SIMULATING THE CYCLICAL BEHAVIOR IN METROPOLITAN

HOUSING MARKETS

by

Jane Xinxin Zhang

A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF REGIONAL PLANNING

WASHINGTON STATE UNIVERSITY
Program in Environmental Science and Regional Planning

August 2001

To the Faculty of Washington State University:

       The members of the Committee appointed to examine the thesis of Jane Xinxin

Zhang find it satisfactory and recommend that it be accepted.

                                                     Chair

ACKNOWLEDGMENTS

I would like to thank the many individuals who have contributed guidance and support during the preparation of my thesis and throughout my stay at Washington State University. First and foremost, I would like to thank Andy Ford, my committee Chair, for providing tutelage, encouragement, useful ideas, and countless hours of help, and for providing the concept that blossomed into the central theme of my thesis: using a system dynamics model for simulating the cyclical behavior in real estate markets. I would also like to thank the other members of my committee, William Budd and William Hendrix, for their helpful suggestions and reviews of drafts.

Many thanks to friends past and present in the ESRP program for the much needed diversions.

Finally, I wish to express my love to my parents and husband, for their helpfulness and emotional support during my educational endeavor. Without them this thesis would not have been possible.

To my parents and husband

SIMULATING THE CYCLICAL BEHAVIOR IN METROPOLITAN

HOUSING MARKETS

Abstract

by Jane Xinxin Zhang, M.R.P.
Washington State University
August 2001

Chair: Andrew Ford

Urban housing markets have historically experienced cyclical patterns. They are among the most unstable and cyclic asset markets, exhibiting large amplitude cycles of 10-20 years. Denise DiPasquale and William Wheaton (1996) built a mathematical model of a urban housing market to illustrate the cyclical behavior. In this thesis, a system dynamics version of Denise DiPasquale and William Wheaton's mathematical model was developed to represent the model and verify the results. Further developments were added into the system dynamics model to simulate the cyclical movements more realistically. The developments help one understand the underlying cause of the cycles. Zoning restrictions are then added to test whether Zoning boards can reshape the pattern of boom-and-bust. The simulation results indicate that delays existing in bankers' responses and developers' forecasts are the main reasons for cycles in housing markets. Zoning boards can help reduce the amplitudes of cycles to some extent, but they can not reshape the pattern of boom-and-bust in a significant manner.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

The Real Estate Construction Cycle

"Real estate markets are among the most unstable and cyclic asset markets, exhibiting large amplitude cycles of 10-20 years. Real estate constitutes a large fraction of the total wealth in any economy, generates a significant fraction of banking activity and debt, and strongly affects the job market. Consequently, real estate booms are often accompanied by periods of intense speculation involving expansion of credit and banking activity, stimulating the local and even national economy. When the bubble bursts, the resulting bad loans, defaults, and unemployment can throw an entire region into recession or even depression." (Sterman, 2000)

Chicago Case

A classic example is the real estate cycle in Chicago from 1830 to 1933, studied by Homer Hoyt (1933), in the book <u>One Hundred Years of Land Values in Chicago</u>. According to Sterman (2000): "over this period Chicago grew from a small town of a few hundred with property valued at less that $100,000 to an economic powerhouse with more that 3 million inhabitants and real estate valued at more that $ 3 billion. Growth, however, was anything but smooth. Land values and development activity went through repeated cycles of boom-and-bust. Land valuations fluctuate roughly ±50% around the trend, while construction activity surges from a low some 60% below average during

1

downturns to more than double the average during booms." (See Figure 1-1). "These amplitudes are much larger and much longer than the business cycle --- the real estate cycle could not be blamed on some external variation in the pace of economic activity." (Sterman, 2000). Hyot defined the Chicago real estate cycle as "a term … to describe the composite effect of the cyclical movements of a series of forces that are to a certain degree independent and yet which communicate impulses to each other in a time sequences, so that when the initial or primary factor appears it tends to set the others in motion in a definite order." (Hoyt, 1933)

Figure 1-1 shows that "land was valued at 80% below normal (the average value) in 1830, but it reached normal values by 1835. Then the values shot off the chart. If you look closely at Hoyt's diagram, you can read that land was 456% above normal in 1836. Within a few years, land value was back to 80% below normal. These were the five booms in land values over the 100-year period. Hoyt's data on new construction begins in 1854 when construction was 60% below normal. Within 2 years it was at normal values; 2 years later it was 120% above normal. The chart shows 4 major booms in construction. The final boom in the 1920s is the most sustained, with above normal construction from 1922 until 1928. Indeed, construction was still booming in 1926-1928 even though land values were declining. Hoyt used the business activity index (shaded in black) of the Cleveland Trust Company. He shows the index to make it clear that the cycles in land values and in construction do not coincide with cycles in business activity." (Zhang and Ford, 2000)
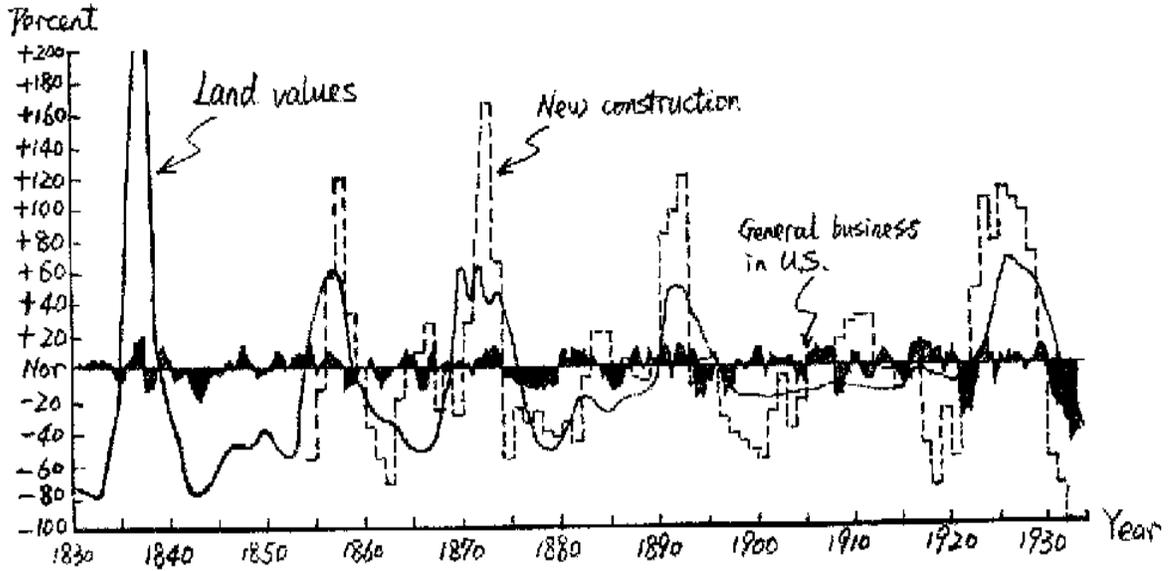
Figure 1-1. The Chicago Land value and building cycles compared with general business activity in the United States, 1830 – 1933. This diagram has been traced from Figure 99 of Hoyt's book of the Chicago cycle. The vertical axis shows % variation from a "normal" (the average) value.
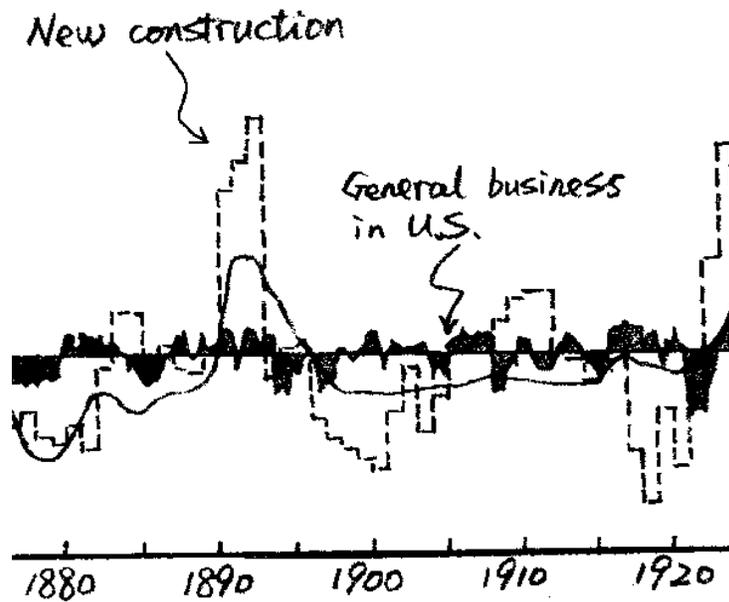
Figure 1-2. Closer look at the Chicago cycle at the end of the 19th century.

3

Figure 1-2 shows a closer look at the Chicago cycle at the end of the 19th century. Hyot used the term of "phases of real estate cycle" to describe the market behavior:

"Phase 1: The Initial Impulse Comes from Population Growth: The demand for land is the aggregate demand for a variety of uses such as streets, parks, home sites, factory sites, stores, churches, schools, governmental building, cemeteries, and railroad rights-of-way. All of these demands increased when there was a surge in population.

Phase 2: Demand Exceeds Supply: Prices Are Rising. Gross rents begin to rise rapidly, at the very time as population is growing. Net rents are the key to developers. (Net rent is gross rent minus maintenance expenditures.) Net rents rise even more rapidly during this phase of the cycle. The surge in net rents causes a surge in prices of existing buildings. At this point, it pays to erect new buildings.

Phase 3: Boom in Construction: Prices Peak during the Boom. Developers scramble to build at many locations around the city. According to Hoyt (1933) "a great many men worked secretly and independently on a great variety of structures in many sections of the city. There was no central clearing house to correlate the impending supply of buildings with the probable demand, so that when all these plans came to fruition, an astonishing number of new structures had been erected."

Phase 4: The Bust --- Falling Prices & Foreclosures: Gross rents fall, and net rents fall even faster. Land values plummet, and foreclosures are everywhere. Nearly all phases of real estate activity are virtually suspended. The lull lasts much longer than the boom. (Hoyt observed that the bust periods were twice as long as the boom periods.) Developers
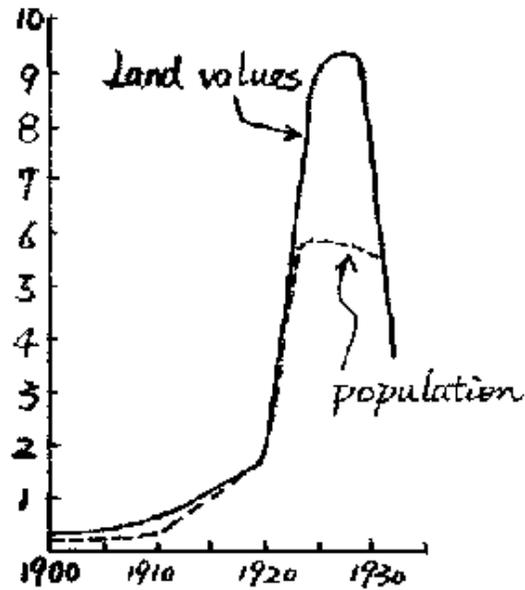
Figure 1-3. Population and Residential Land Values in Yates/Stoney Island in Chicago Area. 1 on Axis = 7,500 population, 1 on Axis = $7.5 million land value.
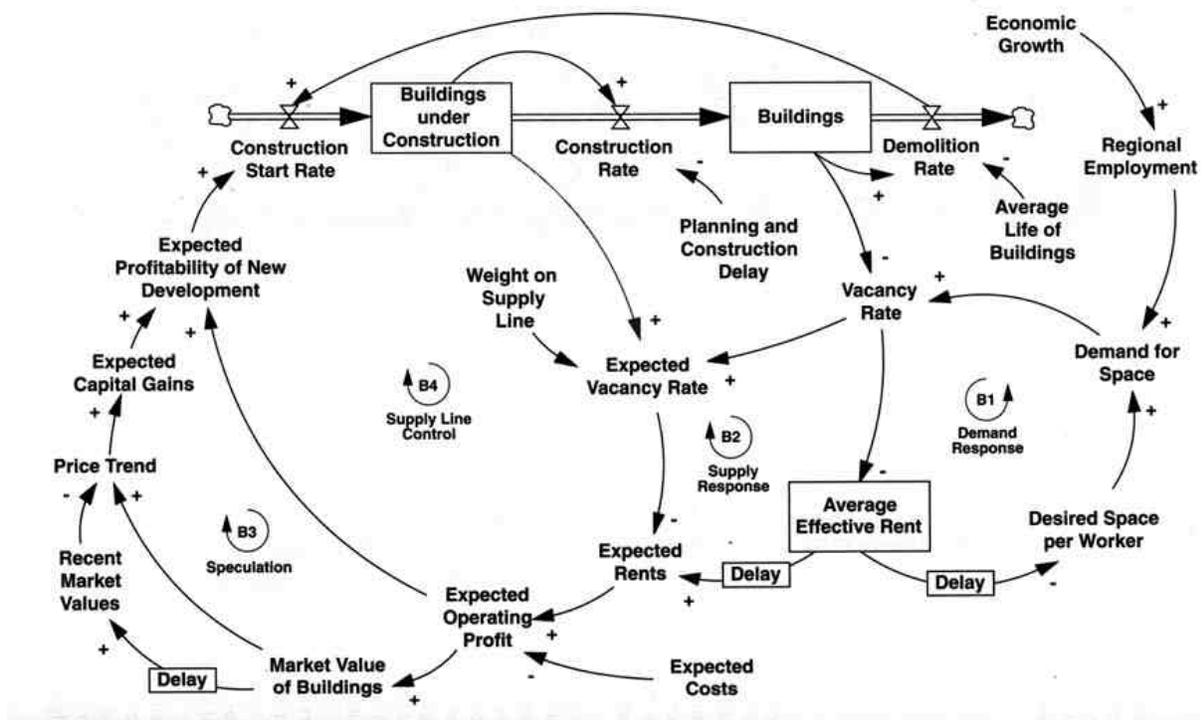
Figure 1-4. Causal structure of commercial real estate markets by Sterman.

are hoping for another surge in population. When it comes, the cycle begins anew." (Zhang and Ford, 2000)

Hoyt pointed out that increasing population growth was one of the factors that led to a boom. At the same time, he gave several examples to illustrate that although population surges can trigger a surge in land values, the real estate industry itself is responsible for amplifying the boom and causing the bust in land values. Figure1-3 shows the role of population growth and the real estate cycle. In this example, the population of a community grew by 12 fold in 3 decades. Land values increased by 18 fold by the middle of the 1920s. Then land values were cut in half in the late 1920s and early 1930s.

The Real Estate Cycle According to John Sterman

John Sterman points out that "Real estate cycles are not limited to Chicago nor are they an artifact of mere archaeological interest. The cycle continues to have a large amplitude and long period. Most recently, North American and European property markets boomed in the late 1980s, only to crash resoundingly in the early 1990s. From the 1980s bubble economy of Japan to the building boom-and-bust in Southeast Asia in the late 1990s, instability in property markets is alive and well." (Sterman, 2000)

Sterman explains how the cycle arises by illustrating the causal structure of commercial real estate markets using Figure 1-4 (quoted from Sterman, 2000, Figure 17-15). Sterman points out that "the demand for commercial space depends on economic activity. The greater the employment in the region, the more space is needed, and vacancy rates fall. When vacancy rates are low, effective rents start to rise (effective rents are gross rents net of tenants concessions such as moving and remodeling expense). Higher

6

rents lead to some reduction in demand as businesses make do with space per worker, but the elasticity of the negative Demand Response of feedback (loop B1) is low and the response time is long. On the supply side, rising rents boost the profitability and market values of existing properties. When prices are high and rising, rents and operating profits are high and developers can realize substantial capital gains as well. High profits attract new developers, who find no shortage of financial backers eager to cash in on the boom. Many new projects are started, swelling the supply line of building under development. After a long delay (2-5 years), the stock of space rises, vacancy rates rise, and rents start to fall, dragging down market values. As profits fall, so does the development rate. The market creates negative loops that attempt to balance demand and supply through prices (the negative Supply Response and Speculation loops B2 and B3)." (Sterman, 2000)

The Real Estate Cycle According to Henry Hoagland

In the book Real Estate Principles, Henry Hoagland (1949) says: "There is some evidence to support the claim that real estate activities may be a major cause of general business conditions rather than their effect. For example, during the First World War private building was greatly curtailed. With the close of the war the backlog of demand resulted in a prolonged active market that produced sharp increases in prices and a great increase in the production of both urban land and its improvements. This market spent its force only after it had overreached itself and created a supply greater than the demand would absorb. Whenever the buying public shows a preference for real estate investment, the resulting active real estate market may be said to be a cause of prosperity rather than

its effect. On the other hand, whenever investment interest deserts real estate, whether to show preference to an alternative outlet for funds or to go into hiding, the resulting dull real estate market is said to be affected by the slowing down of general business. In other words, real estate markets are both cause and effect of general business conditions." (Hoagland, 1949)

Hoagland believes that "both parasitical and self-contained development projects are subject to cyclical periods of growth. Such areas are opened for sale at times when people are prosperous and optimistic. City life palls upon many people. As soon as they feel able to do so, some of them will take advantage of an opportunity to move into the suburbs. Much of our suburban growth to date reflects the increase in size of our city population. As a city grows it must push outward and absorb adjacent agricultural land. But even if the predictions of a slowing down of city growth materialize, the suburban areas will undoubtedly continue to grow at the expense of the older and more congested areas whenever city people feel able to move into the suburbs."

"The success of development projects is gauged by the forecasting abilities of their promoters. If the promoter of a parasitical area makes a wrong guess and attempts a sales campaign when people are not in the mood to buy his wares, his whole project may turn sour and it may take years to revive interest in it. The promoter of a self-contained project has a continuous job, which assumes a variety of activities. When people are optimistic his time for pushing sales has arrived. In the intervals between good seasons, he must try to consolidate his gains, plug the holes left by defaulted contracts, and prepare for the next good season. If he overextends his operations or misses his guess about the future,

he may lose all that he has gained; and, in addition, he may find that his future opportunities pass into the hands of his successor." (Hoagland, 1949)

Hoagland concludes his book with a culminating chapter on the cycle. His description is remarkably similar to the cycle described by Hoyt in Chicago. Zhang and Ford made a table in their web page of the Real Estate Construction Cycle to summary Hoagland's conclusion:

the cycle begins	An increase in demand for real estate services first absorbs existing vacancies. Increased employment means increased savings, a part of which is made available to the purchasers of real estate in the form of more liberal mortgages. By this time prices have increased enough to provide enticing incomes to real estate owners. This invites the construction of more units.
the boom	The boom is started. Eventually the new supply first catches up with the demand and then continues to increase until a surplus is created.
too much construction	The development of this surplus is at first not apparent as long as employment is at a high level. When employment recedes even slightly the surplus of real estate decrease, and vacancies begin to take their toll. Too late to apply the brakes of caution, construction halts until it almost comes to a stop.
the bust	The long discouraging period of waiting for better times and hoping for recovery of lost real estate values has begun. Foreclosures succeed each other in discouraging regularity. The downswing of the cycle feeds upon its own misfortunes.

Table 1-1. Hoagland's summary of the four phases in real estate cycle.

What Do Others Have to Say?

Ironically, most authors in real estate field talk about everything in the market except the real estate cycle. Their books are filled with chapters on locations, incomes, general businesses, and mortgage rates. The real estate cycle, on the other hand, is missing from the table of contents and even from the index. These authors represent the main stream

real estate experts. They include Dumke (1944), Weimer (1972), O'connell (1982) and Nicholas (1982).

As a matter of fact, not only do many authors ignore the cycle, but most real estate developers ignore the supply line of buildings under development. In the late '80s and early '90s a group of students of Sterman at the MIT system dynamics group investigated this question through a series of field studies and laboratory experiments. "Amazingly, almost no developers spontaneously mentioned cycles, time lags, the supply line, or any related dynamic concepts. Instead, their descriptions focused heavily on the detail complexity of the development system---how to select a promising site, how to sell a project and win financial backing, how to navigate the permitting process, and so on." (Sterman, 2000) Sterman's students interviewed one developer who explained the lack of attention to the cyclical factors with a famous cliché: "Location is a bigger factor than the macro market. I know it's a cliche but really the key to real estate is location, location, location." (Sterman, 2000)

DiPasquale and Wheaton's Mathematical Model

Denise DiPasquale and William Wheaton (1996) have built a mathematical model of urban housing markets to illustrate the cyclical behavior. Their model is "based on the stock-flow theory of highly durable goods. The stock-flow approach holds that in the short run, house prices adjust quickly to equate housing demand to the existing stock of units. By contrast, adjustments to the stock of housing (such as new construction) occur

only slowly over time, and often with lags. Such stock adjustments respond to the prices determined by the market's short-run equilibrium." (DiPasquale and Wheaton, 1996)

"The stock-flow approach assumes that house prices in any period are determined only by current values of the model's other variables, while the stock of housing depends on the historic values of these variables." (DiPasquale and Wheaton, 1996) The equations of the mathematical model are:

$$D_t = H_t (\alpha_0 - \alpha_1 U_t) \tag{1}$$

$$U_t = P_t (M_t - I_t) \tag{2}$$

$$D_t = S_t \tag{3}$$

$$P_t = (\alpha_0 - S_t/H_t) / \alpha_1(M_t - I_t) \tag{4}$$

$$S_t - S_{t-1} = C_{t-1} - \delta S_{t-1} \tag{5}$$

$$ES_t = -\beta_0 + \beta_1 P_t \tag{6}$$

$$C_t = \tau (ES_t - S_t) \geq 0 \tag{7}$$

$$P^* = (\alpha_0 - S^*/H_t) / \alpha_1(M_t - I_t) \tag{8}$$

$$S^* = \tau (-\beta_0 + \beta_1 P^*) / (\delta + \tau) \tag{9}$$

Where,

α_0 Fraction of households who would own homes if the annual cost were zero

β_0 Minimum price increasing to cover construction cost

α_1 Fraction to changes in the cost of owning

β_1 Parameter determines how rapidly increased prices bring forth new land for development.

δ Fraction of the last period's stock that is lost to scrappage or demolition

τ	Speed with which construction occurs in response to difference between the actual housing stock and the long-run equilibrium (construction growth rate)
C_t	Current construction
C_{t-1}	construction begun one period ago
D_t	Current demand for owner-occupied housing units
ES_t	Long-run equilibrium stock of housing
H_t	Number of current households
I_t	Expected rate of future house-price appreciation
M_t	Current after-tax mortgage rate
P^*	Steady-state level of price
P_t	Current price level
S^*	Steady-state level of housing stock
S_t	Stock of owner-occupied units that currently exists
S_{t-1}	Stock of owner-occupied units in previous period
U_t	Annual cost of owning a house, the owner cost of capital

The subscript *t* represents current time, while the subscript *t-1* or *t+1* represents one period back or forward from the current period. Variables without subscripts are assumed to be constant over time. In order to test the model year by year, the unit of periods is explained as years in this thesis.

Equation (5) represents the main stock-flow relationship in the model: S_t is the stock; C_{t-1} is the flow. By inspecting equation (8) and (9), it can be seen that P* (steady-state

level of price) increases with more households, higher expectations about future price inflation, or lower current mortgage rate. Once P* is higher, then S* will be as well.

The authors also point out that "the steady-state solution to the model is a hypothetical equilibrium that, in practice, is probably rarely, if ever, obtained in an actual market. The reason is that a market's exogenous variables are generally not constant for a period that is long enough for the full stabilization to occur." (DiPasquale and Wheaton, 1996)

Exogenous Expectations

In order to complete the model, the authors must specify a process by which consumers form expectations about future house price inflation: I_t. There are two ways to specify the process of forming expectations. The first one is called "exogenous expectation", which is the simpler one. The other is named "myopic expectation". Exogenous expectation assumes that consumer expectations are exogenous to the model and therefore formed independently of local housing market behavior. While myopic expectation assumes that consumers form their estimates of future price inflation from past periods, which is in adaptive or backward-looking manner. For the first run, the authors apply exogenous expectation to complete the model, in which I_t equals to zero.

Exogenous expectation might exist "if households believe that future prices grow with general economic inflation, or follow some long-run growth rate that is largely unaffected by short-run movements in the local housing market. The level of anticipated inflation is not important here; rather, the crucial assumption is that household beliefs, for

whatever reason, are constant over time and not affected by recent price behavior in the local housing market." (DiPasquale and Wheaton, 1996)

The authors give a specific numerical example of the stock-flow model. The values of the parameters are selected to be representative for a medium-sized metropolitan area.

$\alpha_0 = 1.0$ means that all households would own homes if the annual cost of owning a home was zero

$\alpha_1 = 0.00003$ fraction to changes in the cost of owning a house is 0.003%

$M_t = 0.1$ after-tax mortgage interest rate is 10%

$I_t = 0$ no price inflation is expected

$H_t = 1,000,000$ number of current households is 1 million

$\beta_0 = 230,000$ intercept in equation (6)

$\beta_1 = 10$ slope in equation (6)

$\delta = 0.005$ scrappage rate is 0.5%

$\tau = 0.05$ construction is 5% per year of the difference between ES and S as shown in equation (7)

Based on these parameter values, the authors figure out the solutions to the equations in (8) and (9) are:

$S^* = 700,000$ (steady-state level of housing stock is 700,000 units)

$P^* = 100,000$ (steady-state level of housing price is $100,000)

The solutions mean that in the assumed market situation, 700,000 units of housing with the average price of $100,000 will make the market in a steady state. This price will remain indefinitely as long as there are no shocks to the system.

The authors then test "what happens to a market that is initially in the steady state above and then receives a positive demand shock?" A 10 percent increase in the number of households is made, which means H_t (number of current households) increases from 1,000,000 to 1,100,000. Resolving the equations in (8) and (9), there is eventually a new equilibrium at which P* = $105,650 and S* = 751,357. Figure 1-5 traces the movements, year by year, in price, construction, and the stock of housing.

The authors explain the simulation results: "with equation (4), more households always means a higher price. Price in the first few periods after the change in demand overshoots the ultimate long-run equilibrium value. This must always be true, because it takes time for supply to react to the demand shock. As new construction begins to occur, and the stock of units begins to rise, prices gradually decline, eventually reaching the new steady state. Construction exactly follows the movement in price. First, construction rises well above the replacement level then, gradually declines to that rate needed to sustain the new steady-state level of the stock." (DiPasquale and Wheaton, 1996)

The authors also study the reaction of the market to a negative demand shock and find that it is not the inverse of its response to a positive change. "The reason is that supply behaves differently. With a positive change, higher rates of new construction occur, but negative change can only bring a slow decline in the stock through depreciation." (DiPasquale and Wheaton, 1996). Figure 1-6 portrays the year-by-year reaction of the market to a 10 percent decline in households, from 1,000,000 to 900,000.
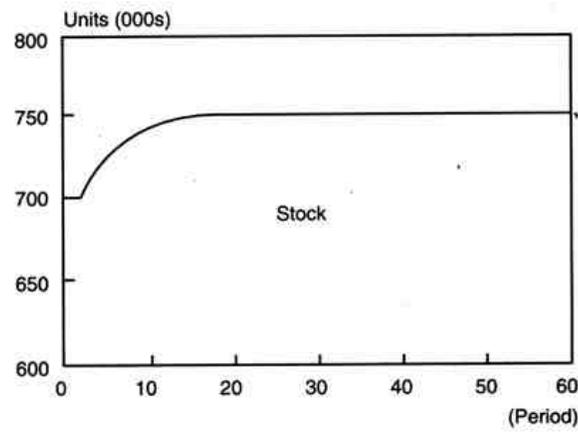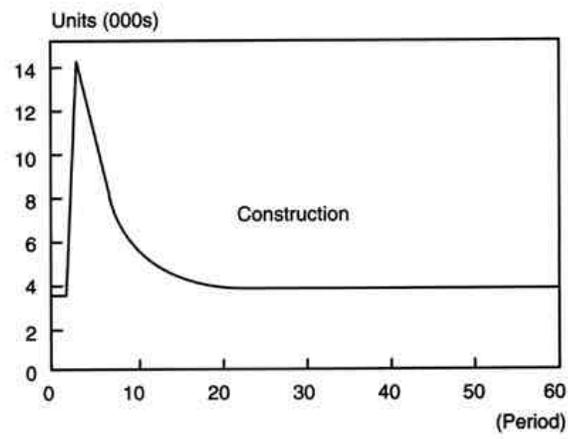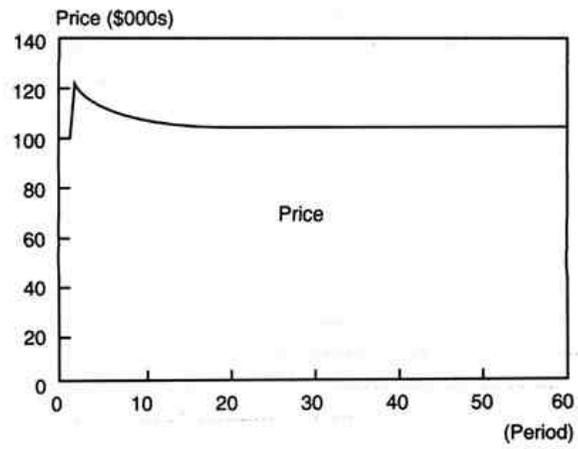
Figure 1-5. Market reaction to a positive demand shock: exogenous expectations.

16
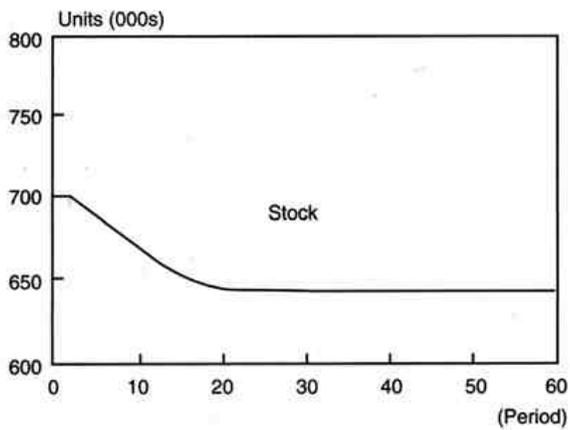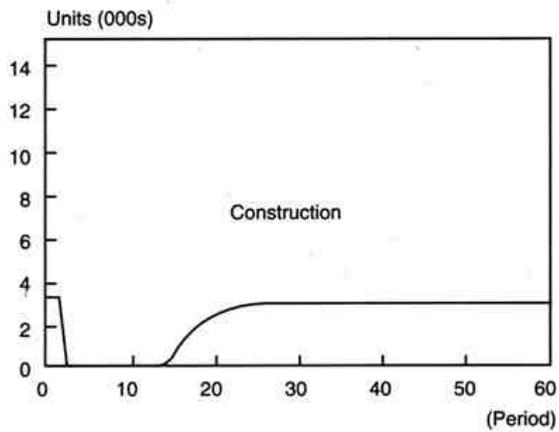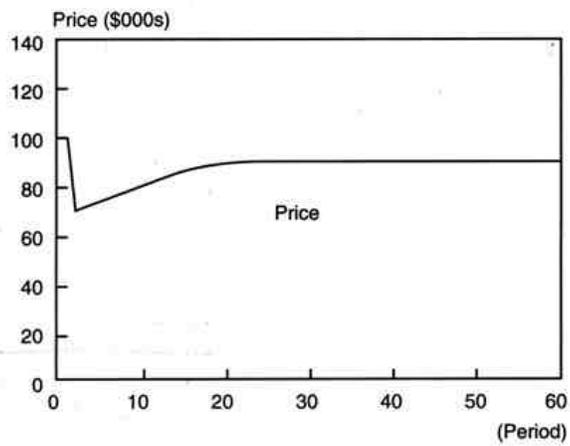
Figure 1-6. Market reaction to a negative demand shock: exogenous expectations.

17

"Prices drop initially, as the reduction in households cannot be matched by a decline in the stock. If the price drop is large enough, construction may cease altogether and the stock may decline at the scrappage rate. A gentler price drop will lead to only a decline in construction, with the stock declining at less than the scrappage rate. In either case, and after many periods, the stock erodes enough so that prices and construction begin to recover, eventually returning to a new steady state: $P^* = \$94,063$, $S^* = 646,029$." (DiPasquale and Wheaton, 1996)

The general behavior of this model is one of stability and convergence. A positive/negative market shock leads prices and construction to overshoot/undershoot their new equilibrium values only once and then settle down. The stock of units never overshoots its new target, and there is no possibility of repeated oscillations or cycles.

The authors believed that these conclusions had important implications. The previous Chicago case and other authors have demonstrated that residential real estate is cyclical, in the sense that it exhibits movements in prices and construction that are repeated. The model above, however, clearly suggests that "these movements are not inherent in the real estate market itself." (DiPasquale and Wheaton, 1996) The stability of the stock-flow model implies that any cyclical behavior in real estate must be due to cyclical behavior in the exogenous variables that drive the real estate market, such as population.

Myopic Expectations

The authors continue to ask questions: "Are consumer expectations about future house prices really formed independently from actual behavior in the housing market?" In the model, "for owner-occupied housing, demand depends not just on current population,

income, and the level of house prices, but also on expectations about future prices. While high current house prices dampen demand, the anticipation of capital gains through rising prices stimulates demand. It turns out that the dynamic behavior of their housing model is keenly dependent on how important such anticipated capital gains are to consumers and how consumers form judgements or estimates about them." (DiPasquale and Wheaton, 1996) There is evidence from consumer surveys that indicates that consumers frequently operate in adaptive or backward-looking expectations manner, in other words, myopic expectations manner. "When prices are rising, queried households will often respond that they expect future prices to rise similarly. Myopic foresight may turn out to be a bad forecasting tool, but there is evidence to suggest that consumers may, in fact, be bad forecasters." (DiPasquale and Wheaton, 1996)

In order to relate the expected rate of price inflation to current or past price movements, the authors added an equation to the model:

$$I_t = [1/(n-1)] \, [(P_{t-1} - P_{t-n}) / P_{t-1}] \tag{10}$$

I_t Expected rate of future house-price appreciation

P_{t-1} Price level one period back from the current period

P_{t-n} Price level n period back from the current period

n   number of recent periods of price movements that expectations formed over

In equation (10), if n = 2, then consumers form their estimates of future price inflation only from that of the past period. This is myopia in the extreme. More realistically, expectations might be formed over several recent periods of price movements, for example, n = 5.

From equation (2): $U_t = P_t (M_t - I_t)$, we see that once I_t is a none-zero value, the effective mortgage rate, $(M_t - I_t)$, would be different from mortgage rate, M_t. If consumers expect price rising, I_t would be a positive value, which can result in lowering mortgage rate, and vise versa. Influences on mortgage rate can finally result in changing housing price according to equation (8): $P^* = (\alpha_0 - S^*/H_t) / \alpha_1(M_t - I_t)$.

The authors found that the implications of adding equation (10) to the price determination equation (4) are quite profound. "No longer are current prices determined solely by the current value of exogenous variables. The role of history cannot be avoided. Two markets with the same current households, stock, and interest rates could have very different current prices. In a market experiencing a boom, expectations of future price appreciation would be high, and thus the anticipated total cost of ownership low. This would generate stronger demands, with resulting higher prices. A market experiencing a recent price slump would have lower prices, since the expectation of continued downward price movements would raise the cost of owning a house." (DiPasquale and Wheaton, 1996)

With myopic expectations, consumers estimate future house prices based on past trends in house prices. "Once past price inflation influences current price level, the stock-flow model can easily exhibit oscillating behavior in reaction to a market shock or change in parameters. In the period in which the shock occurs, the model reacts as before---with a positive shock, prices rise to clear the market. In the next period, however, the initial price rise has created the expectation of future price inflation. Thus, even as new supply begins to arrive, prices may continue to increase, fueled by expected future price inflation. This continued rise in price pushes up construction and makes it more likely

that construction will be high enough so that the stock eventually overshoots its target. Once this happens, prices peak and then start to drop. This then creates the expectation of negative price inflation, which reduces demand and, thus, actual prices." (DiPasquale and Wheaton, 1996) See Figure 1-7.

"In most cases, the main factor generating a turning point is the arrival of new supply. As prices initially take off, it is only a matter of time until enough new supply arrives to begin exerting a strong downward force on prices. For the case of negative shock, the absence of new construction and a gradual decline in the stock together help to turn around a sliding market." (DiPasquale and Wheaton, 1996)

The point, however, is that "myopic expectations about house price inflation are easily capable of creating a repetitive cycle in reaction to a single, one-time market shock. Such expectations generate a separate real estate cycle that can exist by itself without any cyclic movements in the market's exogenous variables." (DiPasquale and Wheaton, 1996)

Which Model Fits the Data?

After studying the two models above, the authors went further to find out which of the two models explains the Boston price data shown in Figure 1-8. The authors found that a model with myopic expectations fits the real data in Figure 1-8 best. Based on the Boston data, therefore, the authors were convinced that a model with myopic expectations was the best forecasting tool. To prepare a forecast, the authors were required to adopt some assumption about growth in personal income. Since the growth of income is highly
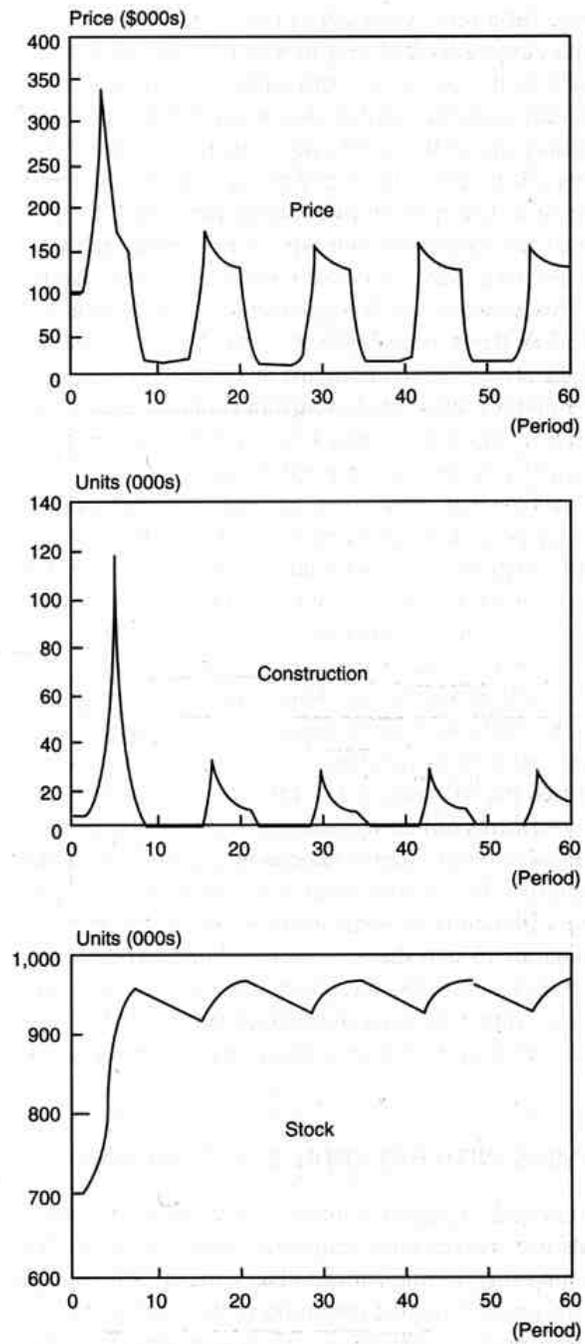
Figure 1-7. Market reaction to a positive demand shock: myopic expectations.

uncertain, the authors adopted two scenarios on income. Their corresponding forecasts are shown in Figure 1-9 and 1-10.

The first forecast assumes that the Boston economy only gradually recovers from the recession of 1989-92. Employment begins to expand at only 0.5 percent annually and personal income increases 1.0 percent annually over the decade form 1993 to 2002. Inflation is set at 3.5 percent annually; mortgage interest rates are held constant at 8.11 percent. These rates of growth are considerably below both the long-run historic growths of the Boston metropolitan area, as well as economic forecasts made in 1993.

The second forecast is based on a more optimistic scenario. The authors assume that economic growth in the Boston area returns to levels characteristic of historic expansionary periods. Job growth is assumed to be 2 percent annually, while personal income grows at 3.5 percent annually throughout the 1990s. Inflation is again set at 3.5 percent annually and mortgage interest rate at 8.11 percent. This outlook has somewhat more growth occurring than economic forecasters were predicting in 1993.

The authors make us notice that like the pessimistic forecast, the optimistic forecast also has a strong cyclic movement around the longer-term trend. The important part that the authors want readers to know is that "these cycles occur without any cyclic fluctuation in economic growth." (DiPasquale and Wheaton, 1996) They make it clear that a cycle in prices and permits is likely to continue into the future. Regardless of whether you adopt pessimistic or optimistic assumptions about personal income, the Boston housing market is forecast to be headed into another period of boom-and-bust.
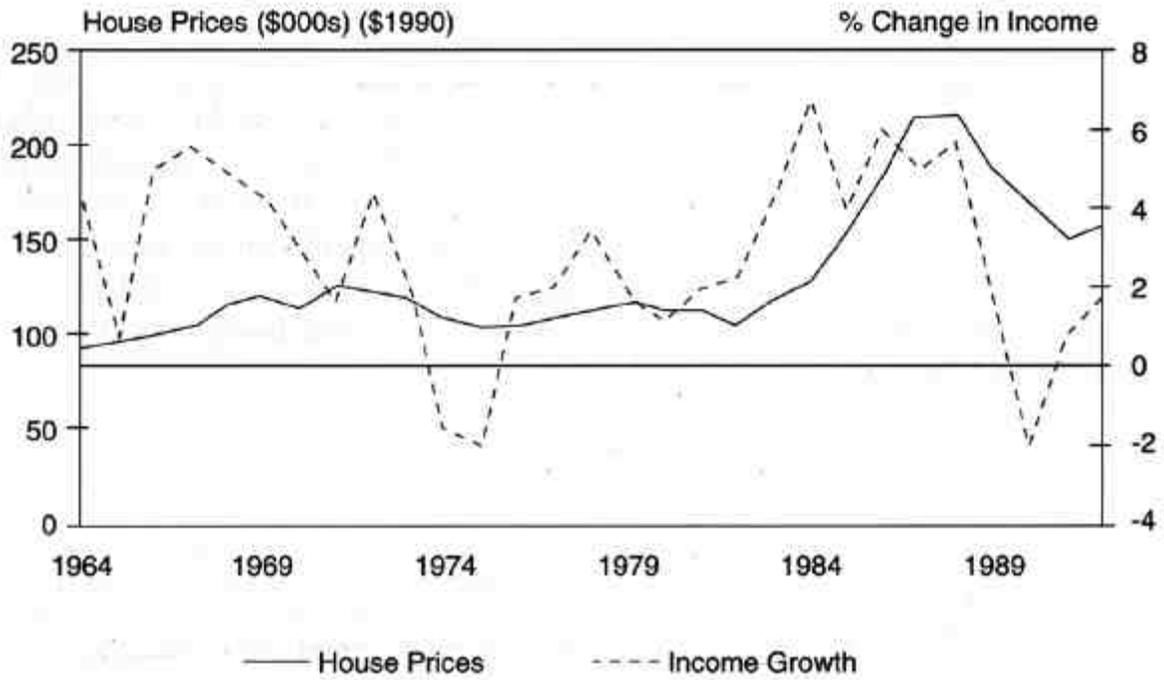
Figure 1-8. Boston house prices and income growth, 1964-1992.
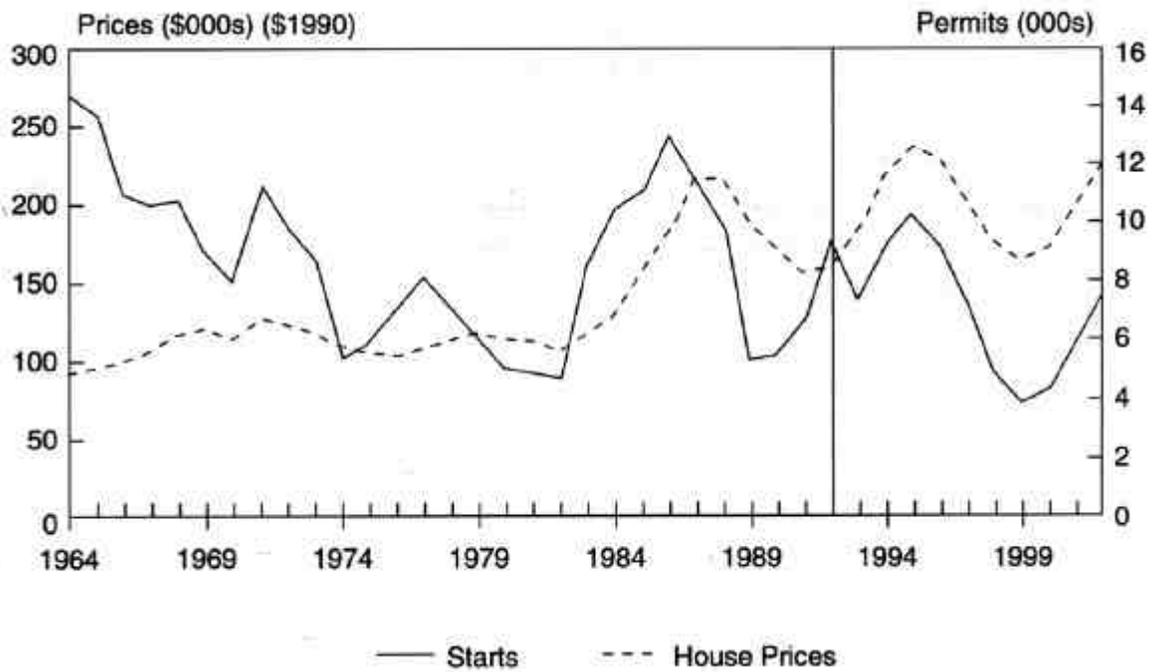
Figure 1-9. Pessimistic Boston construction and price forecasts, 1964 – 2002.
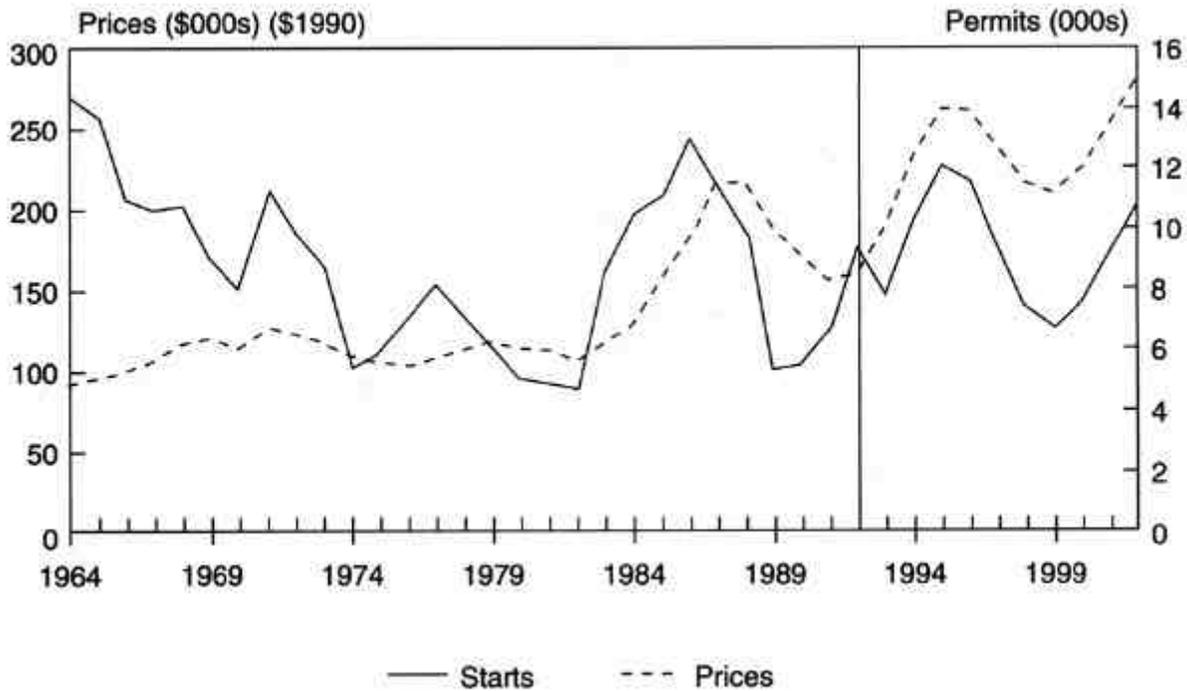
Figure 1-10. Optimistic Boston construction and price forecasts, 1964 – 2002.

Thesis Objectives

DiPasquale and Wheaton's mathematical model carefully describes the dynamic response to a shock in the real estate market. This thesis presents building a system dynamics version of the mathematical model, which honors as many as possible of the assumptions by DiPasquale and Wheaton. The model is constructed with the Ithink software to verify that it can produce the same general patterns as published in the text. Then the thesis expands upon the model with two purposes. The first purpose is to understand what should be responsible for causing cycles in housing markets. The second purpose is testing whether Zoning boards can "reshape" the pattern of boom-and-bust by the way in which they issue construction permits.

25

CHAPTER TWO

METHODS

The First model: Verifying DiPasquale and Wheaton's Results

The first system dynamics model is shown in Figure 2-1. It is made based on DiPasquale and Wheaton's mathematical model. The 9 equations noted in Chapter One are incorporated to formulate the relationships between stocks, flows and converters in the model. For example, in equation (5): $S_t - S_{t-1} = C_{t-1} - \delta S_{t-1}$, the relationship between housing stock, new construction and demolition is translated into a stock and flow relationship represented by one stock and two flows: houses, completions and demolitions. The equivalent equation in the System dynamics model is: houses(t) = houses(t - dt) + (completions - demolition) * dt, in which t represents time, dt represents change of time. The converters with the symbol of "~" represent linear relationships to honor DiPasquale and Wheaton's model.

The initial values of the parameters follow the assumptions made by the authors to simulate the housing market in a medium-sized metropolitan area. Table 2-1 shows the parameter values in model 1 and their equivalents in DiPasquale and Wheaton's mathematical model or explanations of their meanings. For those parameter values that are not included in Table 2-1, like $\alpha_0 = 1.0$, $\alpha_1 = 0.00003$, $\beta_0 = 230,000$, $\beta_1 = 10$, and $\tau = 0.05$, they are incorporated into the linear relationships in converters.

Initial values of parameters in the system dynamics model	Equivalents in the mathematical model or their explanations
Initial houses = 700 k units	S* = 700,000 units
Initial price = 100 k dollars	P* = 100,000 dollars
Initial units under construction = 3.5 k units	value comes from the text
alpha = 0	It = 0
demolition rate = 0.005/year	δ = 0.5% per year
households = 1000 k	value comes from the text
income to shelter ratio = 4	the households' payments for shelter, largely mortgage payments, should not exceed 25% of household income
max construction possible = 35 k units/year	the maximum is ten times larger than the construction need to simply replace demolitions
minimum cost = 90 k dollars	minimum price for the developer to earn a profit on a standard size house
mortgage rate = 0.1/year	Mt = 10% per year

Table 2-1. Initial values of parameters in model 1 and their equivalents in DiPasquale and Wheaton's mathematical model or explanations of their meanings.

The story that model 1 tells is that the price of a homes determines the effective mortgage rate, which influences how much income bankers require households have to make loans to. The converter "fraction qualified" is a negative relationship with required income: higher required income results in lower fraction qualified. The number of households and a certain fraction qualified determines the amount of qualified demand, which are the households ready to purchase a house. One minus the ratio of the amount of

Figure 2-1. Model 1: Verifying DiPasquale and Wheaton's Results.

qualified demand and number of houses in the market gives the effective vacancy rate. It's easy to find that once a market with a small amount of houses receives a great number of qualified demand, the effective vacancy rate will be low, and vise versa. A low vacancy rate results in price rise by the functioning of the converter of price change rate and the flow of price change. At the same time, in the developer side, the difference between price of selling a house and the minimum cost of building a house is the profit. There is a converter called maximum construction possible in the building part of the model. The product of maximum construction possible and the fraction of maximum construction started determine the number of starts by developers in the market. Obviously, more profit attracts more developers to build. So the relationship between profit and fraction of maximum construction started is positive. Units under construction is special type of stock called a conveyor. It simulates material moving through the system in a tightly controlled pattern. Because house building needs time, there, for sure, is a time delay between starts and completions of building houses. So a conveyor simulating the building pipeline is necessary. The transit time in the pipeline is set to 1 year to match the one year lag from C_{t-1} in equation (5). Higher profit eventually results in more housing construction and then more houses in the market. The demolition rate is a constant of 0.005 according to DiPasquale and Wheaton. It indicates that 0.5% of houses get demolished from the market annually.

A special function in system dynamics, named TREND, is applied in the converter of trend in price to simulate how consumers and bankers forecast trending in housing price. Since consumers and bankers expectation of future price inflation is represented by I_t, which is the expected rate of future house-price appreciation, and I_t has different values

under the assumptions of exogenous expectation and myopic expectation, a converter of alpha is added to help simulating I_t. Under exogenous expectation assumption, I_t is set to zero. So alpha is set to zero as well. Under myopic expectation assumption, I_t is a none-zero value, so as alpha. Once alpha is zero, the effective mortgage is the same as the mortgage rate. But when alpha is a non-zero value, the effective mortgage rate equals to mortgage rate minus the product of trend in price and alpha. Thus, controlling the value of alpha is a way to simulate different price-forecasting behaviors of consumers and bankers.

Figure 2-2 shows the causal loop diagram of model 1. Each arrow is labeled + or – depending on whether the causal influence is positive or negative. For example, the symbol besides the arrow from houses to effective vacancy rate is "+". It means more houses result in higher value of effective vacancy rate. The two variables change in the same direction, which is a positive relationship. The (+) or (-) in the middle of each loop indicates the type of feedback. There are three major loops and a minor loop for demolitions. The three major loops are: House Purchase Loop, House Building Loop and Price Trend Loop. The House Purchase Loop goes from price to required income, to fraction qualified, to qualified demand, to effective vacancy rate, and finally back to price. House Building Loop goes from price to profit, to fraction of maximum construction started, to start, to houses, to effective vacancy rate, and then back to price. The symbol // marks the delay for housing construction. The Price Trend Loop starts from price to trend in price, to reduction in mortgage rate from price trend, to mortgage rate, then overlapped with House Purchase Loop from required income to price. Alpha is a
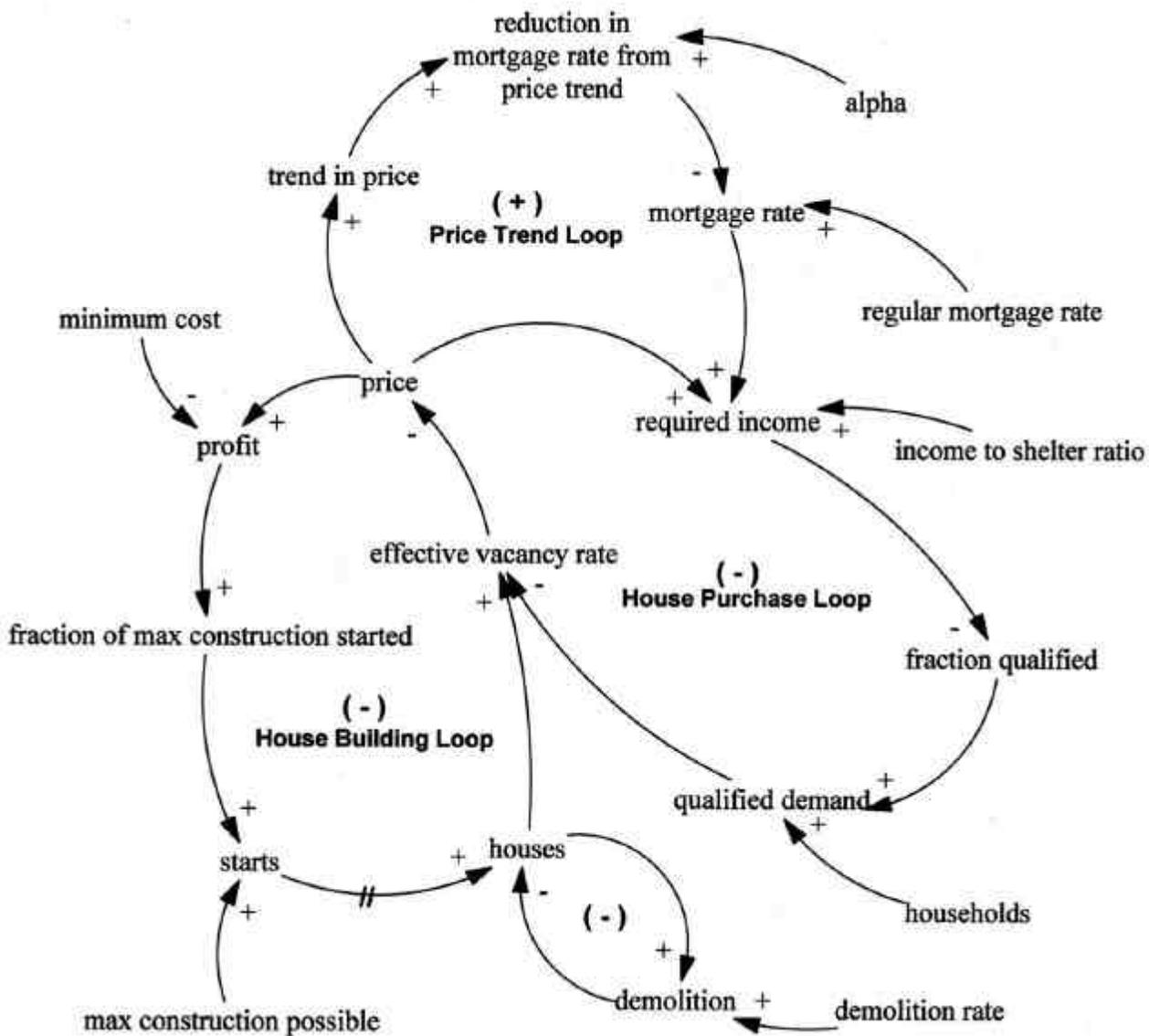
Figure 2-2. Causal loop diagram of model 1.

31

"outside" factor involving in Price Trend Loop. The relationship between alpha and reduction in mortgage rate from price trend is a positive one. For model 1, alpha is set to zero, which means reduction in mortgage rate from price trend is zero as well. Since mortgage rate is the difference between regular mortgage rate and reduction in mortgage rate from price trend, mortgage rate should be the same as regular mortgage rate when alpha is zero; the price trend dose not really influence the mortgage rate. Thus, the Price Trend Loop is not active in model 1.

In these three loops, House Purchase Loop and House Building Loop are negative feedback loops, which can balance themselves. While Price Trend Loop is a positive feedback loop, which tends to make the system grow bigger and bigger over time. The minor loop in the diagram is a negative one with two factors: houses and demolition. Because demolition is the product of the amount of houses and demolition rate, which is 0.5%, more houses in the market would result in more demolition, which leads to less amount of houses. Thus, it looks like three of the four loops are negative. However, since Price Trend Loop is actually cut off in model 1, only the three negative feedback loops work in model 1.

Because the parameter values in model 1 are set according to the equilibrium state in the DiPasquale and Wheaton's model, the result of running model 1 should be the same pattern of the equilibrium state, which means the values of prices, houses and units under construction should be stable for the whole studying period. Figure 2-3 shows the simulation results of model 1. In the diagram, we see the value of price is 100,000 dollars, houses is 700,000 units, and units under construction is 3,500 units for the whole period of 120 years, which are the exact values given by DiPasquale and Wheaton.
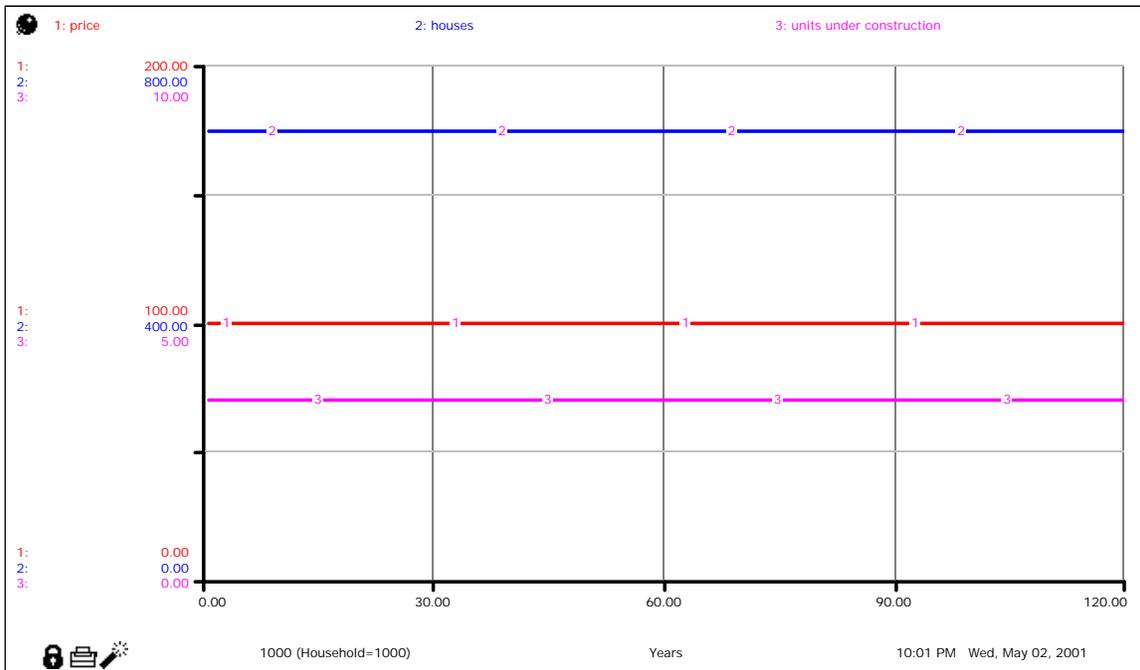
Figure 2-3. The equilibrium state of model 1.
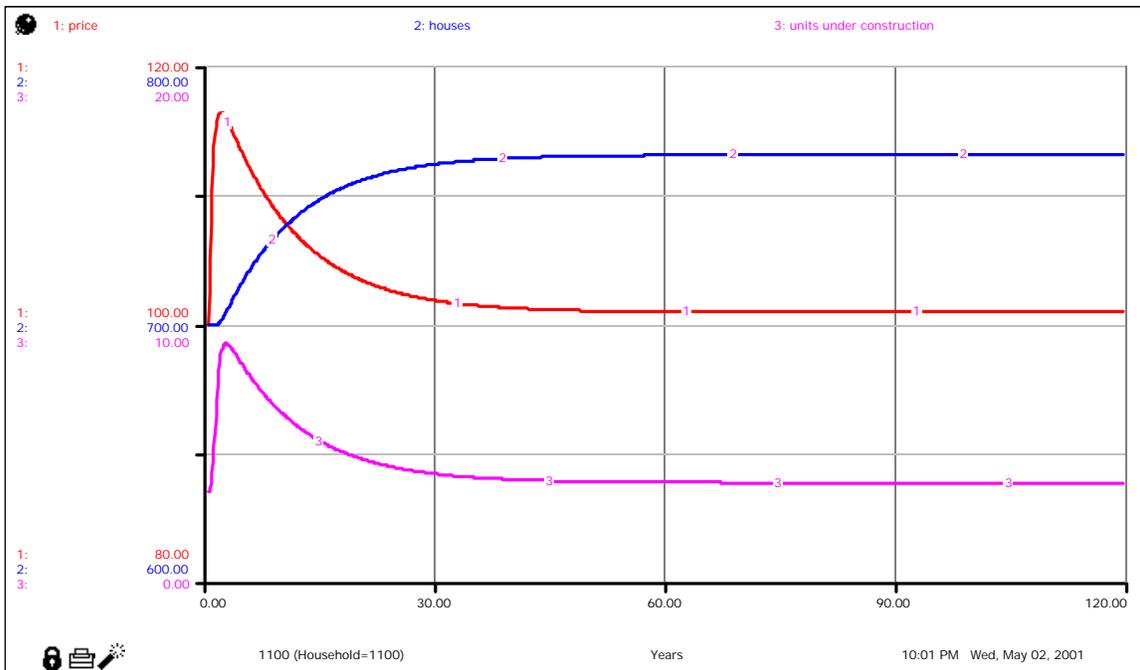
Figure 2-4. Market reaction to a positive demand shock with exogenous expectation (α=0) in model 1.

The results of model 1 verifies that model 1 can represent the equilibrium state in DiPasquale and Wheaton's model. Before concluding model 1 is equivalent to DiPasquale and Wheaton's model, three more experiments should be done.

The first experiment is a test of market reaction to a positive demand shock with exogenous expectations. The number of households is set to experience a 10 percent increase, from 1,000,000 to 1,100,000. In DiPasquale and Wheaton's model, that is the value of H_t. In model 1, that is the value of the converter of households. If model 1 was constructed correctly, the simulation results should be similar to Figure 1-5. Figure 2-4 shows the simulation results of model 1. Here we see market behavior very similar to Figure 1-5. Price, houses and new constructions jump to a very high level responding to the demand shock. They eventually decline after years to a new equilibrium state with higher price, more houses in the market and more new constructions annually.

The second experiment is testing market reaction to a negative demand shock also with exogenous expectations. The market receives a 10 percent decrease in the number of households, from 1,000,000 to 900,000. Also, in DiPasquale and Wheaton's model that is the value of H_t. and in model 1, that is the value of the converter of households. If model 1 was constructed correctly, the simulation results should be similar to Figure 1-6. Figure 2-5 shows the simulation results of model 1. These simulations confirm that the system dynamics model is successful in representing the "exogenous expectation" market behavior provided by DiPasquale and Wheaton.

The next experiment is to test myopic expectation. As in the first two experiments, the positive demand shock comes from 10 percent increase in the number of households,
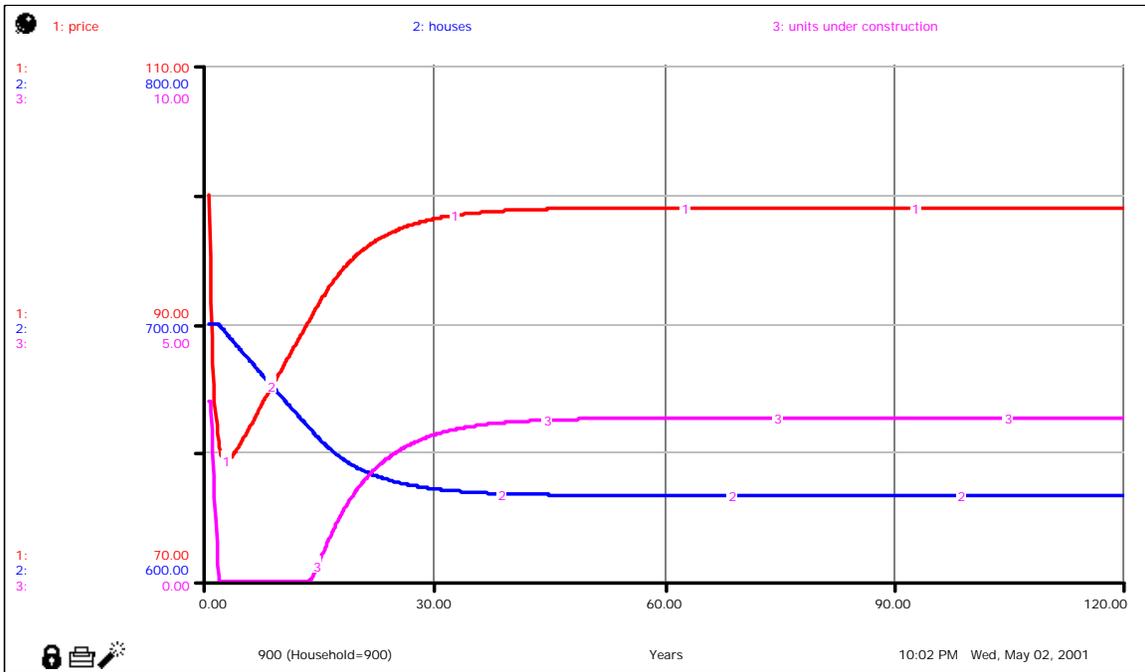
Figure 2-5. Market reaction to a negative demand shock with exogenous expectation (α=0) in model 1.
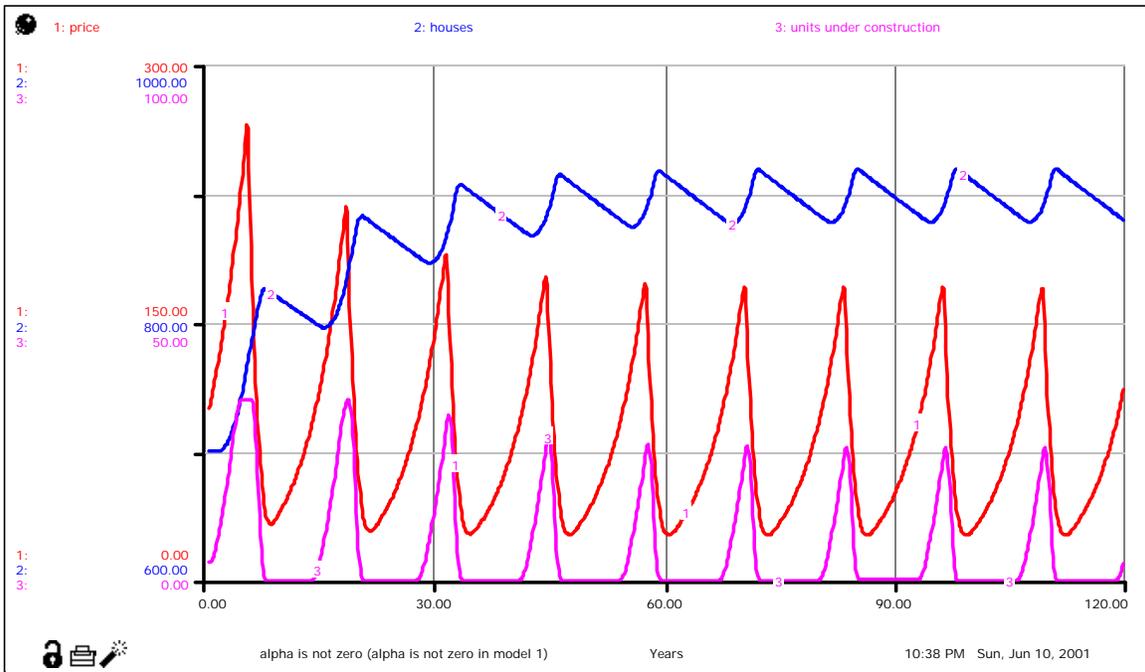
Figure 2-6. Market reaction to a positive demand shock with myopic expectation (α=0.32) in model 1.

from 1,000,000 to 1,100,000. For the myopic expectation, equation (10) is added to DiPasquale and Wheaton's model: $I_t = [1/(n-1)] [(P_{t-1} - P_{t-n}) / P_{t-1}]$, to simulate how consumers and bankers form their estimates of future price inflation from past periods. In model 1, however, function of TREND is applied to simulate the forecasting behavior with "trend in price = TREND(price,1,0)". As noted above, another parameter determines how expectation is formed is alpha. In previous tests, alpha is set to zero. It means that consumer's expectations of future house price formed independently from actual behavior in the housing market, which is called exogenous expectations. For myopic expectation, alpha is set to be a non-zero value, 0.32. If model 1 was well built, the simulation results should be in the same pattern as in Figure 1-7. Figure 2-6 shows the simulation results of model 1. It is easy to see that Figure 1-7 and Figure 2-6 are telling the same story. Price, houses and new construction are experiencing boom-and-bust in period of approximately 12 years. Five cycles are formed caused by a single shock in the market.

The difference between these two figures lies in the gradients of fluctuation amplitude. Figure 1-7 shows a sharp fall from the top of the first boom of price and construction to the following boom tops. While in Figure 2-6, there is no such a big drop. Booms of price and construction are falling down gradually to a quite stable level. For the stock of housing, the curve in Figure 1-7 grows rapidly in the first 10 years then starts to cycle itself. While in Figure 2-6, the curve grows gradually and starts the cycles from the beginning of the first year. The equations in DiPasquale and Wheaton's model could be responsible for the sudden changes. From system dynamics view, gradual changes are plausible. Because it takes time for variables to respond to the shock. Cycles of price,

construction and houses occur to adjust to the shock in myopic pattern. Changes take place not in a sudden, but gradually. So, the differences can be regarded minor.

So far, the conclusion of model 1 is equivalent to DiPasquale and Wheaton's mathematical model can be made. The first thesis objective of verifying that the system dynamics model can produce the same general patterns as provided by DiPasquale and Wheaton is accomplished.

The Second model: Adding Bankers' Response Delay

Although model 1 successfully simulates the market behavior according to DiPasquale and Wheaton's mathematical model, I do not believe it represents the real world in a realistic manner. In real markets, bankers adjust the required income for the households to loan money to according to current price. But they usually can not make the adjustment immediately after changes in the market. A time delay exists in banker's response. Model 2 is an expansion of model 1 to include the bankers' delay. A converter: bankers adjustment lag time is added into model 1 to simulate bankers' response delay. The delay time is set to 3 years. At the same time, another converter: delayed value of required income, is needed. The delayed value of required income is a function of required income and bankers adjustment lag time. The function itself is SMTH3, which performs a third-order exponential smooth of input. By adding these two converters into the model, fraction qualified now is determined by delayed value of required income, in stead of the original required income. Figure 2-7 shows model 2. The House Purchase Loop is still a negative feedback loop, but "the delay in the action of this loop could cause major changes in the simulated behavior" (Ford, 1999).
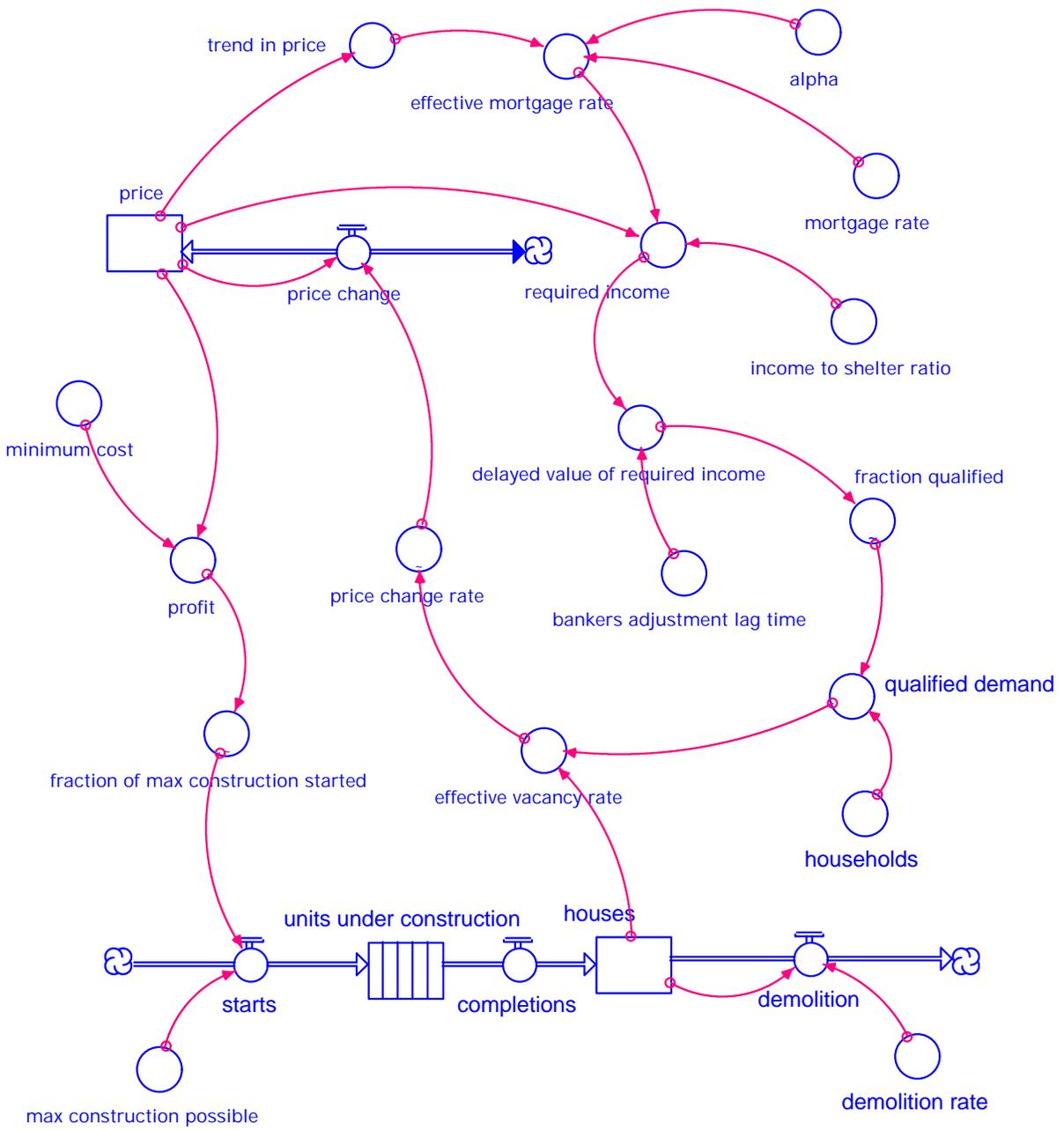
Figure 2-7. Model 2: Adding Bankers' Response Delay.

To test model 2, the assumption is the same as in previous experiments: the market receives a 10 percent increase in the number of households, from 1,000,000 to 1,100,000. For the first try, alpha is set to zero, which means that no price trend is counted into the market. The simulation results are shown in Figure 2-8. We see four cycles in houses, price and units under construction. The periods are approximately 15 years. The highest value for price in the 60-year period is $180,000, which is 80% higher than the equilibrium value.

The results tell us that cyclical movements could happen while time delay exists in the market. The model for now is made up of negative loops. Since alpha is zero, the positive feedback loop of Price Trend Loop is actually cut off from the model. Usually, negative loops can balance themselves and make system stable. However, once there is a delay functioning in the system, the balance may be difficult to achieve and the system may show sustained oscillations.

What if alpha is set to a non-zero value to simulate how consumers and bankers form their estimates of future price inflation from past periods? Figure 2-9 shows the simulation results of model 2 with alpha value of 0.32. We see big differences. There are huge fluctuations and long periods for each of the three variables. The periods are as long as 36 years. The highest value of price is $370,000, which is 270% higher than the equilibrium value.

Although it is reasonable to expect severe oscillations for the second test with a non-zero value of alpha, the length of the period is far beyond the general range in real markets. Sterman (2000) points out that real estate markets exhibit large amplitude cycles

Figure 2-8. Market reaction to a positive demand shock with exogenous expectation (α=0) and bankers adjustment delay in model 2.

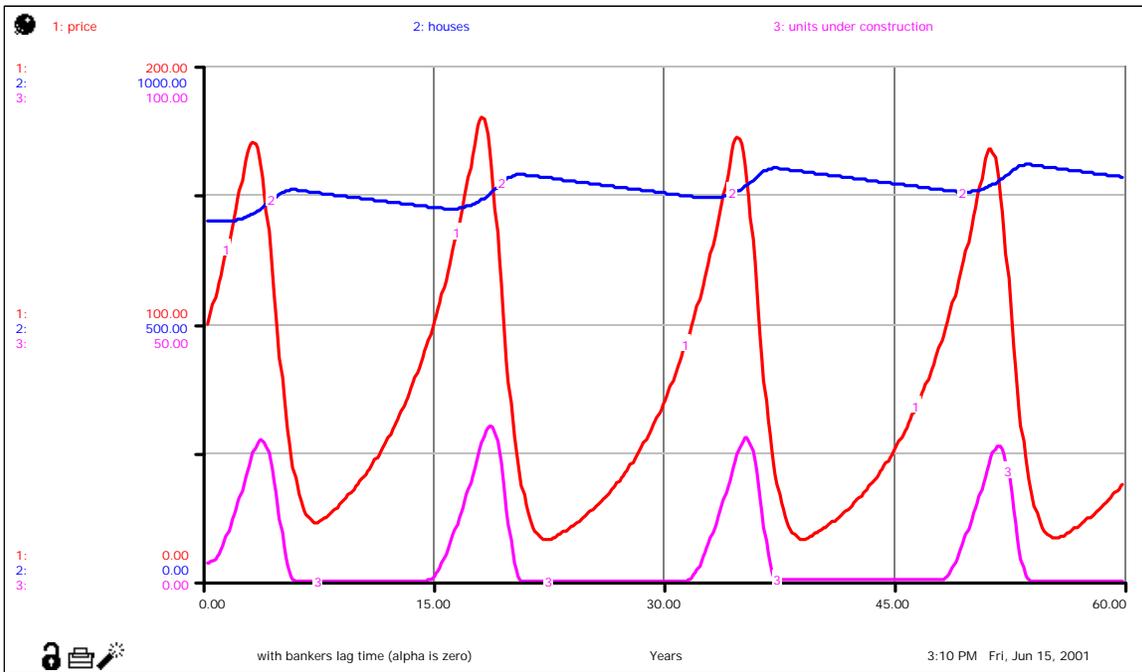Figure 2-9. Market reaction to a positive demand shock with myopic expectation (α=0.32) and bankers adjustment delay in model 2.

of 10-20 years. The results look unrealistic. Comparatively, the simulation results with alpha set to zero look more like common cyclical behavior in real estate markets.

Disregarding the differences between the two simulations, both of the results tell that banker's delay in adjusting required income does cause cycles in the housing market.

The Third model: Adding Developers' Forecasting of Profitability

Model 2 has included bankers' response delay into the simulation process, but there is no factor in the developing side of the model talking about how developers forecast housing price inflation. Model 3 is built to solve this problem by expanding model 2 with three new converters. They are forecasted price, forecasted profit and construction lag time. Forecasted profit is simply the difference of forecasted price and minimum cost. While forecasted price comes from a special function: FORCST, which is able to make forecasts, based on the value of current price and construction lag time. The construction lag time is set to 1 year, same as the transit time of the conveyor of units under construction. Thus the number of new construction started by developers is not determined by the current profit, but by their forecasted profit for the future. Developers intend to build for forecasted profit as far as they can see it. In a boom period, "it is little wonder that there was such a rush to erect new buildings…." (Hoyt, 1933)

Figure 2-10 shows model 3. The same assumption is made to test model 3: the market receives a 10 percent increase in the number of households, from 1,000,000 to 1,100,000. Alpha is set to zero for the first run to test the situation with developers forecasted profit and bankers adjustment delay. The simulation results are shown in Figure 2-11.

trend in price

effective mortgage rate

alpha

price

mortgage rate

price change

required income

income to shelter ratio

minimum cost

delayed value of required income

forecasted price

price change rate

fraction qualified

forecasted profit

bankers adjustment lag time

construction lag time

fraction of max construction started

effective vacancy rate

qualified demand

units under construction

houses

households

starts

completions

demolition

max construction possible

demolition rate

Figure 2-10. Model 3: Adding Developers' Forecasting of Profitability.

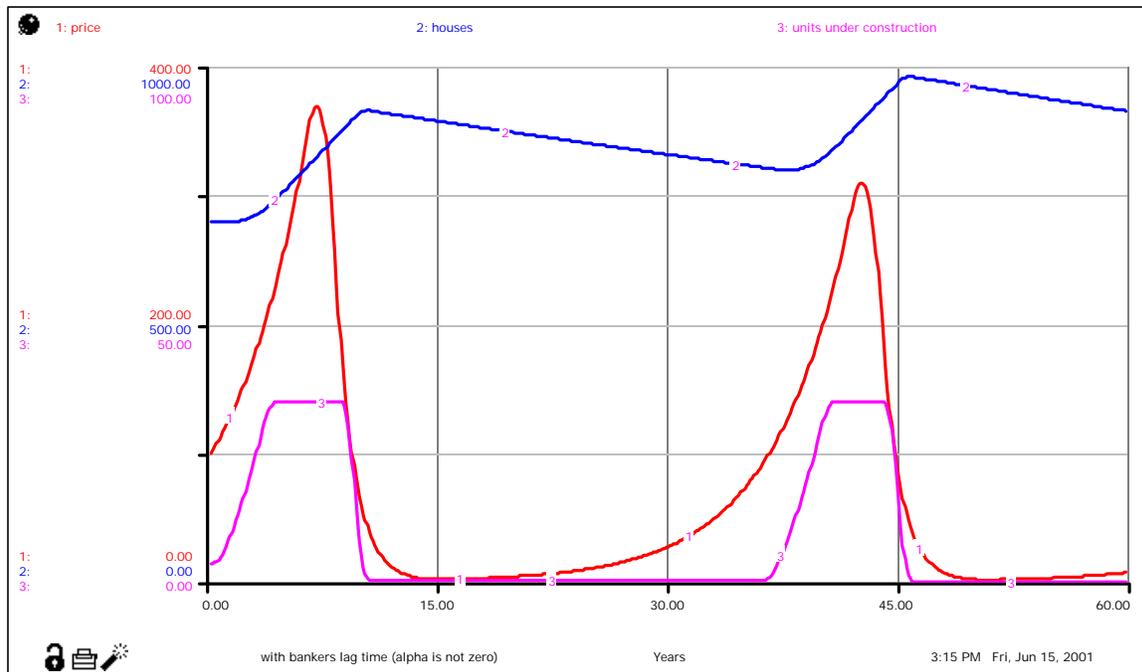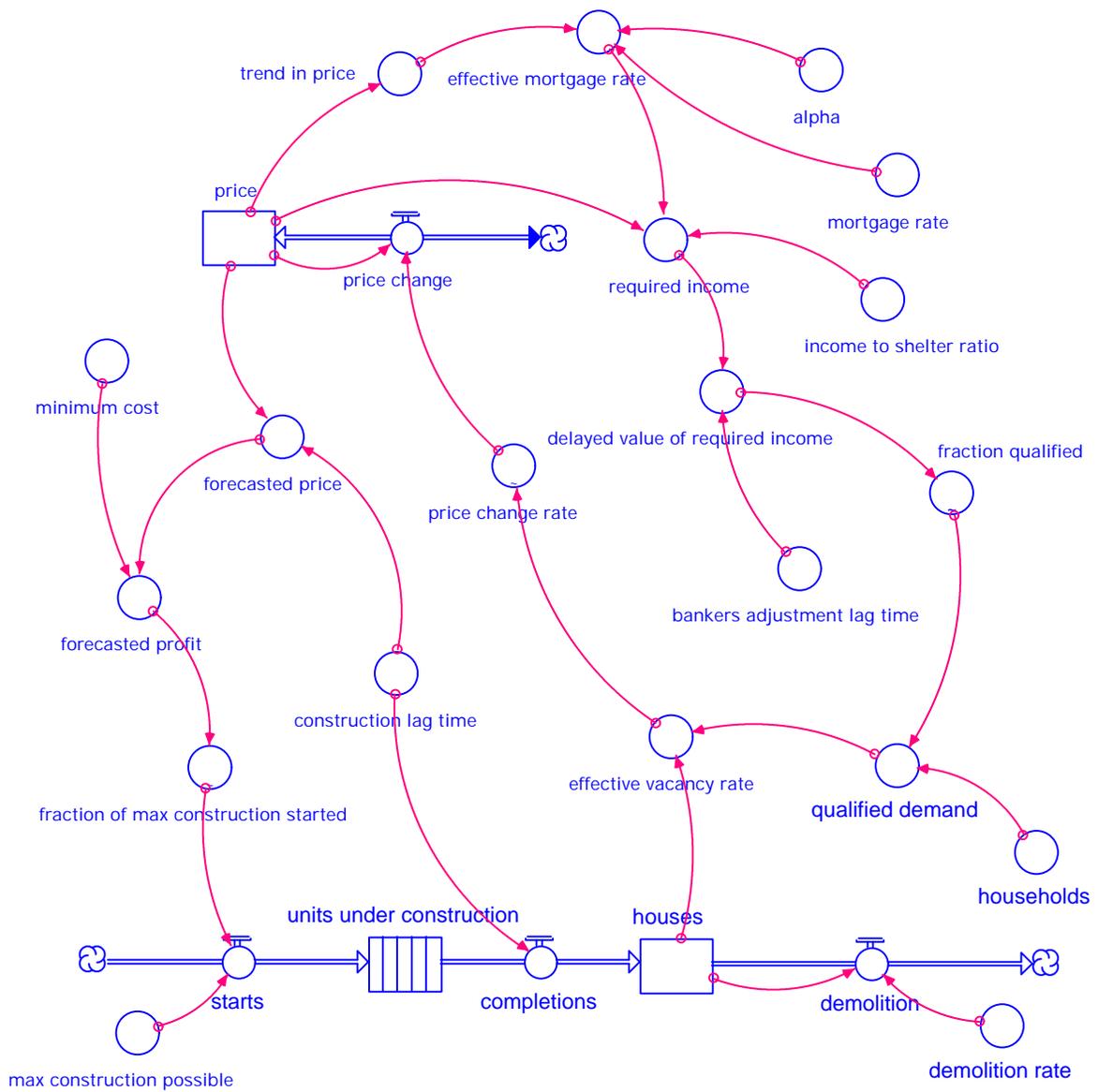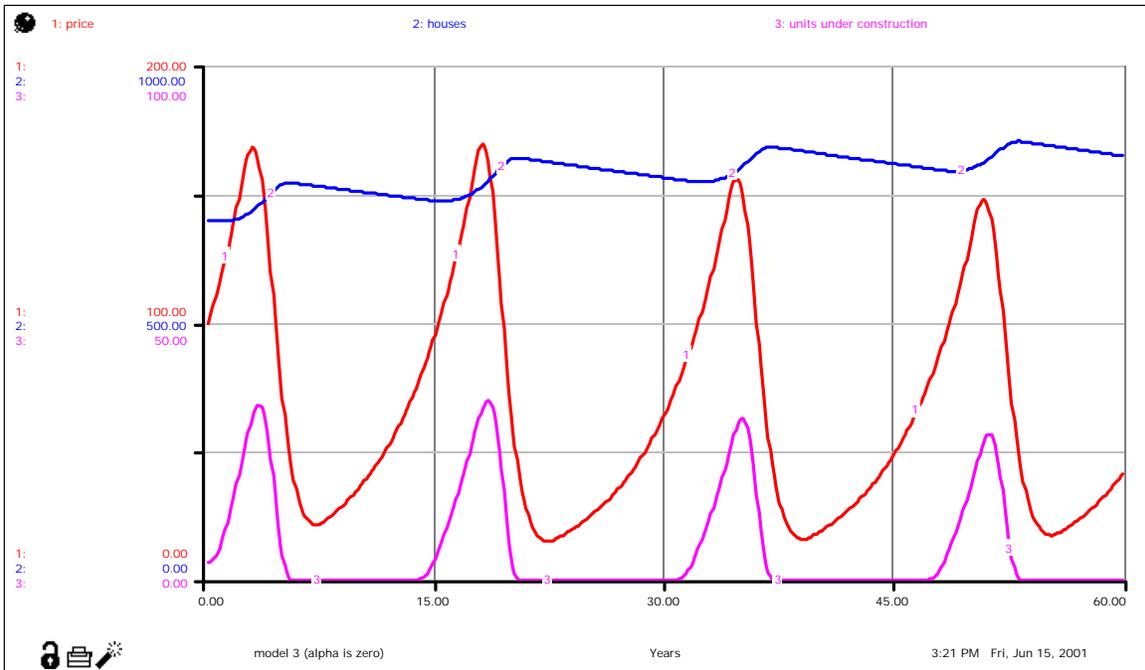Figure 2-11. Market reaction to a positive demand shock with exogenous expectation ($\alpha=0$), bankers adjustment delay and developers forecasted profit in model 3
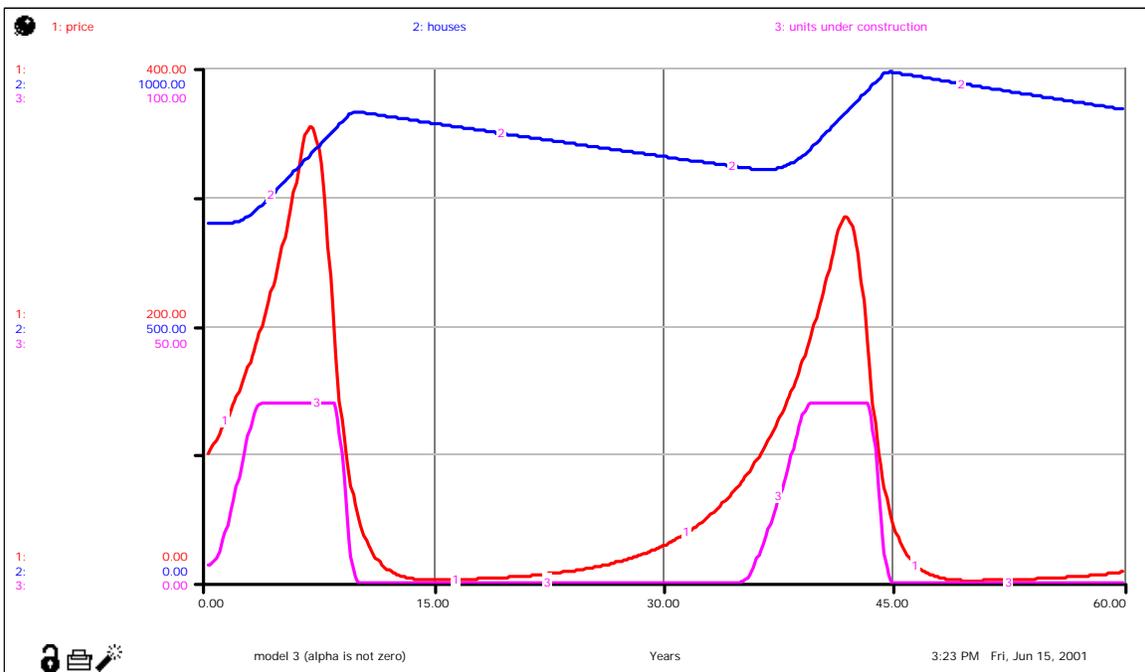

Figure 2-12. Market reaction to a positive demand shock with myopic expectation ($\alpha=0.32$), bankers adjustment delay and developers forecasted profit in model 3

We see a familiar diagram. It has minor differences with Figure 2-8, which describes market reaction to a positive demand shock with only bankers' adjustment delay. Comparison of the two results in Figure 2-11 and 2-8 tells that the amplitude of fluctuations are slightly different. In Figure 2-11, the highest value of price is $170,000; of houses is 855,000 units, of units under construction is 35,000. While in Figure 2-8, the highest value of price is $180,000; of houses is 810,000 units, of units under construction is 30,000. So, adding developers' forecasting of profitability leads to smaller fluctuations in price and higher fluctuations in stock of houses and new construction. It's a logical process to figure out why: when developers' forecasts are included in the model, developers forecast housing price based on price trend, while ignoring the construction pipeline. When they see good profits, they neglect the number of construction that is under development and will go to the market soon. Comparing with model 2, developers start/stop building sooner once there is a good/bad trend, which results in volatile stock of houses and new constructions. At the same time, since their faster responses to the market help to balance the supply and demand difference, the price fluctuations get smaller.

What if alpha is not zero? The second run sets the value of alpha to 0.32. All the other factors keep the same as in the first run. The results are shown in Figure 2-12. We see another familiar diagram. It's quite similar with Figure 2-9. Also, there are minor differences in fluctuations of price and houses. As the same pattern of comparison for the first run, in Figure 2-12, price fluctuation is smaller than in Figure 2-9, while houses fluctuation is bigger. The amplitudes of new constructions in the two figures are same: 35,000 units, which is the maximum construction possible. Maximum construction possible limits the amount of new construction for both of the case. The reason of the

differences is the same as described above. The periods of the cycles in Figure 2-12 is also very long, around 36 years, which makes the simulation look quite unrealistic.

After running model 2 and model 3 under same assumptions, we find that these two models tell similar stories. Both of them tell us that delays definitely result in cycles and fluctuations. It is one important reason that should be responsible for cycles in the market. At the same time, we realize that when alpha is set to zero, the simulation results do a good job in telling the same stories as what Hoyt and Sterman have described. But when alpha is not zero, the simulation results look quite unrealistic. DiPasquale and Wheaton's assumption of consumers and bankers expectation of future price inflation does not offer reasonable results in these two models. As a matter of fact, none of Hoyt, Sterman or Hoagland talk about how consumers and bankers expectation will result in mortgage rate change. In the real world, when housing price rises, consumers won't get a reduction in mortgage rate from bankers. Bankers adjust required income according to current housing price. Housing price changes frequently. But bankers can not change their required income as often as price change. The delayed value of required income decides the number of households qualified for purchasing houses. Meanwhile, developers build for their forecasted profit, which contains a delay in counting construction pipeline. These two delays make the simulation results more realistic.

So far, we find those delays of bankers and developers should be responsible for the cyclical behavior. Alpha should set to zero in further expansions of the model.

The Fourth model: Adding Zoning Restrictions

After making and testing the first 3 models, we come to the final stage of the thesis: checking whether Zoning boards can "reshape" the pattern of boom-and-bust by the way in which they issue construction permits. The fourth model, model 4, focuses on expanding model 3 with a section depicting Zoning boards involving in housing markets. Figure 2-13 shows model 4. The annual amount of permit application is decided by several factors. Developers have a target number of approved sites in their minds, which is the amount of permits that they want. They get permits approved from Zoning boards. But it is possible that permitted sites expire after average site shelf time. Developers take the expired sites into account while applying. Once permitted sites under construction, they would want new permits to fill the stock of approved sites up to the target site number. So, the amount of permit application is the total of target sites, sites under construction and sites expired, minuses the amount of approved sites. Since the initial value of the units under construction is 3,500, the value of the target sites is set to 35,000 based on the developers' desires to have options on "ten years worth of construction". An interview from a real estate expert (Klammt, 2001) revealed that: "10 years of approved site development would be a… developer's dream come true." The stock of permits under review is a conveyor, because it takes time for Zoning boards review permit applications. The transit time is 1 year. After permits are issued, they flow into the stock of approved sites. Part of the approved sites goes to the flow of sites under construction. While rest of them expire if they cannot be built on after average site shelf time. The two converters of standard value for annual starts and years worth of sites do not really involve in the process of sites approving. But they are indicators of real estate market factors. Notice the

46

Figure 2-13. Model 4: Adding Zoning Restrictions

47

connection between the old and new part of the model. The value of the flow of sites under construction in the new part is equal to the flow of starts in the old part. In model 3, maximum construction possible is a constant. But in model 4, it may vary depending on the number of approved sites. In order to compare the effects of zoning restrictions, maximum construction possible can be set to two values respectively. One is the amount of approved sites. The other is the old value of 35,000 units which is the value of the converter of Old Value. The transaction of controlling which of the two values is given to the maximum construction possible is made by the converter called "Use the Zoning Result?" If "Use the Zoning Result?" is 1, then the value of approved sites will be given to maximum construction possible; if it is 0, then the value of Old Value will be given. It is obvious to see that once the maximum construction possible is set to the constant of the old value, the new section of the zoning restriction actually is not involved in the simulation process (model 4 is the same as model 3). But once the value of approved sites is equal to maximum construction possible, the new section is linked to the old part of the model and Zoning boards play a role in the model.

The first step of testing model 4 is to check whether the new model is in equilibrium state under the assumption that has been used in the text: the number of households is set to 1,000,000. All the other parameters keep the same value as before. From previous tests, we know that alpha should set to zero. The testing results are shown in Figure 2-14. All the three essential variables are in equilibrium state. The equilibrium values are the same as described by DiPasquale and Wheaton: price is $100,000; houses are 700,000 units; units under construction are 3,500 units.
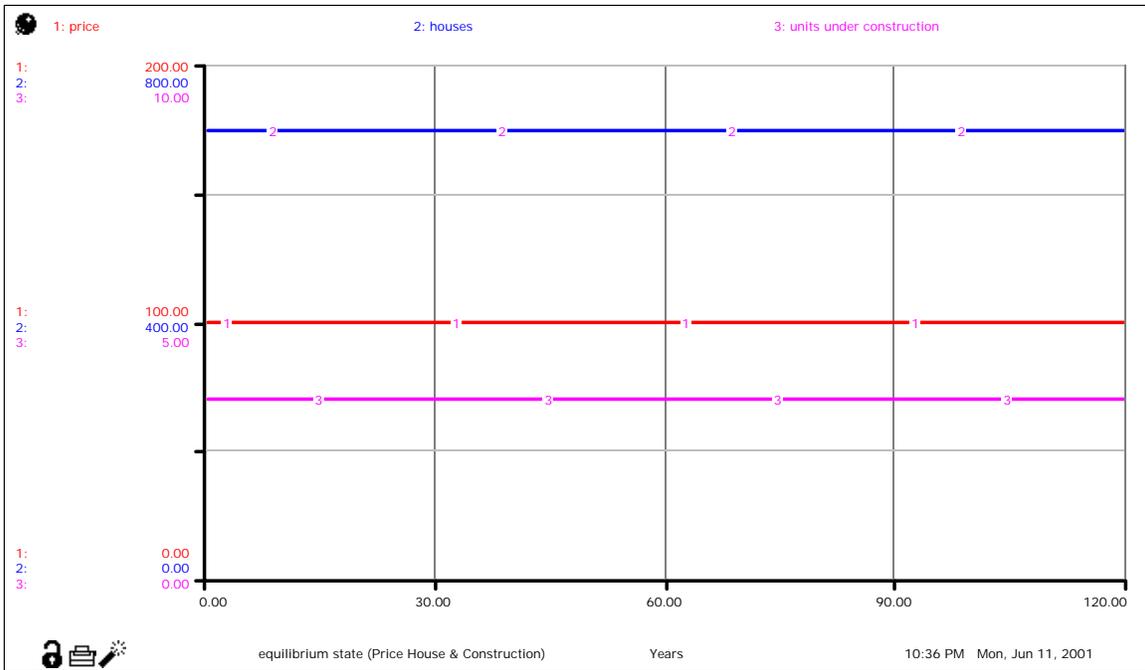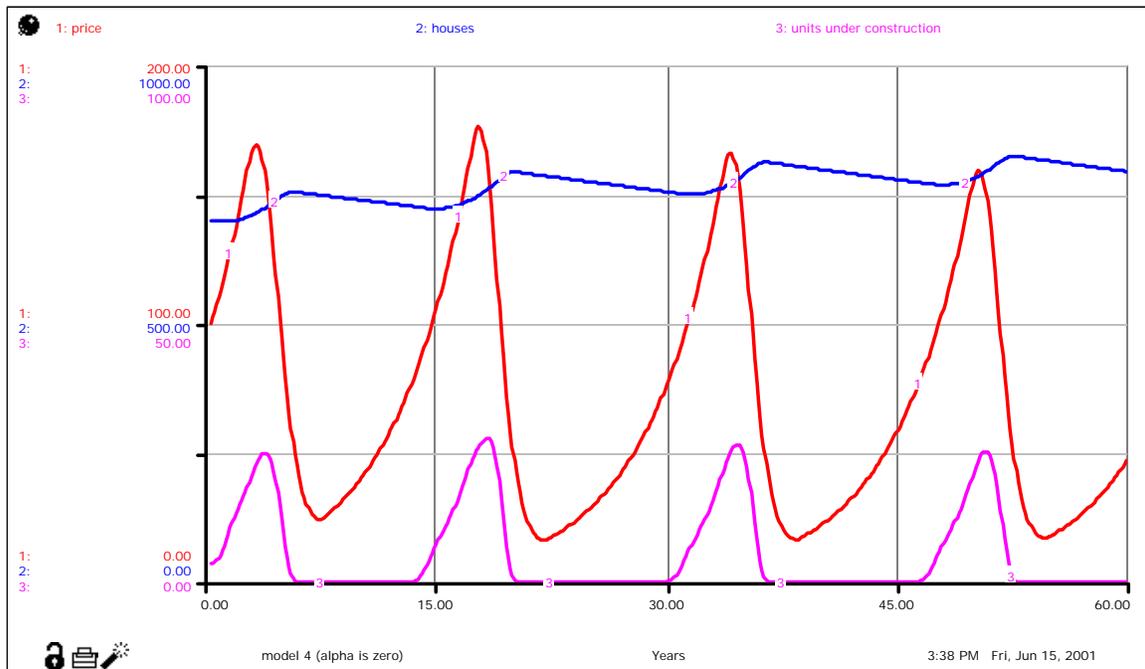
Figure 2-14. Equilibrium state in model 4

Figure 2-15. Market reaction to a positive demand shock and zoning restrictions involving in model 4

As in previous tests, a 10% increase in demand side is introduced into model 4. The number of households rises from 1,000,000 to 1,100,000. If the value of "Use the Zoning Result?" is set to 0, the simulation results are identical to the results of model 3, shown in Figure 2-11. If "Use the Zoning Result?" is set to 1, the simulation results shall tell us what will happen when Zoning boards are involved in the market. Figure 2-15 shows the results. The results seem like what we've got in model 3. The general pattern is similar as in Figure 2-11. A detailed comparison shows that amplitudes of price, houses and new constructions are different. Comparing with results in model 3, the results in model 4 show smaller amplitudes in houses and construction, while larger amplitudes in prices. To show these differences in one diagram, Figure 2-16, 2-17 and 2-18 provide comparative graphs showing the two simulation results of new construction, houses and prices respectively. Curves labeled 1 in each of the three figures represent simulation results with Zoning boards involved; curves labeled 2 represent simulation results with the Zoning boards not involved.

Although zoning restrictions' effects are not significant, evidence of Zoning boards functions can be found. With Zoning boards involved, fluctuations of new constructions and houses cycles are smaller, which is helpful to solve the problem of boom-and-bust. The analysis of why the amplitudes of price are even larger is a logical process. With the zoning restrictions, there is one more delay before developers start building. They need to get their applications approved by the Zoning boards. The permit issuing process gives developers fewer choices and thus the housing price receives more freedom, which results
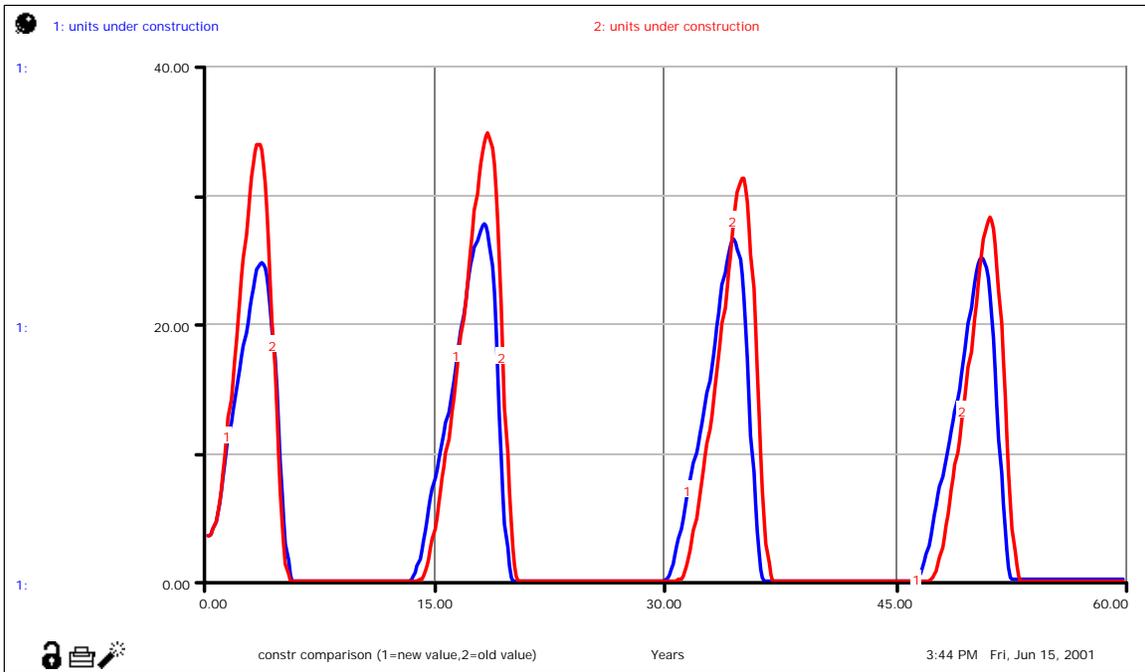
Figure 2-16. Comparative test for new construction in model 4. Run 1, Zoning involved; Run 2, Zoning not involved.
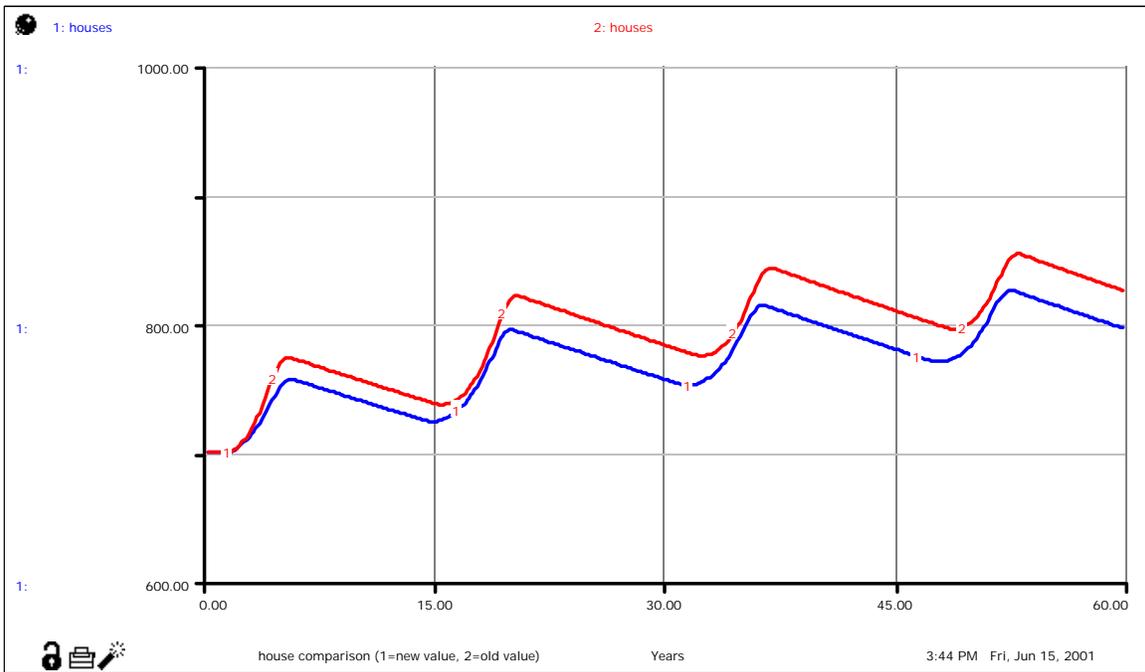
Figure 2-17. Comparative test for the amount of houses in model 4. Run 1, Zoning involved; Run 2, Zoning not involved.
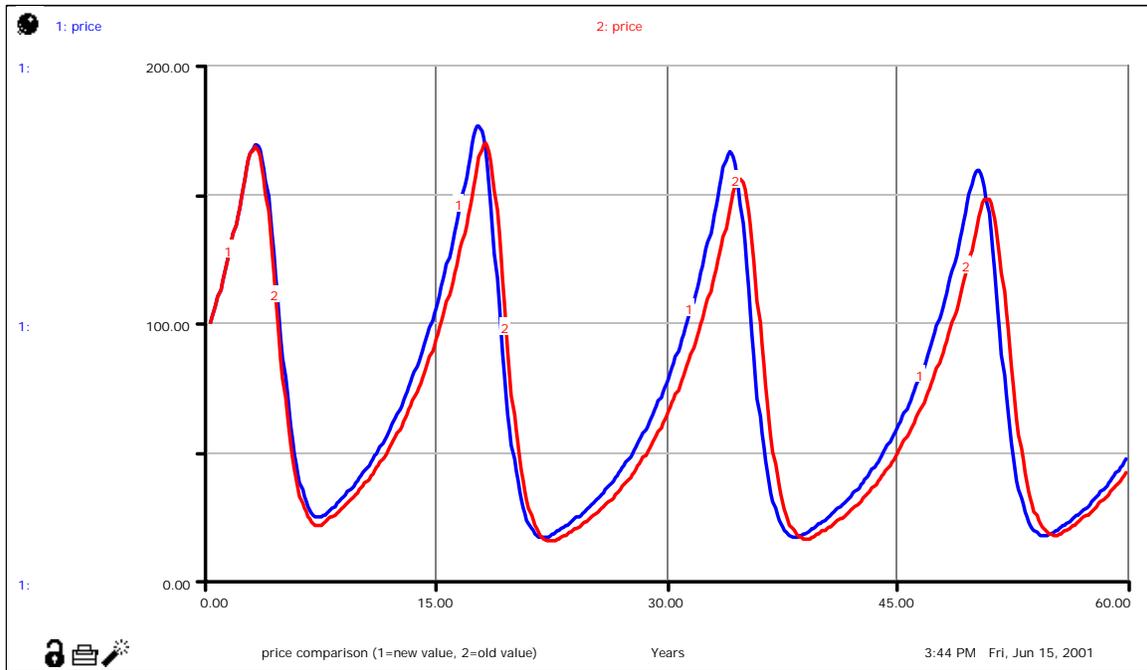
Figure 2-18. Comparative test for housing price in model 4. Run 1, Zoning involved; Run 2, Zoning not involved.

in bigger cycles. But that's not the only effect; developers' less choices also lead to smaller cycles in new constructions and eventually less amplitudes in the stock of houses.

These tests with model 4 indicate that Zoning boards are helpful to some extent in housing markets. It helps reducing the fluctuation of cycles in new construction and existing houses by issue construction permits. But the amplitudes of price cycles may increase slightly. Zoning boards can not significantly reshape the boom-and-bust pattern in housing markets. Cyclical behaviors still exist.

History shows that real estate markets have not avoided cycles after Zoning boards are set in cities or communities. Although "all land use controls affect the cost and availability of housing in some way" (Kelly, 1993), Warner and Molotch argued that: "we found scant evidence that controls had much of an effect, particularly on the supply of new housing ---- the kind of construction most controls had been aimed at curtailing."

Maisel (1970) pointed out that "the probabilities of continued instability ... appear to remain unaltered. Basic factors of lags, acceleration, and poor information have not changed, and the system continues to be plagued by unstable forces. Only a major increase in knowledge, combined with government policies specifically designed to compensate for, rather than accentuate, normal market instability would appear to offer much hope for improvement."

However, it is necessary to point out that the above tests operate with a very large number of pre-approved sites: ten years worth of construction. This assumption was used to allow model 4 to match model 1, 2 and 3. The role of Zoning boards could be studied further with a smaller number of approved sites.

CHAPTER THREE

SUMMARY AND CONCLUSIONS

Summary

By building a system dynamics version of DiPasquale and Wheaton's mathematical model, I have verified the same general patterns as published in the text under the same assumptions. Model 1 tells us that consumers and bankers expectations of future housing price inflation play a critical role in shaping market behaviors. With exogenous expectations, housing markets' response to shocks can be stable. New equilibrium state can be achieved by the market itself after about 30 years. No cyclical behavior would happen in housing markets with exogenous expectations. But with myopic expectations, one single shock in the market can result in sustained oscillations in housing price, stock of houses and the amount of new constructions. The market can not balance itself to new equilibrium state.

Model 2 expands upon model 1 by slowing the action of the House Purchase Loop. A bankers' adjustment delay was included to represent the time for households and their bankers to adjust to changes in housing prices. Model 3 expands on model 2 by simulating the developers' attempt to forecast future housing prices. The forecast looks 1 year into the future to allow the developers to estimate profitability at the time when newly constructed houses would be available for sale. These expansions allow for more realistic simulations. Tests of these models reveal that the cycles arise from the delayed action of the House Purchase Loop and the House Building Loop. The cycles are also due to the assumption that developers neglect to count houses under construction in their

estimate of future profitability. This combination of assumptions produces a construction cycle with a reasonable period, and the simulations are consistent with the descriptions by Hoyt, Sterman and Hoagland. These models follow the same "stock-flow" approach used effectively by DiPasquale and Wheaton, and they extend their explanation of cyclical behavior in metropolitan housing markets.

Model 4 expands upon model 3 with simulations of zoning restrictions involving in housing markets. With Zoning boards functioning, changes in the amplitudes of fluctuations are found in cyclical movements in the market. But the boom-and-bust pattern is not avoided. The tests show that Zoning boards can help reduce the market's cyclical behavior to some extent, but it can not reshape the cyclical pattern in a significant manner.

Further Expansions

Model 3 is mature simulation model compared to model 1 or model 2. It includes bankers' response in House Purchase Loop and developers' response in House Building Loop. Comparing to the other two models, model 3 is able to simulate housing markets more realistically.

However, the real world is much more complex than the model simulations, especially in bigger cities: "the areas are greater, the population is diverse, life style vary, and the objectives are much different." (Siegan, 1972) There are hundreds of additions which can be put into the model: distinguishing between big houses and small houses, between permanent homes and mobile homes, between rich households and poor households, etc. Some important factors, which are not included into the model, may

make huge influences on housing markets. For instance, transportation, may lead to housing developments to very different spatial patterns while urban sprawl. It is said that "until the early twentieth century there was no precedent in human culture for cities that were not compact and centralized." (Kunstler, 1996) Changing the spatial pattern of housing development may eventually result in changing purchasing and developing behaviors. Muth (1970) suggests that "housing prices decline with distance; prices decline at a decreasing rate with distance." For households, the most important decision of purchasing a house may not be "how much" the house costs, but "where" that home is ---- because a fantastic sum of money on cars over time can be saved if living close to both working and shopping. House buyers may rather purchase a house in suburban area or nearby towns and commute every day. Developers may apply for sites outside of tightly controlled areas. Simulating surrounding residential area developments and how they balance with the traditional residential areas may be interesting for future model development.

For model 4, the expansion section of Zoning boards involving is a very simplified one. Permit application denying process, distributions of approved sites, influences of economy movements on permit granting process, and so on, are not included in the model. "The purpose of zoning is to lessen congestion in the streets; to prevent the overcrowding of land and buildings; and to avoid undue concentration of the population." (Pearson, 1973) The function of the zoning section in model 4 is far less than what Pearson specified. Further studies could expand the model into a three-dimension one to describe how both temporal and spatial factors work together to shape housing markets.

Further studies in cyclical behavior in metropolitan housing markets may expand the models to make the simulations more realistic and holistic. The models, then, can serve better as a "teaching tool". They could also be helpful for planners to understand the cyclical behavior.

Conclusions

This research tests the mechanism of cyclical movements in housing markets by system dynamics modeling. The simulation results represent the cyclical behaviors of housing market in a realistic manner, building upon the stock-flow approach by DiPasquale and Wheaton. The final simulations reveal that zoning restrictions do not reshape the boom-and-bust pattern in a significant manner.

REFERENCES

Collison, Koder M. 1974. *The Developers' Dictionary and Hankbook.* Lexington Books.

DiPasquale, Denise and Wheaton, William C. 1996. *Urban Economics and Real Estate Markets.* Prentice Hall, Englewood Cliff, NJ 07632.

Dumke, Glenn S. 1944. *The Boom of the Eighties in South California.* San Marino, California, Huntington Library.

Ford, Andrew. 1999. *Modeling the Environment, An Introduction to System Dynamics Modeling of Environmental Systems.* Island Press.

Hoagland, Henry E. 1949. *Real Estate Principles.* McGraw-Hill, New York, Second Eddition.

Hoyt, Homer. 1933. *One Hundred Years of Land Values in Chicago, the Relationship of the Growth of Chicago to the Rise in Its Land Values, 1830-1933.* The University of Chicago Press.

Johnsich, John Robert. 1975. *Modern Real Estate Dictionary.* Canfield Press San Francisco, A Department of Harper & Row, Publishers, Inc.

Kelly, Eric Damian. 1993. *Managing Community Growth, Policies, Techniques, and Impacts.* Praeger Publishers.

Klammt, Fred. 2001. Interview by Andrew Ford and author through email. Pullman, WA.

Kunstler, James Howard. 1996. *Home form Nowhere, Remaking Our Everyday World for the Twenty-First Century.* Simon & Schuster

Maisel, Sherman J., 1970. "A Theory of Fluctuations in Residential Construction Starts", *Urban Analysis, Readings in Housing and Urban Development.* page 135. Scott, Foresman and Company.

Muth, Richard F., 1970. "The Spatial Structure of the Housing Market", *Urban Analysis, Readings in Housing and Urban Development.* Page 197. Scott, Foresman and Company.

Nicholas, James with Olsen, Mary C., Costomiris, Joyce, and Levesque, Adele. 1982. *State Regulation/Housing Prices.* New Brunswick, N.J., Center for Urban Policy Research.

O'connell, Daniel J. 1982. *Apartment Building Valuation, Finance and Investment Analysis.* New York : Wiley.

Pearson, Karl G. 1973. *Real Estate; Principles & Practices.* Grid, Inc.

Raymond G. Torto and William C. Wheaton. 1998. *Real Estate Cycles and Outlook 1999.* Torto Wheaton Research.

Siegan, Bernard H. 1972. *Land Use Without Zoning.* Lexington Books.

Sterman, John D. 2000. *Business Dynamics, Systems Thinking and Modeling for a Complex World.* Irwin McGraw-Hill Companies, Inc.

Warner, Kee and Molotch, Harvey. 2000. *Building Rules, How Local Controls Shape Community Environments and Economies.* Westview Press.

Weimer, Arthur, Hoyt, Homer and Bloom, George F. 1972. *Principles of Urban Real Estate*. New York, Ronald Press Co., Sixth Eddition.

Wheaton, William C., Torto, Raymond G., Evans, Peter and Torto Wheaton Research. 1995. *The Cyclic Behavior of the Greater London Office Market*. Torto Wheaton Research.

Zhang, Jane X. and Ford, Andrew. 2000. *The Real Estate Construction Cycle*. Andrew Ford's Home Page. Program in Environmental Science and Regional Planning, Washington State University. Available from: http://www.wsu.edu/~forda/welcome.html Most Recent Accessed on 6/18/2001.

APPENDIX

1. Equations of model 1

```
houses(t) = houses(t - dt) + (completions - demolition) * dt
INIT houses = 700
INFLOWS:
completions = CONVEYOR OUTFLOW
OUTFLOWS:
demolition = houses*demolition_rate
price(t) = price(t - dt) + (price_change) * dt
INIT price = 100
INFLOWS:
price_change = price*price_change_rate
units_under_construction(t) = units_under_construction(t - dt)+(starts -
completions) * dt
INIT units_under_construction = 3.5
      TRANSIT TIME = 1
      INFLOW LIMIT = INF
      CAPACITY = INF
INFLOWS:
starts = max_construction_possible*fraction_of_max_construction_started
OUTFLOWS:
completions = CONVEYOR OUTFLOW
alpha = 0
demolition_rate = 0.005
effective_mortgage_rate = mortgage_rate-trend_in_price*alpha
effective_vacancy_rate = 1-qualified_demand/houses
households = 1100
income_to_shelter_ratio = 4
max_construction_possible = 35
minimum_cost = 90
mortgage_rate = .1
profit = price-minimum_cost
qualified_demand = households*fraction_qualified
required_income = price*effective_mortgage_rate*income_to_shelter_ratio
trend_in_price = TREND(price,1,0)
fraction_of_max_construction_started = GRAPH(profit)
(0.00, 0.00), (10.0, 0.1), (20.0, 0.2), (30.0, 0.3), (40.0, 0.4), (50.0,
0.5), (60.0, 0.6), (70.0, 0.7), (80.0, 0.8), (90.0, 0.9), (100, 1.00)
fraction_qualified = GRAPH(required_income)
(0.00, 1.00), (10.0, 0.915), (20.0, 0.83), (30.0, 0.75), (40.0, 0.665),
(50.0, 0.575), (60.0, 0.5), (70.0, 0.41), (80.0, 0.33), (90.0, 0.245),
(100, 0.155)
price_change_rate = GRAPH(effective_vacancy_rate)
(0.00, 0.2), (0.025, 0.1), (0.05, 0.00), (0.075, -0.1), (0.1, -0.2),
(0.125, -0.3), (0.15, -0.4), (0.175, -0.5), (0.2, -0.6), (0.225, -0.7),
(0.25, -0.8)
```

2. Equations of model 2

```
houses(t) = houses(t - dt) + (completions - demolition) * dt
INIT houses = 700
INFLOWS:
completions = CONVEYOR OUTFLOW
OUTFLOWS:
demolition = houses*demolition_rate
price(t) = price(t - dt) + (price_change) * dt
INIT price = 100
INFLOWS:
price_change = price*price_change_rate
units_under_construction(t) = units_under_construction(t - dt)+(starts -
completions) * dt
INIT units_under_construction = 3.5
      TRANSIT TIME = 1
      INFLOW LIMIT = INF
      CAPACITY = INF
INFLOWS:
starts = max_construction_possible*fraction_of_max_construction_started
OUTFLOWS:
completions = CONVEYOR OUTFLOW
alpha = 0
bankers_adjustment_lag_time = 3
delayed_value_of_required_income =
SMTH3(required_income,bankers_adjustment_lag_time,40)
demolition_rate = 0.005
effective_mortgage_rate = mortgage_rate-trend_in_price*alpha
effective_vacancy_rate = 1-qualified_demand/houses
households = 1100
income_to_shelter_ratio = 4
max_construction_possible = 35
minimum_cost = 90
mortgage_rate = .1
profit = price-minimum_cost
qualified_demand = households*fraction_qualified
required_income = price*effective_mortgage_rate*income_to_shelter_ratio
trend_in_price = TREND(price,1,0)
fraction_of_max_construction_started = GRAPH(profit)
(0.00, 0.00), (10.0, 0.1), (20.0, 0.2), (30.0, 0.3), (40.0, 0.4), (50.0,
0.5), (60.0, 0.6), (70.0, 0.7), (80.0, 0.8), (90.0, 0.9), (100, 1.00)
fraction_qualified = GRAPH(delayed_value_of_required_income)
(0.00, 1.00), (10.0, 0.915), (20.0, 0.83), (30.0, 0.75), (40.0, 0.665),
(50.0, 0.575), (60.0, 0.5), (70.0, 0.41), (80.0, 0.33), (90.0, 0.245),
(100, 0.155)
price_change_rate = GRAPH(effective_vacancy_rate)
(0.00, 0.2), (0.025, 0.1), (0.05, 0.00), (0.075, -0.1), (0.1, -0.2),
(0.125, -0.3), (0.15, -0.4), (0.175, -0.5), (0.2, -0.6), (0.225, -0.7),
(0.25, -0.8)
```

3. Equations of model 3

```
houses(t) = houses(t - dt) + (completions - demolition) * dt
INIT houses = 700
INFLOWS:
completions = CONVEYOR OUTFLOW
        TRANSIT TIME = construction_lag_time
OUTFLOWS:
demolition = houses*demolition_rate
price(t) = price(t - dt) + (price_change) * dt
INIT price = 100
INFLOWS:
price_change = price*price_change_rate
units_under_construction(t) = units_under_construction(t - dt)+(starts -
completions) * dt
INIT units_under_construction = 3.5
        TRANSIT TIME = varies
        INFLOW LIMIT = INF
        CAPACITY = INF
INFLOWS:
starts = max_construction_possible*fraction_of_max_construction_started
OUTFLOWS:
completions = CONVEYOR OUTFLOW
        TRANSIT TIME = construction_lag_time
alpha = 0
bankers_adjustment_lag_time = 3
construction_lag_time = 1
delayed_value_of_required_income =
SMTH3(required_income,bankers_adjustment_lag_time,40)
demolition_rate = 0.005
effective_mortgage_rate = mortgage_rate-trend_in_price*alpha
effective_vacancy_rate = 1-qualified_demand/houses
forecasted_price = FORCST(price,2,construction_lag_time,0)
forecasted_profit = forecasted_price-minimum_cost
households = 1100
income_to_shelter_ratio = 4
max_construction_possible = 35
minimum_cost = 90
mortgage_rate = .1
qualified_demand = households*fraction_qualified
required_income = price*effective_mortgage_rate*income_to_shelter_ratio
trend_in_price = TREND(price,1,0)
fraction_of_max_construction_started = GRAPH(forecasted_profit)
(0.00, 0.00), (10.0, 0.1), (20.0, 0.2), (30.0, 0.3), (40.0, 0.4), (50.0,
0.5), (60.0, 0.6), (70.0, 0.7), (80.0, 0.8), (90.0, 0.9), (100, 1.00)
fraction_qualified = GRAPH(delayed_value_of_required_income)
(0.00, 1.00), (10.0, 0.915), (20.0, 0.83), (30.0, 0.75), (40.0, 0.665),
(50.0, 0.575), (60.0, 0.5), (70.0, 0.41), (80.0, 0.33), (90.0, 0.245),
(100, 0.155)
price_change_rate = GRAPH(effective_vacancy_rate)
(0.00, 0.2), (0.025, 0.1), (0.05, 0.00), (0.075, -0.1), (0.1, -0.2),
(0.125, -0.3), (0.15, -0.4), (0.175, -0.5), (0.2, -0.6), (0.225, -0.7),
(0.25, -0.8)
```

4. Equations of model 4

```
sites_expired) * dt
INIT approved_sites = 35
INFLOWS:
permits_granted = CONVEYOR OUTFLOW
OUTFLOWS:
sites_under_construction = starts
sites_expired = approved_sites/average_site_shelf_time
houses(t) = houses(t - dt) + (completions - demolition) * dt
INIT houses = 700
INFLOWS:
completions = CONVEYOR OUTFLOW
     TRANSIT TIME = construction_lag_time
OUTFLOWS:
demolition = houses*demolition_rate
permits_under_review(t) = permits_under_review(t - dt) +
(permits_application - permits_granted) * dt
INIT permits_under_review = 7
     TRANSIT TIME = 1
     INFLOW LIMIT = INF
     CAPACITY = INF
INFLOWS:
permits_application = target_sites-
approved_sites+sites_under_construction+sites_expired
OUTFLOWS:
permits_granted = CONVEYOR OUTFLOW
price(t) = price(t - dt) + (price_change) * dt
INIT price = 100
INFLOWS:
price_change = price*price_change_rate
units_under_construction(t) = units_under_construction(t - dt) + (starts
- completions) * dt
INIT units_under_construction = 3.5
     TRANSIT TIME = varies
INFLOW LIMIT = INF
     CAPACITY = INF
INFLOWS:
starts = max_construction_possible*fraction_of_max_construction_started
OUTFLOWS:
completions = CONVEYOR OUTFLOW
     TRANSIT TIME = construction_lag_time
alpha = 0
average_site_shelf_time = 10
bankers_adjustment_lag_time = 3
construction_lag_time = 1
delayed_value_of_required_income =
SMTH3(required_income,bankers_adjustment_lag_time,40)
demolition_rate = 0.005
effective_mortgage_rate = mortgage_rate-trend_in_price*alpha
effective_vacancy_rate = 1-qualified_demand/houses
forecasted_price = FORCST(price,2,construction_lag_time,0)
forecasted_profit = forecasted_price-minimum_cost
households = 1100
income_to_shelter_ratio = 4
max_construction_possible = if Use_the_Zoning_Result?=1 then
approved_sites else Old_Value
minimum_cost = 90
mortgage_rate = .1
```

```
Old_Value = 35
qualified_demand = households*fraction_qualified
required_income = price*effective_mortgage_rate*income_to_shelter_ratio
standard_value_for_annual_starts = 3.5
target_sites = 35
trend_in_price = TREND(price,1,0)
Use_the_Zoning_Result? = 0
years_worth_of_sites = approved_sites/standard_value_for_annual_starts
fraction_of_max_construction_started = GRAPH(forecasted_profit)
(0.00, 0.00), (10.0, 0.1), (20.0, 0.2), (30.0, 0.3), (40.0, 0.4), (50.0,
0.5), (60.0, 0.6), (70.0, 0.7), (80.0, 0.8), (90.0, 0.9), (100, 1.00)
fraction_qualified = GRAPH(delayed_value_of_required_income)
(0.00, 1.00), (10.0, 0.915), (20.0, 0.83), (30.0, 0.75), (40.0, 0.665),
(50.0, 0.575), (60.0, 0.5), (70.0, 0.41), (80.0, 0.33), (90.0, 0.245),
(100, 0.155)
price_change_rate = GRAPH(effective_vacancy_rate)
(0.00, 0.2), (0.025, 0.1), (0.05, 0.00), (0.075, -0.1), (0.1, -0.2),
(0.125, -0.3), (0.15, -0.4), (0.175, -0.5), (0.2, -0.6), (0.225, -0.7),
(0.25, -0.8)
```