Housing Investment in the United States
Author(s): Robert Topel and Sherwin Rosen
Source: *Journal of Political Economy*, Vol. 96, No. 4 (Aug., 1988), pp. 718-740
Published by: The University of Chicago Press
Stable URL: http://www.jstor.org/stable/1830471
Accessed: 30-09-2016 03:26 UTC

Housing Investment in the United States

Robert Topel and Sherwin Rosen

University of Chicago

A supply-determined model of housing investment is estimated from quarterly data over the 1963–83 period. The model is built on dynamic marginal cost pricing considerations and allows short- and long-run supply elasticities to differ. These are estimated as 1.0 and 3.0, respectively, but most of the long-run response occurs within 1 year. Rapid adjustment speed and the sizable long-run elasticity of supply are important factors in understanding the volatility of housing investment. The data also suggest some anomalies in the expected present value theory of asset pricing for housing capital.

I. Introduction and Summary

The housing market is an attractive candidate for studying investment behavior because housing construction is highly volatile and the data are among the best available. Market prices of capital are directly observed in the housing sector, and available price data are adjusted for quality change. We develop and estimate a supply-determined model of investment in single-family housing, in which short-run supply is less elastic than long-run supply.

The next section presents informal evidence suggesting that cyclical movements in housing construction are driven largely by demand fluctuations along a rising supply curve of new homes. Factor prices are positively correlated with the level of new construction, and construction itself is positively correlated with the relative price of housing. Rising supply price of investment is the focus of the theoretical

We are indebted to Lars Hansen, Kevin M. Murphy, Michael Mussa, and the referees for helpful comments and criticism, to Andy Sparks and David Ross for research assistance, and to the National Science Foundation for financial support.

[*Journal of Political Economy*, 1988, vol. 96, no. 4]

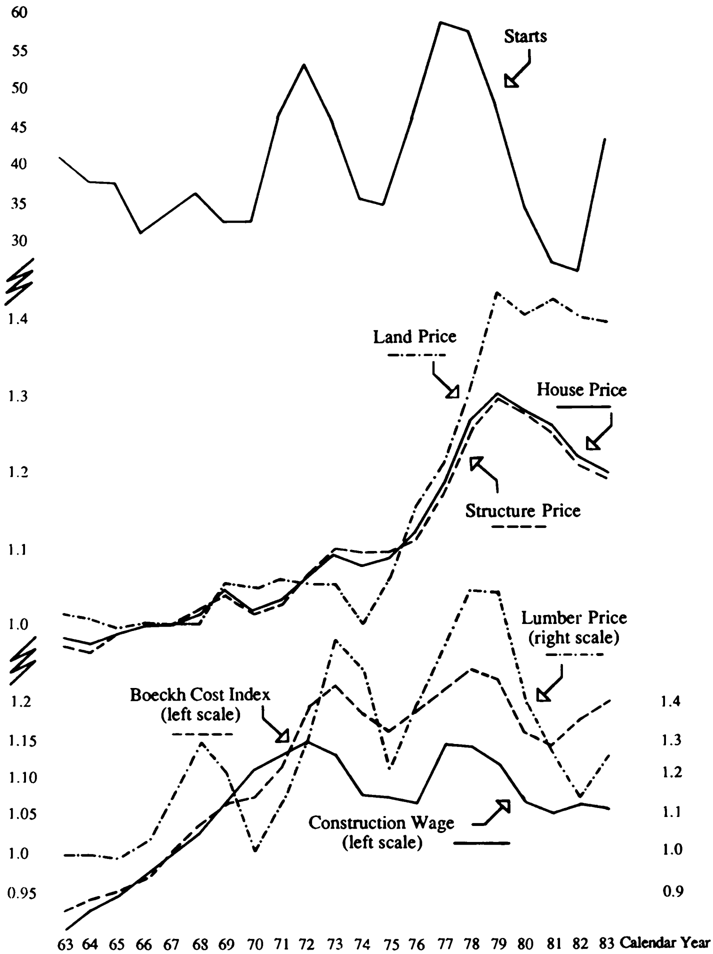

FIG. 1.—Annual time-series data

model developed in Section III. This model consists of three equations: a new housing supply decision built up from dynamic marginal cost pricing considerations, the flow demand for housing services, and the expected present value theory of asset pricing.

We present empirical estimates in Section IV using quarterly data over the 1963–84 period. The long-run supply elasticity of new housing is 3.0 and the short-run (one-quarter) elasticity is 1.0. Most of the difference between long-run and short-run supply vanishes within 1 year, implying that resources are highly mobile between the single-family housing investment sector and other sectors of the economy. Attempts to estimate demand and intertemporal price arbitrage conditions are less successful because of data limitations and because no exogenous variables can explain the sustained rise in real housing prices between 1974 and 1979, when after-tax implicit rental prices were negative. We believe that the market excessively discounted expected capital gains over this period, but ex post instrumental variable predictors track realized prices too closely to prove it.

II. Cost and Construction Activity

Figure 1 shows some of the data in annualized form to exhibit the cyclical patterns most clearly (quarterly data are used in the empirical work). The main series to be explained is housing starts. They took a gentle downward course in the 1963–70 period, with a few wiggles associated with the 1967 and 1970 recessions. The next episode was a boom in 1970–73 followed by a decline of equal magnitude in 1973–75. A more substantial boom and bust occurred during the 1975–82 period, with a peak in activity in 1977–78. The peak-to-trough ratio of building activity in the second and third episodes is approximately 2.0: an expansion doubles the output of new homes and a contraction cuts it in half. Quarterly starts data (not shown) exhibit enormous seasonal variations. Summertime construction activity is twice as large as in winter, so seasonals rival cyclical variations in amplitude. Since the industry is highly volatile and large flows of resources move in or out within a few quarters, we expect to find a large supply elasticity.

The relative price of new homes refers to a hedonically adjusted "house of 1977 characteristics" deflated by the consumer price index (excluding the shelter component). Visually comparing prices and starts suggests that price movements and construction activity are positively correlated, though construction activity appears to turn down prior to the downturn in prices. Apart from that detail of timing, this observation suggests a rising supply price of new homes. The Boeckh index of real residential construction costs lends additional support for the hypothesis of a rising supply price. Construction costs as a whole closely match the movements in housing prices and in construction activity. Examination of the individual cost components (not shown) reveals similar comovements. The market for construction labor exhibits high unemployment rates, a high level of job turnover, and the most volatile employment patterns of any industry (Topel and Ward 1987). Hourly wage rates and employment of construction labor closely follow the price and output series. Real lumber prices and lumber consumption, a major materials component of house construction, also closely track house prices and new construction. That wage rates and prices of building materials are positively correlated with factor utilization and with the price of new houses is consistent with a rising supply price of factors of production to the construction sector. In sum, the raw data are consistent with a rising supply curve of new houses traced out by shifts in demand.

III. Investment and the Housing Market

Most empirical studies of housing investment have followed the stock-adjustment demand model of Muth (1960, 1981). Later work by Kearl (1979) and Poterba (1984) views investment as determined by supply conditions (Witte 1963). The basic idea of the supply theory is easily stated. Assume that asset prices clear the stock market so that existing stock is willingly held by the public. Then desired stock is identical to actual stock and the "demand for investment" is not defined. Since investment is a small fraction of existing stock, any new units appearing on the market can be sold at existing prices. The number of new units forthcoming at any time then depends on the level of market prices relative to marginal costs of decentralized construction firms and developers. The number of new homes produced is a point on the construction supply curve.

The relation between this decentralized market framework and adjustment cost theory has been clarified by Mussa (1977). For the economy as a whole, external adjustment costs amount to rising supply price; increasing marginal cost is equivalent to external adjustment costs. The production possibilities curve between the output of investment goods and that of all other goods is concave because different industries use different factor proportions. Similarly, Abel (1980) and Hayashi (1982) have clarified the connections between Tobin's (1969) Q theory of investment and adjustment cost theory. The marginal cost of construction equals the marginal value of additional stock (its price) in adjustment cost theory, whereas the averages are proportional to each other in Q theory. In either case investment is determined by the intersection of an infinitely elastic "demand curve" with an investment supply curve, so rising supply price is necessary for investment to be finite in any period. Investment is spread over an extended interval of time because it is too expensive to do it all at once.

The simplicity of these models arises because investment decisions are myopically determined by comparing *current* asset prices with *current* marginal costs of production. Current asset prices are "sufficient statistics" for investment. However (see Kydland and Prescott 1982), the sufficiency of current prices for investment rests on the assumption that short- and long-run investment supply coincide. If short-run supply is less elastic than long-run supply because it takes some time to move factors of production between industries, then the current price is no longer sufficient for investment decisions. Builders must form expectations of future prices in choosing current construction. Our model incorporates this Marshallian distinction between short-run and long-run supply by superimposing an internal adjustment cost mechanism on the representative construction firm. The long-run production possibilities curve between investment and other goods can be thought of as the outer envelope of a family of short-run curves, with the envelope exhibiting less curvature and greater supply elasticity than any of the subsets from which it is formed.[1]

The general model consists of three relationships: supply, demand, and expectational linkages between stock and flow prices. For expository convenience, the discussion in this section is set up in terms of a continuous-time, nonstochastic model, though the empirical work uses a discrete-time, stochastic framework.

A. *Supply of New Homes*

A complete model of the dynamics of new housing supply requires detailed specification of supply dynamics for all factors of production to the industry. We cut through these immense complications and approximately incorporate dynamic factor supply conditions into industry supply by allowing marginal cost to vary with both the level of output and its rate of change; that is, "internal" adjustment costs are superimposed on the rising long-run supply price for the representative construction firm. Short-run supply is more elastic than long-run supply because rapid changes in the level of construction activity are penalized by higher costs.

Specify the industry cost function as

$$C = C(I, \dot{I}, \mathbf{y}), \tag{1}$$

where C is total cost corresponding to gross investment level I, $\dot{I}$ is the rate of change of gross investment, and $\mathbf{y}$ is a vector of variables that shift the cost function: the level of factor prices for those factors that are elastically supplied to the industry and factor supply shifters for those that are supplied less elastically. Gross housing investment is the

[1] A theorem of Benveniste and Scheinkman (1979) implies that the marginal value of a unit of capital is the gradient of a value function. These marginal values generally must be estimated from stock and bond market data but are the directly observed housing prices in this case. Current Q is sufficient to describe value if short- and long-run supply are identical, but past as well as current values of Q are necessary if short- and long-run supply differ. Summers's (1981) finding that current and past values of Q affect manufacturing investment is consistent with the model presented here. Chirinko (1986) discusses other aspects of these theories.

output of the construction industry, defined in the usual way:

$$I = \dot{K} + \delta K, \tag{2}$$

assuming exponential depreciation at rate δ. The following properties are imposed on the cost function (1). First, $C_1 = \partial C/\partial I > 0$ and $C_{11} = \partial^2 C/\partial I^2 > 0$: marginal cost is positive and increasing in output. Second, $C_2 = \partial C/\partial \dot{I} \geq 0$ and $C_{22} = \partial^2 C/\partial \dot{I}^2 \geq 0$: there is a nondecreasing cost penalty for changing the level of output.

In making its supply decision, the representative firm chooses I and $\dot{I}$ to maximize expected discounted value. With $P(t)$ written for the competitively determined (stock) price of a standard unit of housing at time t, the firm maximizes

$$\int_0^\infty [P(t)I(t) - C(I(t), \dot{I}(t), \mathbf{y}(t))]e^{-rt}dt, \tag{3}$$

where r is the rate of interest. The Euler condition is

$$P(t) - \frac{\partial C}{\partial I} = r\left(\frac{\partial C}{\partial \dot{I}}\right) - \frac{d(\partial C/\partial \dot{I})}{dt}. \tag{4}$$

Equation (4) nests the myopic supply case within a more general framework of differences between long- and short-run supplies. For if $\partial C/\partial \dot{I} = 0$, construction activity is determined by equating marginal cost to market price for all t, and current price alone is sufficient for supply. However, equation (4) shows that costs of changing output impose a wedge between price and marginal cost. The wedge causes long-run supply to be more elastic than short-run supply.

To illustrate these points, linearize the cost terms in equation (4). With operator notation $DZ = dZ/dt$ and so forth, equation (4) becomes

$$(1 + r\beta D - \beta D^2)I(t) = \left(\frac{\beta}{c_{22}}\right)P(t) - \left(\frac{\beta}{c_{22}}\right)[c_1 + rc_2 + c_{13}\mathbf{y}(t)], \tag{5}$$

where the terms in c_i and c_{ij} are derivatives of the cost function evaluated at a stationary point, and $\beta = c_{22}/(c_{11} + rc_{21})$. The crucial parameter c_{22} is the second derivative of costs with respect to $\dot{I}$, so equation (5) illustrates a well-known result that adjustment costs must be increasing to have any consequences.[2]

[2] The quadratic approximation imposes symmetry in costs for changes in both directions. If expansions are capacity constrained by availability of skilled labor or by fixed capital requirements of materials suppliers, then costs are not symmetric with respect to expansions and contractions. These refinements are not pursued here. We assume for simplicity that $c_{23} = 0$ (marginal adjustment costs are independent of supply shifters), though these can be easily reincorporated without affecting the subsequent analysis.

The partial equilibrium path of investment supply is found as follows: Define $\theta(t)$ as the right-hand side of equation (5), a linear function of $P(t)$ and $\mathbf{y}(t)$. Dividing through by β results in

$$\left(D^2 - rD - \frac{1}{\beta}\right)I(t) = (D - \lambda_1)(D - \lambda_2)I(t) = \frac{-\theta(t)}{\beta}, \tag{6}$$

where λ_1 and λ_2 are the roots of the characteristic equation $\lambda^2 - r\lambda - (1/\beta) = 0$. Both roots are real; one is negative (λ_1), and one is positive (λ_2). The solution (this is a partial equilibrium solution because $P(t)$ is endogenous in the full market equilibrium) to equation (6) takes the unstable positive root forward and the stable (negative) root backward (Sargent 1979). Performing these operations results in

$$\begin{aligned} I(t) = {} & e^{\lambda_1 t}\left\{I_0 - \frac{1}{\lambda_2 - \lambda_1}\int_0^\infty \left[\frac{\theta(\tau)}{\beta}\right]e^{-\lambda_2\tau}d\tau\right\} \\ & + \frac{1}{\lambda_2 - \lambda_1}\left\{\int_0^t \left[\frac{\theta(\tau)}{\beta}\right]e^{\lambda_1(t-\tau)}d\tau + \int_t^\infty \left[\frac{\theta(\tau)}{\beta}\right]e^{\lambda_2(t-\tau)}d\tau\right\}, \end{aligned} \tag{7}$$

where $I_0 = I(0)$ is the initial condition for the problem. Equation (7) describes the distributed lag and lead responses of investment to the forcing function $\theta(t)$. The exponential weights on $\theta(t)$ in the last two integrals are declining in both directions so that forcing data affect current investment $I(t)$ through a backward and forward exponential "window." The weighting functions are concentrated on current data $\theta(t)$, and supply decisions become myopic as β approaches zero because $\lim_{\beta\to 0}|\lambda_i| = \infty$. This occurs when c_{22} approaches zero, from the definition of β.

A partial equilibrium conceptual experiment illustrates the distinction between short- and long-run supply. Start from a situation in which $\theta(t)$ has been constant at a value θ_1 and investment has settled down to its long-run level $I(t) = I_1 = \theta_1$, a point on the long-run supply curve. Take this as an initial condition in (7) and suppose that the price of housing takes an unexpected jump to P_2, where it remains thereafter. Then $\theta(t)$ jumps from θ_1 to some higher value θ_2 and $I(t)$ converges asymptotically to a new long-run value of $I_2 = \theta_2$, also on the long-run supply curve. Substituting $\theta(t) = \theta_2$ into (7) yields the path by which $I(t)$ travels from I_1 to I_2:

$$I(t) = \theta_2 - (\theta_2 - \theta_1)e^{\lambda_1 t}. \tag{8}$$

The exponential response is largest at the beginning and smallest at the end. Manipulations of equation (8) lead to the flexible accelerator: $\dot{I}(t) = -\lambda_1[I_2 - I(t)]$, where I_2 is the target to which $I(t)$ converges when $P(t) = P_2$. This form is familiar from early discussions of adjustment cost models (Eisner and Strotz 1963; Lucas 1967; Gould 1968;

Treadway 1969). This experiment depicts an evolving supply curve if various short runs are identified with specific intervals of time and the long run with an arbitrarily long interval. The long-run supply curve connects the points (I_1, P_1) and (I_2, P_2) in the investment-price plane. Short-run supply curves are spun out of the point (I_1, P_1) and are less elastic than long-run supply, with the elasticity increasing as time goes by.

Equation (7) also shows how supply responds to temporary changes in price. Suppose that price unexpectedly rises from P_1 to P_2 for a finite interval of time T, after which it returns to P_1. The price disturbance is "more permanent" the larger is T and is "more transitory" the smaller is T. Differentiating (7) with respect to t and evaluating at $t = 0$ yields an expression for the initial (impact) response:

$$\dot{I}(0) = \lambda_1\theta_1 + \int_0^\infty \left[\frac{\theta(\tau)}{\beta}\right] e^{-\lambda_2\tau} d\tau. \tag{9}$$

For the postulated square wave pulse in $P(t)$ this becomes

$$\dot{I}(0) = -\lambda_1(\theta_2 - \theta_1)(1 - e^{-\lambda_2 T}), \tag{10}$$

which is increasing in T, that is, the more permanent the pulse. How long must the pulse in $P(t)$ last for the impact response to be m percent of the impact response to a permanent change in price? From equation (10) the pulse must have length $T^* = -\ln(1 - m)/\lambda_2$; T^* is decreasing in λ_2 or increasing in c_{22}, another way of saying that differences between short- and long-run responses to price changes vanish as internal adjustment costs get small.

Specification (4) or (5) has more than academic interest. We were led to it because the simpler model does not allow short-run/long-run differences in supply. It also fits the data better. The cost of this generality, as is clear from (7), is that current $P(t)$ no longer incorporates all current and future information that is relevant for investment decisions. Expectations of future asset prices affect current supply.

B. Demand, Expectations, and Market Equilibrium

The supply function is the main focus of this study but is only one element of a structural model of the overall market. To understand how all these elements interact in determining market dynamics, it is helpful to outline the larger model.

Consider the simplest possible demand specification in which frictions generated by heterogeneity of units and the matching of buyers and sellers are ignored. In particular, assume that housing units can be measured on a homogeneous scale through use of a hedonic index, that market transactions can be treated as if they occur in a frictionless auction, and that the capital market is perfect. Let K_t denote the stock of housing capital and assume a proportional service flow. Then the inverse demand for housing services can be written as

$$R = \alpha K + \mathbf{x}, \tag{11}$$

where R is the implicit rental price of a unit of housing services, $\mathbf{x}(t)$ is a vector of exogenous demand shifters, and $\alpha < 0$.

Connections between stock prices and expected future rental prices complete the model. The rational expectations hypothesis (perfect foresight in this deterministic model) is used here. When taxes are ignored to simplify, the rental price of a house is its amortized stock price including allowances for interest, depreciation, and capital gains, or

$$R = (r + \delta)P - \dot{P}, \tag{12}$$

where r is the rate of interest. The value of the housing stock must be bounded so that $\mathbf{x}(t)$ and $\mathbf{y}(t)$ cannot grow too fast and the discounted future price of capital converges:

$$\lim_{t \to \infty} P(t)e^{-(r+\delta)t} = 0. \tag{13}$$

Integrating (12) and using boundary condition (13) yields the familiar asset pricing equation:

$$P(t) = \int_t^\infty R(s)e^{-(r+\delta)(s-t)}ds. \tag{14}$$

The price of a house is its discounted future market equilibrium rental.[3]

When (12) is substituted into (11) and (5) is rewritten in the obvious notation, the complete market dynamics of stocks and prices are described by two linear differential equations:

$$(1 + r\beta_1 D - \beta_1 D^2)I(t) = \beta_0 + \beta_2 P(t) + \mathbf{y}(t), \tag{15}$$

$$(r + \delta)P(t) - \dot{P}(t) = \alpha K(t) + \mathbf{x}(t), \tag{16}$$

along with the connection between $I(t)$ and $\dot{K}(t)$ in equation (2), initial conditions for $K(0)$ and $I(0)$, and terminal condition (13). Differentiating (16) with respect to t and substituting from (2) yields

$$(1 + rBD - BD^2)P(t) = \alpha BI(t) + B(D + \delta)\mathbf{x}(t), \tag{17}$$

where $B = [\delta(\delta + r)]^{-1}$.

[3] With the method of Lucas (1981), it is readily shown that this model is the decentralized market equivalent of a social planning problem that maximizes discounted consumer and producer surplus. Rationality in the sense of (14) is necessary for efficiency, that is, for market prices to reflect the true social value of additional capital.

Analysis of this system reveals the partial equilibrium nature of the discussion surrounding equations (5)–(10) above. In the special myopic case in which $\beta_1 = 0$, (15) and (16) are the familiar second-order system analyzed by Sheffrin (1983) and Poterba (1984). Dynamics are easily analyzed using phase-plane methods (Abel 1982; Drazen 1985; Judd 1985). It pays to build ahead of anticipated demand when there is rising supply price in order to distribute costs over an extended interval of time. For instance, an anticipated transitory increase in future demand causes bubble-like price and investment responses: House prices increase immediately in a rational market, and this signals increased construction activities prior to the time the change occurs. Rental prices fall during this phase because of accumulating stock. At the point at which demand actually jumps up, rational agents anticipate its transitory nature, so price starts falling and construction turns around. After the shock has passed, the housing stock is too large and must be worked down to its steady-state level. Further reductions in price reduce investment below steady-state values, while price and investment gradually rise back to steady-state levels. Rising supply price spreads investment and price responses both backward and forward from the time anticipated shocks occur.

The generalized model in which $\beta_1 \neq 0$ is (15) and (17). This is a fourth-order system in $P(t)$ and $I(t)$ and cannot be analyzed in the phase plane. Nonetheless, its solution is qualitatively similar to the simpler model. Now the incentives to spread adjustments over an extended interval of time are even larger because of the extra penalty of internal adjustment costs. Responses are more sluggish than when $\beta_1 = 0$ for this reason. The characteristic equation for system (15) and (17) can have complex roots, however, something that cannot happen when $\beta_1 = 0$. This leads to damped sinusoidal distributed lagged responses of price and investment to pulses in $\mathbf{x}(t)$ and $\mathbf{y}(t)$ and occurs when demand for housing services is very inelastic. Space limitations preclude analyzing full system dynamics here.

IV. Estimation

A. *Supply*

The supply function is estimated with quarterly time-series data on U.S. housing starts over the 1963:I–1983:IV period. The empirical form of the myopic ($\beta_1 = 0$) supply model (4) is

$$I_t = \beta_0 + \beta_2 P_t + \beta_3 \mathbf{y}_t + v_t, \tag{18}$$

where I_t denotes new single-family housing units started during quarter t, P_t is the (real) hedonic price index for 1977-quality homes, and $\mathbf{y}_t$ is a vector of cost shifters. Unobserved cost shifters account for v_t, and these are assumed to be orthogonal to observable supply and demand shifters. Summary statistics for variables entering (18) are reported in the last row of table 1. Data sources and definitions of variables are found in the Appendix.

Several alternative specifications are shown in table 1. The first four rows ignore any autoregressive structure in the residuals, and the last two assume an AR(2) process. The estimation method is instrumental variables using current and lagged exogenous variables as instruments because of the endogeneity of P_t. In practice, the first-stage instrumenting equation has a large R^2. This "overfitting" means that the point estimates differ little from least squares. Still, endogeneity is unlikely to be a serious problem because investment is such a small fraction of existing stock. Seasonally unadjusted data are used, including seasonal dummies in the regression (not shown), plus another dummy for the severe winter of 1979. The real price index includes the value of the site plus structure, though similar results were obtained using the structure price alone.

The first column of table 1 indicates positive supply responses to changes in the price of housing. The implied supply elasticity at sample means ranges between 1.4 and 2.2 and is not sensitive to the specification of the error process.[4]

Our initial specifications of supply included real interest rates as cost shifters, meant to reflect the cost of working capital to builders. The magnitude of the effect of interest rates on new investment suggests that more is involved, however. We find a strong response of housing starts to changes in both the real rate of interest and expected inflation, and the hypothesis that nominal rates of interest affect housing investment cannot be rejected. The reported specifications include both the ex ante real rate of interest and the expected 3-month rate of price inflation. Both have similar negative effects on construction. The estimates in row 5 imply that a one-point increase in either the annual real rate of interest or the expected rate of inflation reduces new construction by about 8.0 percent. These effects are too large to be generated by changes in the cost of capital to builders. When the model includes both current and lagged effects of these

[4] There may be selection problems in the price data because they are constructed from actual transactions. For example, if there are no sales in a particular location in some quarter, that location gets no weight in the price index. This is not a serious problem for estimating an aggregate supply function because it approximates the appropriate "marginal" concept. However, it may affect more detailed inferences concerning timing and lags. Also, approximately 25 percent of units are built on contract and the rest for the market at large. This introduces some noise, for our purposes, in linking starts with prices on a quarter-to-quarter basis. Experiments with one-quarter leads and lags of prices and with two-quarter price averages revealed that the estimates of supply parameters are insensitive to these refinements.

TABLE 1

Two-Stage Least Squares Estimates of Housing Investment: Rising Supply Price Model, 1963:I–1984:IV

Equation	P_t	$E_{t-1}r_t$	$E_{t-1}\pi_t$	$E_{t-2}r_{t-1}$	$E_{t-2}\pi_{t-1}$	Months_t	Wage_t	Trend	Intercept	AR(1)	AR(2)	R^2	SE
1	4,110.64	−452.86	−370.93	...	...	...	...	1.54	−809.31	...	...	.76	154.5
	(984.83)	(46.36)	(42.26)					(1.97)	(414.82)				
2	3,925.87	−273.20	−240.52	...	...	−304.21	...	1.20	−365.17	...	...	.89	102.0
	(648.95)	(35.65)	(30.84)			(31.07)		(1.31)	(277.47)				
3	3,709.95	−142.24	−115.03	−177.28	−177.34	−236.73	...	2.41	−340.74	...	...	.91	96.3
	(615.83)	(62.49)	(47.56)	(68.32)	(53.97)	(35.73)		(1.30)	(262.79)				
4	4,049.33	−266.72	−242.83	...	...	−291.15	59.74	.66	−667.17	...	...	.90	101.5
	(660.02)	(36.35)	(30.82)			(34.10)	(66.20)	(1.43)	(430.04)				
5	2,589.62	−313.62	−244.21	...	...	...	...	1.67	−222.77	.69	−.16	.91	109.1
	(1,177.54)	(53.12)	(44.48)					(2.60)	(506.30)	(.11)	(.11)		
6	3,693.73	−131.06	−120.38	−133.05	−136.82	−261.59	...	1.31	−302.21	.58	.13	.93	69.87
	(920.85)	(44.04)	(32.72)	(46.87)	(37.52)	(35.70)		(2.13)	(399.36)	(.11)	(.11)		
Mean	.527	.20	1.50	.20	1.50	1.67	2.83	43.5	...	...	...	...	...
(Standard deviation)	(.055)	(.66)	(.90)	(.70)	(1.00)	(.49)	(.13)	(23.90)					

NOTE.—Asymptotic standard errors are in parentheses. Dependent variable is quarterly single-family housing starts. Variable definitions: P_t is the hedonic price index for new, 1977-quality single-family homes sold in quarter t; $E_{t-1}r_t$ is the real quarterly rate of interest; $E_{t-1}\pi_1$ is the expected rate of inflation; Months is the median time on the market since the beginning of construction for houses that are for sale in quarter t; Wage is the average hourly real wage of construction workers. All data are seasonally unadjusted. Regressions include seasonal dummies and a dummy for the severe winter of 1979:I. Instruments: Variables used as instruments are current and lagged values of interest rates on 25-year term mortgages, aggregate real consumption expenditure (as a proxy for permanent income), an index of family formation, and an energy price index.

variables, both have similar statistically significant negative effects on current supply.

Sensitivity of housing construction to interest rates is well known (e.g., Muth 1981) but is surprising because all demand-side effects should be embodied in asset prices in an ideal market. There are reasons why nominal interest rate changes affect housing demand; for example, higher nominal rates increase current real interest payments on fixed-rate mortgage loans (Kearl 1979). Another possibility for demand-side effects is that credit was rationed during the sample period (Poterba 1984). Effects of either kind should reduce investment by causing prices to fall. They should have no independent direct effects on supply. Perhaps the lag structure of model (18) is too simple, and changes in current interest rates signal changes in future asset prices. Alternatively, fluctuations in the nominal rate may signal changes in the ability to sell new homes at the current price.

This last interpretation is supported by the finding that time to sale has a large effect on new construction. The Months variable in table 1 is the median time on the market for new houses for sale in quarter t. Sales delay entails forgone interest costs to the builder and can be incorporated by discounting the price to reflect expected waiting time to sale (Poterba 1984). However, table 1 shows that delay effects are much too large to be interpreted as forgone interest costs alone.[5] The incremental cost of a 1-month increase in time to sale surely is less than 1 percent of the price because it is just 1 month's interest. A supply price elasticity of 2.0 implies an effect of less than 2 percent, yet the direct estimates show that an additional month's delay reduces investment by 30 percent. Similarly, the typical house is on the market for 2 months prior to sale, so a one-point increase in the real rate increases a builder's cost by 0.2 percent, yet the directly estimated effect is 8 percent.[6] These findings suggest that a pure auction model of trade in homogeneous units does not completely describe the housing market, even for aggregate time-series analysis.

We have experimented with including the Boeckh index of construction input costs, the manufacturing wage, and the average wage of construction workers as cost shifters. None had important effects. For example, row 4 reports estimates that control for the hourly wage of construction workers. After instrumenting to account for rising

[5] We have considered the case in which Months is endogenous. When this variable is instrumented, the results differ trivially from those reported here.

[6] These effects are much larger than Poterba's (1984) constrained estimates, though the specification in table 1 is otherwise similar to his, except for the trend term. Dropping Trend from the investment equation increases the supply elasticity by 20 percent; it is included to allow for technical change in the industry and because of the marked trend in prices apparent in fig. 1.

supply price of labor to the industry, we find no evidence that wage fluctuations were exogenous cost shifters. Rather, they are endogenously determined from shifts in the derived demand for construction labor. Finally, the last rows report variants of the myopic supply model when the errors follow an AR(2) process. The main results are not affected. However, the statistical significance of the autoregressive structure suggests misspecification of supply dynamics. We turn to the dynamically enriched model next.

The discrete-time stochastic analogue of the Euler condition (5) or (15) is

$$I_t = \beta_0 + \beta_1 I_{t-1} + a\beta_1 E_t I_{t+1} + \beta_2 P_t + \beta_3 \mathbf{y}_t + v_t, \tag{19}$$

where E_t denotes expectation given period t information, a is a discount factor, and $\beta_1 > 0$ reflects internal adjustment costs (c_{22} above). If β_1 is significantly positive, then long-run supply is more elastic than short-run supply. Of course, $\beta_2 \geq 0$ and $\beta_3 < 0$. The appearance of I_{t-1} and EI_{t+1} in (19) adds econometric complications. We continue to assume that the error term represents unobserved cost shifters. The expectation is unobserved, and, as before, P_t is endogenous. To estimate (19) replace $E_t I_{t+1}$ with its realization I_{t+1}:

$$I_t = \beta_0 + \beta_1 I_{t-1} + a\beta_1 I_{t+1} + \beta_2 P_t + \beta_3 \mathbf{y}_t + v_t - a\beta_1 \epsilon_{t+1}, \tag{20}$$

where $\epsilon_{t+1} = I_{t+1} - E_t I_{t+1}$ is orthogonal to period t information under rational expectations; I_{t+1} is endogenous and correlated with the composite error term. We assume that $E(x_{t-j} v_t) = E(y_{t-j} v_t) = 0$ at all lags j, so that lagged supply and demand shifters are valid instruments for I_{t+1} and P_t. Two sets of estimates are reported in table 2, depending on the v_t process.

First, if v_t follows an arbitrary time-series process, then lagged endogenous variables are also correlated with the error, so consistent parameter estimates are obtained by using current and lagged values of exogenous variables as instruments. With the composite errors in (20) denoted by $\eta_t = v_t - a\beta_1 \epsilon_{t+1}$, the error covariance at lag 1 is

$$E(\eta_t \eta_{t-1}) = E(v_t v_{t-1}) - a\beta_1 E(v_t \epsilon_t). \tag{21}$$

Innovations in v_t are components of the forecast error ϵ_t, so (21) is nonzero (Hansen 1982). Since $E(v_t \epsilon_t)$ is positive, η_t is negatively autocorrelated at lag 1, even if v_t is white noise, if $\beta_1 > 0$. If v_t is serially correlated as well, the negative correlation in η_t persists at higher lags. If v_t is AR(1) with parameter μ, then

$$E(\eta_t \eta_{t-j}) = \mu^j \sigma_{vv} - \mu^{j-1} \sigma_{v\epsilon} = \mu^{j-1} E(\eta_t \eta_{t-1}). \tag{22}$$

In calculations of standard errors for the instrumental variable estimates of (20), the errors are allowed to follow (22), where a consistent

TABLE 2

INSTRUMENTAL VARIABLES ESTIMATES OF HOUSING INVESTMENT: ADJUSTMENT COST MODEL, 1963:I–1984:IV

Equation	P_t	$I_{t-1} + aEI_{t+1}$	$E_{t-1}r_t$	$E_{t-1}\pi_t$	$E_{t-2}r_{t-1}$	$E_{t-2}\pi_{t-1}$	Months_t	Wage_t	Intercept	Corr $(\eta_t\eta_{t-1})$	μ	SE
1	805.76	.496	−35.78	35.12	...	...	...	...	−580.71	−.29	.41	74.19
	(348.79)	(.04)	(32.44)	(27.87)					(100.51)			
2	1,699.21	.339	−89.85	−85.89	...	...	−144.31	...	−392.27	−.01	.45	68.31
	(510.25)	(.05)	(35.75)	(30.82)			(32.68)		(163.98)			
3	1,945.41	.274	−50.16	−37.42	−95.05	−103.67	−131.03	...	−367.07	−.36	.44	66.98
	(555.76)	(.06)	(25.75)	(36.75)	(25.31)	(39.93)	(34.35)		(182.73)			
4	1,496.96	.356	−75.14	−72.37	...	...	−131.99	−5.1	−364.72	−.15	.43	67.85
	(491.28)	(.05)	(32.20)	(28.98)			(28.86)	(24.94)	(244.05)			
5	1,676.37	.300	−154.86	−143.05	...	...	...	...	−657.14	−.20	.29	78.28
	(606.65)	(.04)	(43.85)	(37.83)					(216.59)			
6	2,130.20	.209	−109.62	−100.25	−80.07	−79.66	−52.73	...	−579.02	−.22	.34	69.45
	(589.47)	(.05)	(66.05)	(55.14)	(67.36)	(57.29)	(37.50)		(194.16)			

NOTE.—Asymptotic standard errors are in parentheses. Seasonal dummies, 1979:I winter dummy, and Trend variable are included in all regressions. Dependent variable is quarterly single-family housing starts. Variable definitions: I_{t-1} and I_{t+1} denote starts from quarters $t - 1$ and $t + 1$, respectively. For definitions of other variables, see the note to table 1.

estimate of μ in (22) is used to form the error covariance matrix in (20).

Second, if v_t truly is AR(1), it is appropriate to quasi-difference (20) (see Cumby, Huizinga, and Obstfeld 1983). The model becomes

$$I_t = (1 + \mu a\beta_1)^{-1}[\beta_0(1 - \mu) + (\mu + \beta_1)I_{t-1} - \mu\beta_1 I_{t-2} + a\beta_1 I_{t+1} + \beta_2(P_t - \mu P_{t-1}) + \beta_3(\mathbf{y}_t - \mu\mathbf{y}_{t-1}) + \eta_t - \mu\eta_{t-1}], \tag{23}$$

$$\eta_t - \mu\eta_{t-1} = u_t - a\beta_1\epsilon_{t+1} + \mu a\beta_1\epsilon_t, \tag{24}$$

where u_t is white noise. Equation (23) can be estimated by instrumental variables and imposing the nonlinear restrictions across parameters.[7] We report estimates of the parameters of (20) in both differenced (eq. [23]) and nondifferenced form. Estimates based on higher autoregressive processes did not differ from those reported here.

Table 2 reports the estimates. Rows 1–4 are based on equation (20), using only lagged supply and demand shifters as instruments for investment and price. In all specifications, the error covariance at lag 1 is negative, as implied by (21) if the covariance between v and ϵ is large and $\beta_1 > 0$. This does not mean that the "true" errors, v_t, are negatively serially correlated: the estimated autoregressive parameter for v_t is always positive, a plausible result if v_t represents unobserved cost shifters. The quasi-differenced form in rows 5 and 6 produces a slightly smaller autoregressive parameter, though still positive.

The main result in table 2 is that the time-invariant rising supply price model of table 1 is rejected: the estimated internal adjustment cost parameter is numerically large and always more than triple its estimated standard error. The estimates of β_1 are found in the second column and were obtained by constraining the coefficients of I_{t-1} and E_tI_{t+1} to differ by an assumed discount factor of $a = .98$. This restriction is not rejected in any form of the model. Estimates of β_1 and other parameters are insensitive to choice of a in the neighborhood of .98, and when the restriction is not imposed, the point estimates for independent coefficients on I_{t-1} and EI_{t+1} are nearly identical to the reported values of β_1. Estimated adjustment costs are slightly smaller in the quasi-differenced form in rows 5 and 6, but the fundamental finding is not affected: There are differences in the response of current investment to permanent and transitory changes in price, as well as differences between short- and long-run production adjustments.

[7] The appearance of the forecast error ϵ_t in (24) means that current demand and supply shifters are not exogenous. These variables are in the information set at t, and they are components of ϵ_t. Thus $\mathbf{y}_t$ also must be instrumented. On the other hand, lags of investment and price are valid instruments under this assumption, so some trade-off in efficiency is involved.

The estimated adjustment cost effects are somewhat sensitive to specification: the model in row 1 implies large adjustment costs (and small current investment response to current price changes), but including lagged interest rates and median time on the market substantially increases the immediate response of investment to price. As in table 1, both median time to sale and interest rates have strong negative effects on current investment, and the hypothesis that decisions are driven by the nominal rate of interest still cannot be rejected in any form of the model.[8] This suggests that their significance is not due to dynamic misspecification but rather to a conceptual inadequacy of treating the housing market as if it were a homogeneous auction market. If we exclude row 1, the long-run effects of price on investment are not much different among the models in table 2.

To quantify the experiments analogous to (8)–(10) above, consider the one-sided forward solution to (20):

$$I_t = \frac{\beta_0 \kappa}{a\beta_1(1 - \kappa)} + \frac{\kappa}{a} I_{t-1} \frac{\beta_2 \kappa}{a\beta_1} \underset{t}{E} \sum_{i=0}^{\infty} \kappa^i P_{t+i} + \frac{\beta_3 \kappa}{a\beta_1} \underset{t}{E} \sum_{i=0}^{\infty} \kappa^i \mathbf{y}_{t+i}, \tag{25}$$

where κ is determined (from the characteristic polynomial of [20]) by

$$\kappa = \frac{1}{2\beta_1}\left(1 - \sqrt{1 - 4a\beta_1^2}\right). \tag{26}$$

From (25), the *current* impact of an unanticipated unit pulse in price that is thereafter expected to last exactly T periods is

$$\left.\frac{dI_t}{dP_t}\right|_T = \frac{\beta_2 \kappa}{a\beta_1} \sum_{i=0}^{T} \kappa^i = \frac{\beta_2}{a\beta_1} \frac{\kappa}{1 - \kappa}(1 - \kappa^{T+1}) \tag{27}$$

and is increasing in T. Note that even for $T = 1$, the response exceeds the price coefficient in table 2 because the experiment in (27) allows future levels of planned investment to adjust optimally. As in Section III, the response path of investment to a permanent change in P allows comparison between short- and long-run supply response. Straightforward calculations give the time path as

$$\frac{dI_{t+j}}{dP} = \frac{\beta_2}{a\beta_1} \frac{\kappa}{1 - \kappa} \frac{1}{1 - (\kappa/a)}\left(1 - \frac{\kappa}{a}\right)^{j+1}, \tag{28}$$

which is increasing in j. The change in long-run equilibrium levels of investment is obtained by letting $j \rightarrow \infty$.

[8] The shifter for the winter of 1979 has a larger coefficient in the adjustment cost model of table 2 than in table 1. We included this variable on examining the residuals for models in table 2. Excluding it has no appreciable effect on the other estimates.

TABLE 3

ESTIMATED SUPPLY ELASTICITIES FOR PERMANENT AND TRANSITORY PRICE CHANGES (Evaluated at Sample Means)

	A. Current Response to a Price Shock Lasting T Quarters				B. Response by Quarter to a Permanent Price Increase			
Model	$T = 1$	$T = 4$	$T = 8$	$T = \infty$	$T = 1$	$T = 4$	$T = 8$	$T = \infty$
1. $\kappa = .82$	.72	2.18	3.15	3.94	3.94	12.27	18.22	23.83
2. $\kappa = .34$	1.04	1.64	1.68	1.68	1.68	2.69	2.76	2.76
3. $\kappa = .22$	1.18	1.51	1.51	1.51	1.52	1.93	1.93	1.93

NOTE.—κ computed from eq. (27).

Table 3 reports supply responses for the models in rows 1, 2, and 6 of table 2. For ease of interpretation, the effects are expressed as elasticities evaluated at sample means; for example, the first entry of 0.72 corresponds to equation (27) with $T = 1$, $\beta_1 = 0.496$, and $\beta_2 = 805.76$. For these parameters the impact of adjustment costs on supply decisions is large ($\kappa = 0.82$), so adjustments are spread over a long period of time (see panel B). The current response to a permanent price increase has an elasticity of 4.0, and the long-run supply elasticity is nearly 24.0. These estimates are very large because no allowance is made for time to sale effects and β_1 is overestimated in that specification. Rows 2 and 6 produce smaller adjustment cost effects. In these models, a permanent price increase has a 50 percent greater impact on current investment than a one-period price shock does. However, almost all this difference is accounted for by a relatively short disturbance lasting 1 year. In our judgment the best estimate of the long-run elasticity of supply is model 2, which yields an elasticity of 2.76. For comparison, the rising supply price model in table 1 yielded an elasticity of 2.08 for both long- and short-run price changes.

B. Demand

It has not been possible to estimate meaningful demand parameters from these data. There are two reasons for this. One is a limitation of data, and the other is an anomaly in imputed rents during the 1974–79 period.

Estimating equation (16) requires constructing a time series on stocks K_t using perpetual inventory methods. But investment is such a small fraction of existing homes that the imputed stock series is too smooth and trendlike to be informative about demand. The quasi-difference form in equation (17) uses directly observed investment, but prices appear in second-difference form, and this compounds

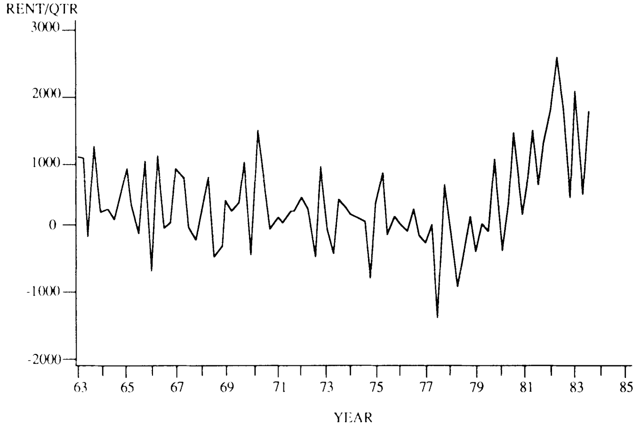

FIG. 2.—After-tax real rent, 1977 dollars

measurement errors and timing problems in the price data. The second-differenced price series is so noisy that it too is uninformative about demand parameters. The data simply do not allow us to estimate this component of the model.

Figure 2 graphs a time series of the after-tax rental price index R_t imputed from real stock prices (see the Appendix for details). Visually filtering quarter-to-quarter noise, it exhibits disturbingly low values during the 1974–79 period, when relative housing prices increased dramatically, and rises rapidly thereafter. Feldstein (1982) has pointed out that general price inflation during this period increased the income tax subsidy to home ownership, making housing a more attractive investment than other assets and causing its relative price to rise. But figure 2 suggests that taxes were only part of the story. To the first order, greater subsidies should be capitalized in house prices but leave real rents unchanged for given demand for housing services. To the second order, higher asset prices encourage greater investment, increase the stock of homes, and decrease rents a little. But after-tax rents in figure 2 declined far too much during 1974–79 to be attributed to the minor increase in stocks. The marked increase in implicit rents during 1979–82 suggests that capital gains expectations were too pessimistic in the 1974–79 period.

The values in figure 2 are ex post rentals. Ex ante rentals would exhibit less of a decline if the market systematically underpredicted capital gains over that period. The negative ex post real interest rates observed during the inflation support this possibility, but we are unable to construct an ex ante series on capital gains that differs from the ex post realizations in any meaningful way. Retroactively, it is too easy to make one-step-ahead forecasts of prices within the sample period, a difficulty associated with the "overfitting" of instrumental variables noted above. Rosen, Rosen, and Holtz-Eakin (1984) suggest that uncertainty increased during the period when housing prices increased. Attaching an additional risk premium to the real rate of interest in the rental imputation would indeed temper the decline in rents shown in figure 2. However, there is no persuasive evidence that real mortgage interest rates rose or that mortgage credit was excessively rationed over the period in question, so the decline in rents remains an unresolved question.

V. Conclusion

The main empirical findings support the view that investment responds elastically to changes in asset prices. The estimated long-run supply elasticity of about 3.0 is the largest that has been found so far in quarterly time-series data (see the surveys by Olsen [1986] and Weicher [1979]). The estimated short-run supply elasticity of 1.0 is much smaller than the long-run elasticity, but the differences between the two converge within the time frame of 1 year. There are good economic reasons for rapid convergence in the construction industry. Labor and other resources used in house construction are not highly specialized to the industry and are widely used in all sectors of the economy. Perhaps the pronounced seasonal and cyclical fluctuations in construction promote a certain adaptability and built-in flexibility in the organization of the industry that allow resource movements to respond quickly to changing economic conditions.

The estimates also reveal deficiencies of an investment model based on homogeneous capital and costless auction market assumptions. The evidence that nominal interest rates and expected waiting time to sale have large direct effects on housing investment is not consistent with these assumptions. Better understanding of the timing of transactions and of market participation is necessary to fill out knowledge of dynamics. Fragmentary data on transactions volume in the overall housing market appear to be positively correlated with housing starts. Externalities of matching and search imply that it is more advantageous to participate in an active market than in an inactive one. The implied intertemporal substitution may provide the link between asset pricing, new construction, and transactions volume now missing from conventional capital theory. It remains to be studied in detail. Nonetheless, the large price elasticity of supply of new houses estimated here must be an important consideration for understanding the great variability in housing investment.

Data Appendix

Time-series data used in the empirical work were obtained from the following sources.

New single-family housing prices.—The price data were obtained from a survey conducted by the Bureau of the Census since 1963 for new single-family homes actually sold during the reference period. The index refers to characteristics of a standard 1977-quality house as obtained from a hedonic regression of actual price data on a vector of house characteristics in each year. Source: U.S. Bureau of the Census, *New One-Family Houses Sold and for Sale* (Construction Reports, ser. c25).

Investment.—Housing starts are new one-unit structures on which construction was started during the reference period. Similar results were obtained from real dollar values of gross investment and are not reported. Source: U.S. Bureau of the Census, Construction Reports, series c20.

Interest rates.—The nominal rate of interest for the supply function is the 3-month Treasury bill rate quoted by Salomon Brothers on the last day of the previous period. The real rate used is the one-step-ahead forecast from an estimated AR(2) regression in the first differences of the real rate (Fama and Gibbons 1982). Since r_t is estimated, standard errors are corrected (Murphy and Topel 1985). Mortgage interest rates for first mortgage loans on single-family homes are published by the Federal Home Loan Bank Board. The series used to construct R_t refers to the effective interest rate on 25-year maturity loans with a loan to price ratio of 25 percent.

Months.—Median months on the market for new units sold during the quarter. Source: Unpublished data obtained from the Bureau of the Census.

Boeckh cost index.—A weighted average of construction input prices for small residential structures. Source: U.S. Department of Commerce, Bureau of Industrial Economics, *Construction Review.*

Personal consumption expenditures.—Source: U.S. Bureau of Economic Analysis, *The National Income and Product Accounts of the United States.*

Families.—The number of married-couple family households. Source: U.S. Bureau of the Census, *Current Population Reports,* series p-20.

Fuel price index.—Source: U.S. Department of Labor, Bureau of Labor Statistics, *Monthly Labor Review.*

Real implicit rental price.—Define the income-tax-adjusted real interest rate as $\hat{r}_t = (1 - \tau_t)i_t - \pi_t$, where i_t is the nominal interest rate, τ_t is the marginal income tax rate, and π_t is the rate of inflation. Anticipated real rent is the expected present value of a round-trip buy and sell transaction over one quarter (ignoring transactions costs), or $R_t = P_t - E_tP_{t+1}(1 - \delta)/(1 + \hat{r}_t)$, where P_t is the real asset price and δ is the quarterly depreciation rate, calculated at 0.0035 per quarter from a perpetual inventory method. This expression ignores maintenance expenditures and property taxes and assumes no taxation of capital gains (see Hendershott and Hu [1981] and Dougherty and Van Order [1982] for a discussion of those refinements). The ex post numbers shown in figure 2 replace the expectation with realized values, using the 3-month Treasury bill interest rate and assuming that capital gains are taxed at rate τ_t. Assuming no taxation of capital gains yields a series with the same general appearance but with more pronounced fluctuations and a much larger drop in rent during 1974–79. Two alternative estimates of τ_t were tried. One is Barro and Sahasakul's (1983) estimates of the average marginal tax rate; the other is the estimated tax bracket that makes tax-free municipal bonds a marginally profitable investment. In figure 2, τ_t is set at 0.3. The time-series character of the R_t series is insensitive to these differences in taxes. The quarter-to-quarter noise in figure 2 arises from measurement error in price differences in the computational formula.

References

Abel, Andrew B. "Empirical Investment Equations: An Integrative Framework." *Carnegie-Rochester Conf. Ser. Public Policy* 12 (Spring 1980): 39–91.

———. "Dynamic Effects of Permanent and Temporary Tax Policies in a *q* Model of Investment." *J. Monetary Econ.* 9 (May 1982): 353–73.

Barro, Robert J., and Sahasakul, Chaipat. "Measuring the Average Marginal Tax Rate from the Individual Income Tax." Manuscript. Rochester, N.Y.: Univ. Rochester, 1983.

Benveniste, Lawrence M., and Scheinkman, José A. "On the Differentiability of the Value Function in Dynamic Models of Economics." *Econometrica* 47 (May 1979): 727–32.

Chirinko, Robert S. "The General Structure of Investment Models and Their Implications for Tax Policy." Manuscript. Cambridge, Mass.: NBER, 1986.

Cumby, Robert E.; Huizinga, John; and Obstfeld, Maurice. "Two-Step Two-Stage Least Squares Estimation in Models with Rational Expectations." *J. Econometrics* 21 (April 1983): 333–55.

Dougherty, Ann, and Van Order, Robert. "Inflation, Housing Costs, and the Consumer Price Index." *A.E.R.* 72 (March 1982): 154–64.

Drazen, Allan. "Cyclical Determinants of the Natural Level of Economic Activity." *Internat. Econ. Rev.* 26 (June 1985): 387–97.

Eisner, Robert, and Strotz, Robert H. "Determinants of Business Investment." In *Impacts of Monetary Policy,* by the Commission on Money and Credit. Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Fama, Eugene F., and Gibbons, Michael R. "Inflation, Real Returns and Capital Investment." *J. Monetary Econ.* 9 (May 1982): 297–323.

Feldstein, Martin. "Inflation, Tax Rules and the Accumulation of Residential and Nonresidential Capital." *Scandinavian J. Econ.* 84, no. 2 (1982): 293–311.

Gould, John P. "Adjustment Costs in the Theory of Investment of the Firm." *Rev. Econ. Studies* 35 (January 1968): 47–55.

Hansen, Lars Peter. "Large Sample Properties of Generalized Method of Moments Estimators." *Econometrica* 50 (July 1982): 1029–54.

Hayashi, Fumio. "Tobin's Marginal *q* and Average *q*: A Neoclassical Interpretation." *Econometrica* 50 (January 1982): 213–24.

Hendershott, Patric H., and Hu, Sheng Cheng. "The Allocation of Capital between Residential and Nonresidential Uses." Manuscript. Cambridge, Mass.: NBER, 1981.

Judd, Kenneth L. "Short-Run Analysis of Fiscal Policy in a Simple Perfect Foresight Model." *J.P.E.* 93 (April 1985): 298–319.

Kearl, James R. "Inflation, Mortgages, and Housing." *J.P.E.* 87, no. 5, pt. 1 (October 1979): 1115–38.

Kydland, Finn E., and Prescott, Edward C. "Time to Build and Aggregate Fluctuations." *Econometrica* 50 (November 1982): 1345–70.

Lucas, Robert E., Jr. "Optimal Investment Policy and the Flexible Accelerator." *Internat. Econ. Rev.* 8 (February 1967): 78–85.

———. "Optimal Investment with Rational Expectations." In *Rational Expectations and Econometric Practice,* vol. 1, edited by Robert E. Lucas, Jr., and Thomas J. Sargent. Minneapolis: Univ. Minnesota Press, 1981.

Murphy, Kevin M., and Topel, Robert. "Estimation and Inference in Two-Step Econometric Models." *J. Bus. and Econ. Statis.* 3 (October 1985): 370–79.

Mussa, Michael L. "External and Internal Adjustment Costs and the Theory of Aggregate and Firm Investment." *Economica* 44 (May 1977): 163–78.

Muth, Richard F. "The Demand for Non-Farm Housing." In *The Demand for Durable Goods,* edited by Arnold C. Harberger. Chicago: Univ. Chicago Press, 1960.

———. "Is the Housing Bubble about to Burst?" *Papers Regional Sci. Assoc.* 48 (1981): 7–18.

Olsen, Edgar O. "The Demand and Supply of Housing Services: A Critical Survey of the Empirical Literature." In *Handbook of Urban Economics,* edited by Edwin S. Mills. Amsterdam: North-Holland, 1986.

Poterba, James M. "Tax Subsidies to Owner-occupied Housing: An Asset Market Approach." *Q.J.E.* 99 (November 1984): 729–52.

Rosen, Harvey S.; Rosen, Kenneth T.; and Holtz-Eakin, Douglas. "Housing Tenure, Uncertainty, and Taxation." *Rev. Econ. and Statis.* 66 (August 1984): 405–16.

Sargent, Thomas J. *Macroeconomic Theory.* New York: Academic Press, 1979.

Sheffrin, Steven M. *Rational Expectations.* Cambridge: Cambridge Univ. Press, 1983.

Summers, Lawrence H. "Taxation and Corporate Investment: A *q*-Theory Approach." *Brookings Papers Econ. Activity,* no. 1 (1981), pp. 67–127.

Tobin, James. "A General Equilibrium Approach to Monetary Theory." *J. Money, Credit and Banking* 1 (February 1969): 15–29.

Topel, Robert, and Ward, Michael. "Job Mobility and the Careers of Young Men." Manuscript. Chicago: Univ. Chicago, Grad. School Bus., 1987.

Treadway, Arthur B. "On Rational Entrepreneurial Behaviour and the Demand for Investment." *Rev. Econ. Studies* 36 (April 1969): 227–39.

Weicher, John C. "Urban Housing Policy." In *Current Issues in Urban Economics,* edited by Peter Mieszkowski and Mahlon Straszheim. Baltimore: Johns Hopkins Univ. Press, 1979.

Witte, James G., Jr. "The Microfoundations of the Social Investment Function." *J.P.E.* 71 (October 1963): 441–56.