

Real Estate “Cycles”: Some Fundamentals

William C. Wheaton*

This paper demonstrates that different types of real estate can have very different cyclic properties. Empirically, it is shown that they do, and the question is posed as to what might distinguish between property markets where movements are largely stable responses to repeated economic shocks and those undergoing a continuing endogenous oscillation. A stock-flow model is built in which the future expectations of agents, the development lag, the degree of durability and market elasticities all can vary. Experiments reveal the dynamic behavior of the model varies quite sharply with all these factors. Forward forecasting by agents leads to stability, while myopic behavior promotes oscillations. Oscillations are also much more likely when supply is more elastic than demand, development lags are long, and asset durability is low.

The overbuilding of office real estate that occurred in the 1980s has been widely documented and written about. Rather than an isolated event, there is growing evidence that the office market was also overbuilt during the late 1960s through mid-1970s (Grebler and Burns 1982, Wheaton 1987, King and McCue 1987). To some, this pattern of periodic over- and underbuilding may appear to be a prime example of an old-fashioned cobweb or corn–hog cycle. The argument is further made that real estate is particularly prone to such instabilities or oscillations because of its durability and because of the long lag between capital demand and delivery. Within modern economics, however, such cyclic behavior is most often dismissed as being the product of uninformed agents making systematic errors about future market conditions. With rational expectations, such endogenous market cycles should not occur. Thus modern economists tend to seek the cause for each overbuilding in a unique shock. The overbuilding in the 1980s, for example, is often attributed to the investment incentives provided by the tax reform act of 1980 (Auerbach and Hines 1988, DiPasquale and Wheaton 1992). Against this background, the current paper attempts to provide some common ground with which to evaluate the determinants of real estate cyclicity. More specifically, the paper has four objectives.

First, to demonstrate empirically that different types of real estate have quite different cyclic behavior. For some types of property, movements are closely

*Massachusetts Institute of Technology, Cambridge, MA 02139 or wheaton@mit.edu.

related to the U.S. economy. Thus the “cycle” in these property types is largely due to alternating economic demand shocks. Other types of real estate, however, have much longer swings that bear almost no relation to broader economic cyclicity. These apparent repeated oscillations more closely resemble an endogenous real estate cycle.

Second, to prove that when market agents are rational and able to correctly forecast the results (but not timing) of unanticipated shocks, endogenous market oscillations normally are not possible. This suggests that some kind of irrational price formation might be a necessary condition for the existence of any endogenous real estate cycles.

Third, to illustrate that when market agents are irrational and make systematic mistakes in forecasting the impact of unanticipated shocks, the occurrence of oscillations depends crucially on the important features that characterize different types of real estate: asset durability, investment lags and supply or demand elasticities. This shows that irrationality is not sufficient to generate real estate cycles. It further suggests that the cyclic behavior of real estate markets could be intrinsically quite different across property types.

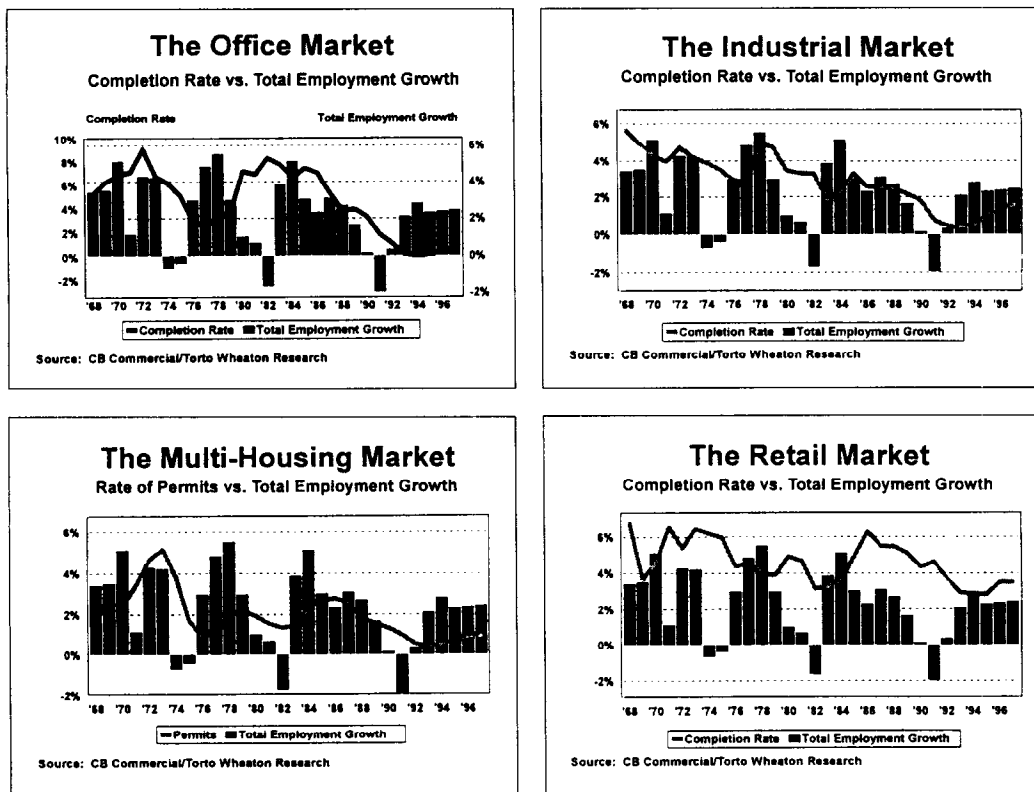
Fourth, to illustrate that fully rational models may be capable of oscillations if they incorporate some institutional features that characterize real estate markets. Long-term leases and the use of credit to finance development, for example, may create backward historical linkages that are strong enough to generate some degree of market oscillation—even with rational asset pricing—where the oscillations are perfectly forecast.

The discussion in this paper takes place with a model in which there is a single exogenous economic variable whose future is known with certainty—except for the occurrence of a large and unanticipated shock. With either rational or irrational behavior, the occurrence of the shock is not expected: the distinction involves only agent behavior after the shock. Rational agents are able to correctly forecast the market response to the shock, and thus asset prices will equal the present discounted value of actual post-shock rents. Irrational agents adopt an ad hoc rule, such as basing prices on the present discounted value of current rents.

Cycles vs. Cyclicity in Real Estate Markets

Figure 1 displays annual gross investment in four types of commercial real estate. Each series is measured as a percentage of the stock, covering the period 1968–1996. All of the series are measured in either square footage

Figure 1 ■



or units, rather than value, since historical price indexes for the existing stock do not exist. The time series apply not to the nation as a whole, but only to the largest 54 metropolitan areas. In the major MSAs of the U.S., detailed inventories of the stock are available. These allow a more carefully defined stock series to be constructed than is possible with only dollar delineated permits or starts data.¹

Also, in each figure is depicted the annual percentage change in total employment in these same largest 54 MSAs. A comparison across the four types of property shows that real estate certainly does not behave uniformly as a single sector within the economy. With apartments and industrial space, there appears to be considerable correlation between real estate and the

¹ The series and their sources are as follows: (1) completions of office buildings in 54 MSAs, buildings with more than 10,000 square feet (square footage): CB Commercial Real Estate Group; (2) U.S. multi-family housing starts (2+ units): U.S. Department of Commerce; (3) completions of industrial buildings in 54 MSAs, buildings with more than 10,000 square feet (square footage): CB Commercial Real Estate Group; (4) completions of shopping centers in 54 MSAs (square footage): National Research Bureau.

economy. Shortly after each recession (1969, 1975, 1981, 1991) investment turns down, with corresponding investment upturns during economic recoveries. For investment in office and retail properties, however, there is little relationship to the economy. These types of real estate have seen two longer-term investment oscillations during the same time in which there were four economic shocks. Statistical tests confirm the visual impressions conveyed by the figure.²

The series in Figure 1 suggest that some types of real estate do not have an *intrinsic* cycle, or oscillation, but merely react to national or regional economic shocks. Other property types, however, seem to behave as if there were some longer-range oscillation in their markets. What is it about different types of real estate that might explain such behavioral differences?

Can stock-flow theory be useful in differentiating the conditions under which real estate dynamics are simply well behaved reactions to exogenous shocks as opposed to an endogenous oscillation?

A Stock-Flow Model Driven by Asset Durability

Durable-goods markets in general, and real estate in particular, are most often modeled within a *stock-flow* framework. In its most simple form, where vacancy is ignored, it is assumed that the market clears in each period: rents adjust until demand (*ex post*) equals the current stock of space. In the long run, the stock adjusts gradually because of lags in the delivery of new capital. Capital investment decisions are based on a forecast of asset prices at the time of new space deliveries. Thus rents and prices react quickly to change, while physical assets do not.

This paper conducts most of its analysis using a version of the stock-flow model with specific functional forms, and even parameter values. It does this because such functional specificity permits the drawing of quite strong conclusions about the model's dynamic behavior. Without this specificity, the dynamic properties of higher-order difference equations are very difficult to determine. Of course the downside of this strategy is the risk that the conclusions drawn do not generalize.

² A regression between each investment series and employment growth lagged 0, 1 or 2 years produces the following results (the *F*-test is for the cumulative impact of the three employment variables; similar results are obtained with a full VAR model in which lagged investment is included as well): Apartments: $R^2 = .51$, $F = 7.01$ (.001). Industrial: $R^2 = .36$, $F = 4.19$ (.016). Office: $R^2 = .09$, $F = 0.76$ (.524). Retail: $R^2 = .16$, $F = 1.46$ (.232).

The model begins by assuming that space is rented with a demand function that depends proportionately on an exogenous economic variable (*e.g.* office employment, E_t), and responds to space rental rates (R_t) with the constant elasticity $-\beta_1$:

$$D_t = \alpha_1 E_t R_t^{-\beta_1} \quad (1)$$

Without vacancy, the market clears and demand is equated to the current stock (S_t). This yields the short-run relationship between the space utilization rate (S_t/E_t) and market equilibrium space rental rates:³

$$R_t = (S_t/\alpha_1 E_t)^{-1/\beta_1} \quad (2)$$

In this version of the model, the future level of the economic demand instrument will be constant, but will be subject to an exogenous economic shock. This shock permanently shifts the level of demand, but is completely unanticipated by agents:

$$E_t = E \quad (3)$$

The stock of space evolves according to the difference equation

$$\frac{S_t}{S_{t-1}} = 1 - \delta + \frac{C_{t-n}}{S_{t-1}} \quad (4)$$

when new space C_t is delivered n periods after it is begun. The n -period lag reflects delays due to both construction and project planning. Depreciation or scrapping of the stock occurs at the constant rate δ and provides the only ongoing source of demand for new space.

The deliveries of new space (begun n periods earlier) are determined by estimates of asset prices at the time of delivery (P_t). Ignoring, for the moment, the issue of how such future asset prices are forecast (n periods prior to delivery), the stock-flow model in this paper will have the *rate* of

³ If vacancy (V_t) is introduced, then Equation (1) will determine the occupied stock: $(1 - V_t)S_t$. Numerous authors (*e.g.* Rosen and Smith 1983, Wheaton and Torto 1994) have found empirically that current vacancy is highly correlated with the change in rents over the next period ($R_{t+1} - R_t$). While search theory can explain why landlords might select rents that yield positive vacant space (*e.g.*, Arnott 1989, Wheaton 1990), none of these theories explains why the effect of vacancy would be gradual. Thus, introducing frictional vacancy and a rental-adjustment differential equation has some empirical justification, but little theoretical underpinning.

construction depend on asset prices, rather than the more common assumption that prices determine the absolute level of construction. In the long run, as an economy (and its stock of space) grows, the (constant dollar) price of space should determine the *share* of national resources that can be devoted to the real estate sector:

$$C_{t-n}/S_{t-1} = \alpha_2 P_t^{\beta_2} \quad (5)$$

It should be noted that this particular supply function has a constant price elasticity (β_2) and has no *floor* (minimal price necessary to cover construction costs). This modest lack of realism leads to a significant degree of mathematical convenience, and seems to have little effect on the model's qualitative properties.⁴

A Stock-Flow Model Driven by Economic Growth

Some may take objection to a model of real estate that does not incorporate economic growth or some trend in demand, E_t . It could easily be argued that the rate of depreciation is quite small for many types of property, and property demand more realistically originates from an expanding economy. Mathematically, this is exactly equivalent to the model just described in the preceding section. Equation (3) is replaced with

$$E_t = (1 + \delta)E_{t-1} \quad (3')$$

and (4) with

$$\frac{S_t}{S_{t-1}} = 1 - \frac{C_{t-n}}{S_{t-1}} \quad (4')$$

In effect the rate parameter δ is shifted from being a constant rate of depreciation to being a constant rate of economic expansion. In this version of the model, a permanent shock will still be suffered by the demand variable, which now will jump (up or down) and then resume its continuous growth rate δ .

⁴ We adopt the standard view that the flow of capital assets depends upon their price (at the delivery date) relative to replacement costs. Implicitly this assumes decreasing returns in the creation of capital assets (Hayashi 1982, Abel and Blanchard 1986). Construction costs (K) could be explicitly incorporated by replacing P with $P - K$.

As the dynamic behavior of these two systems is analyzed in more detail, their equivalence will become clear. In fact, the value of δ can be interpreted as the sum of the stock depreciation rate and the trend growth rate in the demand instrument.

Price Forecasting

Since investment depends on (future) prices at the time of new space delivery, agents must forecast these. Either one of two types of price forecasting are assumed. The first might be named *irrational* or *myopic* price forecasting. The most simple form of this kind of behavior is to assume that forecasts of asset prices n periods hence are simply a constant capitalization (with a discount rate r) of known rents at the time the investment decision is made (Hendershott and Kane 1995). Extrapolating current rents forward is the classic mistake that generates cobweb or corn–hog cycles:

$$P_t = R_{t-n}/r \text{ (myopic/prices)} \quad (6)$$

It is possible to imagine many alternative kinds of such systematic irrationality. For example, perhaps it is the recent growth rate in rents that gets extrapolated forward, rather than recent rent levels. Each such form of backward-looking behavior will generate a different dynamic model, but many of these models will have similar qualitative features to the one illustrated here.

The alternative method of forecasting follows from the *rational-expectations* school of macroeconomics. In the context of this model, that means we assume that agents perfectly understand the equations that govern market behavior and thus can make correct forecasts of rents—conditional on a particular realization of the exogenous future demand variable. If this demand variable is stochastic, with a known distribution, rational agents will be able to forecast its expected future value, and it is this which they use for making investment decisions (*ex ante*). Their actual (*ex post*) behavior, of course, can differ from this plan as specific realizations of demand occur.

When the exogenous variable in the model is known with certainty, or equivalently its distribution is a mass point, then rational expectation is equivalent to perfect foresight. If an unanticipated shock occurs to the demand variable, its effect on the future path of all market variables can be forecast correctly, even though the occurrence of the shock itself caught the market by surprise. In effect, market participants have perfect foresight with respect to the effects, but not the timing, of the shock.

With perfect foresight, real estate prices will equal the present discounted value of the future rents that actually unfold after the unanticipated shock. Thus prices at time t will follow the asset market equilibrium condition (6) with respect to the *subsequent* movement of rents that results from a shock (Abel and Blanchard 1986). The equilibrium return to capital (r) is assumed to be exogenous:

$$P_t = P_{t-1}(1 + r) - R_{t-1} \quad (\text{perfect foresight}) \quad (7)$$

In the 1990s it has become quite fashionable to dismiss market irrationality, or simplistic myopic behavior by economic agents. Particularly in the presence of liquid, publicly traded asset markets, systematic forecasting mistakes would lead to huge arbitrage opportunities. Since these appear not to exist, rationality is a common assumption in most of recent economics. In real estate, however, assets are mostly privately held and traded, and are highly illiquid. Several recent papers find very predictable components in real estate investment returns, suggesting that some form of irrationality may still be occurring in this sector of the economy (Case and Shiller 1989).

Model Steady States and Oscillations

Either of the models described above has a unique steady-state solution that holds regardless of whether agents behave rationally or irrationally. When asset durability and depreciation drive the model, the solution is a true steady state in which all variables are constant through time. When economic growth drives the model, rents, prices and the rate of construction will be constant across time, while the stock and the demand variable will both grow proportionately. The rate of space utilization (S/E) will have a steady state in both models.

Proposition 1: Steady State. There exists a unique price P^* and rent R^* which solve the model (1)–(5) for a C^* and S^* such that

$$C^*/S^* = \delta, \quad \frac{S_t}{S_{t-1}} = 1, \quad P^* = R^*/r$$

Proposition 2: Steady Growth. There exists a unique price P^* and rent R^* which solve the model (1), (2), (3'), (4'), (5) for a C^* and S^* such that

$$C^*/S^* = \delta, \quad \frac{S_t}{S_{t-1}} = \frac{E_t}{E_{t-1}} = 1 + \delta, \quad P^* = R^*/r$$

It is instructive to consider whether there might exist an equilibrium to either model in which rents and prices grew smoothly over time. In the current models this is impossible. If rents were growing, then so would be prices, and the stock would be growing at a rate greater than δ . This would lead to an increase in space utilization, but by (2), increases in space utilization could occur only if rents were falling.

The steady solutions to the model are remarkably easy to obtain numerically. In fact, Equations (2)–(6) can be solved sequentially; they are not even simultaneous. The parameter δ is used in conjunction with (5) to determine the equilibrium price. Equation (6) is then used to calculate the equilibrium rent. Finally, Equation (2) takes this rent and calculates the equilibrium stock. The comparison of steady states is also quite easy, since there are only two exogenous parameters that determine the model's solution.

Proposition 3. A higher rate of depreciation (or faster economic growth) δ necessitates a higher rate of construction, which requires higher prices and rents. Space utilization (S/E) declines. A higher opportunity cost for capital (r) leads only to higher rents and lower space utilization.

A particularly convenient feature of these models is the fact that the steady-state solution depends only on the parameters r and δ , and *not* on the level of the demand variable E . A long-run increase in E will increase the stock proportionately, which (in the steady state) requires the same *rate* of new construction and hence no change in prices or rents. Rents and prices will change only during the transition period while the market is adjusting from a shock.

It will become clear below that when there are space delivery lags, a stock-flow model will always tend to react to a positive (negative) demand shock with a movement in rents and prices that suddenly rises (falls) and then gradually falls (rises). This reaction pattern is inherent in durable capital and investment lags, and will occur regardless of how agents make price forecasts. Thus up-and-down movements of real estate market variables do not necessarily imply an endogenous cycle. Rather the economic environment in which the market operates may simply be subject to a series of shocks.

The traditional definition of a cycle involves repeated market oscillations around a steady state that result from a single economic shock. It is useful to distinguish between two levels of such instability.

Definition 1: Over- and Underbuilding. In reaction to a single positive (negative) demand shock, the real estate stock will increase (decrease) and then pass through the model's steady state, leading to overbuilding (underbuilding), before it converges to the steady state.

A more restrictive definition of a real estate cycle involves repeated oscillations of a market, as it continually overshoots and then undershoots its own steady state.

Definition 2: Oscillations. In reaction to a single positive or negative demand shock, the real estate stock will repeatedly pass through the model's steady state, in alternating directions.

In short, real estate cycles are defined as some degree of instability in the market whereby a single economic shock leads the market to oscillate around its steady state (for some number of iterations).⁵ This might be contrasted with a situation where a market that is inherently stable repeatedly passes through its steady state because it is subject to alternating positive and negative shocks.

Model Dynamics with Perfect Foresight

When agents act rationally and are able to correctly forecast post-shock market behavior, past economic conditions do not influence new investment. It is price at the time of new space delivery that matters—and this is based only on rents from the delivery time forward. Furthermore, estimates of prices at time t , when made at n periods earlier, are completely self-fulfilling except if another unanticipated shock occurs. As long as both of these assumptions hold, a fundamental result of rational expectations by market participants is that cycles by either definition cannot occur (Poterba 1984).

To prove this result within the current model, Equations (2), (4) and (5) are combined with (7) to yield the following second-order non-linear difference equation:

$$\left[\frac{P_t(1+r) - P_{t+1}}{P_{t-1}(1+r) - P_t} \right]^{-\beta_1} = 1 - \delta + \alpha_2 P_t^{\beta_2} \quad (8)$$

⁵ It is of course possible that the model *explodes*, that is, the oscillations increase in amplitude. In this paper we do not find examples of such behavior using realistic parameter values.

Proposition 4. If the market is initially in a steady state and receives an unanticipated permanent positive (negative) shock to demand, then prices, rents, and construction suddenly rise (fall) and then smoothly converge down (up) to and never pass through the steady state.

Proof. By contradiction, if prices were to oscillate across the steady state, then there would exist local maxima or minima. If P_t is at a local maximum, the RHS of (8) will be greater than unity, since the price exceeds the steady state. Taking both sides of (8) to the $-1/\beta_1$ power, the fraction within brackets on the LHS of (8) will have to be less than unity (but still positive). This implies that $P_t < [P_{t-1}(1 + r) + P_{t+1}]/(2 + r)$. This, however, contradicts the assumption that P_t is a local maximum. A similar argument provides a contradiction if P_t is assumed to be a local minimum. Q.E.D.

In the proof above the contradictions are all caused by the fact that with perfect foresight (rational expectations) it is the price at time t that winds up determining the current stock at that same time. The current price is merely the discounted value of present and future rents. Thus if the market is overbuilt, it is because future rents are too high. Yet, how can rents be too high if the market is overbuilt? If the stock today is determined by prices and rents a number of periods ago, then this contradiction does not exist and the model can behave quite differently.

It should be clear that with this strict version of rational expectations, the only way that the market can exhibit the *symptoms* of a repeated cycle is for it to be subject to some alternating pattern of exogenous economic shocks. In principle the distinction between oscillations and a repeated pattern of shocks is empirically testable: is the demand variable (E_t) tightly co-integrated with the swings in the market?

Model Dynamics with Myopic Prices

When agents act irrationally, as with myopia, the stock at time period t will be determined by past market conditions. It is rents at period $t - n$ which determine forecast asset prices at time t , which in turn guide new construction at $t - n$ and hence the stock n periods later. It is this historical dependence that generates the possibility of oscillations. When Equations (2), (4), (5) and (6) are solved by substitution, the result is the following non-linear n th-order difference equation:

$$(P_{t+n}/P_{t+n-1})^{-\beta_1} = 1 - \delta + \alpha_2 P_t^{\beta_2} \quad (9)$$

The existence of oscillations, or even simple over- or underbuilding, hinges

on having a combination of the model's parameters that generates the following behavior. At time t , when prices are equal to their steady-solution values, they must also be crossing them from below or above. This pattern is clearly possible in (9). If prices are at the steady solution at time t , the RHS of Equation (9) equals unity, and this requires that prices be stable n periods hence. This can occur only if, n period hence, prices have either converged to the steady state permanently (stability), or reached a local maximum or minimum (oscillation). The question to be asked is what combinations of parameters generate this latter kind of behavior.

Difference equations, and in particular higher-order ones, exhibit oscillations when the equation has complex roots. If an n th order equation is written as a first-order vector equation (of dimension n), this is equivalent to saying that the coefficient matrix has complex eigenvalues. With real values, the equation either converges or diverges monotonically in reaction to a shock (Hamilton 1994). Oscillations require that at least some of the eigenvalues be complex. The existence of complex roots in a difference equation depends not just on the functional form of the equation, but in general on the specific numerical values of its parameters. Thus evaluating the dynamic properties of (9) inherently involves some form of numerical simulation. Throughout the rest of the paper, a variety of numerical solutions are displayed using different values for the following behavioral parameters of the model:

- β_1 : rental elasticity of demand
- β_2 : price elasticity of supply
- δ : stock depreciation rate or demand growth rate
- n : space delivery lag

In each simulation, the parameters of Equations (2)–(6) are calibrated to mirror the aggregate office market of the largest 54 U.S. metropolitan areas as displayed in Figure 1. This is done by taking the four parameters above and then scaling the model's constants (α_1 , α_2) to yield the following steady-state solution:

$$\begin{aligned}
 E_t &= 10 \text{ million (workers)} \\
 S^* &= 2,500 \text{ million square feet} \\
 R^* &= \$20.00 \text{ per square foot} \\
 r &= 0.05 \\
 P^* &= \$400.00 \text{ per square foot}
 \end{aligned}$$

Base Parameter Values

The first simulation with myopic behavior uses identical unitary demand and supply elasticities ($\beta_1 = \beta_2 = 1.0$), along with a 5% rate of growth and depreciation ($\delta = 0.05$), and a five-period space delivery lag ($n = 5$). The economic shock that we impose on the model's initial steady solution is a 50% permanent increase in the employment demand variable (a movement from 10 million to 15 million workers). Figure 2 displays the results. With these values, the impulse response function in Figure 2 looks quite well behaved. Prices (and rents) first rise right after the shock because of the delay in new supply. They then gradually fall as new supply arrives, and finally smoothly approach the model's steady state. A negative demand shock generates a similar response pattern, only rotated around the steady state. With myopia, prices do not anticipate the forthcoming supply, but at least with the base parameter values this does not lead to any overbuilding. The adjustment in the stock is quite slow, however, and 30 periods after the shock the excess demand has been only 75% erased.

A very important feature of this model is that as long as the elasticity of supply is less than or equal to that of demand, the impulse response always seems to display the stable convergence pattern of Figure 2. If the delivery lag is lengthened to as long as 10 periods, or the depreciation rate is varied from 0 to 20%, the myopic model never displays overbuilding or oscillations—if demand is at least as elastic as supply.

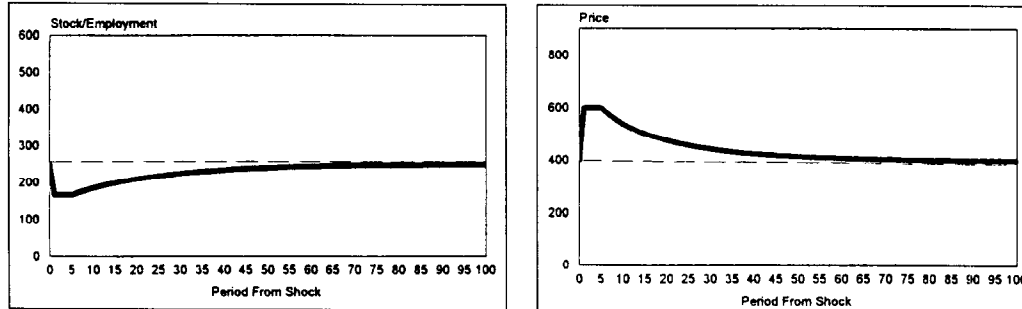
Result 1. In simulated solutions, a *necessary* condition for over- or underbuilding, or for market oscillation, is that supply is more elastic than demand: $\beta_1 \leq \beta_2$.

Supply and Demand Elasticities

In the remaining simulations, the rental demand elasticity is most often set to -0.4 ($\beta_1 = 0.4$), while the price elasticity of new construction is usually set to 2.0 ($\beta_2 = 2.0$). Elasticities in this range have been reported for office space (Wheaton, Torto and Evans 1997) and hotel space (Wheaton and Rossoff 1998). With these elasticities, and continuing the assumptions of five-period delivery lags ($n = 5$) and 5% depreciation–growth ($\delta = 0.05$), the demand shock leads to the results in Figure 3.

Figure 3 displays the first example of clear overbuilding. With myopic forecasting and a (relatively) elastic supply, the short-run shock to rents generates enough new construction “momentum” so that the stock badly overshoots the steady state (by 60%). After this, however, the stock

Figure 2 ■ Market reaction to a 50% demand shock (lag: $n = 5$; depreciation–growth: $\delta = 0.05$; demand elasticity = 1.0; supply elasticity = 1.0).



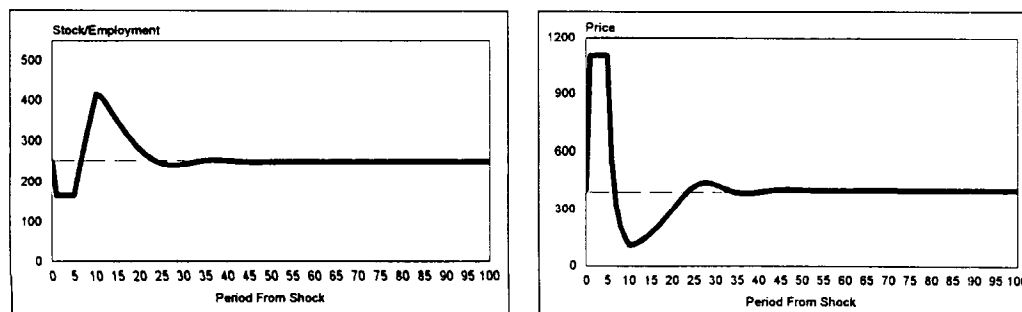
converges, overshooting only once more, and then by only 2%. If the difference between supply and demand elasticities is increased—for example, if they are changed to -0.20 and 2.0 —the model's overshooting becomes more severe and the oscillations will continue with little convergence.

It is important to state that when delivery lags and the depreciation rate (or growth rate) are much smaller (*e.g.*, $n = 2$, $\delta = 0.02$), it still seems always possible to find a set of (ever more disparate) elasticities that generate overbuilding or oscillations. As the two elasticities come close to each other, while still meeting the conditions of Result 1, it seems also possible to find a longer delivery lag and greater depreciation–growth rate that will generate overbuilding. This clearly is indicative of the role these parameters play.

Space Delivery Lags

As the lag between current market conditions and future space deliveries increases, the model become increasingly unstable, *ceteris paribus*. Continuing the simulations described above, the depreciation–growth

Figure 3 ■ Market reaction to a 50% demand shock (lag: $n = 5$; depreciation–growth: $\delta = 0.05$; demand elasticity = 0.4; supply elasticity = 2.0).



parameter remains at $\delta = 0.05$, while the demand and supply elasticities are held at $\beta_1 = 0.4$, $\beta_2 = 2.0$. As the lag is lengthened, the impulse response begins to display more severe and repeated oscillations. Figure 4 presents the results when $n = 8$. Here the oscillations are still gradually converging, but by the 79th period after the shock, the stock of space is still fluctuating $\pm 8\%$ around its steady-state value.

As the delivery lag on new supply lengthens, the length of the cycle does as well. When $n = 5$, the stock cycle peaks at the 10th, 38th and 56th periods. When $n = 8$, it peaks at the 16th, 52nd and 79th. If the same iterations are compared, the cycle also increases in amplitude as the delivery lag is increased. At $n = 5$, the second time the stock overshoots its steady state, it does so by only 2%. The second overshoot when $n = 8$ involves overbuilding the stock by 16%.

Result 2. In simulated solutions, as the delivery lag n on new space lengthens, the model begins to oscillate, with local minima and maxima at increasingly lower frequency. As the lag increases, the same-order minima and maxima display greater amplitude.

Depreciation or Growth Rate

The parameter δ turns out to play a surprisingly strong role in the dynamic stability of the model. Again this can have two interpretations. First, a higher δ can mean that the stock depreciates faster—necessitating a greater rate of construction to keep the stock at its steady state. Alternatively, δ can represent the long-term (trend) rate of growth in the demand instrument. Types of real estate that are very durable and/or have slow demand growth can be expected to have δ -values in the 0.01–0.02 range. At the other extreme, for faster-depreciating buildings in rapidly growing economies, δ might run as high as 0.10. In Figure 4, the rate used was $\delta = 0.05$. If the

Figure 4 ■ Market reaction to a 50% demand shock (lag: $n = 8$; depreciation–growth: $\delta = 0.05$; demand elasticity = 0.4; supply elasticity = 2.0).

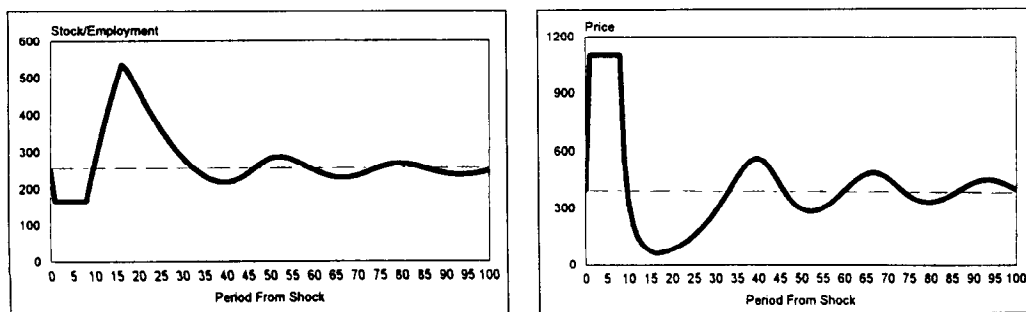
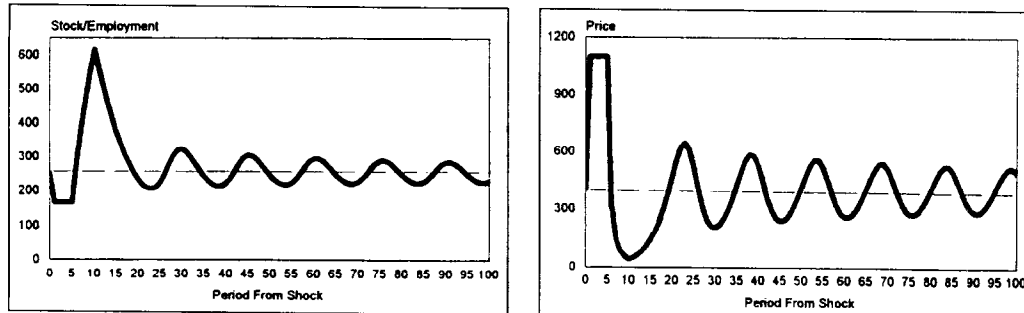


Figure 5 ■ Market reaction to a 50% demand shock (lag: $n = 5$; depreciation–growth: $\delta = 0.10$; demand elasticity = 0.4; supply elasticity = 2.0).



model's other parameters are fixed ($n = 5$, $\beta_1 = 0.4$, $\beta_2 = 2.0$), but δ is lowered to 0.02, then only one local maximum of overbuilding occurs, and it is relatively mild (15%). In contrast, if $\delta = 0.10$, the model begins to oscillate quite wildly, as displayed in Figure 5.

Result 3. In simulated solutions, as the depreciation–growth rate δ is increased, the model begins to oscillate, with local minima and maxima at increasingly greater amplitude and higher frequency.

When δ exceeds 0.10, the model becomes completely unstable: the amplitude of the oscillations increases, and the steady state appears to be unreachable. In general then, the model's dynamics are quite sensitive to what part of the parameter space is tested.

Can Rational Pricing Generate Cycles?

Much current research is focused on the question of whether markets that are rational and forward looking can exhibit some form of overbuilding or even oscillating behavior. To date, this issue has been studied largely with models that incorporate anticipated uncertainty. Thus Genadier (1995a,b) is able to show that vacancy can exhibit overbuilding cycles when there is an optional value to holding vacant space because of adjustment costs. Similarly, both Childs, Ott and Riddiough (1996) and Grenadier (1996) have recently developed models of strategic-developer *herd* behavior. If development generates informational externalities (about market demand), then agents may decide either to all act or to all wait, rather than pacing development more smoothly. Can this hold in a model without (anticipated) uncertainty?

In the rational model developed here, it is possible to generate cyclic behavior—if one is willing to impose some exogenous structure on the

market's operation that leads to historical dependence. What seems necessary is to introduce a technological or institutional feature that generates a longer-term feedback relationship among the model's variables. A recent example of this kind of feedback is Kiyotaki and Moore's model of collateralized borrowing and credit cycles (1997).

Two ideas come to mind for creating this kind of historical dependence in real estate. First, it might be assumed that while supply depends only on asset prices at the time of delivery, prices incorporate historical as well as future rents because assets are occupied (leased) by multiple tenants. Alternatively, asset prices might only reflect future rents, but supply be at least partly determined by prices at the time of decision, because projects are debt-financed.

Blended Leases

Many types of commercial property have a broad and heterogeneous mix of tenants with leases of varying lengths. This is particularly true in shopping centers and office buildings. The asset price for an existing property at time t thus depends not just on expected market rents from t forward, but also on historical rents going back some number of years. The blending of leases with different maturities creates a well-known lag between movements in market rent and real estate property income. Thus at the time an investment decision is made, the n -period-forward asset price for existing real estate can certainly incorporate market rents from as far back as the decision period. In the current model, this historical tie can be mimicked almost perfectly by simply saying that investment decisions at time period $t - n$ depend on rationally forecast property prices at time $t - n$ rather than the delivery date t .⁶

Now it could be argued that the price of newly created real estate can incorporate only rental income from the opening date forward. However, this would ignore the widespread practice of pre-leasing space that is under development. At the day of opening, it is quite common to find that the majority of space in a new project has been leased at the rental rates prevailing throughout the development period.

⁶ Strictly speaking and ignoring discounting, in the current model market rents at $t - n$ receive the same weight as those at t in determining a (lagged) asset price at period $t - n$. If $1/n$ of the leases in a building roll over each period, market rents at $t - n$ apply only to $1/n$ of the space for one period, while those from t on apply to $1/n$ of the space for n periods in determining asset prices at t .

Debt and Liquidation

The development of real estate is frequently undertaken by an entrepreneur and financed with construction debt that rolls over into a long-term mortgage. Several recent articles have advanced theories about corporate financial structure based either on the risk that the project will go awry, or on the risk that the entrepreneur will default on purpose to expropriate his proprietary knowledge of the project (Hart and Moore 1994). The liquidation value of the project during development thus plays an important role in the investment decision. Schleifer and Vishny (1992) further argue that this liquidation value is likely to depend totally on the value of similar (existing) assets. With asset specificity, the only prospective buyers of the liquidated project are those firms owning similar existing assets. Thus it could be argued that in making investment decisions the price of real estate at the time the investment is undertaken is almost as important as its price at the delivery date.

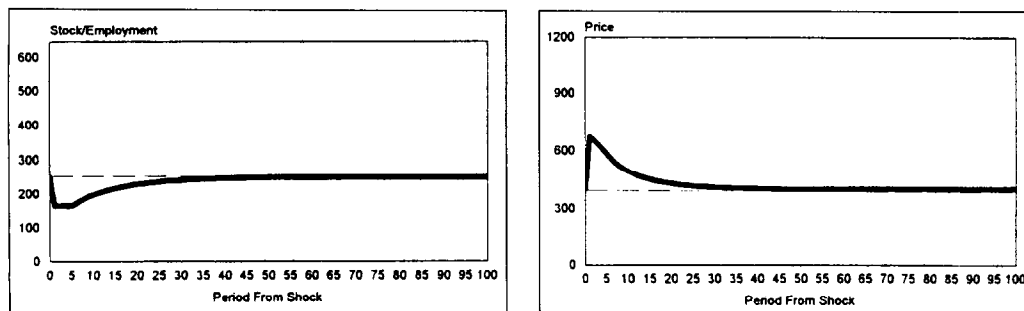
Either of these arguments can be implicitly incorporated into the current rational, forward-looking model by making supply depend on prices at the time of decision rather than delivery. Those prices, however, continue to perfectly reflect post-shock rents. With this lag, Equation (8) turns into

$$\left[\frac{P_t(1+r) - P_{t+1}}{P_{t-1}(1+r) - P_t} \right]^{-\beta_1} = 1 - \delta + \alpha_2 P_{t-n}^{\beta_2} \quad (10)$$

and the contradiction of Proposition 4 no longer holds. This at least opens up the possibility of oscillations.

For comparison purposes, Figure 6 displays the impulse response (to a 50% demand shock) under rational price forecasting without lags, using Equation (8). The parameter values chosen are those that would generate a clear

Figure 6 ■ Market reaction to a 50% demand shock (lag: $n = 5$; depreciation–growth: $\delta = 0.05$; demand elasticity = 0.4; supply elasticity = 2.0; price lag = 0).



oscillation with myopic behavior ($\delta = 0.05$, $n = 5$, $\beta_1 = 0.2$, $\beta_2 = 2.0$). In Figure 6, convergence is smooth and the model is perfectly stable. Prices just following the onset of the shock do not rise by anywhere near as much as in Figure 3 or 4, since new investment and the concomitant decline in rents are anticipated with rational forecasting.

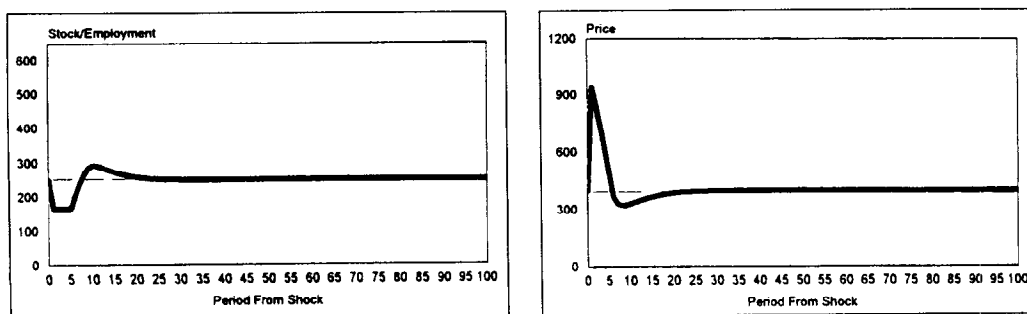
In Figure 7, the same impulse response is generated using Equation (10)—the rational model where investment depends on prices n periods prior to delivery (the date of decision). The parameter values used are also the same as those in Figure 6 ($\delta = 0.05$, $n = 5$, $\beta_1 = 0.2$, $\beta_2 = 2.0$). The result is a clear pattern of overbuilding, although the model does not oscillate repeatedly as it does in Figure 4 or 5.

Further simulations demonstrate that if the parameter values are made even more extreme (longer lags, higher growth or depreciation, more disparate elasticities), a second oscillation can be made to occur. Thus the rational model with lags behaves somewhat like the myopic model with respect to how parameter values influence the impulse responses. The parameter values necessary to generate these higher-order oscillations, however, are extreme enough to be unrealistic. Thus clearly, the effect of the induced historical "momentum" in a rational model is nowhere near as extreme as that generated by the inefficient pricing of the myopic model.

Conclusions: Stable and Unstable Parameter Combinations

The lessons from these simulations are quite clear. Hopefully they will generalize, at least qualitatively, to other stock-flow models as well. In the model developed here, and using either type of price formation (myopic or rational), certain combinations of parameters will generate impulse responses to shocks that exhibit more instability, while other combinations will lead the model to converge back smoothly to the steady state. The degree of

Figure 7 ■ Market reaction to a 50% demand shock (lag: $n = 5$; depreciation–growth: $\delta = 0.05$; demand elasticity = 0.2; supply elasticity = 2.0; price lag = 5).



instability, however, also varies dramatically by the type of price expectations assumed to hold.

Result 4. In simulated solutions, the model exhibits stability (does not cross the steady state) as long as demand is more elastic than supply or, if less elastic, as long as the delivery lag is short and depreciation or growth slow. The model exhibits increasing instability as supply becomes more elastic than demand and as the delivery lag and depreciation–growth rate increase.

Given Result 4, what is known about the parameters of different property types? Is this knowledge consistent with the model's prediction about their cyclic behavior? In the case of apartments and industrial buildings the development lag is widely known to be quite short (*e.g.*, 1 year). In contrast, major office buildings or regional shopping centers often can take 4–10 years to develop. Historically, Figure 1 shows that the growth rate of the housing and industrial stock has also been relatively slow (*e.g.*, 1–3% annually). With suburbanization and rapid growth in the service sector, the stocks of office and retail space have increased much faster during the postwar period (*e.g.*, 4–8% annually). Finally, what is known about elasticities also tends to support Result 4. Rental housing has inelastic demand, but recent arguments also suggest that supply is also not very elastic (DiPasquale and Wheaton 1994, Blackley 1996, Topel and Rosen 1988). By contrast, office demand is inelastic, but several estimates of supply suggest considerable elasticity (Wheaton, Torto and Evans 1997). At this date, little is known about behavioral parameters in the industrial market, although several authors have demonstrated its close link to the U.S. economy (*e.g.*, King and McCue 1991). As for shopping centers, there is little aggregate time-series research.

In summary, the only common component among real estate property types is a high degree of asset durability. But even small differences in durability turn out to make a considerable difference in the market's potential for instability. Beyond that, elasticities can vary significantly, as can development lags. Stock-flow models with myopic behavior turn out to be quite sensitive to all of these parameters. Even with rational behavior (and lags), these parameters matter. This gives added credence to the notion that real estate investment is not a uniform sector within the economy and that market behavior and investment performance can be fundamentally different across property types.

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