

Real Estate Cycles: A Theory Based on Stock-Flow Structure of Durable Goods Markets

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Abstract

In this paper by means of a simple system dynamics model, we have addressed a cycle-producing mechanism in the owner-occupied real estate market which has not been discussed in the real estate economics literature before. This mechanism is based on accumulation of supply and demand which arises from specific stock-flow structure of a durable goods market like the owner-occupied market. Comparison between our model and a famous model of rental market (Wheaton, 1999) shows that despite the rental market, in the owner-occupied market an increase in durability of buildings leads to more intensive oscillations. Also the effect of price elasticity of supply on the cycles in the owner-occupied market is much more complex than that of the rental market. Furthermore a model integrating the two markets is developed. Model analysis reveals that the interrelations between the two markets make the effect of some parameters on the rental market cycles different from what is suggested by the rental market model. Our work uncovers the rich dynamic complexity of the real estate system and can serve as a good example of applying systems thinking principles to complex real world problems.

Keywords: Real Estate Cycles; Owner Occupied Market; Durable Goods; Cycle-Producing Mechanism (CPM); Dynamic Complexity; System Dynamics Modeling.

1. Introduction

Real estate market cycles are common to most countries (Harris, 2003) Real estate cycles have been of great importance to investors and researchers, due to considerable effects on capital

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return and economic failure or success (Pyhrr, 2003). The real estate cycles have effects not only on economy, but also on political issues and even society (Weiss, 1991). The interdisciplinary nature of the field, along with the numerous research done in this area would create a number of classifications to organize the studies in the field (Pyhrr, 2003). All of these issues indicate that the real estate cycles are of great importance and require a detailed investigation.

Analysis of dynamic behavior of the real estate cycles is a very complex task to be performed (ECB, 2003; Harris, 2003). But a more convenient approach is to employ the dynamic modeling based on simulation to analyze systems with high dynamic complexity (Forrester, 1991; Homer and Olivia, 2001). In spite of providing the value added, the approaches not based upon dynamic modeling and simulation may cause misunderstanding. For example Kaiser (1997) considers cycles with different periods resulting from different roots, while the results of dynamic modeling done by Wheaton (1999) show that by changing market parameters, the period of cycles produced by the same mechanism changes. Reed (2002) and Wilson and Okunev (1998) have employed Fourier Analysis Method to separate different cycles. They postulated that cycles produced by different cycle-producing mechanisms² (CPMs) show their effects on the time series of real estate cycles in an additive fashion. But as simulation results in this paper suggest, when there is a CPM in the real estate market, the other CPMs may have nonlinear effects (such as changing the period of the previous cycles or changing the reaction of the cycles in relation to changes in market parameters) rather than adding their own cycles to the time series, which is a linear effect and can be analyzed by Fourier tools.

There are good samples of dynamic modeling in real estate cycles literature. In these models, the focus is on the *structure* producing cyclical dynamic *behavior* in market. For example Malpezzi and Wachter (2003) developed a dynamic model to study the amplifying effects of speculative activities on real estate cycles. Wheaton (1999) built his famous stock-flow model to study the cyclical behavior of price in the office rental market and showed that the supply lag is the main factor causing cycles. In fact each of these models focuses on the recognition of one of the CPMs.

In this paper, by means of a System Dynamics model for owner-occupied real estate market (which is a simple model in detail, but dynamically complex), we introduce a CPM which exists in owner-occupied markets and has never been discussed in real estate economics literature before. We introduce this CPM based upon a comparison between owner-occupied and rental markets. For this purpose, we compare our model of owner-occupied market and a famous model of office rental market (Wheaton, 1999). By conducting experiments on the models, we will show that unlike the rental market model, a model for durable goods market like owner-occupied

²Cycle-producing mechanisms cause cyclical dynamic behavior in real estate markets. There are some examples of cycle-producing mechanisms like supply lag and speculation. From now on, for the purpose of simplification, we will use abbreviated form, **CPM**, instead of cycle-producing mechanism.

market model, even after removing the supply lag, still exhibits cyclical behavior. Then we develop a theory in order to describe the CPM producing these remaining cycles and we show that such a CPM may cause differences between characteristics of cycles in rental and owner-occupied markets.

Finally, we argue that because of the interrelation between owner-occupied and rental markets, the CPM introduced for owner-occupied markets, may affect the characteristics of the rental market cycles and neglecting this CPM may give rise to a lot of trouble, even when we are trying to make policy for only rental market.

2. Structures of the Two Models

2.1 Structure of office rental market model (Wheaton, 1999).

Wheaton (1999) introduced his model with mathematical equations (not in SD format). The following SD model (figure 1) has the same equations. However, for more clarification, the names of some variables have been modified.

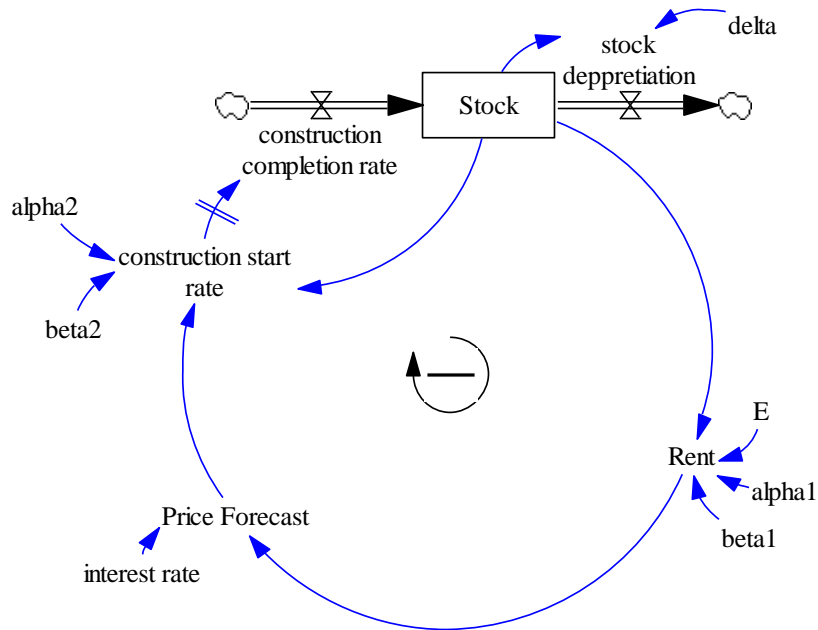


Figure 1. Rental Market Model Structure (Wheaton, 1999)³

³ Although, this model deals with rental market, one can see that there is a parameter named "price forecast". That is because Wheaton makes a distinction between constructors and landlords. Here, price is related to Asset Market in which constructors build houses and sell them to landlords. Rent is related to space market in which landlords supply those houses in Space Market. Price is of no importance to us in this regard, and if constructors and landlords are considered to be the same, price forecast (and Asset Market) is (are) omitted from the model and "rent forecast" affects construction directly, without influencing the behavior

The only stock variable in this model is “Stock” showing space available for rent. Despite having just one stock, due to one “fixed delay”, the model is not first order. This stock increases via completion of under construction units (i.e. inflow) and decreases via depreciation (i.e. outflow). This stock is supplied as rental. The rent is characterized through equating the stock with the demand. The price of one unit of “Stock” is forecasted by dividing current rent into interest rate (Wheaton, 1999), and this price forecast in turn, determines construction (the higher price, the higher construction). Construction determines “stock increase rate” after some years delay.

In this model, for the purpose of simplification it is supposed that the rent adjusts to the amount determined by supply demand curve immediately. Therefore, in this model, rent is not a stock variable. Incidentally, it is supposed that landlords supply all “Stock” regardless of rent (supply curve is flat in the short run⁴). Therefore, rent is determined by equating demand with “Stock”⁵.

Note that in spite of being concerned with “office” rental market the model can be applied to “housing” rental market. The only modification needed, which does not affect the model behavior, is to substitute “Employment” (E) with “Population”.

2.2 The Structure of Owner-Occupied Market Model.

The model structure is depicted in figure 2. The structure of this model is similar to the Wheaton’s rental model but there exist certain differences between them. Some are simple and small. For instance delay in construction is modeled as a first-order delay rather than a fixed delay. In addition, in this model, price doesn’t adjust to the amount determined by supply and demand immediately. Rather, the price is modeled as a stock variable whose flow is determined by demand-supply ratio. If supply and demand are equal, the flow is zero and if demand-supply ratio rises, the flow increases (Mashayekhi, 2006; Sterman, 2000).

But the main difference between the two models is concerned with the stock-flow structures. This difference arises from particular characteristics of owner-occupied market, as a durable goods market, which are absent in rental market.

of the model. But remaining loyal to Wheaton’s equations, we do not remove the price forecast parameter from the Wheaton’s model.

⁴ Wheaton postulates that supply is nearly inelastic in the short run (*i.e.* the period of time in which stock change is disregarded). This approximation has been confirmed in real estate economics issues (DiPasquale, 1997; Herring, et al., 2002). But in the long run, this approximation is not appropriate. Because rent affects construction and construction in turn, after some delays, affects supply. Consequently, we note that the price elasticity of supply, brought up in Section 4, is in fact the price elasticity of construction.

⁵ Demand = $\alpha_1 * Rent^{\beta_1}$, therefore equating “Stock” with “Demand” results in $Rent = (Stock / (\alpha_1 * E))^{(-1/\beta_1)}$. Therefore, despite being used, demand is not displayed in the model as a variable.

Goods traded in owner-occupied market are basically different from those of rental market. Goods traded in rental real estate markets are not real estate but the use of real estate for a certain period of time. Seeking simplicity we can say one year use of real estate. This is not durable goods, because it endures less than one year. In fact, “Stock” has a role equivalent to “Production Capacity”, because if “Stock” increases, the landlords can supply more goods (i.e. “the use of real estate for one year”). This is exactly the role of “Production Capacity” in a factory.

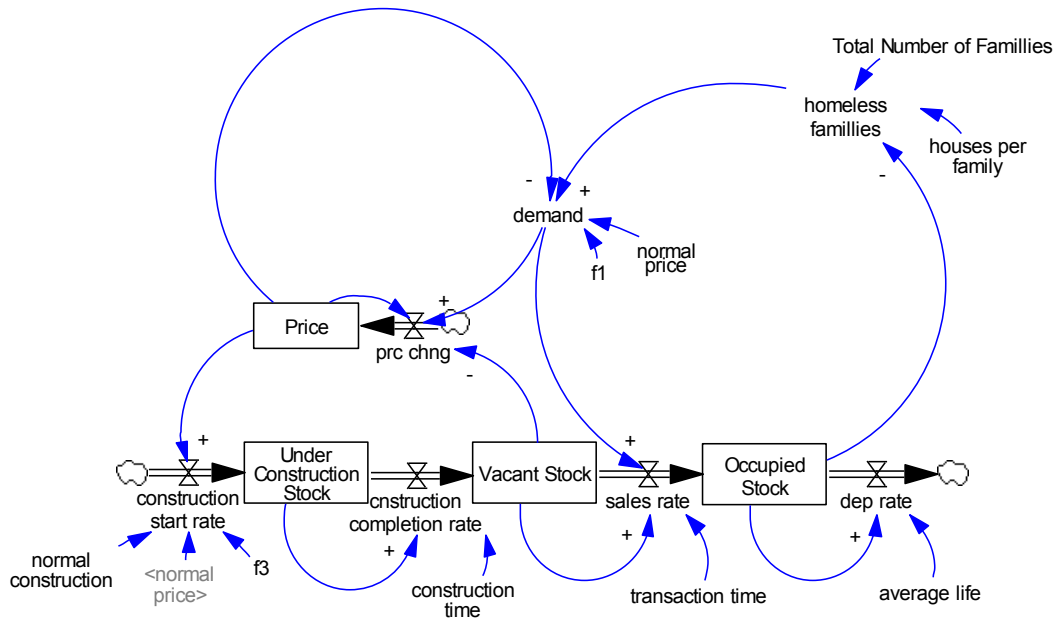


Figure 2. Owner-Occupied Market Model Structure

But the situation is different in owner-occupied market. The very houses are supplied and traded. Consequently, in such a market, real estate is transferred from sellers to households. On the basis of this transfer, there is a stock variable named “Occupied Houses” whose flow, “sales rate”, transfers houses from “Vacant Houses” into this stock. “sales rate” is equal to demand divided by transaction time when there is not supply shortage in the market. When supply (i.e. “Vacant stock”) is less than demand, sales rate is equal to supply divided by transaction time. One can formulate this logic using a fuzzy minimum.

This is the difference between stock-flow structures of owner-occupied and rental markets. Here, supply and demand are stocks in nature. Supply is equivalent to vacant houses stock, whose flows are “construction completion rate” and “sales rate”. Demand is a function of “homeless families”, which is determined by subtracting a stock (i.e. occupied houses) from a constant (i.e. all families). Therefore, “depreciation rate of houses” and “sales rate” are flows which change the number of homeless families. Such a stock-like nature can result in the accumulation of supply or demand over a period of time. If construction completion rate is

greater than sales rate, “Vacant Houses” (i.e. supply) is accumulated. On the other hand, if sales rate is less than depreciation rate of houses, homeless families are accumulated.

In this model, for the purpose of simplification, it is supposed that there is no speculative demand in the market, and like the rental market model (Wheaton, 1999), sellers supply all of the houses regardless of price. In addition, population is supposed to be constant, but including depreciation in the model is equivalent to incorporating population growth or some trend in demand (Wheaton, 1999).

3. Real Estate Cycles Are Produced By Different CPMs

3.1 Supply lag, the common CPM in Owner-Occupied and rental markets.

In both markets, the negative loop of supply-price has a lag which produces cycles (figures 3 and 4).

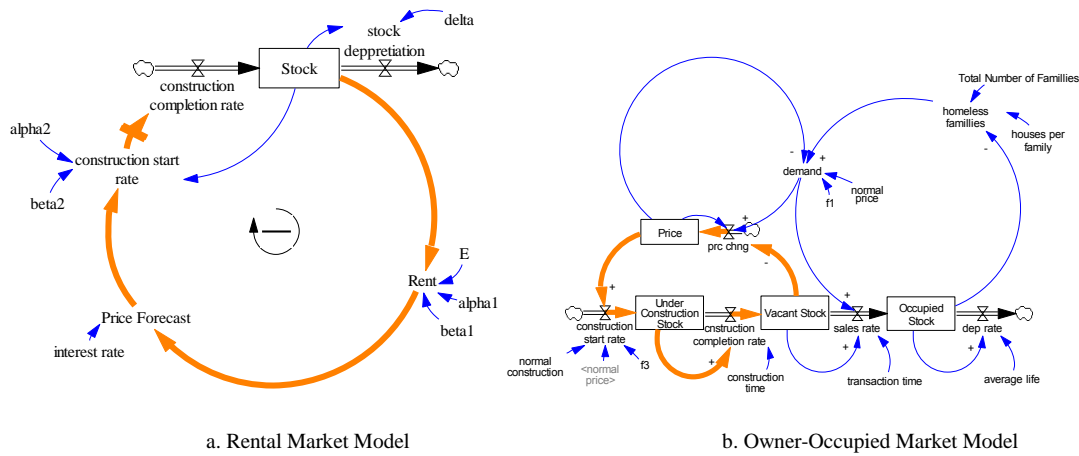


Figure 3. Negative Loops of Supply-price in the Two Models

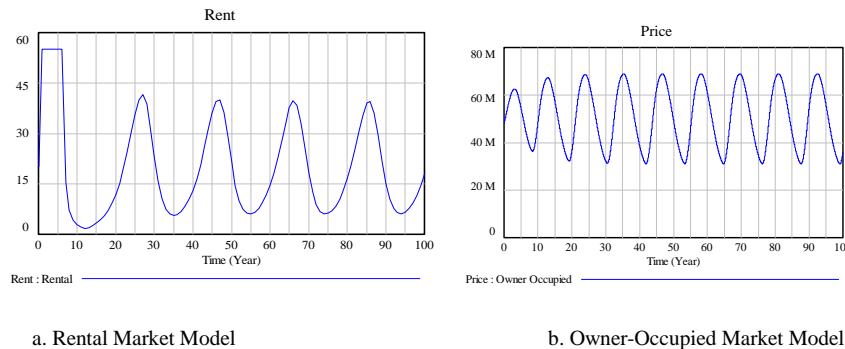


Figure 4. Oscillatory Behavior of Rent and Price⁶

⁶ One may ask why periods of cycles in rental market differ from those of owner-occupied market. To answer this question, we note that what synchronizes oscillations in rental and owner-occupied markets is relationship between the two markets and this

Here is the hypothesis which relates the negative feedback loops of supply-price to the oscillatory behavior of markets:

Suppose the demand rises. Then the price rises too. The increase in price raises construction. High construction, *after a time lag* (i.e. supply lag), can lead to an increase in supply and a decrease in price. Such a time lag means the price remains high for a long time. Therefore, construction remains high for a long time and that is just what is called overbuilding in the real estate economics literature (Wheaton, 1999; Kaiser, 1997; Mueller, 2002). Overbuilding leads to oversupply after the time lag (Mueller, 2002). So price drops substantially. This is followed by what had happened in overbuilding period (but in the opposite direction) and we face an underbuilding period. This period in turn leads to the next overbuilding period and so on.

3.2 The role of supply and demand accumulation and stock-flow structure in the formation of cycles of owner-occupied market.

If supply lag is removed from both owner-occupied market and rental market models (figure 5), the price behaves as depicted in figure 6:

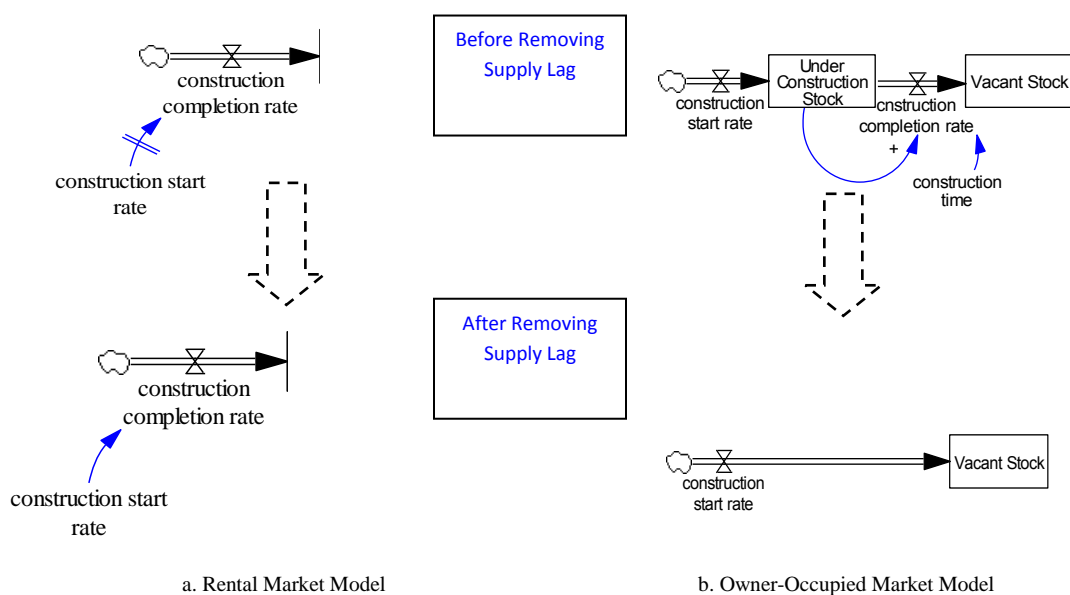


Figure 5. Removing Supply Lag from the Structure of the Models

relationship cannot be seen until we discuss the two markets in the form of one integrated model (rather than two separate models). This relationship will be discussed in section 5 in detail.

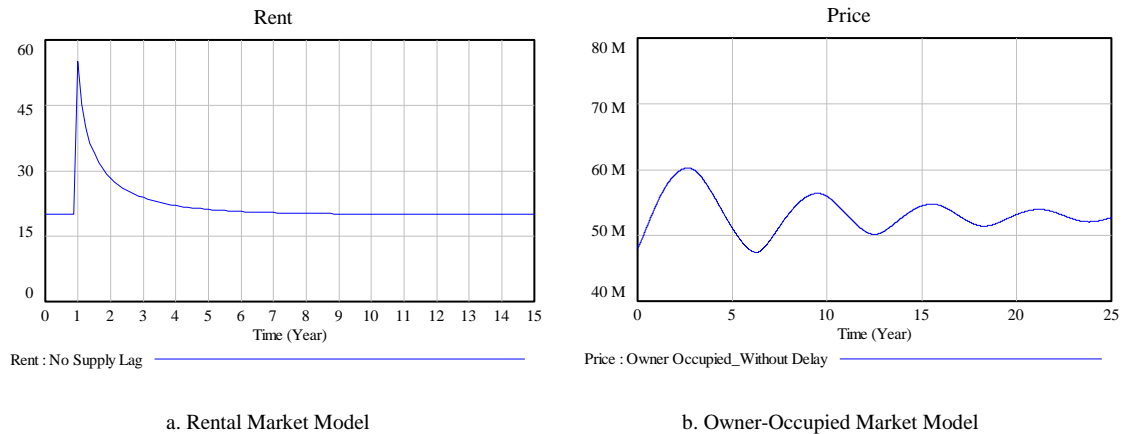


Figure 6. Price and Rent Behavior after Removing Supply Lag

Cycles disappear in the rental market model. But there still remain cycles in the owner-occupied market model. So, in owner-occupied market, there is a CPM which is absent in rental market. This CPM arises from the underlying stock-flow structure of owner-occupied market and stock-like nature of supply and demand in that market. Nathaniel J. Mass (1980, p.27) mentions,

"... economic theories still revolve primarily around flow concepts of supply and demand ... [S]tock-variable concepts of supply and demand must be incorporated explicitly in economic models in order to capture the rich disequilibrium behavior characteristics of real socioeconomic systems."

Now, we can see how this stock-like nature causes oscillations. As discussed in the previous section, the stock-like nature of supply and demand in the durable goods market may lead to accumulation of supply and demand. Accumulation of supply and demand may force them not to behave according to the price signals (Mashayekhi, 2006). For instance, as is clear from phase I in figure 7, while price is decreasing, supply rises, and in phase III demand rises despite an increase in price. In owner-occupied market, in addition to price mechanism which is present in every market and makes supply and demand close to each other through price adjustment (Mashayekhi, 2006), there exists an "accumulation mechanism". In this mechanism supply shortage through limiting sales, causes homeless families to accumulate, and demand shortage through limiting sales, accumulates supply.

Now, we formulate a hypothesis of 4 phases which explains the cyclical behavior of price *in the absence of supply lag* (figure 7) and on the basis of interaction of these two mechanisms and dominance shifts between them. As is clear from the following hypothesis, neither accumulation mechanism nor price mechanism is a CPM. But their combination, to which we will refer as "durability mechanism" can serve as a CPM.

I. In the beginning of this phase, supply and demand are equal and the price is high. High price leads to high construction which, in turn, leads to accumulation of supply.

An increase in supply reduces price and consequently construction, through price mechanism. But price, in spite of the downward trend, is still high, and therefore, demand is low. Therefore, sales are low and supply accumulation continues as long as construction is higher than sales.

II. In this phase, due to a decrease in price, construction gets so low that it falls behind the sales (*i.e.* price mechanism dominates accumulation mechanism). Therefore, supply starts to diminish up until it meets demand at the end of the phase.

III. In the beginning of this phase, supply and demand are equal, and price, which was reducing during the two previous phases, is very low. Therefore, construction is low. Low construction rate leads to supply shortage which, in turn, restricts the sales. Thus, the homeless families begin to accumulate and demand increases. Demand increase causes price to rise, and this reduces percentage of homeless families who look for houses. But in this phase, the effect of “an increase in the number of the homeless families” dominates that of “a decrease in the percentage of the applicants for the houses” and demand rises as a whole (in this phase accumulation mechanism is dominant).

IV. In this phase price mechanism dominates accumulation mechanism. Due to price increase, the percentage of those homeless families who want houses reduces. Moreover, price increase leads to higher construction which boosts sales through supply increase. Therefore, the number of the homeless families decreases. At the end, supply and demand intersect each other and the price is high.

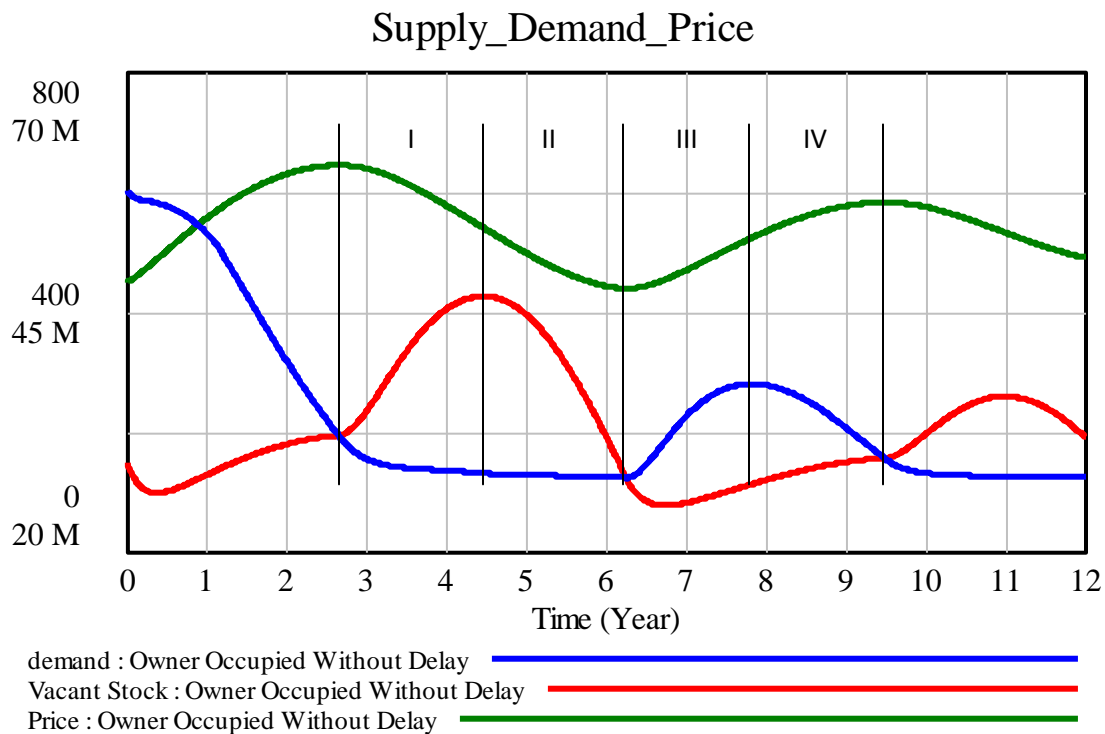


Figure 7. Price, Supply, and Demand Behavior in Owner-Occupied Market Model after Removing Supply Lag

You can see that at the end of phase IV the conditions are like the beginning of phase I. so the cycle repeats itself.

Note that in addition to demand/supply shortage which leads to supply/demand accumulation through limiting sales, the very accumulated supply/demand intensifies demand/supply shortage, because existing demand/supply, due to accumulated supply/demand is traded immediately and there is no possibility that demand/supply rises (look at figure 7).

In figure 8, we see loops of accumulation and price mechanism.

Note that in price mechanism, if we move from demand to supply or vice versa on arrows (figure8), in both cases we pass even number of negative relations which means a positive change in demand causes a positive change in supply and vice versa. But in accumulation mechanism in both cases we pass through odd number of negative relations. Therefore, accumulation mechanism pushes supply and demand away from each other while price mechanism makes them close to each other.

What actually causes cycles in owner-occupied market is *a combination* of the durability CPM (which is peculiar to owner-occupied market) and the supply lag CPM (which is present in rental market, too). Accordingly, the negative loop of supply-price plays two roles in our model of owner-occupied market: first, producing cycles through overbuilding and underbuilding periods, and second, participating in price mechanism and confronting accumulation mechanism (see figures 3 and 8).

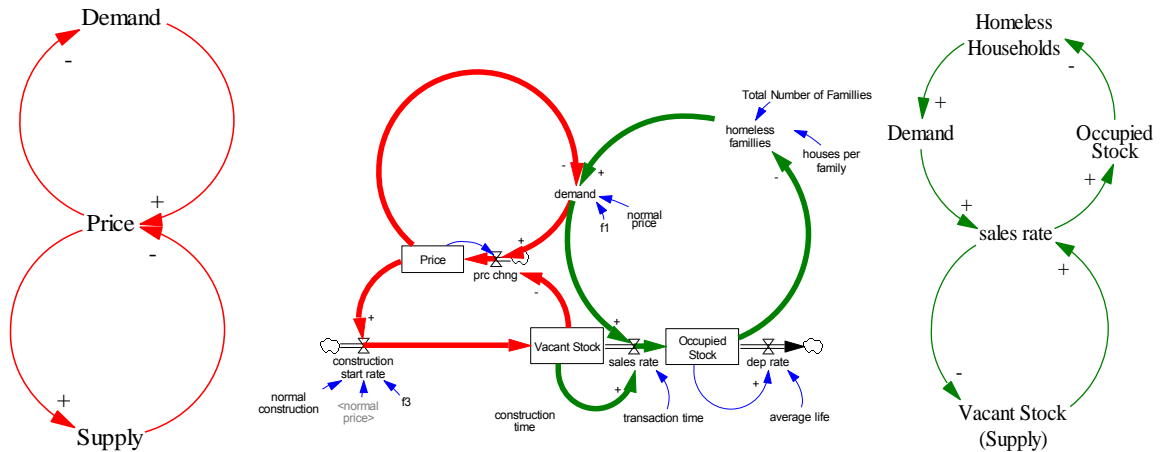


Figure 8. Price and Accumulation Mechanisms in Owner-Occupied Market Model

4. Different CPMs Produce Cycles with Different Characteristics

As discussed, there is a CPM in owner-occupied market which is absent in rental market. In this section we will carry out some experiments on the models of rental and owner-occupied markets and we will see that the cycles of those markets have different characteristics due to existence of different CPMs (they react differently to changes in market parameters). The differences of the characteristics of the cycles are of importance because if we have little recognition of them, we may face difficulty in policy recommendation.

The effect of average life of the houses

By doing experiment on his model, Wheaton (1999) showed that in rental market model, an increase in the average life of the buildings lowers the amplitude of real estate cycles. But in owner-occupied market model presented in this paper, an increase in the average life of the houses has an inverse effect on the amplitude of the cycles (figure 9).

The rental model: suppose there is not enough “Stock” in the market and, hence, the price is high. Because of the lag in construction, “Stock” can not adjust quickly. Here, if the depreciation fraction is high (*i.e.* the average life is low), there will be a severe decrease in “Stock” (*i.e.* supply) and, consequently, there will be a very high price in the market. This leads to an intensive overbuilding period which, in turn, makes the upcoming underbuilding period intensive as well.

The owner occupied model: in this model, in spite of the rental model, depreciation rate has nothing to do with supply and, consequently, with overbuilding and underbuilding periods. Because the variable “depreciation rate” is, here, an outflow not for “Vacant Stock” (*i.e.* Supply), but for “Occupied Stock”.

The more rapidly “Occupied Stock” depreciates, the less accumulative in character “Potential demand” is. That is, to say, the goods are less durable. In an extreme case of a very rapid depreciation, “Potential demand” is almost equal to “Total Population”. So, “Potential demand” is constant over time and one can expect the durability CMP not to work. This is the case with non-durable goods like juice.

Therefore, in rental market, in order to lower amplitude of real estate cycles, maintenance of houses is recommended. But in owner-occupied market, destruction of worn out houses is an appropriate policy to pursue.

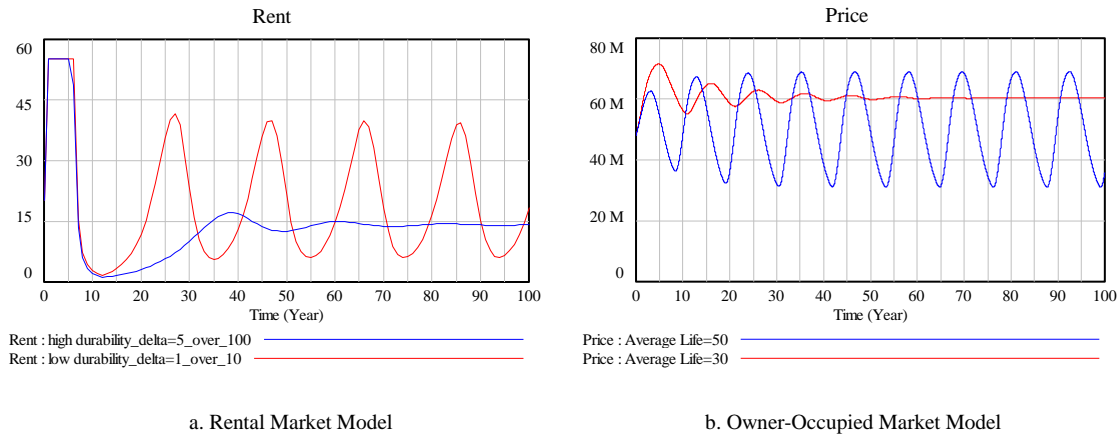


Figure 9. The Effect of Change in Average Life of the Houses on the Oscillations of Price and Rent

The effect of price elasticity of supply

In owner-occupied model, it is supposed that the sellers market all the “Vacant Houses” regardless of the price. In rental market model (Wheaton, 1999) similar assumptions have been made. Thus, by price elasticity of supply we mean *price elasticity of “construction start rate”*

By conducting experiment on his model, Wheaton (1999) showed that in rental market, higher price elasticity of supply leads to higher amplitude of cycles. But in owner-occupied market model presented in this paper, the effect of price elasticity of supply on the cycle amplitude strongly depends on the model parameters and, as explained below, cannot be easily described as “increasing” or “decreasing” (figure 10).

- In rental market, when the price grows, higher price elasticity of supply causes construction to grow more, in comparison with the case of lower price elasticity of supply. Therefore, market will experience a more intensive overbuilding and this makes amplitude of the cycles increase.
- The effect of overbuilding, which exists in rental market is present in owner-occupied market, as well. But there is another effect in owner-occupied market. As discussed in the previous section, cycles of durability CPM, are results of price changes caused by price mechanism in order to act against the accumulation mechanism by balancing supply and demand. Higher price elasticity of supply indicates that in order to make supply and demand close to each other, less change in price is needed. Therefore, an increase in price elasticity of supply has a negative effect on the intensity of price oscillation. But in order to know whether this negative effect or the positive effect of overbuilding is dominant, we should refer to simulation results.

The fact that the differences between cycle characteristics in the two markets arise from durability of buildings should seem more reasonable when we have a look at figure 10.c. This figure shows the dynamic behavior of price in the owner occupied market when the average life

of houses is reduced from 50 years to 30 years. As shown in this figure, an increase in price elasticity of supply leads to an increase in the amplitude of the cycles. So as we expected, the cycle characteristics of owner occupied market become similar to those of the rental market as durability of owner occupied building decreases.

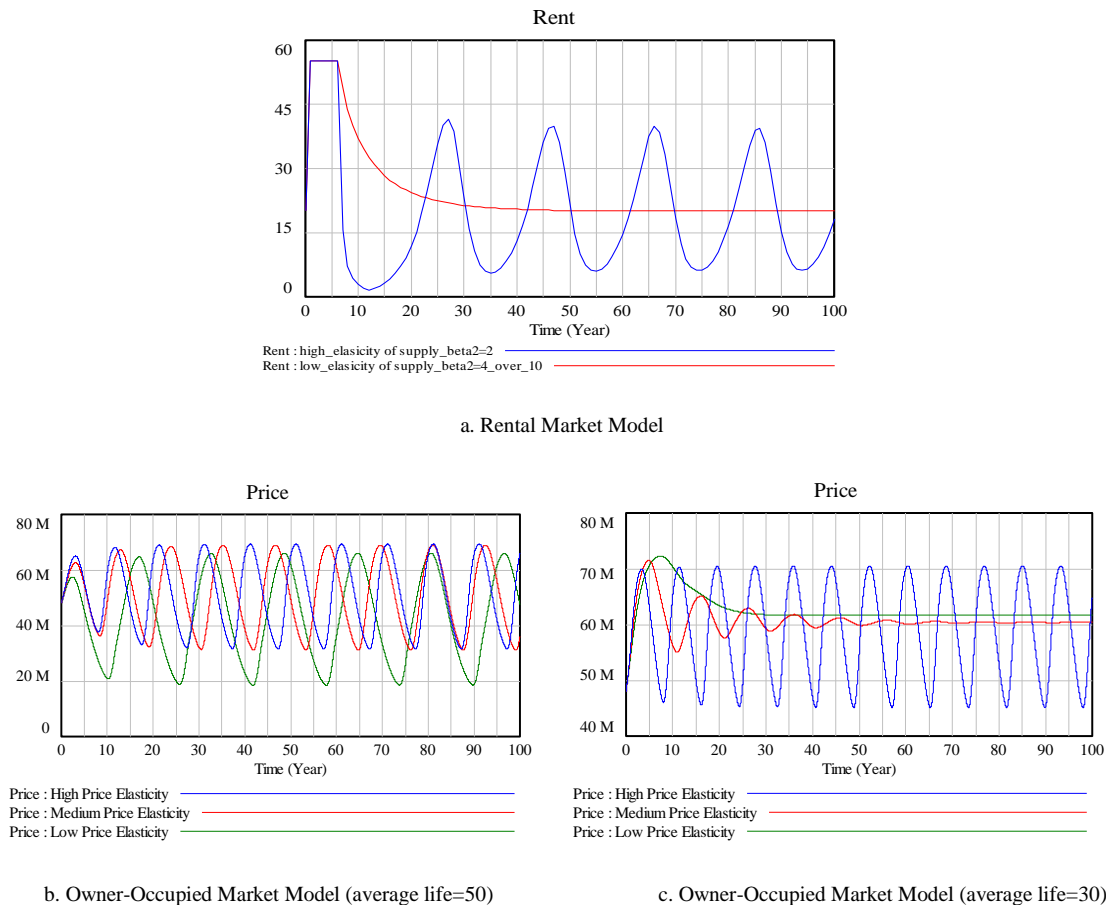


Figure 10. The Effect of Change in Price Elasticity of Supply on the Oscillations of Price and Rent

Now we can see another aspect of *dynamic complexity* in owner-occupied market. We saw that after omitting supply lag, the remaining oscillations would be damped (figure 6). Therefore, if one had a linear thinking (*i.e.* thought of this system as linear) which leads to Fourier Analysis, he would say that when the supply lag was present, oscillations caused by specific CPM of the owner-occupied market, after a while, would die, and all the oscillations would result from the supply lag CPM. But surprisingly, as shown in figures 9 and 10, cycle characteristics will change permanently and this change is explained by CPM specific to owner-occupied market which is a sign of permanent presence of this CPM. Therefore, one can see that the interrelationship between the CPMs is much more nonlinear and dynamically complex than they might seem before dynamic modeling.

Note that cycles of rental market and owner-occupied market are not different in all respects, and they have some characteristics in common. For example, in rental market “as the [supply] lag increases, the same-order minima and maxima display greater amplitude” (Wheaton, 1999). That is true in our model, too. In addition, in both model, higher price elasticity of demand leads to lower oscillations (figures 12 and 13).

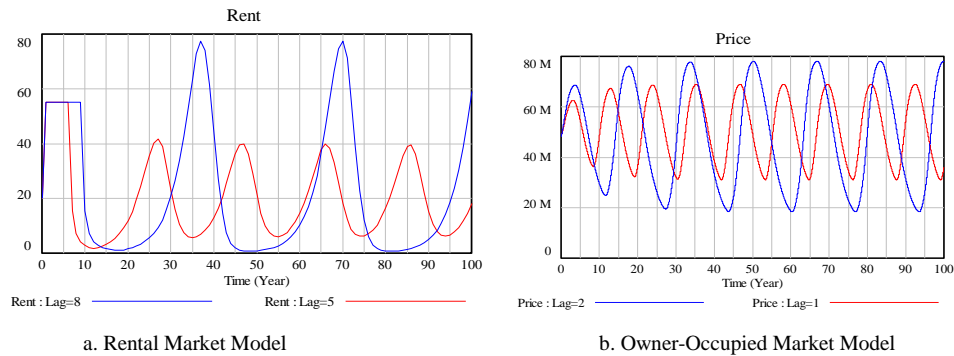


Figure 12. The Effect of Supply Lag on the Price and Rent Oscillations

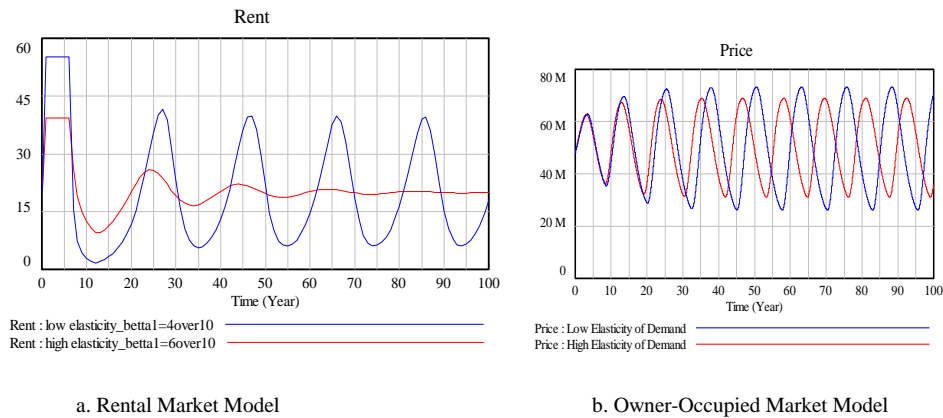


Figure 13. The Effect of Price Elasticity of Demand on the Price and Rent Oscillations

5. Rental Market and Owner-Occupied Market Are Interrelated

The basis of systems thinking is that systems consist of not only their parts but also interrelations among the parts (Ackoff, 1994). Owner-occupied market and rental market are no exception to this rule as parts of the “real estate system” as a whole. Therefore, cycle characteristics in each market are affected by not only the structure of that market, but also the structure of the other market. The behavior of rent and price of real estate in both Iranian real estate market and a model developed by integrating rental and owner-occupied models is displayed in figure 14 (The graphical structure of the integrated model can be found in Appendix 1).

In figure 14 one can feel the strong behavioral relationship between the two markets obviously. Cycles in both markets have the same periods and the peaks and the bottoms point nearly at the same place in the abscissa. The rental market lags behind the owner-occupied market. Such a behavioral relationship can be a sign of a strong structural interrelationship between the two markets. Due to such a structural interrelationship, the cycle characteristics of the rental market may be strongly influenced by the owner occupied market. As simulation results in the integrated model reveal, despite what is suggested by Wheaton (1999), if the average life of houses increases, not only “Price” but also “Rent” undergoes more intensive oscillations (figure 15).

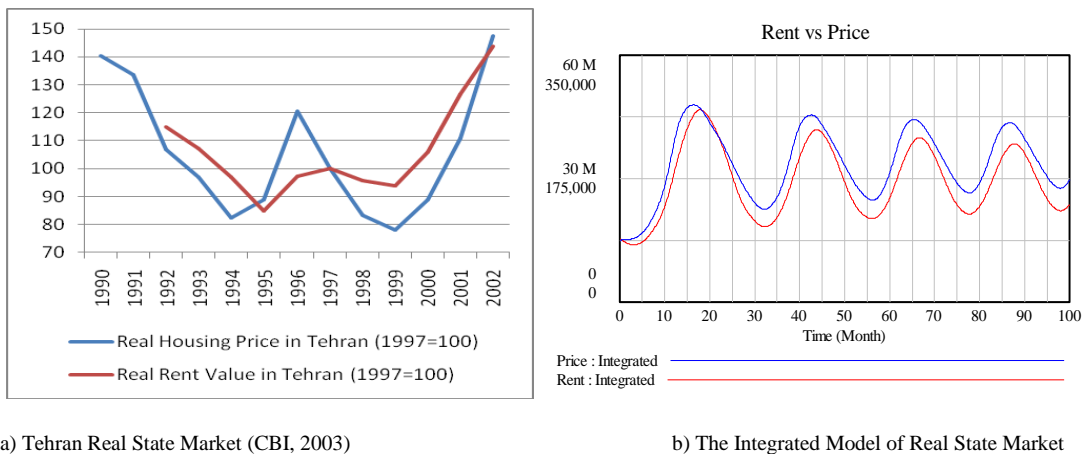


Figure 14. The Relationship Between Price and Rent⁷

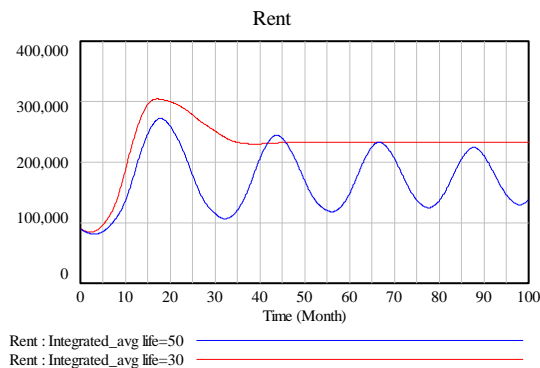


Figure 15. The Effect of Change in Average Life of the Houses on the Oscillations of and Rent in the Integrated Model

⁷ Our purpose is not to calibrate the integrated model with Tehran real estate market but to capture the behavioral relationship between the rental and the owner occupied markets. That’s why the period of the cycles in the integrated model differs from that of Tehran market.

This paper is not intended to deal with Integrated Model of Real Estate Market in detail. But one should take notice that the study of cycle characteristics in rental and Owner-occupied markets as separate models, in spite of providing insights, if left at this point, doesn't suffice for policy recommendation (Lyneis, 1999) because the strong interrelationship between the two markets may affect cycle characteristics.

6. Further Research

As discussed, the study of real estate cycles is a dynamically complex job (Senge, 1994), and there are more than one CPM. So, in order to come to better understanding of such a problem, we should understand dynamic complexity related not only to each of the CPMs (*i.e.* the supply lag, speculation, the CPM peculiar to owner-occupied market, etc), but also to relationship between them. This job may not necessarily lead to finding key points of policy recommendation, but, at least, prevents misconceptions caused by mental analysis (Forrester, 1991).

Understanding the dynamic complexities of the models is of high importance, especially when the models show surprising behavior (Forrester, 1991), like what this paper tries to point out. This is brought about by the fact that getting surprised by the model is highly related to the lack of understanding of its dynamic complexities. In such cases, in addition to the model, a hypothesis explaining the reason behind the surprising behavior of the model should be presented. Researches done in this way will be admitted more easily and will be used more effectively as the basis of further researches.

7. Concluding Remarks

- In owner-occupied real estate market, in addition to supply lag, which produces cycles through creating overbuilding and underbuilding periods, alternating dominance shift between accumulation mechanism (which pushes supply and demand away from each other) and price mechanism (which makes supply and demand close to each other) causes oscillations in the market. Such a mechanism has not been discussed in real estate cycles literature before.
- Cycle-producing mechanism (CPM) specific to owner-occupied market causes some parameters (for example price elasticity of supply and average life of houses) to affect amplitude of cycles differently in comparison with rental market. If we don't consider this issue, our policies in the market may have the reverse effect to what is intended.
- Interrelationship between different CPMs in the market is nonlinear and dynamically complex rather than linear and additive. Accordingly, without dynamic simulation we may face difficulties in studying the real estate cycles.

- Although the CPM presented in this paper, is in relation to owner-occupied market, but owner-occupied and rental markets are interrelated as parts of a general system of “Real Estate Market”. CPMs in owner-occupied market affect characteristics of cycles in rental market and vice versa. Therefore, even when we want to make policy in rental market, we need to know CPMs of owner-occupied market and it is also necessary to consider characteristics of rental market for policy recommendation in owner-occupied market.

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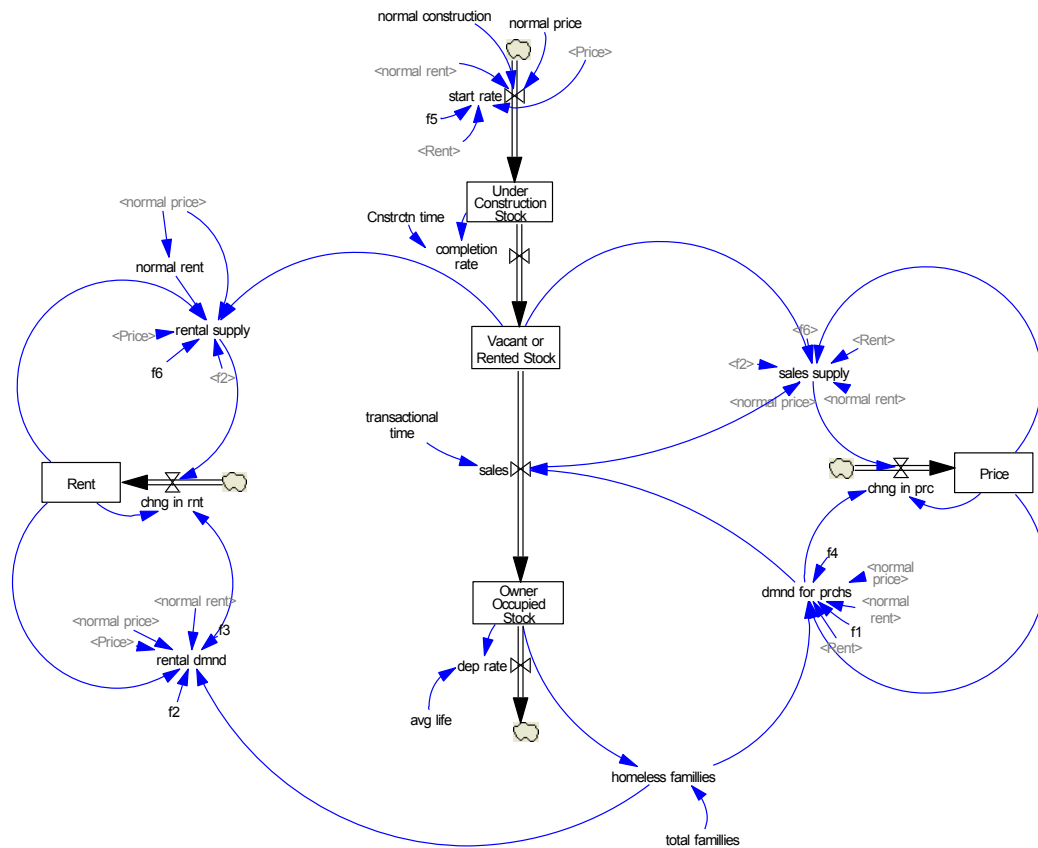
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Appendix 1. Structure of the Integrated Model



Appendix 2. Equations of the Models

1. Rental Market Model (Wheaton, 1999)

(01) $\alpha_1 = 20^{(0.4)} * 2.5e+009 / 1e+007$

*[$\alpha_1 = 20^{(0.6)} * 2.5e+009 / 1e+007$ for "high elasticity of demand_beta1=6_over_10"]*

(02) $\alpha_2 = 0.1 / (400)^2$

[$\alpha_2 = 0.1 / (400)^{(4)}$ for "low elasticity of supply_beta2=4_over_10"]

(03) $\beta_1 = (0.4)$ *[$\beta_1 = (0.6)$ for "high elasticity of demand_beta1=6_over_10"]*

(04) $\beta_2 = 2$ *[$\beta_2 = .4$ for "low elasticity of supply_beta2=4_over_10"]*

(05) construction completion rate = DELAY FIXED(construction start rate, 5, 2.5e+009*0.1)

*[construction completion rate = DELAY FIXED(construction start rate, 8, 2.5e+009*0.1) for "Lag=8"]*

*[construction completion rate= DELAY FIXED(construction start rate, 5, 2.5e+009*0.05) for "high durability_delta=5_over_100"]*

(06) construction start rate= Stock*alpha2*Price Forecast^beta2

(07) delta= 0.1 *[delta= 0.05 for "high durability_delta=5_over_100"]*

(08) E=1e+007 * (1+ STEP(0.5, 1))

(09) FINAL TIME = 100

Units: Year

The final time for the simulation.

(10) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(11) interest rate= 0.05

(12) Price Forecast= Rent/interest rate

(13) Rent= (Stock / (alpha1*E)) ^ (-1/beta1)

(14) SAVEPER = TIME STEP

Units: Year [0,?]

The frequency with which output is stored.

(15) Stock= INTEG (+construction completion rate-stock deppretiation, 2.5e+009)

(16) stock deppretiation= delta*Stock

(17) TIME STEP = 1 *[TIME STEP = 0.125 for "No Supply Lag"]*

Units: Year [0,?]

The time step for the simulation

2. Owner-Occupied Market Model

(01) average life= 50 *[average life= 30 for "AverageLife=30"]*

(02) cnstruction completion rate= Under Construction Stock/construction time

(03) construction start rate= f3(Price/normal price)*normal construction

*[construction start rate=f3(Price/normal price)^.2*normal construction for "Low Price Elasticity"]*

*[construction start rate=f3(Price/normal price)^3*normal construction for "High Price Elasticity"]*

(04) construction time= 1 *[construction time= 2 for "Lag=2"]*

- (05) dep rate= Occupied Stock/average life
- (06) demand=homeless families* f1(Price/normal price)
- (07) f1([(0,0)-(2,1)],(0,1),(0.293578,0.986842),(0.53211,0.969298),(0.691131,0.894737),
(0.825688,0.780702),(0.923547,0.653509),(0.996942,0.5),(1.0581,0.377193),
(1.13761,0.254386),(1.27217,0.144737),(1.45566,0.0614035),(1.71254,0.0219298),
(1.98777,0.00438596))

[f1[(0,0)-(2,1)],(0.00611621,0.995614),(0.238532,0.964912),(0.48318,0.890351),(0.752294,0.72807),(0.990826,0.504386),(1.24159,0.267544),(1.49847,0.100877),(1.77982,0.0219298),(1.99388,0.00877193

For "Low elasticity of demand"]

- (08) f3([(0,0)-(4,2.5)],(0,0),(0.452599,0),(0.685015,0.109649),(0.782875,0.317982),
(1,1),(1.50459,1.88596),(2.25076,2.2807),(3,2.43421),(4,2.5))

- (09) FINAL TIME = 100

Units: Year

The final time for the simulation.

- (10) homeless families=Total Number of Families-Occupied Stock/hs per hshld

- (11) hs per hshld= 1

- (12) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

- (13) normal construction= 1000

- (14) normal price= 2e+007*3

- (15) Occupied Stock= INTEG (sales rate- dep rate,30000)

- (16) prc chng=0.08*Price*LN((0.01+demand)/(0.01+Vacant Stock))

[A look-up function could be used instead of natural logarithm as in Mashayekhi (2006). Natural logarithm works in the same manner. The only problem may be that such a formulation results in an infinite amount for price change (*i.e.* prc chng) when the supply or demand is zero. In order to solve this problem, a small number (0.01) is added to the numerator and denominator of the argument of the logarithm function in order to avoid infinite price change when demand or supply is zero.]

- (17) Price= INTEG (prc chng,1.6e+007*3)

- (18) sales rate=MIN(Vacant Stock, demand) / transactional time

- (19) SAVEPER = TIME STEP
Units: Year [0,?]
The frequency with which output is stored.
- (20) TIME STEP = 0.0078125
Units: Year [0,?]
The time step for the simulation.
- (21) Total Number of Families= 30000+750
- (22) transactional time= 0.2
- (23) Under Construction Stock= INTEG (+construction start rate-cnstruction completion rate, 600)
- (24) vacancy rate= Vacant Stock/(Vacant Stock+Occupied Stock)
- (25) Vacant Stock= INTEG (+cnstruction completion rate-sales rate, 150)

3. The Integrated Model

- (01) average life= 50 [*average life= 30 for "AverageLife=30"*]
- (02) cnstruction completion rate= Under Construction Stock/construction time
- (03) construction start rate= f3(Price/normal price)*normal construction
*[construction start rate=f3(Price/normal price)^.2*normal construction for "Low Price Elasticity"]*
*[construction start rate=f3(Price/normal price)^3*normal construction for "High Price Elasticity"]*
- (04) construction time= 1 [*construction time= 2 for "Lag=2"*]
- (05) dep rate= Occupied Stock/average life
- (06) demand=homeless families* f1(Price/normal price)
- (07) f1([(0,0)-(2,1)],(0,1),(0.293578,0.986842),(0.53211,0.969298),(0.691131,0.894737),
(0.825688,0.780702),(0.923547,0.653509),(0.996942,0.5),(1.0581,0.377193),
(1.13761,0.254386),(1.27217,0.144737),(1.45566,0.0614035),(1.71254,0.0219298),
(1.98777,0.00438596))
- [f1((0,0)-(2,1)],(0.00611621,0.995614),(0.238532,0.964912),(0.48318,0.890351),(0.752294,0.72807),(0.990826,0.504386),(1.24159,0.267544),(1.49847,0.100877),(1.77982,0.0219298),(1.99388,0.00877193*

For "Low elasticity of demand"]

(08) $f3([(0,0)-(4,2.5)],(0,0),(0.452599,0),(0.685015,0.109649),(0.782875,0.317982), (1,1),(1.50459,1.88596),(2.25076,2.2807),(3,2.43421),(4,2.5))$

(09) FINAL TIME = 100

Units: Year

The final time for the simulation.

(10) homeless families=Total Number of Families-Occupied Stock/hs per hshld

(11) hs per hshld= 1

(12) INITIAL TIME = 0

Units: Year

The initial time for the simulation.

(13) normal construction= 1000

(14) normal price= $2e+007*3$

(15) Occupied Stock= INTEG (sales rate- dep rate,30000)

(16) $prc\ chng=0.08*Price*LN((0.01+demand)/(0.01+Vacant\ Stock))$

(17) Price= INTEG (prc chng, $1.6e+007*3$)

(18) sales rate=MIN(Vacant Stock, demand) / transactional time

(19) SAVEPER = TIME STEP

Units: Year [0,?]

The frequency with which output is stored.

(20) TIME STEP = 0.0078125

Units: Year [0,?]

The time step for the simulation.

(21) Total Number of Families= 30000+750

(22) transactional time=0.2

(23) Under Construction Stock= INTEG (+construction start rate-cnstruction completion rate, 600)

(24) vacancy rate= Vacant Stock/(Vacant Stock+Occupied Stock)

(25) Vacant Stock= INTEG (+cnstruction completion rate-sales rate, 150)