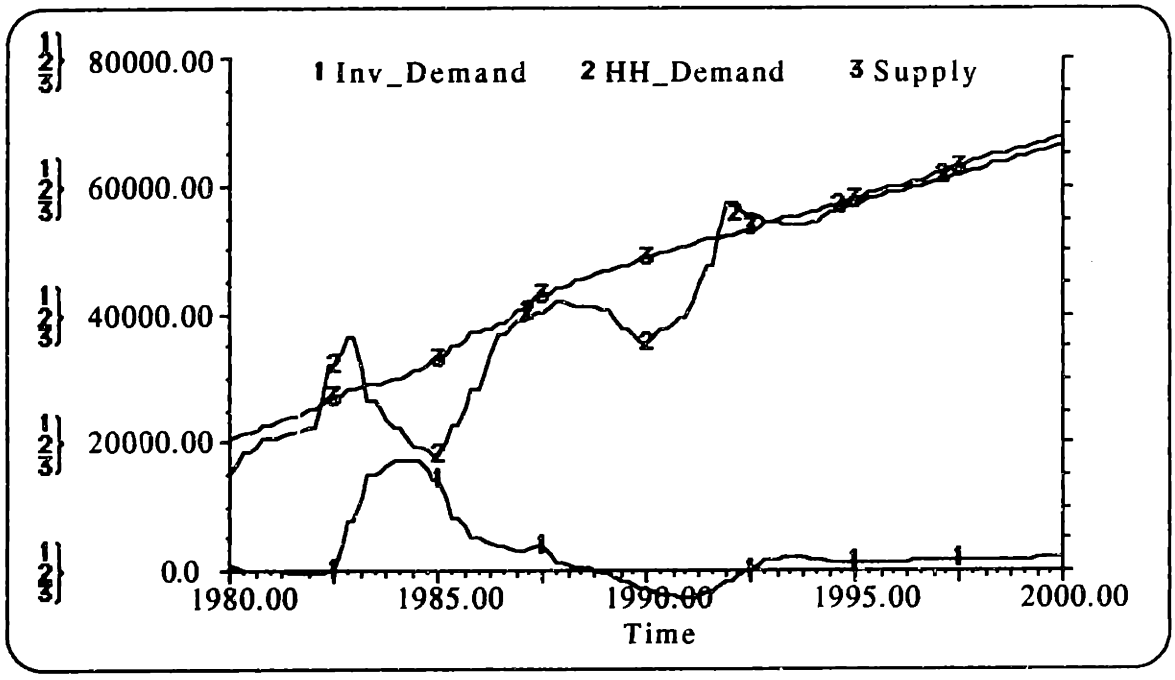


Figure 5.16: **Forecasted Prices in a Mild Recession.**

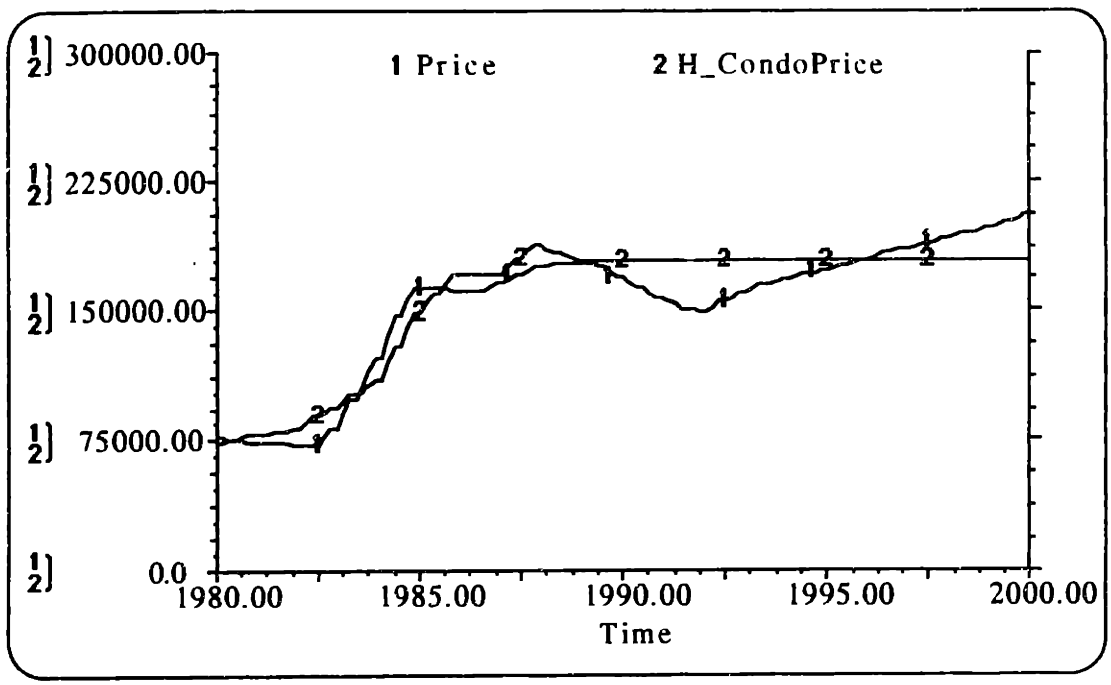


Figure 5.17: **Changes in Prices, Rents in a Mild Recession.**

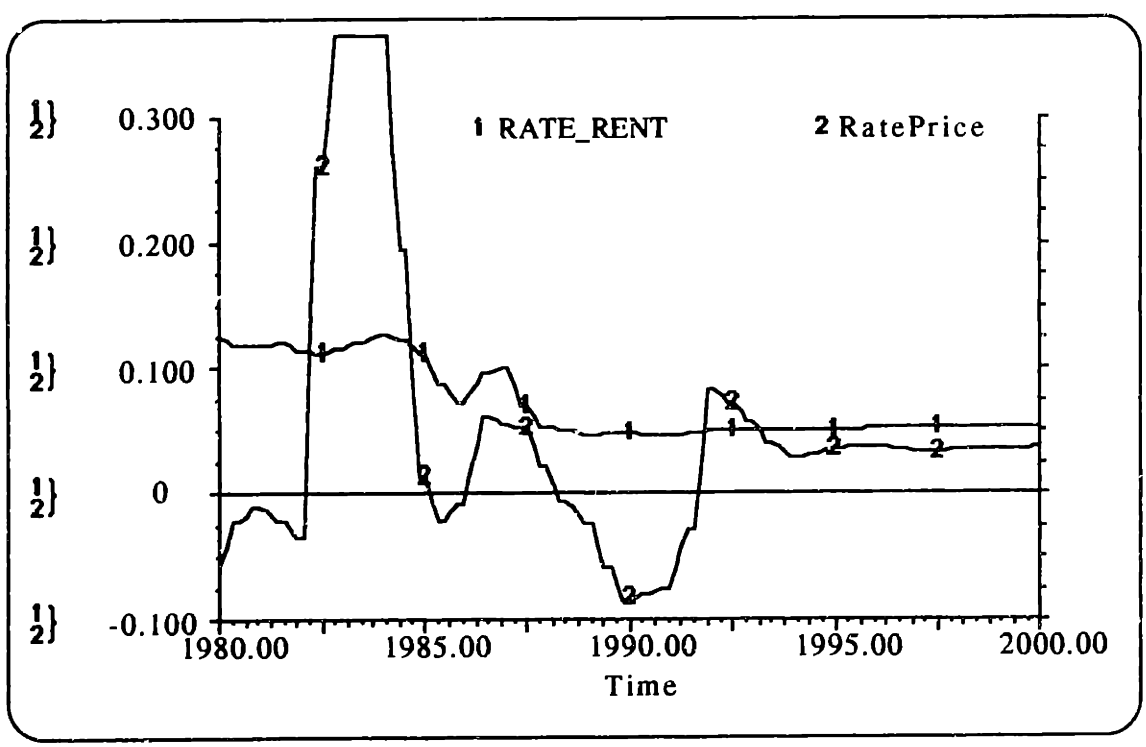
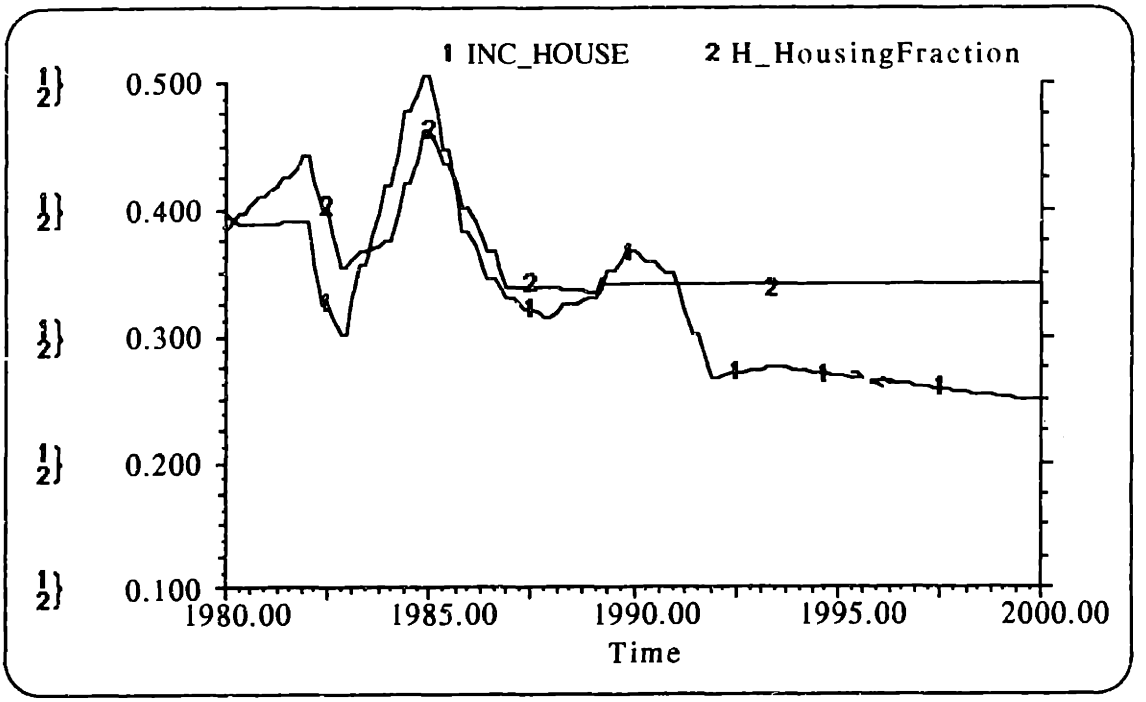


Figure 5.18: Housing Fraction in a Mild Recession.



CONCLUSIONS

The Boston Housing Model shows two distinct phenomena behind the rapid rise in housing prices in the Boston market during the 1980's. Both phenomena resulted in an increase in the demand for housing, the first resulted in a fundamental rise in household demand, while the second is characterized by an increase speculative demand in response to rising prices.

The model shows that several fundamental factors, ranging from rising household incomes to a reversal of twenty-five years of population decline, were in place when interest rates fell following the end of the 1979-82 recession. he drop in interest rates provided the needed impetus to unleash household demand for housing to bid prices upward. With a favorable tax policy, investors soon purchased condominiums for speculative purposes in anticipation of even higher prices in the future. Rising speculative prices, in turn, dampen the demand for housing by limiting the number of households who can afford to purchase. Even with continued economic growth, the price of housing will have to fall by around 5 percent over the next two years before household demand will catch up with supply.

On a broader plane, this paper shows how a complex situation such as the Boston real estate market may be modeled on a desktop microcomputer using a system dynamics approach. To demonstrate the effectiveness of this method, as well as the robustness of the Boston Housing Model, several follow-up studies are proposed. First, the Boston Housing Model should be expanded to include the suburban towns of the Boston SMSA. In this way, the ability of the model to predict the supply and demand characteristics in areas of less restrictive housing supply may be explored. Second, the structure of the model should be used with data from several different markets form around the nation. Through this approach, the robustness

of the model can be explored though simulating markets which have crashed (Houston and Denver) as well as market which are currently in the midst of rapid growth (Los Angeles and Seattle). Third, the system dynamics approach would be an ideal method to model the commercial real estate markets which are all to susceptible to wide swings in supply and demand.

APPENDIX I

SUMMARY HOUSING PRICE AND RENT DATA

On the following pages I have included a summary of the 11,000 observations of Boston Globe classified ads for housing units located in the study area. The data were collected by recording the classified listing for both apartments for rent and real estate for sale. Every listing in the Boston Globe Sunday edition for both apartments and real estate for sale was recorded for the the first Sunday in May for each of the following years: 1970, 1973, 1975, 1978, 1980, 1983, 1985, 1988, and 1989. For the folowing years, I collected housing price data only: 1982, 1984, 1986, 1987.

The summary data is classified by neighborhood, and type of unit. I have included the total number of observations and the average listing for each year and type. In addition if the sample was large enough, I have included the standard deviation of the observations. The standard deviation is expressed as a percentage of the average value. For example: in 1983, I recorded 19 observations for 1-bedroom apartments in East Boston. The average asking rent was $405 per month with a standard deviation of 16 percent ($65).

CHARLESTOWN

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	N/A	N/A	N/A	N/A	1	5	5	9	28	25	28	18
AVG.						69	68.2	85	105	133	126	126	150
STD.								38%	14%	13%	22%	22%	28%
2 BRM. CONDO													
NO.	N/A	N/A	N/A	N/A	N/A	2	7	6	6	23	29	36	34
AVG.						122	107	88	173	172	196	202	206
STD.							14%	18%	36%	24%	27%	27%	32%
SINGLE													
NO.	N/A	1	10	6	5	10	2	8	9	17	10	9	14
AVG.		35	35	51	74	71.7	60	94	253	202	214	286	256
STD.			38%	43%	44%	35%		39%	79%	29%	27%	67%	56%
2-FAMILY													
NO.	N/A	4	8	4	22	4	16	4	12	14	14	20	18
AVG. (Per Unit)		14.2	16.11	29.2	34.9	50	47.4	56.7	99	100.6	113.7	115.4	134
STD.			16%		31%		22%		20%	33%	28%	16%	33%
3-FAMILY	N/A												
NO.		12	24	12	48	18	18	10	25	30	3	6	18
AVG. (Per Unit)		9.25	11.9	24.75	19.2	34.6	41.7	41.48	90.00	90.3	61.6	95.6	102.4
STD.			38%		36%	34%	40%		34%	24%			38%
MULTI													
NO.	N/A	N/A	12		17	4		4	4	4		4	8
AVG. (Per Unit)			11.6		14.4	35		35	81.2	200		60	118.1
STD.													
1 BRM. RENTAL													
NO.	2	9	12	10	4		19		8			29	25
AVG.	90	153	186	198	235		405		397			731	730
STD.		24%	26%	22%			16%		14%			20%	19%
2 BRM. RENTAL													
NO.	N/A	2	4	5	1		11		6			23	21
AVG.		163	341	309	250		554		621			1045	1032
STD.							27%		14%			23%	31%

SOUTH BOSTON

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	N/A	N/A	N/A	N/A	N/A	3	N/A	N/A	7	16	17	6
AVG.							38.7			103	107	117	117
STD.										17%	17%	18%	11%
2 BRM. CONDO													
NO.	N/A	N/A	N/A	N/A	N/A	1	1	5	N/A	9	22	19	15
AVG.						41	68	85		135	147	135	131
STD.								0.08		18%	21%	19%	16%
SINGLE													
NO.	N/A	3	3	1	N/A	3	N/A	2	3	4	6	10	5
AVG.		27.4	31	8.5		64.6		99.5	171	237	193	181	221
STD.											23%	35%	46%
2-FAMILY													
NO.	2	N/A	4	2	4	2	2	4	4	8	4	12	8
AVG. (Per Uni	6.35		7.2	5	26.7	39.5	34	37	53.7	120	107.2	97.5	132
STD.												11%	37%
3-FAMILY													
NO.	3	12	14		9	12	3	N/A	10	33	45	36	12
AVG. (Per Uni	4	9.48	5.9		13	15.4	28.3		42.7	59.3	68.2	82.3	81.5
STD.									35%	23%	17%	41%	18%
MULTI													
NO.	65	35		12	8	N/A	5	N/A	28	34	16	4	10
AVG. (Per Uni	3.87	7.6		10.83	10.6		12.4		36.9	45.4	75.6	66.2	87.5
STD.													
1 BRM. RENTAL													
NO.	1	14	10	3	4		9		11			10	13
AVG.	100	152	162	248	228		306		484			625	671
STD.		18%	21%				12%		17%			16%	12%
2 BRM. RENTAL													
NO.	1	2	3	1	2		2		10			8	14
AVG.	130	187	271	245	497		412		605			791	830
STD.									23%			9%	19%

CENTRAL

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	1	N/A	5	22	14	23	27	23	24	52	70	48
AVG.		15		47	55	69	97	111	146	165	213	193	157
STD.					58%	60%	50%	50%	34%	33%	72%	52%	44%
2 BRM. CONDO													
NO.	N/A	1	N/A	3	10	17	25	14	17	27	41	67	38
AVG.		22		94	70	142	147	145	224	258	220	381	265
STD.					18%	56%	52%	53%	40%	29%	39%	65%	78%
SINGLE													
NO.	N/A	N/A	1	N/A	3	N/A	N/A	1	N/A	N/A	1	N/A	N/A
AVG.			92		235			425			825		
STD.													
2-FAMILY													
NO.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AVG. (Per Unit)													
STD.													
3-FAMILY													
NO.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9	N/A	3	34
AVG. (Per Unit)										127		116.3	90.3
STD.													11%
MULTI													
NO.	24	8	N/A	8	5	7	13	4	15	23	45	N/A	22
AVG. (Per Unit	6	10		15.6	27	34.8	30.7	37	75	88.9	109.8		67.1
STD.													
1 BRM. RENTAL													
NO.	4	16	12	8	13		21		25			45	23
AVG.	145	207	204	367	419		583		615			909	851
STD.		32%	43%	42%	24%		36%		24%			37%	37%
2 BRM. RENTAL													
NO.	2	3	3	9	15		13		19			36	22
AVG.	344	240	317	531	818		855		1065			1245	1130
STD.					30%		38%		21%			47%	56%

BACK BAY / BEACON HILL

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	14	6	19	43	40	67	43	102	82	86	162	103
AVG.		24	29	44	71	77	85	111	146	167	156	174	176
STD.		30%	26%	38%	31%	28%	45%	39%	33%	33%	32%	33%	32%
2 BRM. CONDO													
NO.	N/A	10	7	31	53	52	97	52	93	66	64	151	105
AVG.		44	43	70	130	144	165	179	260	279	279	307	309
STD.		27%	30%	25%	29%	31%	32%	31%	40%	34%	32%	41%	48%
SINGLE													
NO.	N/A	3	3	3	8	4	11	5	23	10	5	28	35
AVG.		68	116	116	203	210.5	303	612	710	787	939	1118	1120
STD.					63%		47%	15%	58%	35%	86%	56%	50%
2-FAMILY													
NO.	N/A	2	N/A	N/A	N/A	N/A	N/A	2	N/A	N/A	2	10	8
AVG. (Per Unit)		35						187.5			487.5	537.5	526.8
STD.												85%	
3-FAMILY													
NO.	3	N/A	15	N/A	7	N/A	3	3	11	9	N/A	8	22
AVG. (Per Uni	20.6		17.3		66.4		103.3	103.3	220	233.3		229.4	237.95
STD.													
MULTI													
NO.	8	30	26	52	93	18	44	44	59	56	37	70	21
AVG. (Per Uni	23.75	13.3	8.1	20.8	24.2	46.3	56	76.6	102.9	93.9	160.5	157.6	222.62
STD.													
1 BRM. RENTAL													
NO.	37	45	12	51	112		72		72			90	61
AVG.	227	195	204	273	420		527		717			825	797
STD.	36%	27%	43%	37%	31%		28%		23%			34%	21%
2 BRM. RENTAL													
NO.	12	37	3	24	47		30		4			51	30
AVG.	338	274	317	460	610		856		1213			1312	1254
STD.	39%	24%		30%	30%		28%		29%			27%	29%

SOUTH END

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	N/A	4	4	10	6	13	17	24	42	32	70	46
AVG.			24	24	40	67	60	80	132	134	151	149	154
STD.			14%		35%	21%	25%	26%	18%	21%	23%	21%	21%
2 BRM. CONDO													
NO.	N/A	N/A	N/A	1	20	14	26	18	35	44	41	84	59
AVG.				45	72	90	101	130	168	208	200	220	220
STD.					15%	32%	27%	28%	20%	22%	22%	28%	25%
SINGLE													
NO.	5	10	19	9	9	8	4	3	13	9	5	13	9
AVG.	33	41	53	62	79	146	144	203.3	365	378	393	358	513
STD.	44%	29%	27%	46%	32%	39%			21%	18%	28%	48%	46%
2-FAMILY													
NO.	N/A	2	6	8	2		4	6	10	6		30	12
AVG. (Per Unit)		32.5	37.3	44.6	75		80.7	116	171.9	194.8		261.6	251.6
STD.									13%			23%	18%
3-FAMILY													
NO.	N/A	3	12	3	6	3	9	9	18	21	6	33	27
AVG. (Per Unit)		13.3	17.3	40	38.3	66.7	52.6	103.3	141.6	137.4	57.5	170.5	136.6
STD.									23%	23%		45%	28%
MULTI													
NO.	N/A	12	37	29	33	14	32	50	92	32	17	8	43
AVG. (Per Unit)		12.85	17.2	14.8	28.6	29.8	28.1	60.9	73.6	99.2	120	131.2	111.79
STD.													
1 BRM. RENTAL													
NO.	5	11	31	16	20		26		24			22	28
AVG.	164	175	226	232	391		470		650			738	844
STD.		17%	20%	24%	29%		14%		21%			18%	21%
2 BRM. RENTAL													
NO.	5	9	14	8	18		15		13			17	18
AVG.	244	260	343	357	613		661		976			994	1147
STD.		27%	17%	26%	18%		20%		27%			15%	33%

FENWAY / SYMPHONY

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	N/A	N/A	1	1	4	6	8	11	13	11	18	19
AVG.				17.4	25	46	53	55	75	100	106	100	111
STD.							26%	28%	20%	28%	32%	24%	38%
2 BRM. CONDO													
NO.	N/A	N/A	N/A	N/A	N/A	N/A	1	2	8	8	10	9	11
AVG.	21.9						65	114	125	160	170	159	131
STD.									18%	14%	22%	23%	35%
SINGLE													
NO.	N/A	N/A	N/A	N/A	1	N/A	N/A	2	N/A	N/A		N/A	N/A
AVG.					60			167					
STD.													
2-FAMILY													
NO.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A
AVG. (Per Unit)													
STD.													
3-FAMILY													
NO.	N/A	N/A	3	N/A	3	3	N/A	N/A	5	3		N/A	N/A
AVG. (Per Unit)			12.5		20	26.3			55.8	63.33			
STD.													
MULTI													
NO.	9	N/A	35	7	33	100	5	34	73	45		N/A	8
AVG. (Per Unit	11.38		7.1	5.5	28.6	15	45	46.3	50	50.8			72.25
STD.													
1 BRM. RENTAL													
NO.	21	25	23	26	23		23		32			40	10
AVG.	158	158	161	184	279		367		474			633	579
STD.	26%	19%	16%	18%	23%		20%		20%			16%	19%
2 BRM. RENTAL													
NO.	6	10	11	8	7		12		20			17	17
AVG.	240	256	213	273	409		541		732			949	942
STD.	42%	10%	17%	13%	9%		16%		17%			13%	24%

ALLSTON / BRIGHTON

	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988	1989
1 BRM. CONDO													
NO.	N/A	N/A	N/A	N/A	8	10	21	23	27	47	49	104	73
AVG.					24	32	45	59	74	100	99	103	108
STD.					13%	24%	24%	18%	21%	19%	15%	19%	25%
2 BRM. CONDO													
NO.	1	N/A	1	N/A	7	20	29	20	35	71	60	103	72
AVG.	21.9		28		36	47	58	74	109	134	141	141	150
STD.					11%	22%	23%	20%	20%	16%	20%	18%	21%
SINGLE													
NO.	9	7	16	8	8	7	3	3	9	7	13	7	21
AVG.	28	35	37	40	69	71	69	123.7	182	190	193	221	248
STD.	19%	37%	20%	23%	20%	11%			37%	27%	16%	20%	28%
2-FAMILY													
NO.	16	16	36	30	34	5	10	12	14	42	14	32	40
AVG. (Per Uni	19.01	22.2	20.8	23.6	44	49.6	58.2	70.6	115.6	126.9	132.2	131.8	133.4
STD.	7%	26%	21%	22%	31%	13%	14%	19%	31%	22%	11%	12%	16%
3-FAMILY													
NO.	9	9	12	21	6	9	12		15	9	15	18	15
AVG. (Per Uni	10.54	18.7	14.5	17.2	34.7	36.9	43.1		86.4	111.4	88.6	110.7	97.9
STD.			17%	25%					14%		9%	16%	13%
MULTI													
NO.	30	148	146	75	19	80	4	6	12	25	40	20	132
AVG. (Per Uni	12.5	12.24	10.44	8.59	16.1	28.1	18.7	36.7	90.4	56	77.6	72.9	57.9
STD.													
1 BRM. RENTAL													
NO.	28	39	32	43	56		43		37			53	40
AVG.	161	172	178	210	288		387		502			604	614
STD.	18%	18%	16%	22%	15%		16%		16%			16%	11%
2 BRM. RENTAL													
NO.	22	37	27	31	47		39		47			47	31
AVG.	220	223	244	284	401		558		713			887	870
STD.	14%	17%	18%	18%	26%		14%		16%			17%	13%

EAST BOSTON

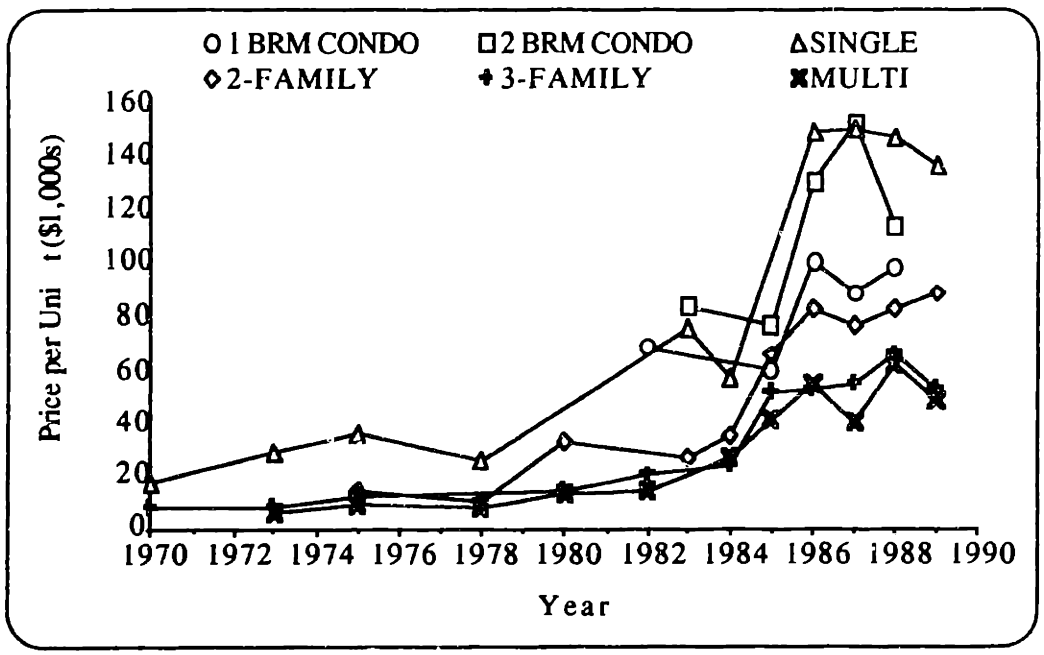
	1970	1973	1975	1978	1980	1982	1983	1984	1985	1986	1987	1988
1 BRM. CONDO												
NO.	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	3	8	10	5
AVG.						69			60	100	88	98
STD.									3%	23%	19%	23%
2 BRM. CONDO												
NO.	N/A	N/A	N/A	N/A	N/A	N/A	1	1	5	16	18	5
AVG.							83	47	77	130	152	114
STD.									13%	17%	42%	13%
SINGLE												
NO.	1	1	2	2	N/A	N/A	2	1	N/A	5	9	4
AVG.	17	28.9	36	25.7			75.5	57		149	150	147
STD.										41%	27%	8%
2-FAMILY												
NO.	N/A	N/A	6	2	4	N/A	8	2	16	12	16	8
AVG. (Per Unit)			13.6	10	33.2		26.6	34.5	65.5	82.2	77.1	81.5
STD.									34%	10%	26%	24%
3-FAMILY												
NO.	12	6	6		18	6	N/A	6	9	42	39	21
AVG. (Per Unit)	8.2	8.32	11.6		14	19.7		24	51.6	53.4	55.1	65.9
STD.									18%	11%	11%	18%
MULTI												
NO.	N/A	24	15	6	11	12	N/A	10	14	26	66	40
AVG. (Per Unit)		5.8	8.8	7.5	13.09	14.2		26.9	40.6	55.1	40.2	61.7
STD.												
1 BRM. RENTAL												
NO.	2	3	3	3	4		3		8			7
AVG.	115	121	183	162	235		315		397			543
STD.									14%			20%
2 BRM. RENTAL												
NO.	N/A	1	3	2	1		3		6			12
AVG.		170	211	182	250		492		621			735
STD.									14%			14%

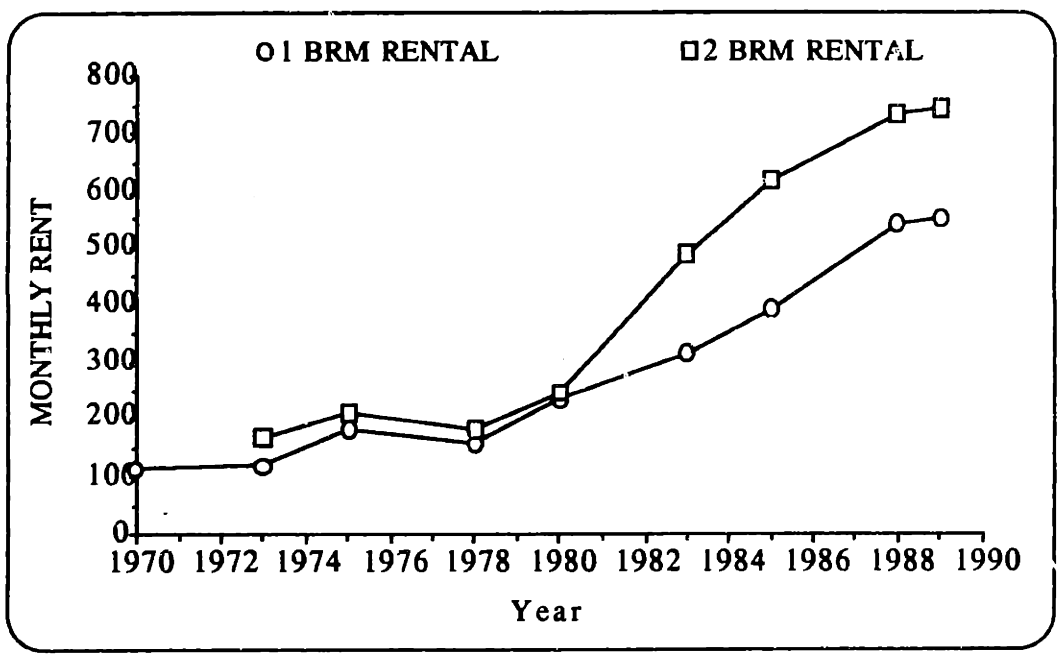
APPENDIX II

TIME SERIES PLOTS OF HOUSING DATA

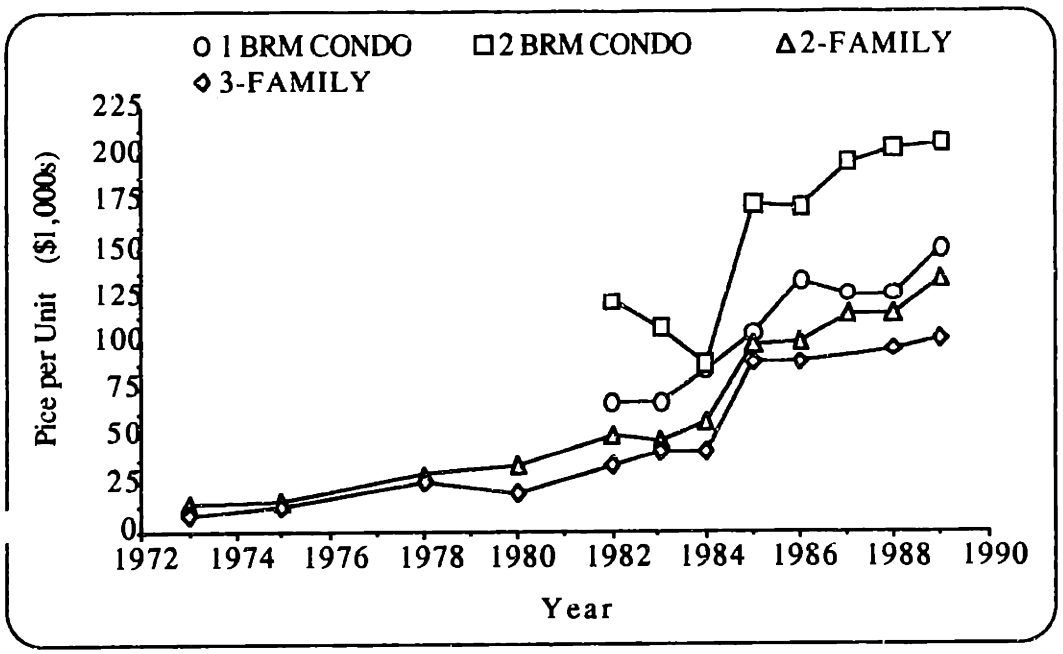
On the following pages, the data from Appendix I is presented in graphical form.

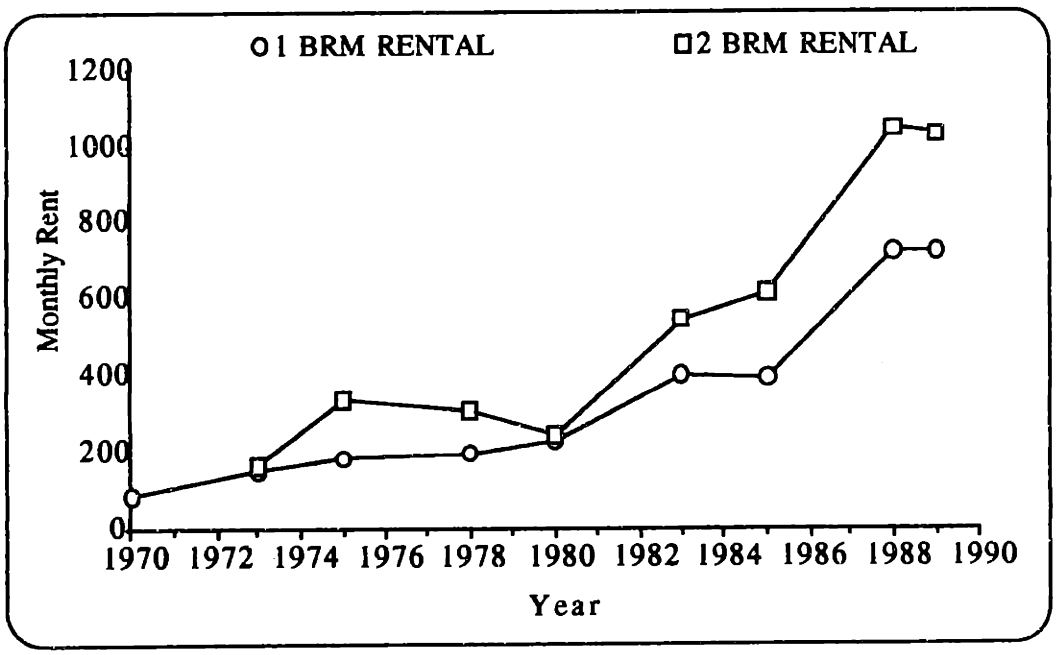
EAST BOSTON


O 1 BRM CONDO
□ 2 BRM CONDO
Δ SINGLE
◇ 2-FAMILY
+ 3-FAMILY
✖ MULTI
Price per Unit ($1,000s)
160
140
120
100
80
60
40
20
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

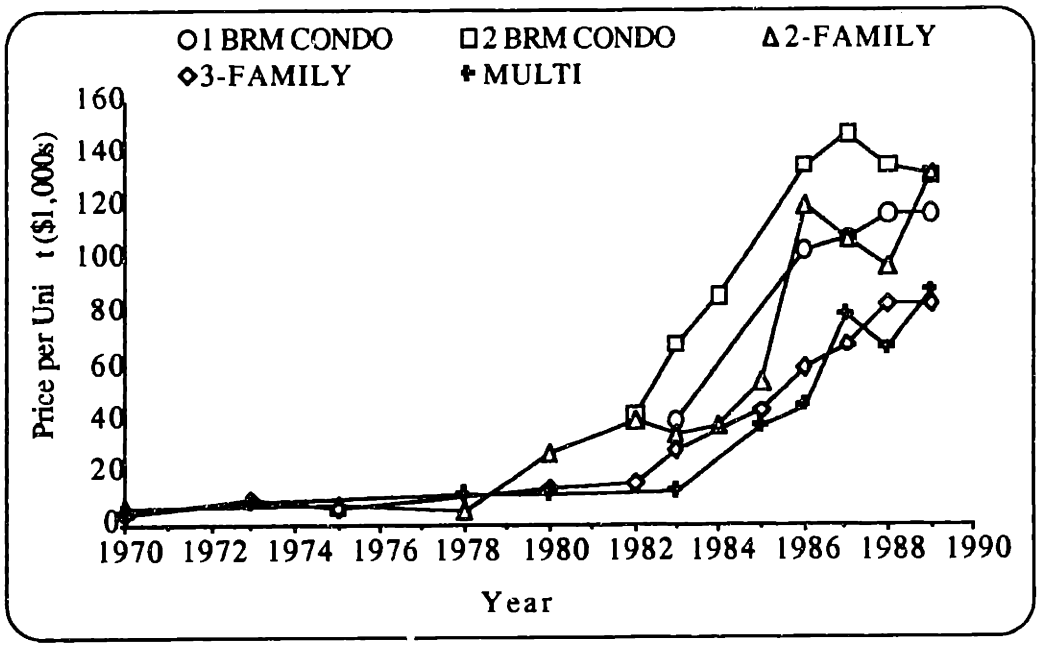

O 1 BRM RENTAL
□ 2 BRM RENTAL
MONTHLY RENT
800
700
600
500
400
300
200
100
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

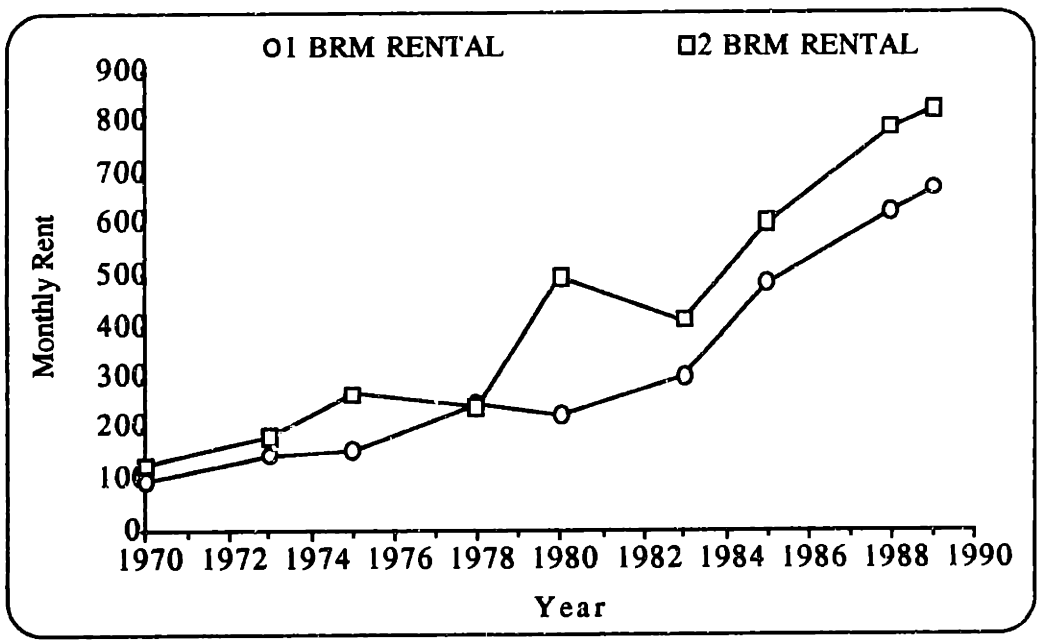
CHARLESTOWN



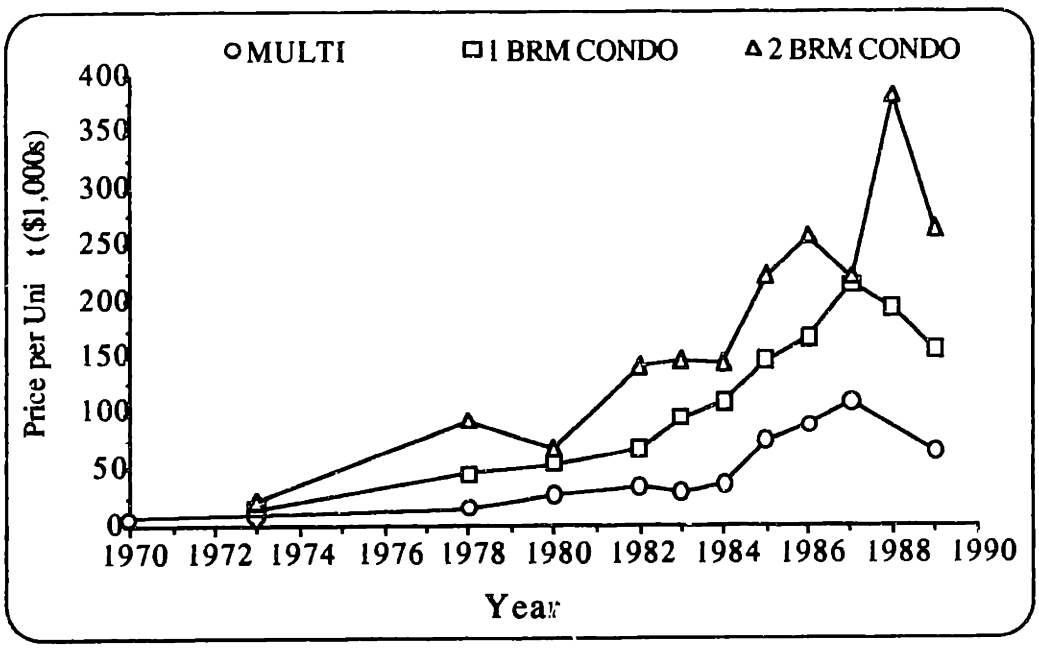


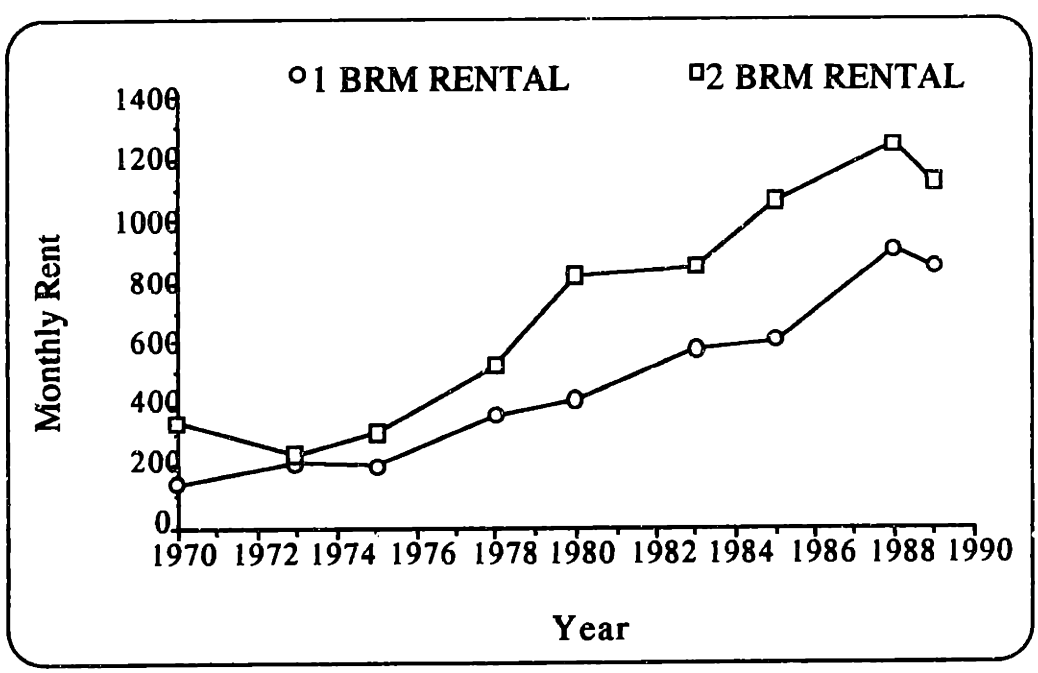
SOUTH BOSTON



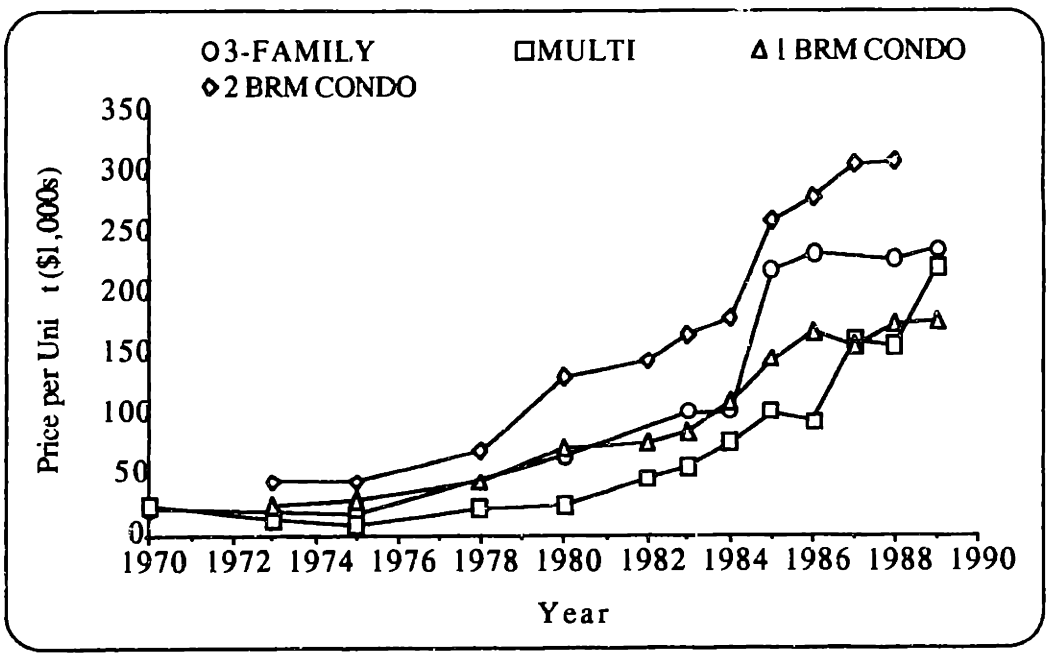


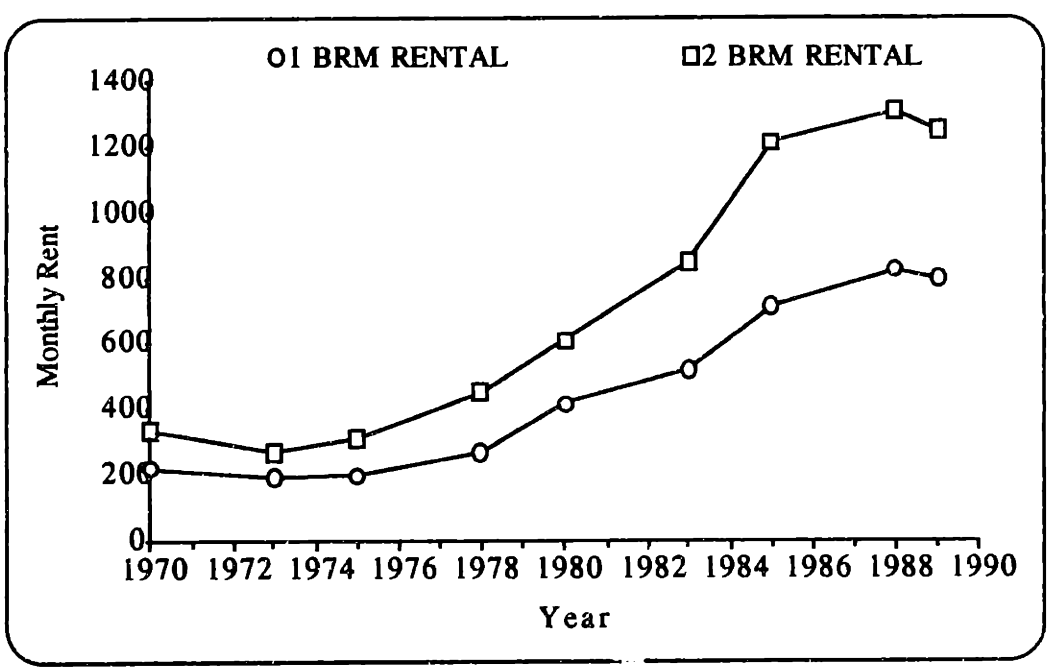
CENTRAL


MULTI
1 BRM CONDO
2 BRM CONDO
Price per Unit ($1,000s)
400
350
300
250
200
150
100
50
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

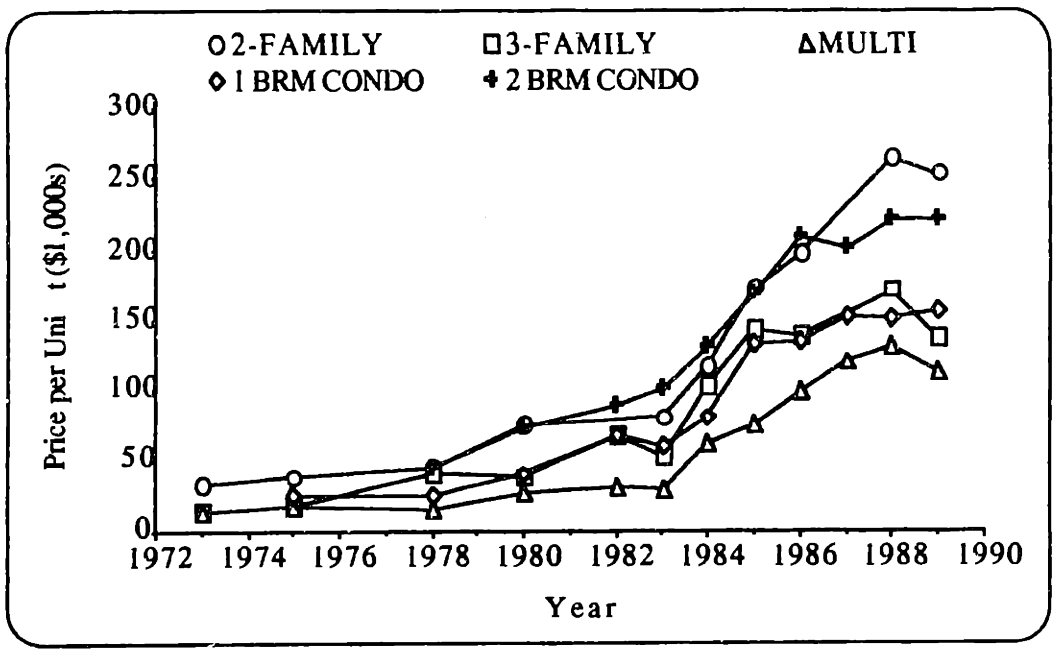

1 BRM RENTAL
2 BRM RENTAL
Monthly Rent
1400
1200
1000
800
600
400
200
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

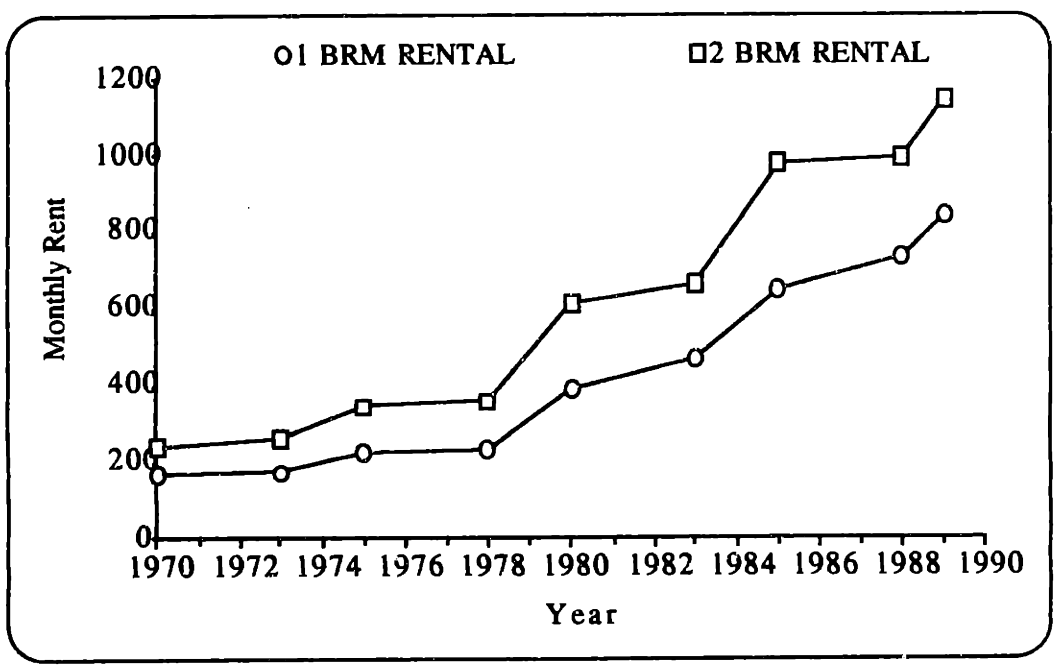
BACK BAY / BEACON HILL



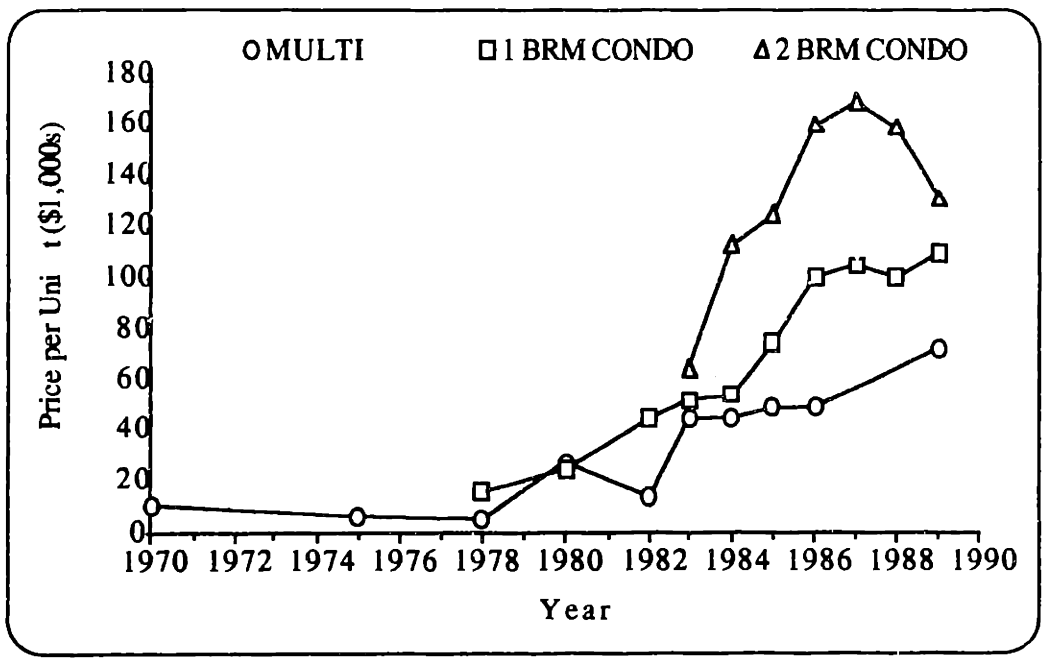


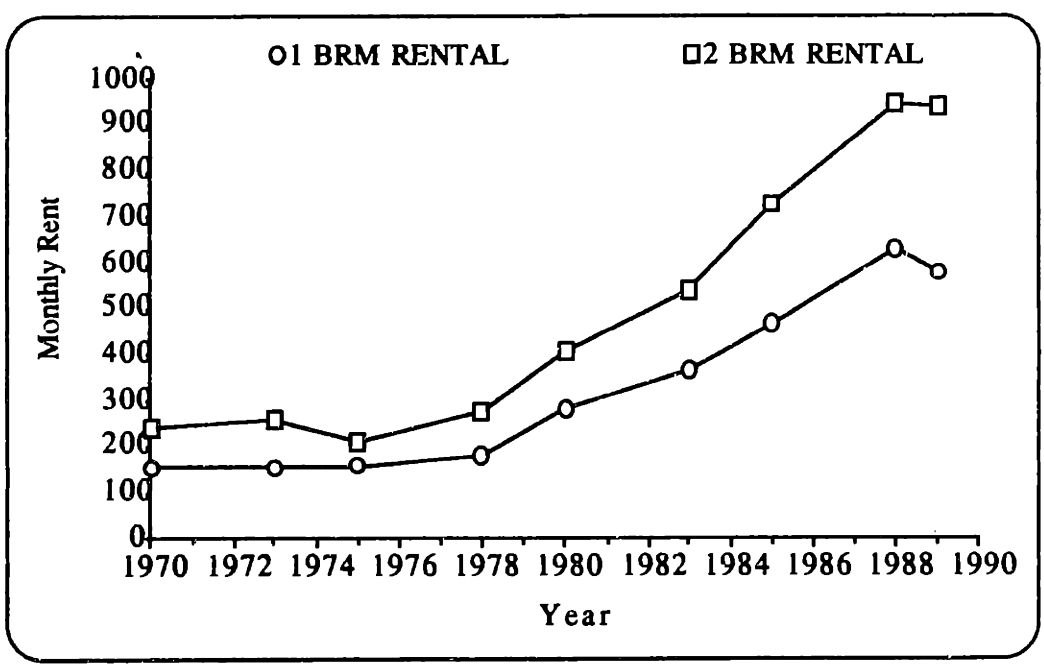
SOUTH END


O 2-FAMILY
□ 3-FAMILY
Δ MULTI
◇ 1 BRM CONDO
+ 2 BRM CONDO
Price per Uni t ($1,000s)
300
250
200
150
100
50
0
1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

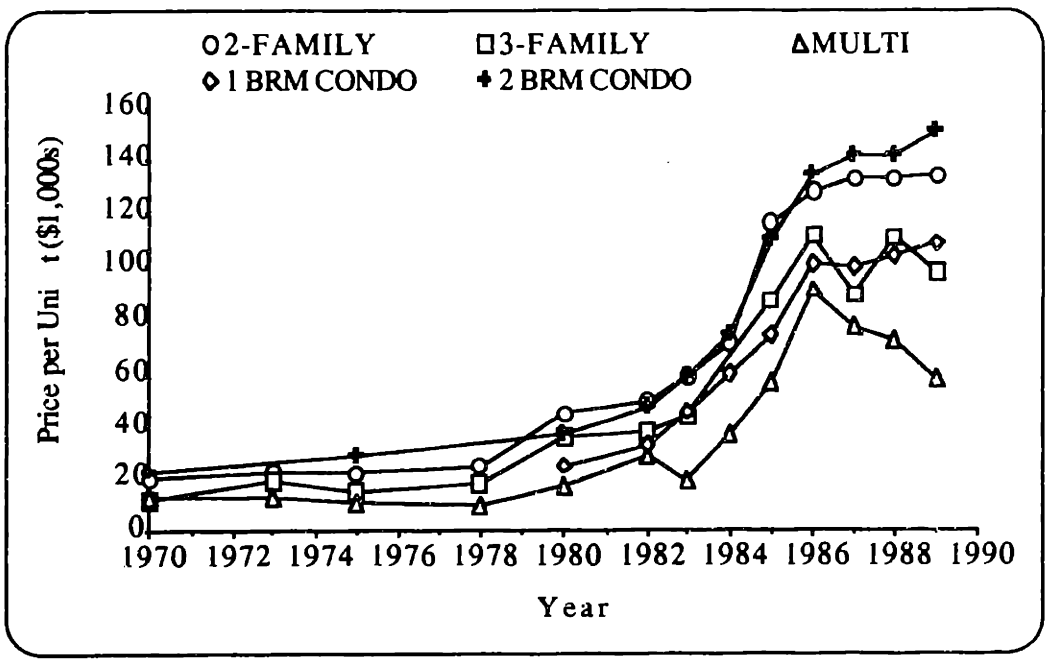

O 1 BRM RENTAL
□ 2 BRM RENTAL
Monthly Rent
1200
1000
800
600
400
200
0
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990
Year

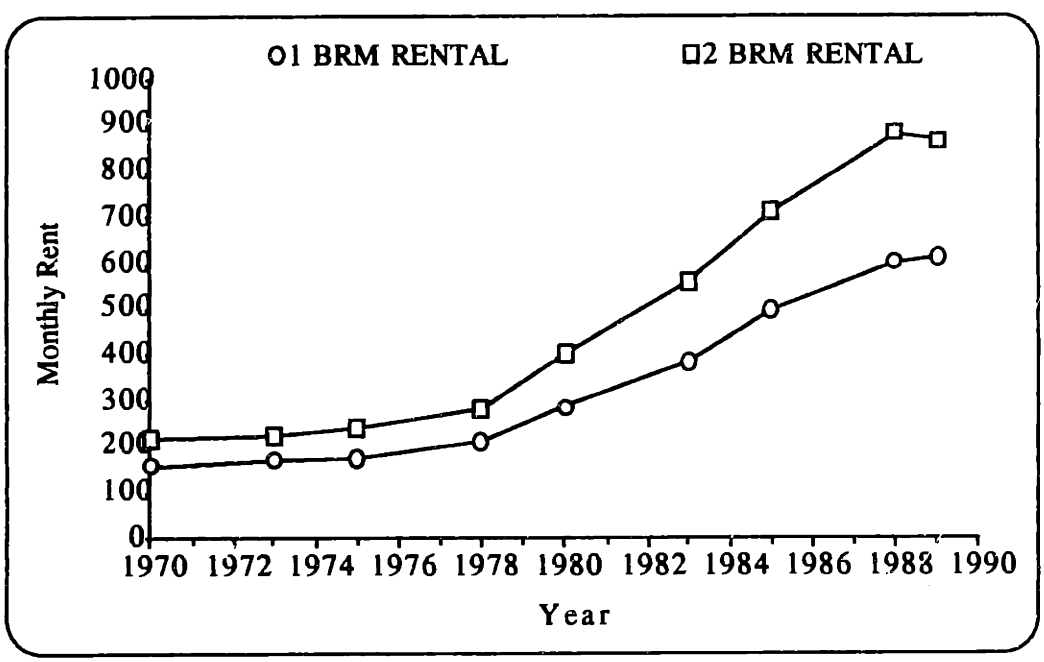
FENWAY / KENMORE





ALLSTON / BRIGHTON

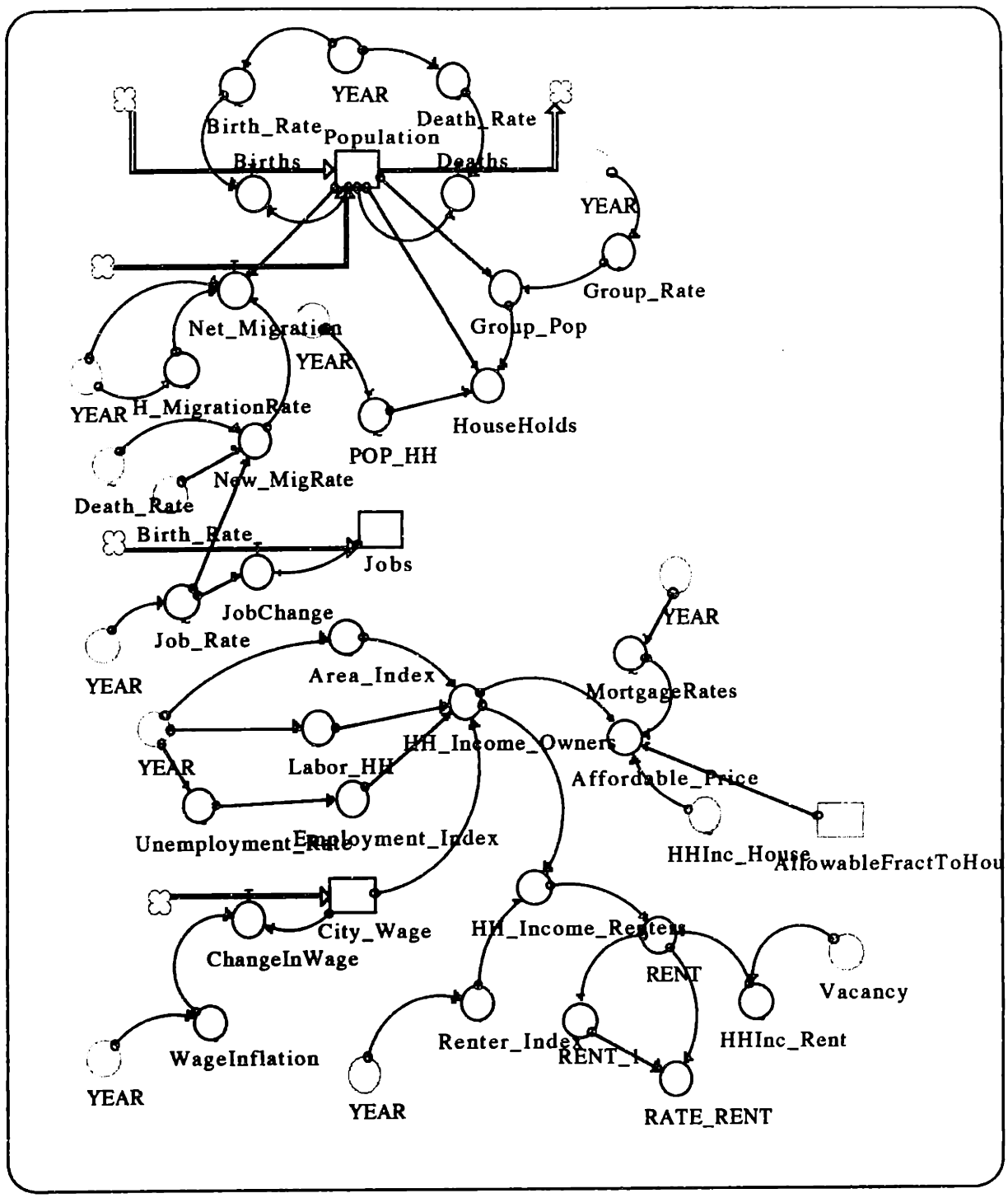


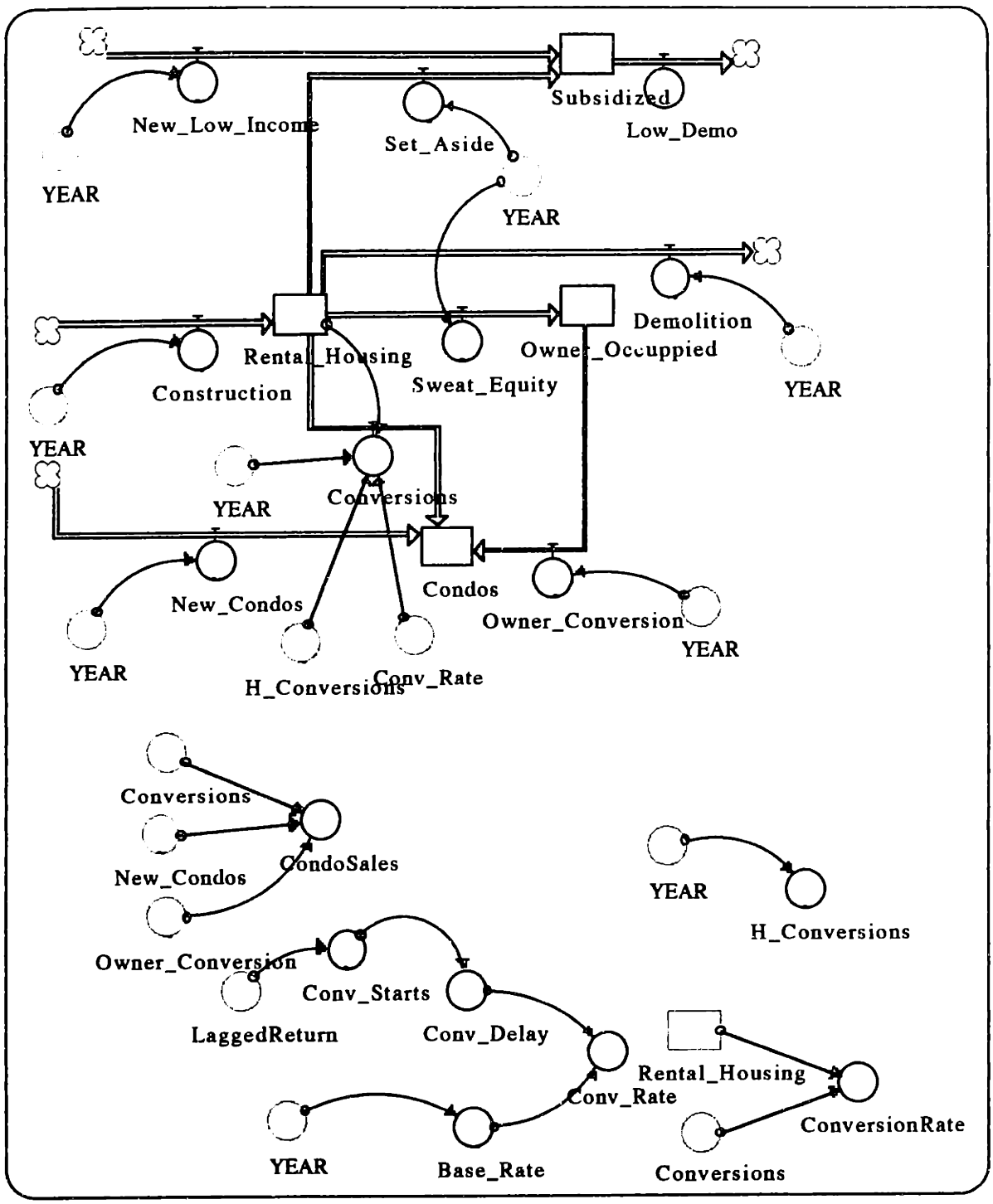


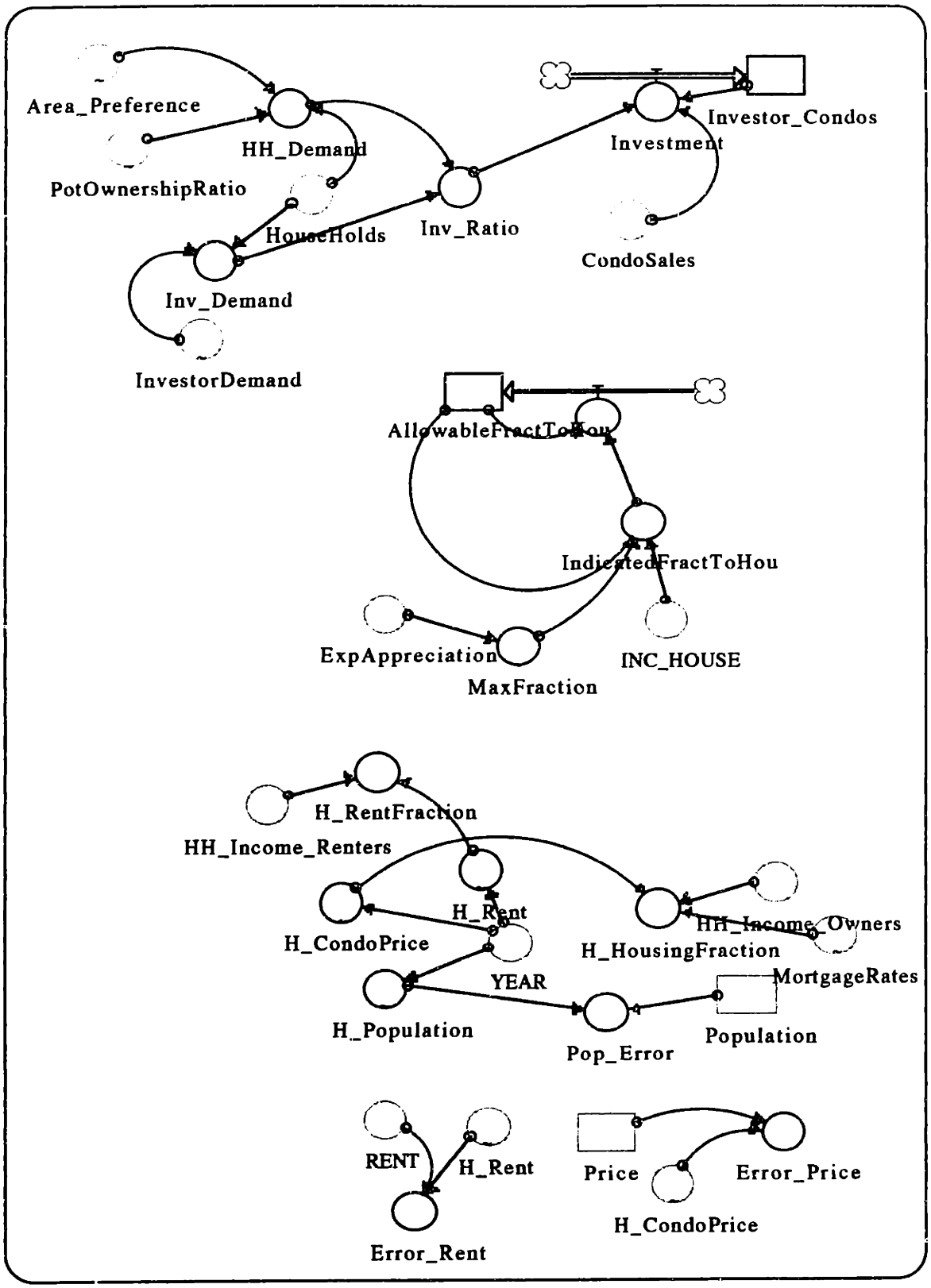
APPENDIX III

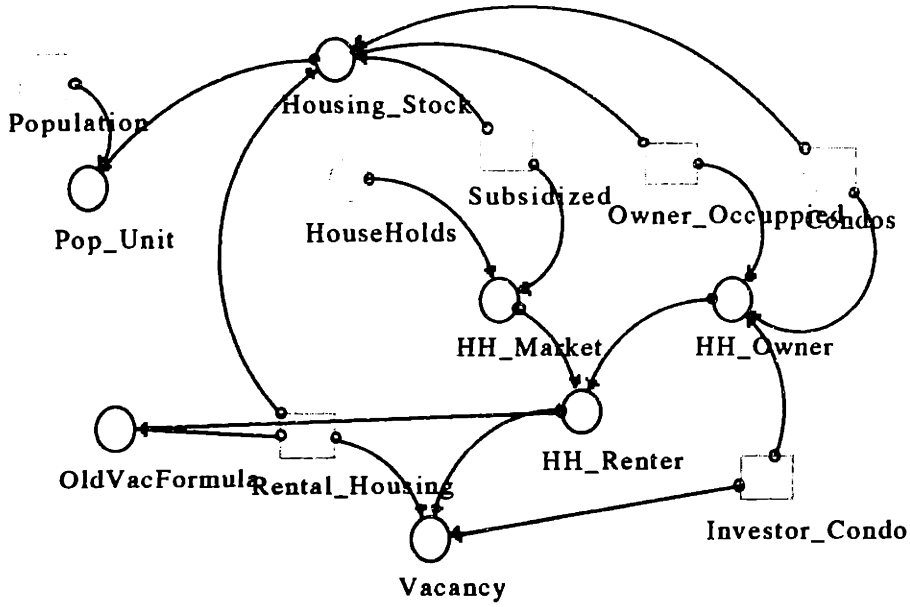
DIAGRAM OF THE BOSTON HOUSING MODEL

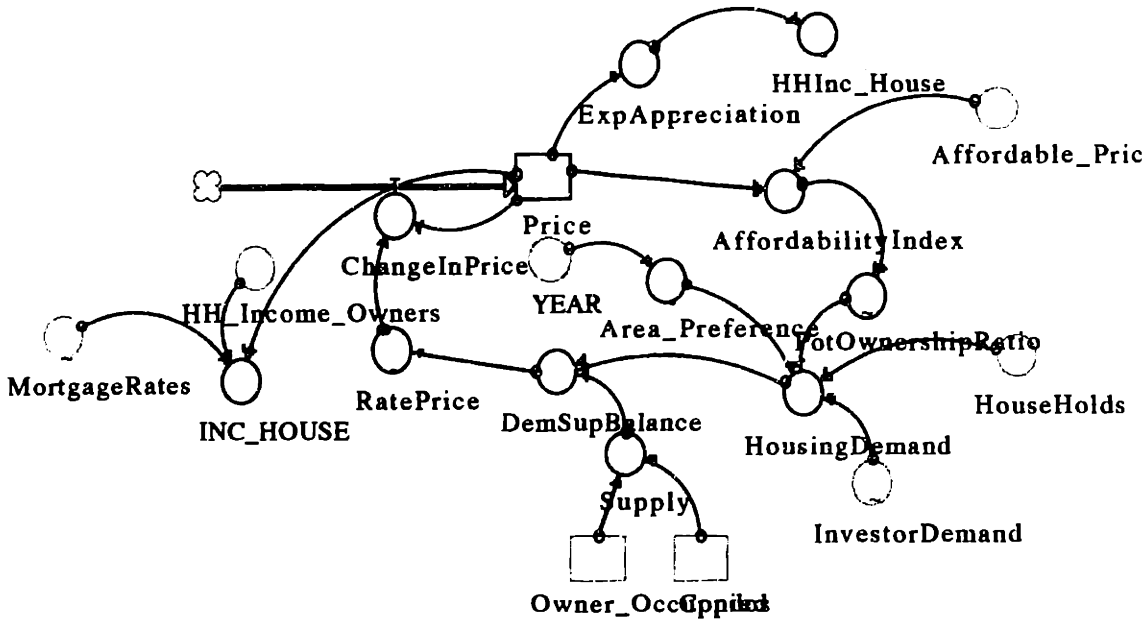
On the following pages, I have included a STELLA diagramtof the Boston Housing Model

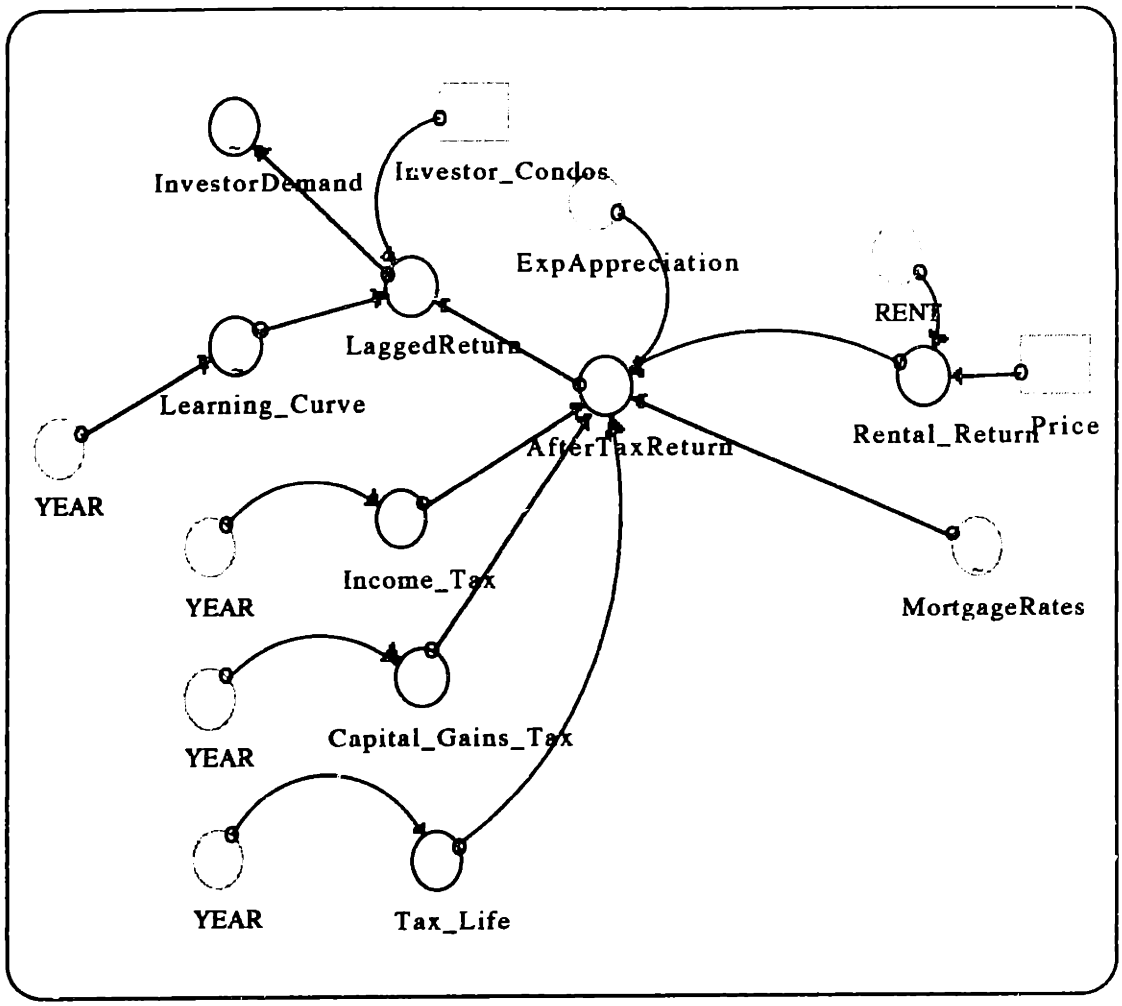

YEAR
Birth_Rate
Population
Death_Rate
Births
Deaths
YEAR
Group_Rate
Net_Migration
Group_Pop
YEAR
YEAR
H_MigrationRate
HouseHolds
POP_HH
New_MigRate
Death_Rate
Birth_Rate
Jobs
JobChange
Job_Rate
YEAR
YEAR
Area_Index
MortgageRates
YEAR
Labor_HH
HH_Income_Owners
Affordable_Price
Unemployment_Rate
Employment_Index
HHInc_House
AffowableFractToHou
City_Wage
HH_Income_Renters
ChangeInWage
RENT
Vacancy
Renter_Index
HHInc_Rent
RENT_I
WageInflation
YEAR
YEAR
RATE_RENT


Subsidized
New_Low_Income
Set_Aside
Low_Demo
YEAR
YEAR
Demolition
Rental_Housing
Owner_Occuppied
Construction
Sweat_Equity
YEAR
YEAR
YEAR
Conversions
Condos
New_Condos
Owner_Conversion
YEAR
YEAR
H_Conversions
Conv_Rate
Conversions
CondoSales
New_Condos
YEAR
H_Conversions
Owner_Conversion
Conv_Starts
LaggedReturn
Conv_Delay
Rental_Housing
Conv_Rate
ConversionRate
YEAR
Base_Rate
Conversions


Area_Preference
HH_Demand
PotOwnershipRatio
HouseHolds
Inv_Ratio
Investment
Investor_Condos
CondoSales
Inv_Demand
InvestorDemand
AllowableFractToHou
IndicatedFractToHou
ExpAppreciation
MaxFraction
INC_HOUSE
H_RentFraction
HH_Income_Renters
H_Rent
H_CondoPrice
H_HousingFraction
HH_Income_Owners
YEAR
MortgageRates
H_Population
Pop_Error
Population
RENT
H_Rent
Error_Rent
Price
Error_Price
H_CondoPrice


Population
Housing_Stock
Pop_Unit
HouseHolds
Subsidized
Owner_Occupied
Condos
HH_Market
HH_Owner
HH_Renter
OldVacFormula
Rental_Housing
Investor_Condos
Vacancy


HHInc_House
ExpAppreciation
Affordable_Price
Price
AffordabilityIndex
ChangeInPrice
YEAR
HH_Income_Owners
Area_Preference
PotOwnershipRatio
MortgageRates
RatePrice
HouseHolds
INC_HOUSE
DemSupBalance
HousingDemand
Supply
InvestorDemand
Owner_Occupied


InvestorDemand
Investor_Condos
ExpAppreciation
RENT
LaggedReturn
Learning_Curve
Rental_Return
Price
AfterTaxReturn
YEAR
Income_Tax
YEAR
MortgageRates
Capital_Gains_Tax
YEAR
YEAR
Tax_Life

APPENDIX IV

EQUATIONS BEHIND THE BOSTON HOUSING MODEL

The following is a lising of the equations behind the STELLA model of the Boston Housing Model:

AllowableFractToHou = AllowableFractToHou + dt * (ChAFH)
INIT(AllowableFractToHou) = .2

City_Wage = City_Wage + dt * (ChangeInWage) INIT(City_Wage) = 7760{(Dollars/year) Average annual salary of jobs located in Boston}

Condos = Condos + dt * (Conversions + New_Condos + Owner_Conversion)
INIT(Condos) = 600{(Units) Number of Condominium Units }

Investor_Condos = Investor_Condos + dt * (Investment) INIT(Investor_Condos) = 0

Jobs = Jobs + dt * (JobChange) INIT(Jobs) = 510953

Owner_Occuppied = Owner_Occuppied + dt * (Sweat_Equity - Owner_Conversion)
INIT(Owner_Occuppied) = 16700

Population = Population + dt * (Births - Deaths + Net_Migration) INIT(Population) =257947{Persons}

Price = Price + dt * (ChangeInPrice) INIT(Price) = 25000

Rental_Housing = Rental_Housing + dt * (Construction - Sweat_Equity - Conversions - Set_Aside - Demolition) INIT(Rental_Housing) = 86700{(Units) Number of privately owned rental units, includes both market-rate and rent controlled}

Subsidized = Subsidized + dt * (Set_Aside + New_Low_Income - Low_Demo)
INIT(Subsidized) = 10650{(Units) Number of state owned or subsidized housing units}

AffordabilityIndex = Price/Affordable_Price

Affordable_Price = (HH_Income_Owners* (1*AllowableFractToHou + 0*HHInc_House))/MortgageRates/.90{(Dollars) Median Affordable Price of a House. (Assumes 10% Down Payment and Interest Only)}

AfterTaxReturn = Rental_Return*(1-Income_Tax)+ExpAppreciation*(1-Capital_Gains_Tax)-MortgageRates*(1-Income_Tax)+(1/Tax_Life)*Income_Tax

Births = Population*Birth_Rate

Capital_Gains_Tax = if (YEAR>1981) and (YEAR<1988) then (.20) else (.28)

ChAFH = (IndicatedFractToHou-AllowableFractToHou)/4

ChangeInPrice = RatePrice*Price

ChangeInWage = City_Wage*WageInflation{(Dollars/Year) annual increase in annual city salaries}

CondoSales = New_Condos+Conversions+Owner_Conversion

ConversionRate = Conversions/Rental_Housing

Conversions = IF (YEAR<1988) THEN (H_Conversions) ELSE (Conv_Rate*Rental_Housing)

Conv_Delay = DELAY(Conv_Starts,2)

Conv_Rate = Conv_Delay+Base_Rate

Deaths = Population*Death_Rate

DemSupBalance = (HousingDemand-Supply)/Supply

Employment_Index = (1-(Unemployment_Rate*.01))/.931{Normalized Index for the Employment Level, ie. 1980 = 1.00 (6.9%)}

Error_Price = (Price-H_CondoPrice)/H_CondoPrice

Error_Rent = (RENT-H_Rent)/RENT

ExpAppreciation = TREND(Price,1)

Group_Pop = Population*Group_Rate{(Number of Persons) No. of people living in group quarters, Dormitories, Prisons, Institutions, etc.}

HH_Demand = HouseHolds*PotOwnershipRatio*Area_Preference

HH_Income_Owners = City_Wage*Area_Index * Labor_HH * Employment_Index{(Dollars/Year) Annual Household Incomes of HomeOwners}

HH_Income_Renters =HH_Income_Owners*Renter_Index {(Dollars/Year) Annual Household Income of Renters}

HH_Market = HouseHolds-Subsidized*.95{(Numbers of HH) No. of 'Market-Rate' Households, includes renters, condo owners, and owner-occupants (1-4 family)}

HH_Owner = Owner_Occuppied+Condos*(.95)-Investor_Condos{(Number of HH) Number of Households who own their own unit}

HH_Renter = HH_Market-HH_Owner{(Number of Households) Number of Households who rent in the market-place, includes both full market and rent controlled / stabilized}

HouseHolds = (Population-Group_Pop)/POP_HH{(Households) Total number of Households }

HousingDemand = HouseHolds*(PotOwnershipRatio+InvestorDemand)*Area_Preference

Housing_Stock = Condos+Owner_Occuppied+Subsidized+Rental_Housing

H_HousingFraction = H_CondoPrice*.90*MortgageRates/HH_Income_Owners

H_RentFraction = (H_Rent*12)/HH_Income_Renters

Income_Tax = if (YEAR<1981) then (.70) else if (YEAR<1987) then (.50) else if (YEAR<1988) then (.38) else (.28)

INC_HOUSE = (Price*MortgageRates*.90)/HH_Income_Owners

IndicatedFractToHou = MAX(AllowableFractToHou , MIN(MaxFraction,INC_HOUSE))

Investment = IF(Inv_Ratio<0) THEN(max(-Investor_Condos,CondoSales*Inv_Ratio)) ELSE (Inv_Ratio*CondoSales)

Inv_Demand = InvestorDemand*HouseHolds

Inv_Ratio = Inv_Demand/(Inv_Demand+HH_Demand)

JobChange = Job_Rate*Jobs

LaggedReturn =IF (Investor_Condos>0) THEN (AfterTaxReturn*Learning_Curve) ELSE (0)

Low_Demo = 0

Net_Migration = IF (YEAR<1990) THEN (H_MigrationRate*Population) ELSE (New_MigRate*Population)

New_MigRate = Job_Rate+Death_Rate-Birth_Rate

OldVacFormula = (Rental_Housing*.95-HH_Renter)/HH_Renter

Pop_Error = 100*(Population-H_Population)/H_Population

Pop_Unit = Population/Housing_Stock

RATE_RENT = (RENT-RENT_1)/RENT_1

RENT =(.35+0*HHInc_Rent)*HH_Income_Renters/12{(Dollars/Month) Median Affordable Rent}

Rental_Return = (RENT*12)/Price

RENT_1 = DELAY(RENT,1)

Supply = Condos+Owner_Occuppied

Tax_Life = if (YEAR<1981) then (40) else if (YEAR<1987) then (15) else if (YEAR<1988) then (18) else (28.5)

Vacancy = ((Rental_Housing*.95+Investor_Condos)-
HH_Renter)/(Rental_Housing*.95+Investor_Condos){(Percentage of Total Rental Stock) Vacancy Rate of the existing rental housing stock}

YEAR = time

Area_Index = graph(YEAR)
(1970.00,1.02),(1975.00,1.10),(1980.00,1.19),(1985.00,1.20),(1990.00,1.20),(1995.00,1.20),(2000.00,1.20)

Area_Preference = graph(YEAR)
(1970.00,0.485),(1971.00,0.475),(1972.00,0.465),(1973.00,0.470),
(1974.00,0.495), (1975.00,0.545),(1976.00,0.605),(1977.00,0.705),
(1978.00,0.855),(1979.00,0.940), (1980.00,0.975),(1981.00,0.995),
(1982.00,0.995),(1983.00,1.00), (1984.00,1.00), (1985.00,1.00),
(1986.00,1.00),(1987.00,1.00),(1988.00,1.00),(1989.00,1.00),
(1990.00,1.00),(1991.00,1.00),(1992.00,1.00),(1993.00,1.00), (1994.00,1.00),
(1995.00,1.00),(1996.00,1.00),(1997.00,1.00), (1998.00,1.00),(1999.00,1.00),
(2000.00,1.00)

Base_Rate = graph(YEAR)
(1970.00,0.0),(1971.00,0.0),(1972.00,0.000150),(1973.00,0.000600),
(1974.00,0.00180),(1975.00,0.00345),(1976.00,0.00570),(1977.00,0.00900),
(1978.00,0.0120),(1979.00,0.0160),(1980.00,0.0181),(1981.00,0.0203),
(1982.00,0.0209),(1983.00,0.0207),(1984.00,0.0210),(1985.00,0.0210),
(1986.00,0.0210),(1987.00,0.0209),(1988.00,0.0198),(1989.00,0.0197),
(1990.00,0.0189),(1991.00,0.0183),(1992.00,0.0174),(1993.00,0.0166),
(1994.00,0.0153),(1995.00,0.0144),(1996.00,0.0136),(1997.00,0.0129),
(1998.00,0.0120),(1999.00,0.0117),(2000.00,0.0117)

Birth_Rate = graph(YEAR)
(1970.00,0.0175),(1975.00,0.0124),(1980.00,0.0136),(1985.00,0.0152),
(1990.00,0.0166),(1995.00,0.0154),(2000.00,0.0145)

Construction = graph(YEAR)
(1970.00,550.00),(1971.00,550.00),(1972.00,550.00),(1973.00,550.00),
(1974.00,550.00),(1975.00,915.00),(1976.00,1473.00),(1977.00,308.00),
(1978.00,1148.00),(1979.00,435.00),(1980.00,471.00),(1981.00,812.00),
(1982.00,566.00),(1983.00,708.00),(1984.00,861.00),(1985.00,1184.00),
(1986.00,1216.00),(1987.00,861.00),(1988.00,1200.00),(1989.00,1200.00),
(1990.00,1200.00),(1991.00,1150.00),(1992.00,1150.00),(1993.00,1150.00),
(1994.00,1150.00),(1995.00,1150.00),(1996.00,850.00),(1997.00,850.00),
(1998.00,850.00),(1999.00,850.00),(2000.00,850.00)

Conv_Starts = graph(LaggedReturn)
(0.0,0.000500),(0.0250,0.00600),(0.0500,0.0113),(0.0750,0.0160),(0.100,0.0200),
(0.125,0.0268),(0.150,0.0353),(0.175,0.0395),(0.200,0.0443),(0.225,0.0473),
(0.250,0.0495)

Death_Rate = graph(YEAR)
(1970.00,0.0117),(1975.00,0.0106),(1980.00,0.0108),(1985.00,0.00880),
(1990.00,0.00750),(1995.00,0.00750),(2000.00,0.00750)

Demolition = graph(YEAR)
(1970.00,500.00),(1971.00,500.00),(1972.00,500.00),(1973.00,500.00),
(1974.00,500.00),(1975.00,540.00),(1976.00,540.00),(1977.00,540.00),
(1978.00,540.00),(1979.00,540.00),(1980.00,540.00),(1981.00,240.00),
(1982.00,240.00),(1983.00,240.00),(1984.00,240.00),(1985.00,240.00),
(1986.00,72.00),(1987.00,72.00),(1988.00,72.00),(1989.00,72.00),
(1990.00,72.00),(1991.00,72.00),(1992.00,72.00),(1993.00,72.00),
(1994.00,72.00),(1995.00,72.00),(1996.00,72.00),(1997.00,72.00),
(1998.00,72.00), (1999.00,72.00),(2000.00,72.00)

Group_Rate = graph(YEAR)
(1970.00,0.0954),(1975.00,0.0975),(1980.00,0.102),(1985.00,0.139),
(1990.00,0.150),(1995.00,0.150),(2000.00,0.150)

HHInc_House = graph(ExpAppreciation) (-0.500,0.130),(-0.400,0.144),(-0.300,0.152),
(-0.200,0.176),(-0.1000,0.218),(0.0,0.280),(0.100,0.320),(0.200,0.350),
(0.300,0.368), (0.400,0.374),(0.500,0.380)

HHInc_Rent = graph(Vacancy)
(0.100,0.450),(0.114,0.440),(0.128,0.412),(0.142,0.383),(0.156,0.353),
(0.170,0.341),(0.184,0.336),(0.198,0.334),(0.212,0.331),(0.226,0.329),
(0.240,0.323)

H_CondoPrice = graph(YEAR)
(1970.00,28240.00),(1971.00,29100.00),(1972.00,29900.00),(1973.00,31330.00),
(1974.00,32800.00),(1975.00,34460.00),(1976.00,40600.00),(1977.00,47900.00),
(1978.00,56750.00),(1979.00,64600.00),(1980.00,73910.00),(1981.00,77600.00),
(1982.00,82000.00),(1983.00,94610.00),(1984.00,110990.00),
(1985.00,147760.00),(1986.00,170780.00),(1987.00,170780.00),
(1988.00,188390.00),(1989.00,178220.00)

H_Conversions = graph(YEAR)
(1970.00,60.00),(1971.00,60.00),(1972.00,60.00),(1973.00,60.00),
(1974.00,60.00),(1975.00,60.00),(1976.00,18.00),(1977.00,204.00),
(1978.00,562.00),(1979.00,1321.00),(1980.00,1464.00),(1981.00,2652.00),
(1982.00,2360.00),(1983.00,1546.00),(1984.00,1851.00),(1985.00,3385.00),
(1986.00,3178.00), (1987.00,3676.00),(1988.00, 0.0),(1989.00, 0.0),
(1990.00,0.0), (1991.00,0.0), (1992.00, 0.0),(1993.00,0.0),(1994.00,0.0),
(1995.00, 0.0), (1996.00, 0.0), (1997.00,0.0),(1998.00, 0.0),(1999.00,0.0),
(2000.00, 0.0)

H_MigrationRate = graph(YEAR)
(1970.00,-0.0240),(1975.00,-0.00560),(1980.00,0.00540),(1985.00,0.0133),
(1990.00,0.0183),(1995.00,0.0133),(2000.00,0.0133)

H_Population = graph(YEAR)
(1970.00,257497.00),(1975.00,246612.00),(1980.00,248177.00),
(1985.00,266635.00),(1990.00,304300.00)

H_Rent = graph(YEAR)
(1970.00,200.00),(1971.00,200.00),(1972.00,200.00),(1973.00,200.00),
(1974.00,214.00),(1975.00,229.00),(1976.00,245.00),(1977.00,262.00),
(1978.00,284.00),(1979.00,355.00),(1980.00,442.00),(1981.00,468.00),
(1982.00,496.00),(1983.00,526.00),(1984.00,601.00),(1985.00,683.00),
(1986.00,733.00),(1987.00,776.00),(1988.00,826.00),(1989.00,820.00)

InvestorDemand = graph(LaggedReturn)
(-0.250,-0.0640),(-0.200,-0.0640),(-0.150,-0.0640),(-0.1000,-0.0520),
(-0.0500,-0.0320),(0.0,0.00400),(0.0500,0.0720),(0.100,0.140),(0.150,0.172),
(0.200,0.180), (0.250,0.184)

Job_Rate = graph(YEAR)
(1970.00,-0.0323),(1971.00,-0.00940),(1972.00,-0.0158),(1973.00,0.000600),
(1974.00,-0.0396),(1975.00,-0.0118),(1976.00,0.0178),(1977.00,0.0216),
(1978.00,0.0274), (1979.00,0.0306),(1980.00,0.00570),(1981.00,-0.00790),
(1982.00,0.0160),(1983.00,0.0387),(1984.00,0.000500),(1985.00,0.0231),
(1986.00,0.0253),(1987.00,0.0398),(1988.00,0.0115),(1989.00,0.0100),
(1990.00,0.0200),(1991.00,0.0200),(1992.00,0.0200),(1993.00,0.0200),
(1994.00,0.0200),(1995.00,0.0200),(1996.00,0.0200),(1997.00,0.0200),
(1998.00,0.0200),(1999.00,0.0200),(2000.00,0.0200)

Labor_HH = graph(YEAR)
(1970.00,1.19),(1975.00,1.22),(1980.00,1.24),(1985.00,1.25),(1990.00,1.25),
(1995.00,1.25),(2000.00,1.25)

Learning_Curve = graph(YEAR)
(1970.00,0.0),(1971.00,0.0350),(1972.00,0.0350),(1973.00,0.0650),
(1974.00,0.0750),(1975.00,0.0950),(1976.00,0.130),(1977.00,0.165),
(1978.00,0.210),(1979.00,0.265),(1980.00,0.355),(1981.00,0.585),
(1982.00,0.760),(1983.00,0.875),(1984.00,0.950),(1985.00,0.975),
(1986.00,0.990),(1987.00,1.00),(1988.00,1.00),(1989.00,1.00), (1990.00,1.00)

MaxFraction = graph(ExpAppreciation)
(-0.500,0.380),(-0.400,0.380),(-0.300,0.380),(-0.200,0.380),(-0.1000,0.380),
(0.0,0.380),(0.100,0.380),(0.200,0.380),(0.300,0.380),(0.400,0.380),
(0.500,0.380)

MortgageRates = graph(YEAR)
(1970.00,0.0835),(1971.00,0.0718),(1972.00,0.0723),(1973.00,0.0745),
(1974.00,0.0867),(1975.00,0.0892),(1976.00,0.0880),(1977.00,0.0848),
(1978.00,0.0869),(1979.00,0.103),(1980.00,0.137),(1981.00,0.151),
(1982.00,0.167),(1983.00,0.125),(1984.00,0.124),(1985.00,0.124),
(1986.00,0.0996),(1987.00,0.0918),(1988.00,0.0874),(1989.00,0.0950),
(1990.00,0.100),(1991.00,0.105),(1992.00,0.105),(1993.00,0.105),
(1994.00,0.105),(1995.00,0.105),(1996.00,0.105),(1997.00,0.105),
(1998.00,0.105),(1999.00,0.105),(2000.00,0.105)

New_Condos = graph(YEAR)

(1970.00, 0.0),(1971.00, 0.0),(1972.00, 0.0),(1973.00, 0.0),(1974.00, 0.0),
(1975.00,0.0),(1976.00, 0.0),1977.00,15.00),(1978.00,106.00),(1979.00,159.00),
(1980.00,234.00),(1981.00,295.00),(1982.00,263.00),(1983.00,124.00),
(1984.00,417.00),(1985.00,358.00),(1986.00,530.00),(1987.00,341.00),
(1988.00,440.00),(1989.00,440.00),(1990.00,440.00),(1991.00,800.00),
(1992.00,800.00),(1993.00,800.00),(1994.00,800.00),(1995.00,800.00),
(1996.00,1150.00),(1997.00,1150.00),(1998.00,1150.00),(1999.00,1150.00),
(2000.00,1150.00)

New_Low_Income = graph(YEAR)
(1970.00,600.00),(1971.00,600.00),(1972.00,600.00),(1973.00,600.00),
(1974.00,600.00),(1975.00,380.00),(1976.00,380.00),(1977.00,380.00),
(1978.00,380.00),(1979.00,380.00),(1980.00,380.00),(1981.00,190.00),
(1982.00,190.00),(1983.00,190.00),(1984.00,190.00),(1985.00,190.00),
(1986.00,290.00),(1987.00,290.00),(1988.00,290.00),(1989.00,290.00),
(1990.00,290.00),(1991.00,300.00),(1992.00,300.00),(1993.00,300.00),
(1994.00,300.00),(1995.00,300.00),(1996.00,300.00),(1997.00,300.00),
(1998.00,300.00),(1999.00,300.00),(2000.00,300.00)

Owner_Conversion = graph(YEAR)
(1970.00, 0.0),(1971.00, 0.0),(1972.00, 0.0),(1973.00,0.0),(1974.00, 0.0),
(1975.00,0.0),(1976.00, 0.0),(1977.00, 0.0),(1978.00, 0.0),(1979.00, 0.0),
(1980.00,0.0),(1981.00, 0.0),(1982.00, 0.0),(1983.00, 0.0),(1984.00, 0.0),
(1985.00,0.0),(1986.00, 0.0),(1987.00, 0.0),(1988.00, 0.0),(1989.00, 0.0),
(1990.00,0.0),(1991.00, 0.0),(1992.00, 0.0),(1993.00, 0.0),(1994.00, 0.0),
(1995.00,0.0),(1996.00, 0.0),(1997.00, 0.0),(1998.00, 0.0),(1999.00, 0.0),
(2000.00,0.0)

POP_HH = graph(YEAR)
(1970.00,2.30),(1975.00,2.16),(1980.00,2.09),(1985.00,2.06),(1990.00,2.05),
(1995.00,2.05),(2000.00,2.05)

PotOwnershipRatio = graph(AffordabilityIndex)
(0.0,1.00),(0.100,1.00),(0.200,1.00),(0.300,0.790),(0.400,0.690),(0.500,0.650),
(0.600,0.600),(0.700,0.520),(0.800,0.430),(0.900,0.360),(1.00,0.320),
(1.10,0.255),(1.20,0.230),(1.30,0.205),(1.40,0.190),(1.50,0.165),
(1.60,0.135),(1.70,0.110),(1.80,0.0900),(1.90,0.0850),(2.00,0.0800),
(2.10,0.0800),(2.20,0.0800),(2.30,0.0700),(2.40,0.0600),(2.50,0.0500),
(2.60,0.0400),(2.70,0.0400),(2.80,0.0300),(2.90,0.0300),(3.00,0.0300)

RatePrice = graph(DemSupBalance)
(-0.500,-0.100),(-0.400,-0.100), (-0.300,-0.0750),(-0.200,-0.0500),
(-0.1000,-0.0100),(0.0,0.0300),(0.100,0.120),(0.200,0.280),(0.300,0.390),
(0.400,0.470),(0.500,0.480)

Renter_Index = graph(YEAR)
(1970.00,0.520),(1975.00,0.530),(1980.00,0.550),(1985.00,0.640),
(1990.00,0.650), (1995.00,0.650),(2000.00,0.650)

Set_Aside = graph(YEAR)
(1970.00,520.00),(1971.00,520.00),(1972.00,520.00),(1973.00,520.00),
(1974.00,520.00),(1975.00,320.00),(1976.00,320.00),(1977.00,320.00),
(1978.00,320.00),(1979.00,320.00),(1980.00,320.00),(1981.00,90.00),
(1982.00,90.00),(1983.00,90.00),(1984.00,90.00),(1985.00,90.00),
(1986.00,200.00),(1987.00,200.00),(1988.00,200.00),(1989.00,200.00),
(1990.00,200.00),(1991.00,200.00),(1992.00,200.00),(1993.00,200.00),
(1994.00,200.00),(1995.00,200.00),(1996.00,200.00),(1997.00,200.00),
(1998.00,200.00),(1999.00,200.00),(2000.00,200.00)

Sweat_Equity = graph(YEAR)
(1970.00, 0.0),(1971.00, 0.0),(1972.00, 0.0),(1973.00, 0.0),(1974.00, 0.0),
(1975.00,0.0),(1976.00, 0.0),(1977.00, 0.0),(1978.00, 0.0),(1979.00, 0.0),
(1980.00,0.0),(1981.00,200.00),(1982.00,200.00),(1983.00,200.00),
(1984.00,200.00),(1985.00,200.00),(1986.00,200.00),(1987.00,200.00),
(1988.00,200.00), (1989.00,200.00),(1990.00,200.00),(1991.00, 0.0),
(1992.00,0.0), (1993.00,0.0), (1994.00, 0.0),(1995.00, 0.0),(1996.00, 0.0),
(1997.00, 0.0),(1998.00, 0.0), (1999.00,0.0),(2000.00, 0.0)

Unemployment_Rate = graph(YEAR)
(1970.00,4.30),(1971.00,5.00),(1972.00,5.00),(1973.00,8.40),(1974.00,8.70),
(1975.00,12.70),(1976.00,11.10),(1977.00,9.50),(1978.00,7.90),(1979.00,7.20),
(1980.00,6.90),(1981.00,7.90),(1982.00,9.00),(1983.00,7.80),(1984.00,5.50),
(1985.00,4.50),(1986.00,4.40),(1987.00,3.20),(1988.00,3.30),(1989.00,4.00),
(1990.00,4.50),(1991.00,5.00),(1992.00,5.00),(1993.00,5.00),(1994.00,5.00),
(1995.00,5.00),(1996.00,5.00),(1997.00,5.00),(1998.00,5.00),(1999.00,5.00),
(2000.00,5.00)

WageInflation = graph(YEAR)
(1970.00,0.0800),(1971.00,0.0460),(1972.00,0.0570),(1973.00,0.0630),
(1974.00,0.102),(1975.00,0.0480),(1976.00,0.0700),(1977.00,0.0530),
(1978.00,0.130),(1979.00,0.0940),(1980.00,0.0860),(1981.00,0.0950),
(1982.00,0.0660),(1983.00,0.0620),(1984.00,0.0680),(1985.00,0.0580),
(1986.00,0.0920),(1987.00,0.0500),(1988.00,0.0500),(1989.00,0.0500),
(1990.00,0.0500),(1991.00,0.0500),(1992.00,0.0500),(1993.00,0.0500),
(1994.00,0.0500),(1995.00,0.0500),(1996.00,0.0500),(1997.00,0.0500),
(1998.00,0.0500),(1999.00,0.0500),(2000.00,0.0500)

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