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Investment in residential building: A time-series analysis with aggregate Finnish data

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INVESTMENT IN RESIDENTIAL BUILDING: A TIME-SERIES ANALYSIS WITH AGGREGATE FINNISH DATA

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ABSTRACT. In the paper the supply side of the housing market - investment in residential building - is examined by means of modern time series econometrics. The data are seasonally unadjusted quarterly series from Finland over the period 1979-1996. The housing market is first analyzed as a dynamic system of two endogenous variables, real house prices and real housing investment. The estimated relationships indicate that real house prices have a strong positive impact on housing investment in the long-run. The estimated long-run price elasticity of housing investment is 0.73. House prices are determined mainly by the factors that are exogenous to the system, but influence the demand for housing. At the second stage the housing investment equation is estimated by the method of instrumental variables treating the expected house price change as an endogenous variable. Estimation results suggest that the suppliers of new housing take account of future price changes in making investment decisions. The short-run response from expected house price changes to housing investment is 0.4 and the implied long-run response 0.75 in the model that does not include financial variables as exogenous regressors. The introduction of financial variables into the model reveals that housing investment is positively influenced by the lagged changes in the housing loan stock suggesting that credit rationing affects more the flow supply of new housing than the demand for housing.

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1. Introduction

In the paper I examine the Finnish housing market in the framework of the asset market model developed by Kearl (1979) and Poterba (1984). The focus of the analysis is on the supply side of the housing market, the determination of investment in residential building (housing investment for short). The asset market model implies that the supply of new housing is a rising function of the prices determined in the asset (or stock) market and are in the short-run mainly influenced by the demand-side factors. Topel and Rosen (1988) later extended the model by the inclusion of adjustment costs in the intertemporal optimization problem of the representative firm. Because expanding rapidly the scale of production is costly to the firm, it is profitable to spread investment over the longer period of time. The firm must, therefore, take account of the expected path of future prices in making investment decisions and respond more slowly to changes is current prices than the simple asset market model would predict. The short-run price elasticity of the supply of new housing will then be lower than the long-run elasticity.

The empirical findings of Poterba (1984) and Topel-Rosen (1988) are largely in accordance with their theoretical propositions. Poterba (1984) estimated the housing investment equation with the quarterly US data of the period 1974-82 and obtained a significant positive price elasticity for housing investment (the ratio of housing investment to GNP) the value of which varied from 0.5 to 2.3. Another significant variables in his housing investment equations were the measures of credit availability which, according to him, indicates that builders are more affected by credit rationing than the demand-side actors of the housing market. The results by Topel-Rosen (1988) also support the view that the suppliers of new housing respond elastically to changes in real house prices. According to their estimations (with quarterly US data, the estimation period 1963-83) the long-run price elasticity of the supply is close to 3 and the short-run elasticity about one. The difference between the short-run and long-run elasticities is in accordance with the presence of increasing adjustment costs that penalize too rapid changes of the scale of construction.[1]

A few Finnish studies on housing investment also point at the positive relationship between housing investment and asset market prices, although the elasticities are much lower than in the aforementioned US studies. Tuomala - Takala (1990) run regression on housing investments in which the short-run price elasticity was only 0.15 and the long-run elasticity 0.25 in the period 1980-1987. However, the price variable did not obtain a significant coefficient in the regression that covered the whole period from 1972 to 1987. In Suoniemi (1991) the long-run elasticity of the supply of housing with respect to the difference between the asset market price and construction costs was 0.49 estimated over the period 1971-1989.

In this study housing investment is measured as gross investment in residential construction in the Finnish national accounts. The variable thus includes both the building of new houses and rehabilitation of the old housing stock. It corresponds to the theoretical concept of gross housing investment which is the sum of net additions to stock and replacement investment. The variable used in the USA studies - the number of housing starts - which represents net housing investment is not available at the quarterly basis in Finland. Figure 1 shows the logarithms of the aggregate housing investment series at constant prices (seasonally adjusted in the figure) and the real house price index. Figure 2 presents the fourth differences (i.e. annual growth rates) of the same series. Figures give the impression of a quite close correspondence between the two variables housing investment following the changes of house prices with a short lag. The empirical analysis of this paper aims at testing whether this relationship is, indeed, true and significant, and not only spurious taking account of the fact that both variables are highly nonstationary in

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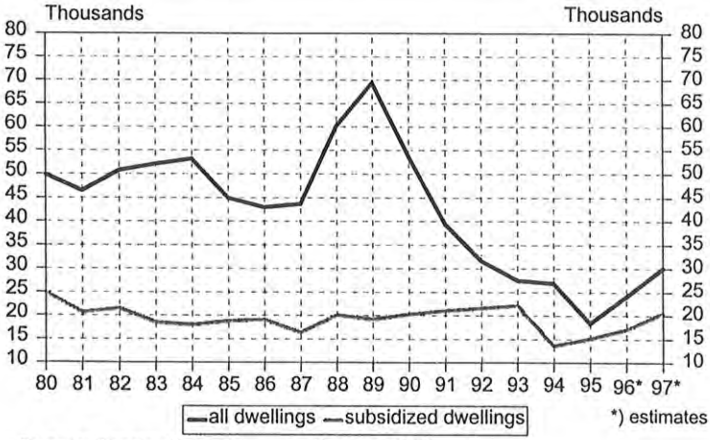
[1] Hakfoot and Matysiak (1966) estimate a housing investment model similar to that of Topel -Rosen (1988) with Dutch data and obtain positive short-run and long-run price elasticities the values of which are 2.3. and 6.1. respectively.

levels and therefore ordinary least-squares regression technics are not adequate. The estimation strategy is explained more closely in the empirical part of the paper.

I have made no attempts to divide the housing investment series into a subsidized and non-subsidized part mainly, because such data is not available at the quarterly basis. Figure 4 presents, however, the annual numbers of housing starts for all dwellings and subsidized dwellings respectively. As can be seen, the evolution of subsidized housing production has been much more stable than that of all dwellings. Large fluctuations of housing investment are thus mainly due to the fluctuations of the unsubsidized housing production. With respect to short-run dynamics the analysis based on the aggregate housing investment series gives, therefore, probably similar results as the analysis based on the unsubsidized part of housing investment alone.

Figure 4. Housing starts in Finland 1980 - 1997



Sources: Construction and Housing Yearbook 1996.
Rakentamisen suhdanteet 1997:1.

The structure of the paper is the following. In chapter 2 the theoretical background of this study is presented. The basic implications of the asset market model with respect to the supply side of the housing market are first scrutinized. The section 2.2. gives an account of the ways adjustment costs are introduced into the economic analyses of investment behavior. The role of adjustment costs in the determination of housing investment is analyzed at the end of the section 2.2. with the model that has otherwise similar characteristics as the Topel - Rosen model but is formulated in a stochastic, discrete-time framework.

The empirical part of the paper begins by analyzing the housing market as a dynamic system of two endogenous variables, housing investment and house prices. The system analysis allows of testing the causal relationship between the endogenous variables and the degree of cointegration in the system. As the second step of empirical analysis the short-run dynamics of housing investment is examined with single equation technics.

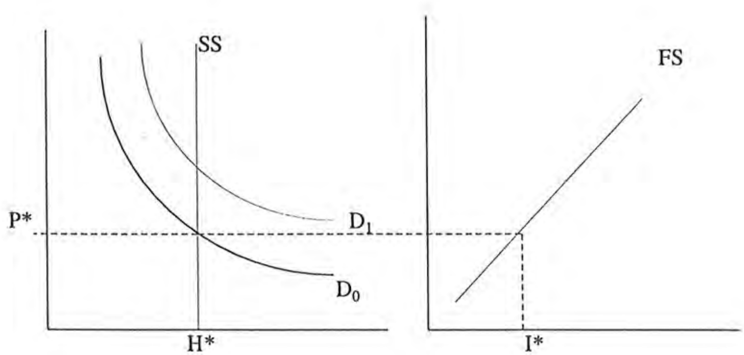
2. The theory of housing investment

2.1. The asset-market approach

The determination of housing investment is often analyzed in the framework of the asset-market model developed by Kearl (1979) and Poterba (1984). The model is highly aggregate and ignores the fact that the housing market is, in reality, divided into several submarkets differentiated by location, tenure form, quality characteristics etc. The simple model is, however, a useful tool for analyzing the dynamic process that determines house prices, the level of construction activity and the causal links between the two.

The basic structure of the model is presented in figure 5. The left-hand side of the figure represents the market for existing houses and the right-hand side the market for new construction. The downward-sloping D-curves depict the demand for housing and the SS-curve the stock supply of housing. The vertical stock supply curve expresses the fact that the housing stock responses only gradually to changes is prices and is therefore fixed in the short-run.

Figure 5. The asset market model



The demand for housing is derived in the following way[2]. The housing stock produces housing services which are consumed by individuals until the marginal values of these services is equal to their marginal cost. The marginal value is the implicit rental price of the unit of housing and the costs consist of the user cost multiplied by the real price of the unit of housing. The user cost is defined as the cost of owning a unit of housing and is the sum of real interest rates net of taxes, depreciation and maintenance costs minus expected capital gains. If the user cost decreases, the individuals are willing to consume more housing services at the same price level and the demand curve shifts upwards (from D_0 to D_1 in the figure). Other factors that shift the demand curve include demographics, household real income and wealth and possibly credit availability.[3]

The market-clearing price of the housing market is in the intersection of the downward-sloping demand curve with the vertical supply curve (P^* in the figure). Because of the fixity of the stock supply the shifts of the demand curve upwards or downwards give rise to the change of market prices of equivalent magnitude in the short-run.

The curve FS in on the right-hand side of the figure is the supply curve of the house building industry. It represents the amount of new housing the building industry is willing to provide at each price level. The supply of new housing is here equivalent to gross housing investment, i.e. net additions to the housing stock plus the replacement of the existing stock due to depreciation. The model assumes implicitly that the industry is competitive in the sense that the firms cannot influence the price level, but take prices determined in the asset market as given. The flow supply is an increasing function of market prices. The more prices increase in the asset market the more the firms are willing to provide new housing. The assumption of the rising supply function is usually rationalized by the presence of some kind of adjustment costs, as will be discussed more in detail in the next section.

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[2] Poterba (1984)

[3] The determination of housing demand is more closely analyzed in Kosonen (1997).

It should be emphasized the determination of housing investment in the asset-market model differs from other economic investment theories in certain aspects. First, there is no discrepancy between the desired and actual housing stock in the model. In the stock market prices always clear the market until the entire stock is willingly held by the public. In this respect the model differs, for instance, from the neoclassical investment theory or stock-adjustment models in which investment demand is a function of the gap between the actual and desired capital stock.[4]

Secondly, as a consequence of the first point, the "investment demand" is not defined in the model, but the firms can always sell all their output at prevailing prices. In other words they face a perfectly elastic demand schedule. The rising supply function is, therefore, necessary to make the amount of housing investment finite in the model. From this it follows that also in the long-run there will be a positive correlation between the supply of housing and the price level. This is contrary to the neoclassical investment theory in which the supply curve is perfectly elastic in the long-run and, therefore, steady state prices or determined solely by construction costs and independent of the level of demand.

To sum up, the empirical implications of the asset market model are the following. House prices are determined mainly by demand conditions, i.e. the factors that shift the demand curve in the stock market. These prices determine, in turn, the level of housing investment, along with cost factors that shift the flow supply curve. In the absence of credit market restrictions house prices are a sufficient statistic for housing investment, since all the information that affect the demand for housing is already incorporated in prices. The demand variables should therefore have no significant effect on housing investment in equations in which house prices are used as regressors. Even in the conditions of credit rationing, the variables such as real

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[4] Muth (1989) represents the stock-adjustment approach and Suoniemi (1991) uses a very similar model in analyzing the Finnish housing market. The study of Egebo- Lienert (1988) on housing investments in OECD countries is also based on the stock-adjustment model.

interest rates or credit availability should not affect housing investment, if they only constrain households or other potential house-buyers. Only if the construction firm are effectively constrained by credit availability or high interest rates on short-term loans that are used to finance the construction period, should housing investment be affected by such variables as real interest rates or proxies for credit rationing.[5] This is again contrary to the predictions of the neoclassical investment theory according to which housing investment is mainly determined by real interest rates and a quantity variable representing aggregate demand such as the real GNP.[6]

Because of the fixity of the housing stock, house prices are not much affected by housing investment in the short-run and can, therefore, quite safely be treated exogenous in the housing investment equation. In the long-run, however, housing investment increase the stock of housing (shifts the stock supply curve) which naturally affects the market-clearing level of prices. From this it follows that houses prices are, in principle, endogenous in the long-run. This should be taken into account in the modeling strategy and formulate the housing market as the system of two dynamic equations, one for prices and one for investment, which are jointly estimated. This strategy is also followed in this study.

A major criticism against the asset market model concerns its dynamic structure. Construction firms act "myopically" in the model in that they respond instantaneously to changes in current prices and don't take account of future prices in making investment decisions. In reality, it may take time and be costly to move productive resources form one place to another and change rapidly the level of activity. The presence of such adjustment costs implies that it may be profitable to spread construction activity over the longer period of time. Current house price will

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[5] As Poterba (1984) remarks, this can be used a simple device for testing how credit market imperfections affect the housing market.

[6] Hall - Taylor (1986).

then no more be a "sufficient statistic" for housing investment and the long-run price elasticity of supply will be higher than the short-run elasticity.[7]

In the next section I consider more closely investment models which treat adjustment costs explicitly and generate a dynamic structure more suitable for empirical analysis than the simple asset-market model.

2.2. The determination of investment in the presence of adjustment costs

Adjustment costs were introduced to the economic theory of investment originally to overcome certain shortcomings of the neoclassical theory of investment and as a tool of modeling explicitly the dynamics inherent in the investment process.[8] The demand for capital is derived in the neoclassical theory as a function of current prices and output levels. In the absence of adjustment costs the optimal capital stock is reached immediately. The dynamics is introduced into this static framework only at the second stage of analysis by assuming that there are delivery lags that prevent the firms of adjusting their capital stock immediately to the desired level. These delivery lags, however, don't affect the optimal solution. As Nerlove (1972) remarks, they are totally unforeseen by the firms in the model have, therefore, an "ad hoc" nature. Another problem of the neoclassical model is that the optimal capital stock is well-defined only if the production function exhibits diminishing return to scale. If the returns are constant which is the usual assumption, the model is consistent only under static expectations.[9]

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[7] Kydland - Prescott (1982) and Topel - Rosen (1988) both make this point.

[8] The neoclassical theory of investment was developed by Dale Jorgenson and his collaborators and has been a dominant theory of investment in macroeconomic textbooks.

[9] The shortcomings of the neoclassical investment theory are analyzed more in detail in Chirinko (1993).

The early models which explicitly incorporate adjustment costs into the optimization problem are those of Lucas (1967), Gould (1968), Treadway (1969) and Nerlove (1972).

In these models adjustment costs are internal to the firm. They arise because the accumulation of capital, for instance the installation of a new equipment, requires resources that otherwise could be used in the production process. Internal adjustment costs, in other words, represent a lost output to the firm.[10] The essential property of these models is that adjustment costs increase at an increasing rate. The more rapid is the rate of capital accumulation the more costly will it be.

In a formal presentation it is convenient to express adjustment cost in the form of a quadratic cost function:

(1) $$C(I)= q_0 I + q_1 I^2$$

where I is gross investment and the coefficients q_0, q_1 > 0. The cost function has requested properties: $C(0) = 0$, $C(I) > 0$, $C'(I) > 0$, $C''(I) > 0$.
The rate of change of capital is gross investment less depreciation and is defined by:

(2) $$\dot{K} = I - \delta K$$

where $\dot{K} = dK / dt$ is the rate of capital accumulation (net investment) and δ is the constant rate of depreciation of the capital stock K.

[10] External adjustment costs are the costs of purchasing capital goods for the capital-using firm and are equal to the supply price of capital goods producers. As Mussa (1977) remarks, although such costs are external to the firm they are internal to the economy as a whole. In the "supply function theory" of investment adjustment costs are external, while in the neoclassical theory in which the investment function is formulated as the demand for capital accumulation they are treated as internal to the firm.

The net returns of the firm consist of the value of output net of costs on variable inputs and adjustment costs represented by C(I):

(3) $R(t) = P(t)\, Q(t) \; - \; w(t)\, L(t) - C(I(t))$

where q is output , P is output price, L is labor input, w is wage rate. The production technology of the firm is expressed by the production function $Q = F(K,L)$ which assumed to be homogenous of degree one.

The objective of the firm is to maximize the discounted present value of the future net returns, i.e. the present value of the firm V:

(4) $$V = \int_0^\infty e^{-rt} R(t) dt$$

where r is the rate of discount assumed to be constant here.

The first-order conditions for the optimization can be presented in the form of a Euler equation which under the quadratic cost of adjustment function and linear homogenous production function is a linear differential equation and, hence, can be exactly solved. The rate of capital accumulation is defined by a second-order differential equation and the rate of investment of a first-order differential equation. The solution to these differential equations has the property that current investment will depend on the entire future path of prices, wages and interest rates.[11] These models illustrate the dynamic, forward-looking nature of the investment process, when adjustment costs are treated as an integral part of the firm's optimization problem.

Tobin's q theory is often seen as an alternative approach for analyzing the firm's investment behavior. Tobin's q, or marginal q, is defined as the ratio of the

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[11] See, Gould (1968), Treadway (1969) and Nerlove (1972).

marginal revenue of the investment project to its replacement cost. The firm invests as long as q exceeds one ($q > 1$), and shrinks its capital stock, if $q < 1$. The equilibrium capital stock is achieved, when $q = 1$. Since marginal q is unobservable, is often replaced by average q- the ratio of the financial value of the firm to the replacement cost of the capital stock - in empirical applications. Hayashi (1982) shows, however, that average q and marginal q are equivalent only under certain conditions.

The q -theory is often rationalized by assuming that the discrepancy between the marginal value and the replacement cost of capital is caused by the adjustment costs related to changing the capital stock.[12] Hayashi (1982) shows formally that optimizing behavior combined with the adjustment cost technology defined in equation (1) leads to the optimal investment rule in which investment is an increasing function q, adjusted for tax parameters. q is defined as the ratio of the present discounted value of future marginal products (the shadow price of capital) to the price of investment goods. By contrast, investment is not dependent on the demand for the firm's output or the form of the production function, because q incorporates all the information that is relevant for the investment decision.[13]

The q theory of investment can be easily reconciled with the asset-market model of Kearl (1979) and Poterba (1984). The value of an additional unit of housing investment is simply the asset market price and the marginal q is defined as the ratio of the house price to the building cost of the unit of housing. Housing investment is an increasing function of this ratio, which is also the "sufficient statistic" for housing investment. In this context the problem of measuring the marginal q is easily solved, because the asset market prices and construction costs are directly observable.[14]

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[12] For instance, Hall-Taylor (1986).

[13] See also Blanchard - Fischer (1989).

[14] For instance, Tuomala - Takala (1990) apply the q theory in their estimations of the housing investment equation with Finnish data.

The model by Topel and Rosen (1988) combines the simple asset-market model with the adjustment cost technology which formally has the similar properties as in the modified neoclassical investment theory. However, the model is formulated rather in the spirit of the "supply function theory" which treats investment as the supply of capital goods rather than the demand for capital accumulation of the users of capital.[15] The choice variable in the model is gross housing investment I(t) which is equal to the output of the representative firm. The firm maximizes the present discounted value of its profits which are equal to the value of the output net of adjustment costs and other costs.

Adjustment costs are associated not only with the level of output I (t) but also with the rate of change of investment $\dot{I} = dI / dt$. The cost function is $C = C(I, \dot{I}, y)$ where y is the vector of cost shifters, i.e. the exogenous cost factors that shift the flow supply function. The cost function has the following properties $\partial C / \partial I > 0,\ \partial^2 C / \partial I^2 > 0,\ \partial C / \partial \dot{I} > 0,\ \partial C^2 / \partial \dot{I}^2 > 0.$

Hence, the marginal cost is positive and increases with the level of output and with the rate of change of its output. Since the rapid rate of output growth is penalized by higher costs, the firm responds more slowly to changes in output prices and the price elasticity of supply is higher in the long-run than in the short-run.

The model is formulated in continuous time, non-stochastic form and solved by the method of calculus of variation. The objective function the firm is maximizing has the form

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

[15] See Mussa (1977) , who emphasized, however, that there is necessarily no conflict between the two; the investment function is at the same time the supply and the demand function and its form is influenced both by internal and external adjustment costs.

The optimization with respect to I(t) gives the Euler-equation which, after linearizing the cost terms, is the second-order linear differential equation. The solution gives current investment as a function of leads and lags of the forcing variables (exogenous output prices and cost shifters). Hence, housing investment depend not only on current, but expected future house prices. The assumption of the adjustment costs that increase with the rate of change of output is crucial for this outcome; without it the model would collapse into the "myopic case" in which the output price is simply equal to the marginal cost of production. The explicit treatment of the dynamics of the investment process makes the model an interesting framework for the empirical analysis.

The following model is formulated in the stochastic, discrete-time framework, but is otherwise similar to the Topel -Rosen model. The decision variable the optimization problem is again the supply of new housing which is equal to gross housing investment I_t. The output price P_t is a random variable exogenously given to the firm. The adjustment costs associated with the level and the change of output are nonnegative and convex, as in the Tope- Rosen model. They are here approximated by a quadratic function

(5) $C(I_t) = \frac{1}{2} q I_t^2 + \frac{1}{2} f \Delta I_t^2$, where q, f > 0.

Hence, the marginal costs with respect the level of output and the change of output are positive ($C'(I_t)>0$, $C'(\Delta I_t)>0$) and increasing ($C''(I_t)>0$, $C''(\Delta I_t)>0$).

The firm chooses the output in such manner that the present discounted value of expected future cash flow is maximized. The cash flow is the value of the output net of the costs of labour and other inputs, the price of which per unit of output is Z_t , and adjustment costs defined in (5). The objective function is now

(6) $V_t = E_t \sum_{j=0}^{\infty} b^j \left\{ P_{t+j} I_{t+j} - Z_{t+j} I_{t+j} - C(I_{t+j}, \Delta I_{t+j}) \right\}$

E_t is the expectation given the information set at time t and b the discount factor that satisfies $0 < b < 1$.

The first order conditions for an optimum are presented in the form Euler equations which are obtained by equating to zero the derivatives of (6) with respect to I_t, I_{t+1}, ..etc. The Euler equations have in this case the following form

$$(7)\quad bE_{t+j}I_{t+j+1} + \left(\frac{q}{f} + (1+b)\right)I_{t+j} + I_{t+j-1} = -f^{-1}(P_{t+j} - Z_{t+j}) \quad \text{for } j = 0,1,2, \ldots$$

To solve the Euler equation two boundary conditions are needed. The first is that the past history of the decision variable I_{t-1} is given and the second is the following transversality condition holds.

$$(8)\quad \lim_{T\to\infty} E_t b^T \{P_{t+T} - Z_{t+T} - qI_{t+T} - f(\Delta I_{t+T})\} = 0$$

The transversality condition is satisfied if the stochastic processes $\{P_t\}, \{Z_t\}$ and the solution $\{I_t\}$ are of exponential order less than 1/b.[16]

The Euler equation is here solved by the method of factorization introduced by Sargent (1979, Ch. IX).[17] The Euler is first transformed by using the definition $E_{t+j}I_{t+j+1} \equiv E_s I_{s+1}$ where s = t+j and shifting it backward by one period

$$(9)\quad bE_{s-1}I_s - \phi I_{s-1} + I_{s-2} = -f^{-1}(P_{s-1} - Z_{s-1})$$

where $\phi = (\frac{q}{f} + 1 + b)$.

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[16] See, Sargent (1979), p. 197.

[17] See also Blanchard - Fischer (1989).

Next the operator B is defined as $B^j E_{s-1} I_s = E_{s-1} I_{s-j}$. Like the ordinary lag operator it shifts the date of the variable backward, but leaves the information set unaltered. With the minus sign the operator shifts the date of the variable forward: $B^{-j} E_{s-1} I_s = E_{s-1} I_{s+j}$.

By applying the operator B the equation (9) is transformed into

(10) $$b(1-\frac{\phi}{b}B+\frac{1}{b}B^2)E_{s-1}I_s = -E_{s-1}(f^{-1}(P_{s-1}-Z_{s-1})$$

The lag polynomial in (10) can be expressed as $(1-\lambda_1 B)(1-\lambda_2 B)$ where λ_1 and λ_2 are the two characteristic roots of the lag polynomial. The roots are the functions of the parameters of the objective function (6) in the following way: $\lambda_1\lambda_2 = \frac{1}{b}$ and $\lambda_1 + \lambda_2 = \frac{\phi}{b}$. It can be shown that the roots are real and distinct and that one of them is less and the other more than one in absolute value. The roots are solved from the characteristic equation $\lambda^2 - \frac{\phi}{b}\lambda + \frac{1}{b} = 0$ and are $\lambda_i = \frac{1}{2}\left(\frac{\phi}{b} \pm \sqrt{(\frac{\phi}{b})^2 - \frac{4}{b}}\right)$ for i= 1,2. The roots are real and distinct, if the term in the square root is positive, i.e. $\frac{\phi^2}{b^2} - \frac{4}{b} > 0$. Assuming first that q, f = 0, the condition for the inequality to hold is that $\frac{1+b}{\sqrt{b}} > 2$ which is always true as long as $0 < b < 1$. If q,f > 0, the condition holds as well, because $\phi = \frac{q}{f} + 1 + b$.

The condition for the first root to be less than one is $\frac{1}{2}\left(\frac{\phi}{b} + \sqrt{(\frac{\phi}{b})^2 - \frac{4}{b}}\right) < 1$. This is equivalent to requiring that $\frac{\phi}{b} - \frac{1}{b} < 1$, which cannot be true if q, f, b > 0.

The condition for the second root to be less than one is $-\sqrt{(\frac{\phi}{b})^2 - \frac{4}{b}} < 2 - \frac{\phi}{b}$ which must hold since the term under the square root is positive and $\frac{\phi}{b} > 2$. Hence, one of the roots is larger than one and the other less than one in absolute value.
Hence, the dynamics of the investment process, as expressed by the equation (9), is characterized by saddle point stability. As Blanchard - Fischer (1989) point out, the saddle point property is, in fact, necessary for any economic model to have a unique equilibrium and nonexploding solution.

In the following it is assumed that λ_1 is the stable root ($\lambda_1 < 1$) and λ_2 is the unstable root ($\lambda_2 > 1$). In order to obtain the solution to (10) that satisfies the transversality condition, the polynomial (1- λ_1B) is expanded backward and the polynomial (1 - λ_2B) forward[18].
The expansion allows of expressing the equation (10) in the following form (making use of the fact that $(b\lambda_2)^{-1} = \lambda_1$)

$$(11)\quad E_{s-1}I_s = \lambda_1 I_{s-1} + \frac{\lambda_1}{f}\sum_{i\_0}^{\infty}(\frac{1}{\lambda^2})^i E_{s-1}(P_{s+1} - Z_{s+1})$$

And, finally, by shifting the conditional expectation from the time s-1 to s, when I_s is actually chosen, one gets

$$(12)\quad I_s = \lambda_1 I_{s-1} + \frac{\lambda_1}{f}\sum_{i=0}^{\infty}(\frac{1}{\lambda_2})^i E_s(P_{s+i} - Z_{s+i})$$

[18] The forward expansion is obtained by applying the following transformation

$$(1-\lambda B)^{-1}{}_1 = \frac{-(\lambda_2 B)^{-1}}{1-(\lambda_2 B)^{-1}}.$$

Current housing investment is thus a function of itself lagged and the current and expected future house prices and construction costs. The coefficient of the lagged investment is the stable root and should thus be less than one in value. The expected path of future house prices and construction costs is discounted by the factor that is also less than one which guarantees that the sum is convergent. The solution presented in (12) represents thus a stable, nonexploding solution.

It is easy to see that without adjustment costs associated with the change of the firm's output I_t current investment would depend solely on the difference between current house prices and construction costs. If $f = 0$, the Euler equation would be $P_{t+j} - Z_{t+j} - q\, I_{t+j} = 0$, and the investment equation would be simply $I_{t+j} = q^{-1}(P_{t+j} - Z_{t+j})$. As in the Topel-Rosen model, only the adjustment costs associated with the rate of change of investment (or the firm's output) makes the model genuinely dynamic and implies that the optimal policy of the firm is to consider not only current but also future prices in making investment decisions. The presence of the lagged dependent variable in the investment equation implies that the long-run elasticity of investment with respect to forcing variables will be higher than the short-run elasticity, provided $0 < \lambda < 1$.

The models presented in this section are examples of linear quadratic optimization problems the remarkable advantage of which is that the Euler equations are linear differential/ difference equations and hence can be analytically solved. There are also certain drawbacks. One of them is that the quadratic function does not properly deal with the uncertainty of future asset values. Investment is here derived only as a function future of future expected prices, but the volatility of prices play no role in the investment decision. This is problematic particularly, if investment expenditures are irreversible (sunk cost), because their sensitivity to the various forms of risks then increases.[19]

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[19] See Dixit-Pindyck (1994) for modeling the investment behavior of firms under the conditions that investment decisions are irreversible and the future value of asset obtained by investing are uncertain.

The other drawback is related to the form of the adjustment cost function. The quadratic form implies that adjustment costs are symmetric and smooth. The firm then responds to the increases and decreases of these costs, however small, in a similar way. This does not seem to correspond very well to the actual behavior of the firms according to recent, microdata-based empirical studies. With asymmetric or lumpy adjustment costs which would be more relevant empirically the analytical solution to the Euler equation, however, is usually not found.[20] The mathematical convenience of linear quadratic problems is hence achieved at the expense of certain realism.

[20] See, Hamermesh - Pfann (1996).

3. Empirical analysis

3.1. The data

The econometric analysis of this study will be based on the Finnish quarterly time-series data covering the period 1979-1976.

The housing investment series is gross investment in residential construction in the Finnish national accounts. The series is expressed at constant 1990 prices and is seasonally unadjusted. It includes both the construction of new houses and rehabilitation corresponding thus roughly to the concept of gross investment in the theoretical part of the paper, defined as the sum of net investment and replacement investment.

The house price index, produced by Statistics Finland, contains only the prices of flats sold in the secondary market, but not the prices of single family houses or newly constructed dwellings.[21] It represents quite well the average price level of the existing housing stock and therefore can be taken as a good approximation to the theoretical concept of the asset-market price. Real prices are deflated by the consumer price index. The real house price index along with the housing investment at constant prices (seasonally adjusted) are shown in figure 1. Figure 2 shows the fourth differences of the same series.

Figure 3 shows the evolution of nominal house prices, consumer prices and building costs. The building cost index, also produced by Statistics Finland, comprehends the costs of labor, materials and other inputs of building trade. Figure 3 demonstrates that it has evolved nearly parallel to the consumer price index. Real house prices are thus, in fact, quite close to Tobin's q which could be measured as the ratio of house prices to construction costs.

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[21] See Kosonen (1997) for the more detailed description of the house price index.

The other variables used in estimated models include real after-tax interest rates, real household disposable income, unemployment rate and a dummy variable capturing the effect of the deregulation of the financial market in 1986-87.[22]

3.2. Cointegration analysis

3.2.1. Methodological considerations

In the first phase of the empirical analysis the housing market is modeled as a dynamic system of two endogenous variables, real house prices and housing investment. A priori both of these variables may influence each other and must be therefore estimated jointly as a system. The system estimation also allows of testing the nature of causal relationship between the two endogenous variables.[23]

Both variables are integrated in levels, but look fairly stationary in first (quarterly) differences.[24] To eliminate nonsense relationships between integrated variables the data must be reduced to a stationary form by differencing and using cointegrating combinations. If two variables are both integrated of order one (I(1)) and there exists a linear combination between them which is stationary (I(0)), then the two variables are said to be cointegrated. Cointegration is a system property and is isomorphic to the error-correction mechanism in single dynamic equations.

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[22] The contents of these variables is explained in Kosonen (1997).

[23] System estimation and cointegration analysis is performed with PcFIML of Doornik and Hendry (1994).

[24] Augmented Dickey-Fuller test statistics are the following: for the level of real house prices 0.31, for the level of real housing investment -0.53, for the first difference of house prices -2.48^{*} and for the first difference of housing investment -2.63^{**}.

The analysis begins by formulating a statistical system that has the following general form:

$$(11)\quad y_t = \sum_{i=1}^{m} \pi_{1i} y_{t-i} + \sum_{j=0}^{r} \pi_{2j} z_{t-j} + Kq_t + v_t, \qquad v_t \to N(0,\Omega)$$

Here y_t is a (n x 1)-vector of n endogenous variables, z_t is a (s x 1)-vector of s non-modeled variables and the vector **q** represents deterministic conditioning variables, such as the constant, trend, seasonals and dummy-variables.

The variables **y**, **z** and **q** and the lag lengths m and r should be chosen in such a way that the system is a congruent representation of the data. Congruency requires a.o. that errors v_t are homoskedastic innovations, the non-modeled variables z_t are weakly exogenous to the parameters of interest (Π_1, Π_2, Ω) and that these parameters are constant over the estimation period. The system (11) is sometimes called the unrestricted reduced form (URF). Its congruency is important, because it serves as a baseline against which the restrictions on parameters are tested at the later stages of analysis.[25]

By using matrix lag polynomials the system (11) can also be written in the form

$$(12)\qquad \left(I - \Pi_1(L)\right) y_t = \Pi_2(L) z_t + Kq_t + v_t$$

The matrix $P_0 = \Pi_1(1) - I$ can be inverted, if it is full rank, .i.e. its rank p is equal to n, in which case the variables **y** and **z** are cointegrated. In such a case the static long-run solution is defined and has the form

$$(13)\quad E(y_t) = -P_0^{-1}\Pi_2(1)E(z_t)$$

[25] See, Hendry (1995), p. 408.

where $\Pi_1(1)$ is the sum of the coefficients $\pi_{11} + \ldots + \pi_{2m}$ and $\Pi_2(1)$ is the sum of the coefficients $\pi_{21} + \ldots + \pi_{2m}$.

Assume for the moment that there are no exogenous variables in the system (s = 0). The system (11) can then be transformed into the following vector equilibrium correction form:

$$(14) \quad \Delta y_t = \sum_{i=1}^{m-1} \xi_i \Delta y_{t-i} + P_0 y_{t-1} + K q_t + v_t$$

The dimension of the matrix $\mathbf{P}_0$ is n x n, so the matrix is of full rank, if $r(\mathbf{P}_0) = n$, the number of the endogenous variables in the system. In that case the error process v_t in (14) is stationary. If, on the other hand, the rank of $\mathbf{P}_0$ is p, so that $p < n$, there are p cointegrating (stationary) combinations of the variables in $\mathbf{y}_t$. The matrix P_0 satisfies then $P_0 = \alpha\beta'$ where α and β are both (n x p) -matrices. The matrix β is the cointegrating matrix and its columns $\beta_1 \ldots \beta_p$ are p cointegrating vectors. Analogous to single equation models the matrix $\beta' \mathbf{y}_{t-1}$ represents the equilibrium relationships (error correction mechanisms) that bind the evolution of variables in the long-run. The matrix α is called the adjustment or feedback matrix[26]: its elements measure the speed of adjustment of particular variables towards the long-run equilibrium. PcFIML estimates the $\mathbf{P}_0$ matrix by the maximum likelihood method proposed by Johansen (1988). The rank of the matrix $\mathbf{P}_0$ can be tested by trace or maximum eigenvalue statistics produced by the procedure.

The conditioning variables **q** may enter the system unrestricted, as in (14), in which case they enter into all the equations of the system, but they are partialled out from $\Delta \mathbf{y}_t$ and $\mathbf{y}_{t-1}$ prior the ML estimation of the cointegrating vectors. In some case it is reasonable to restrict a conditioning variable to lie in the cointegrating space. Such a variable is the trend which, if entered

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[26] See, Charemza - Deadman (1992).

unrestricted, would impose a quadratic trend on the levels of variables, which often is not a sensible assumption. When the system includes non-modeled z-variables and restricted q-variables, the cointegration space in enlarged from $\beta' y_{t-1}$ to $\beta'(y_{t-1};z_r)$,where z_r represents unrestricted and exogenous variables. The dimensions of the long-run matrix $\mathbf{P}_0$ and the matrix β will then p x $(n+s_r)$ where s_r is the number of z_r-variables.

3.2.2. The estimation of the system and the cointegration analysis

The system consists of the two endogenous variables, the logs of real house prices and housing investment measured at constant prices (in levels). The lag length finally chosen for both variables is five.

The housing investment series exhibits strong seasonal variation. Three seasonal dummy-variables were introduced to remove the effects of this variation. The other unrestricted conditioning variables are the constant and a dummy-variable to capture the effects of strike periods. The variable (STR) obtains the value one in the quarters 1979:4, 1980:1, 1980:2, and 1986:2, and is zero otherwise. The trend is used as a restricted variable , as well as the dummy variable to capture the effects of the deregulation of the financial market was entered restricted[27].

The system includes also certain non-modeled variables that are known from previous analyses[28] to affect house prices, such as household disposable income, real after-tax interest rate, the inflation rate and the unemployment rate. These variables are determined at the macroeconomic level and, therefore, can be taken as exogenous to the system that represents only one sector (the housing market) of the national economy. An additional reason for this solution is that

[27] The construction of the deregulation dummy is explained in Kosonen (1997).

[28] Kosonen (1997).

with this size of the data it is nearly impossible to formulate a congruent system with more than two endogenous variables.

The preferred system has reasonable coefficients and is satisfactory in the diagnostic sense. Test statistics reveal no signs of vector residual autocorrelation, non-normality or other problems. House prices have a significant long-run effect on housing investment. Apart from that the housing investment series exhibit a significant negative trend and is positively affected by the inflation rate.

In the house price equation the long-run coefficient of housing investment is not significant at the 5% level. By contrast, house prices are affected negatively by the real after-tax interest rate and the inflation rate, and positively by lagged household disposable real income and the deregulation of the financial market. The house price series exhibits also a strong positive, short-run autocorrelation. The coefficient of the trend variable is not significant in the house price equation.[29]

The cointegration analysis of the system gave the result that the long-run matrix contains two significant eigenvalues implying that the number of cointegrating vectors in the system is two.[30] The attempts to reduce the rank of the matrix $\mathbf{P}_0$ to one were consistently rejected. This outcome implies that the system consist of two stationary processes which, however, are not cointegrated. In other words, the estimated cointegrated vectors represent the two stationary equilibrium relationships governing the long-run dynamics of housing investment and house prices respectively, but these processes are

[29] The result are in accordance with the single equation analysis of house price dynamics in Kosonen (1997).

[30] The trace statistic for $p = 0$ is 40.82^{**} (95% critical value is 19.0) and for $p = 1$ 33.42^{**} (95% critical value is 12.3). The corresponding maximum eigenvalue statistics are 74.24^{**} (95% critical value is 25.3) and 33.42^{**} (95% critical value is 12.3). Test statistics with small sample corrections give essentially similar results.

separate and cannot be reduced to a single cointegrating relationship. Hence, the housing market is a dynamic system of two equations.

Several restrictions on the parameters of the cointegrating vectors were tested.[31] These tests largely confirm the above conclusions. Housing investment is mainly determined by house prices, the trend, and the inflation rate, but not the exogenous demand variables, not even the real interest rates. The latter, in turn affect, house prices significantly. The two cointegrating vectors obtained after these restrictions were imposed are the following:

$$CI1 = LHINV - 0.73PRPH - 0.02INFL + 0.006Trend$$
$$CI2 = LRPH - 0.85LRINC_{-2} - 0.37DEREG + 0.04RIRD + 0.03UER_{-2} + 0.01INFL$$

The symbols are:

LHINV = the log of housing investment, LRPH=the log of real house prices, INFL=the rate of inflation, $LRINC_{-2}$= the log of real household disposable income lagged by two periods, DEREG= the dummy variable for the deregulation of the financial market, RIRD=real after-tax interest rate interacted with DEREG, UER_{-2}_ the unemployment rate lagged by two periods.

The coefficients of the α-matrix associated with the two eigenvectors are

DLHINV	-1.52	0.27
DLRPH	0.15	-0.26

The cointegrating vectors have signs and magnitudes that as a whole are in accordance with economic theory. The long-run price elasticity of housing investment is 0.73 in the system. The other elements of the first vector are the

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[31] The zero restrictions on the parameters that are statistically acceptable are the following: in the first cointegrating vector (CI1) the coefficients of the variables RIRD, UER_{-2}, $LRINC_{-2}$ and DEREG and in the second cointegrating vector (CI2) the coefficients of the variables LHINV and Trend.

small positive effect of inflation on housing investment and a slight negative trend. After the inclusion of these two variables the construction cost- variable lost its significance implying that it plays a similar role in the system as these two variables.

The second cointegrating vector does not include the housing investment term at all indicating that house prices probably can be considered as exogenous to housing investment, at least over the relatively short time horizon the model represents. The "long-run" of the model is not long enough to allow the feedback effect from the supply side of the housing market to house prices to be seen. Restricting the third element of the α-matrix (α_{21}) to zero was, however, not quite accepted which would have confirmed the strong exogeneity of house prices to housing investment.

The coefficients of the α-matrix measure the speed of adjustment with respect to the disturbance in the equilibrium relation represented to the cointegrating vectors. The diagonal elements of the α-matrix are negative which is consistent with the existence of the error-correction mechanism in both house price and housing investment processes. The off-diagonal elements indicate that there is a positive feedback from house prices to housing investment.

Figure 6 shows the two cointegrating vectors, the long-run fitted and actual (that is $-\sum \hat{\beta}_j x_{jt}$ against the normalized variable) and recursively calculated eigevalues. Both vectors look relatively stationary.

3.3. The estimation of the housing investment equation

The previous analysis revealed that the housing market consists of two dynamic equations, one for housing investment and the other for house prices. Housing investment is strongly affected by house prices in the long-run, but house prices are not influenced by housing investment, but are mainly determined by the demand-side variables that are exogenous to the housing market.

To investigate further the exogeneity of house prices for housing investment a few simple tests were performed along the lines proposed by Charemza-Deadman (1992, p. 280). The tests consist of first estimating the house price equation (in fourth differences) by OLS including housing investment (with two lags) as an explanatory variable. The F-test for the significance of the housing investment variable is very low (1.05) and not significant at the 5% level. As the second step the house price equation is estimated without the housing investment variable. The F-test for model reduction gives the same result as the first step. At the third stage the possible covariance between the residuals of the marginal process (the house price equation without the housing investment term) and the conditional process (the housing investment equation with house prices as an explanatory variable) is investigated by adding the residual of the marginal process into the housing investment equation. The value of the test statistic (F(1,56) 0.177 is again far from significant. The result implies that the rate of change house prices is not only weakly, but strongly exogenous for the rate of change of housing investment. The outcome of the test is not entirely consistent with the cointegration analysis in which the restriction to zero of the element α_{21} of the feedback matrix α was not accepted. The difference could be due to the different treatment of seasonal variation here relative to the cointegration analysis which was in the levels of variables and seasonal variation was removed by seasonal dummies (see also footnote 12).

Because of the exogeneity of house prices the housing investment equation is estimated in the following by single equation technics instead of system analysis. The focus of the estimation is on the short-run dynamics of housing investment. The variables of model are therefore expressed in fourth differences which are the measures of the annual growth rates (of the variables measured in logarithms) and have thus an easy practical interpretation. The procedure, also called seasonal differencing, is especially convenient here, because it removes the seasonal pattern from the series and, hence, the need of using seasonal dummies.[32] The other advantage is that the linear trend in the levels of variables is converted into a constant.

The theoretical model derived in the first part of this study (equation (12)) implies that housing investment is a function of itself lagged, and current and expected future house prices. The estimated model is built on these premises.

To incorporate expected house prices in the model I used the following procedure. I first shifted the price variable forward by one period (applied the lag of -1). This variable ($D4LRPH_{+1}$) is the sum of the expected price change and innovation one period ahead. Hence it is endogenous and correlated with the error term. The OLS estimates of the parameters are not consistent in this case, and therefore the method of instrumental variables is used to estimate the model. The instruments are chosen in such a way that they are likely to enter the information set conditioning the expectations with respect to future house price changes. In a previous study it was found that the house price process is characterized by a strongly autoregressive structure and a mean-reverting tendency expressed by a significant error-correction term.[33] The instruments that can best capture this kind of dynamic process are lagged house price changes and the lagged cointegrating vector (CI2) for house prices to represent the error-correction mechanism. Other instruments included the change of real after-tax interest rates, the lagged change of real household disposable income and the dummy for the deregulation of financial market which also were found to affect significantly house prices in the aforementioned study.

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[32] Using seasonal dummies and seasonal differencing are not fully equivalent procedures. The first imposes a deterministic seasonal pattern on the series, while a seasonally differenced variable may exhibit stochastic seasonality (Charemza - Deadman, 1992).

[33] Kosonen (1997).

On the ground of equation (12) the stochastic process governing housing investment can be expected to exhibit similar features as the house price process. In particular, it can be assumed that housing investment also exhibit a mean-reverting tendency: they tend to adjust towards an equilibrium level in the long run, although they may deviate from it in the short-run. To capture this mean-reverting tendency (or the error-correction mechanism) the first cointegrating vector (CI1, lagged by four periods) is included in the estimated model as a regressor.

The first model estimated included only the rate of change of inflation (D4INFL) and the strike dummy (STR) as additional regressors, but no financial variables. The dependent variable is the annual rate of change of housing investment (D4LHINV). The structural estimates of the model are shown in the following equation (t - statistics in parentheses):

$$\text{(15)}\quad D4LHINV = \underset{(2.1)}{0.47} + \underset{(5.3)}{0.46} D4LHINV_{-1} + \underset{(4.8)}{0.40} D4LRPH_{+1} - \underset{(2.1)}{0.08}\, CI1_{-4} +$$

$$\underset{(1.8)}{0.01} D4INFL - \underset{(2.3)}{0.16} STR$$

$\sigma=0.07$ DW=1.96 Specification Chi^2 (5)= 8.6, b=0 $Chi^2(6)$ = 155.3^{**}
Error autocorrelation from lag 1 to 5 $Chi^2(5)$ = 2.6, ARCH 4F(4,51)=0.8, Normality $Chi^2(2)$=1.3, Xi^2 f(11,46)=0.6, Xi*Xj F(21,36)= 0.7.
Additional instruments used: $D4LRPPH_{+1-1}$, $D4LRPH_{+1-2}$, DEREG, D4RATD, $CI2_{-3}$, $D4LRINC_{-2}$.

The model as a whole is well-specified. All the coefficients have reasonable sizes and magnitudes, and are significant with the exception of the inflation rate variable. The test statistic for the validity of instruments (specification $Chi^2(5)$) is not significant indicating that the structural model is a satisfactory representation of the data. The other Chi^2 - test (b=0) test the null hypothesis that all the coefficients except the constant is zero which is clearly rejected. The other test statistics show no sign of residual autocorrelation, heteroskedasticity or non-normality which is also confirmed by the graphical diagnostics shown in figure 7.

The coefficient of the expected house price ($D4LRPH_{+1}$) is in accordance with the view that housing investment is positively correlated with expected house price changes. If the growth rate of house prices changes by 10%, the growth rate of housing investment is changed by 4% after a short lag.

The coefficient of the lagged housing investment variable ($D4LHINV_{-1}$) is positive and smaller than one which is in accordance with the theoretical model. Hence the long-run price elasticity is higher than the short run elasticity, in this model around 0.75.

The coefficient of the cointegrating vector (CI1) has a correct negative sign and is significantly different from zero. The housing investment process is also characterized by an equilibrium correcting mechanism according to this result. The coefficient of this term is rather small, however, and its exclusion from the regression doesn't change essentially the coefficient of other variables, in particular the response of housing investment to price changes. The construction cost variable was also included in the RHS of the model, but never obtains a coefficient significantly different from zero. The strike dummy (STR) obtains a significant negative coefficient expectedly.

In the next stage I introduced financial variables as exogenous regressors into the model. I first changes the status of the real after-tax interest rate variable (D4RATD) from an instrument into the exogenous variable. The coefficient of the variable was negative, but not quite significant at the 5% level. The coefficient is, however, significantly negative in the reduced form equation for expected house price changes ($D4LRPH_{+1}$) and is thus a valid instrument, as the outcome of the specification test also confirms.

Next I introduced the change of the housing loan stock (lagged by one quarter) into the model as an additional repressor. Somewhat unexpectedly this variable turned out to obtain a significantly positive coefficient in the structural equation, but was rejected as an instrument for expected house price changes. The structural estimates of the model are the following:

$$(16)\ \ D4LHINV = 0.42 + 0.35D4LHINV_{-1} + 0.34D4LRPH_{+1} - 0.08CI1_{-4}$$

(1.9) (3.5) (3.9) (2.1)

$$-0.17STR + 0.01D4INFL + 0.38D4LRLOA_{-1}$$

(2.3) (2.0) (1.99)

$\sigma=0.068$, DW=1.89, Specification $Chi^2(5)=9.8$, $(b=0)Chi^2(6)=169^{**}$
Error autocorrelation from lag 1 to 5 $Chi^2(5) = 2.3$, ARCH $4F(4,50)=0.7$, Normality $Chi^2(2)=0.87$, Xi^2 $f(11,46)=0.76$, $Xi*Xj$ $F(21,36)= 0.88$.
Additional instruments used: $D4LRPPH_{+1-1}$, $D4LRPH_{+1-2}$, DEREG, D4RATD, $CI2_{-3}$, $D4LRINC_{-2}$.

I interpret these results in such away that the actors in the supply side of the housing market (developers, construction firms) are not very sensitive to changes in real interest rates, but are (or have been) more subject to quantitative credit rationing. Therefore the volume of residential construction responds positively to changes in the volume of lending. The evidence is here similar to that of Poterba (1984), whose findings also suggest that the "supply effect rationing" is more important in the housing market than the "demand effect rationing". The actors in the demand side of the market (households, landlords), on the other hand, seem to have become responsive to changes in real after-tax interest rates after the deregulation of the financial market which is reflected by the significance of the real after-tax interest rate variable (D4RATD), interacted with the DEREG-dummy, in the reduced form equation for house prices.

The introduction of the financial variable into the structural equation reduces, however, the magnitude of the price coefficient, as can be seen by comparing the two estimated models. According to the second model the short-run price elasticity is only 0.34 and the long-run elasticity 0.53. This could suggest that house price changes interact somehow with changes of the housing loan stock, although this effect does not appear in any of the estimated models.

4. Summary and conclusions

The main interest of the paper in on the supply side of the housing market. In the first part of the study I analyze the determination of housing investment in the framework of the asset market model by Kearl (1979) and Poterba (1984). The model is then extended by taking into consideration the adjustment costs associated with changing the scale of production. Adjustment costs were introduced into economic investment models in the 60's and have since then played an important role in the theoretical and empirical analyses of investment behavior. Topel and Rosen (1988) incorporate the idea of increasing adjustment costs into the asset market model obtaining interesting and empirically plausible results. I have reformulated the Topel-Rosen model here in the stochastic, discrete-time framework, but the empirical substance of the model remains essentially the same.

The empirical analysis of the paper is based on the quarterly, time-series data from Finland in the period 1979-1996. The housing market is first analyzed as a dynamic system of two endogenous variables, real house prices and real residential building investment (housing investment for short). The system analysis allows of investigating the causal relationships between the two endogenous variables and the degree of cointegration in the system. The number of cointegrating vectors estimated was two implying that the system is of full rank, and hence the two endogenous variables are not cointegrated. The cointegrating vectors represent the two equilibrium relationships that govern the dynamic adjustment of house prices and housing investment respectively. The estimated relationships indicate that housing investment is strongly positively correlated with house prices in the long-run. The estimated long-run price elasticity of housing investment is 0.73. Apart from that housing investment is positively influenced only by the rate of inflation and exhibits a slight negative trend. Real interest rates, construction costs or credit availability measures were not found to have any long-run effect on housing investment.

The causal structure of the system was not symmetric. Housing investment did not have a clear-cut long-run effect on house prices in the estimated systems and did not enter significantly into the second relationship. House prices were determined mainly by the factors that were considered as exogenous to the system, but influence the demand for housing. Such factors were real household disposable income, real after-tax interest rate and the deregulation of the financial market. The system analysis and exogeneity tests performed with differenced variables suggest that house prices can be considered exogenous for housing investment, at least in the relatively short period covered by the estimations of this study.

The next step of the empirical analysis was to study the short-run dynamics of housing investment with single equation technics. The outcome of the exogeneity tests justified this solution.

The theoretical model with increasing adjustment costs gave as a result that housing investment is not only a function of current prices but also of expected future house prices. To take this effect into account I used the following procedure. The housing investment equation was estimated by the method of instrumental variables treating the expected real house price changes as an endogenous variables in the system. The instruments were chosen in such a way that they are likely to enter into the information set conditioning the expectations regarding future house price changes. The lagged change of the dependent variable was also included on the right-hand side of the model to capture the effect of increasing adjustment costs on the investment decisions. The models were estimated in fourth differences which gives certain advantages in the case the variables are non-stationary in levels and exhibit a strong seasonal variation.

To investigate the role of financial factors I estimated the model first without financial variables as exogenous regressors, and then added them into the model.

Both estimated models are satisfactory in the diagnostic sense. The residuals seem to be white noise and the specification test accepts the validity of instruments. The outcome as a whole is in accordance with the theoretical model which implies that the suppliers of new housing are forward-looking and take account of expected future prices in making investment decisions. The demand side variables, including real interest rates, affect housing investment through house prices, and not directly, as the asset market model suggests.

In the first model the coefficient representing the short-run response from house prices changes to housing investment is 0.4 and the implied long-run response 0.75. In the second model the estimated price responses are lower, 0.34 and 0.56 respectively. These results support the view that increasing adjustment costs slow down the response of investment to changes in current prices. The magnitudes of coefficients are, however, considerably lower that those obtained by Topel and Rosen (1988) with the US data or Hakfoot-Matysiak (1996) with the Dutch data, but somewhat higher than the estimated price elasticities in the earlier Finnish studies of Takala - Tuomala (1990) and Suoniemi (1991). The relatively low price elasticity of housing investment revealed by this and earlier studies could be one explanation to the observed high volatility of house prices in Finland.

The introduction of the financial variables into the model revealed that the real after-tax interest rate variable affects significantly house prices, but not housing investment. Housing investments are, however, positively influenced by changes in the housing loan stock which could imply, as Poterba (1984) suggests, that credit rationing affects (or has affected) more the flow supply of new housing, than the demand for housing.

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Figure 1. Real house price index and housing investment (in logs)

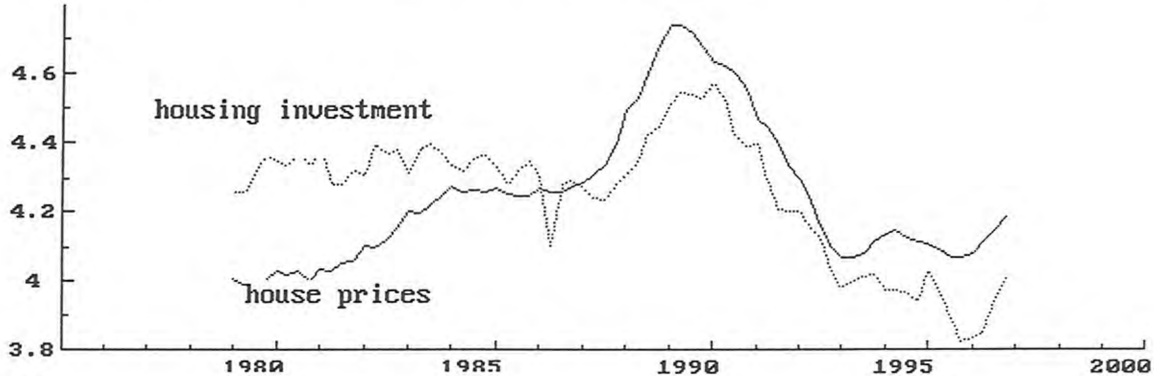


Figure 2. The annual rates of change of house prices and housing investment

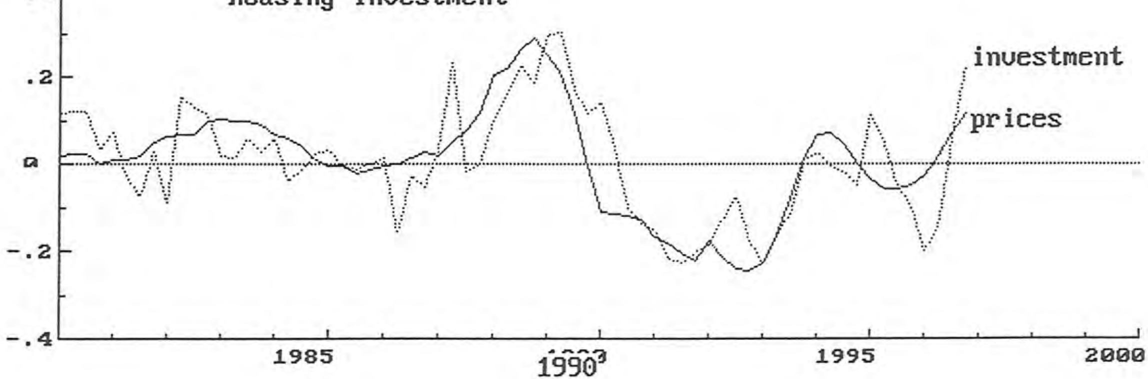


Figure 3. The nominal indices of house prices, construction costs and consumer prices

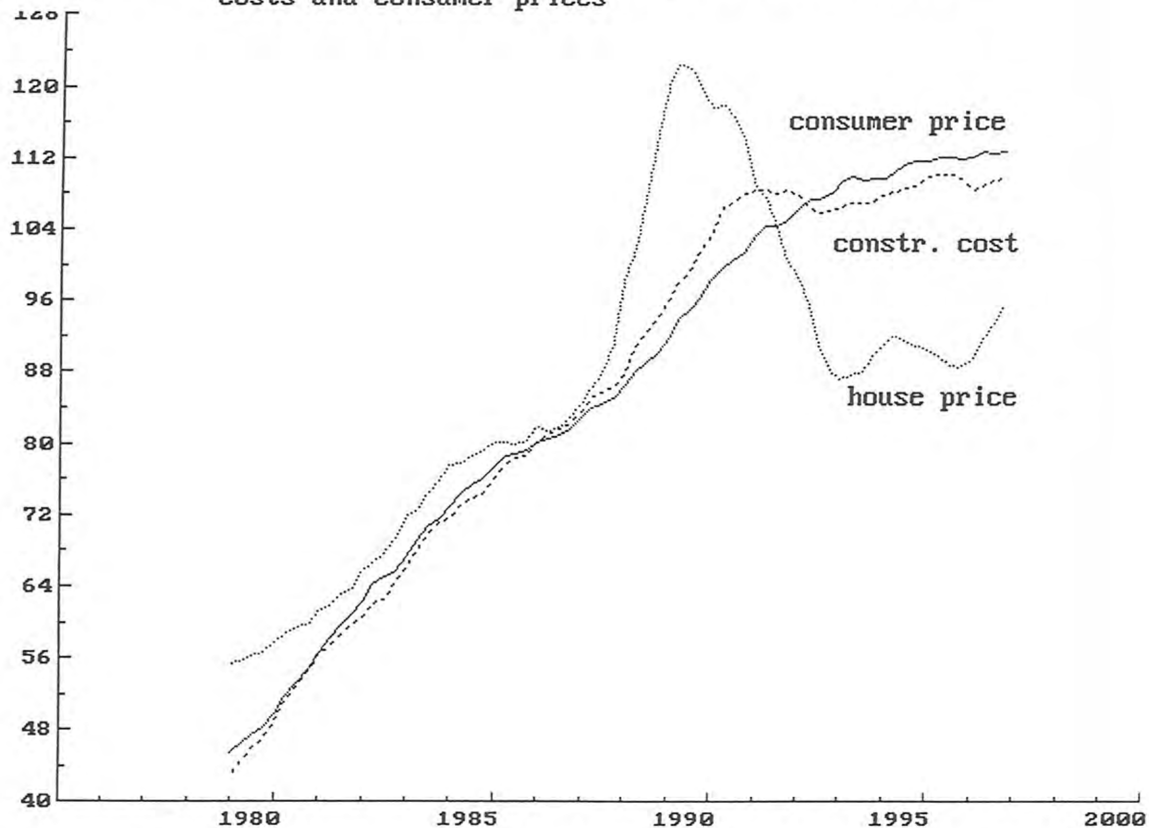


Figure 6.

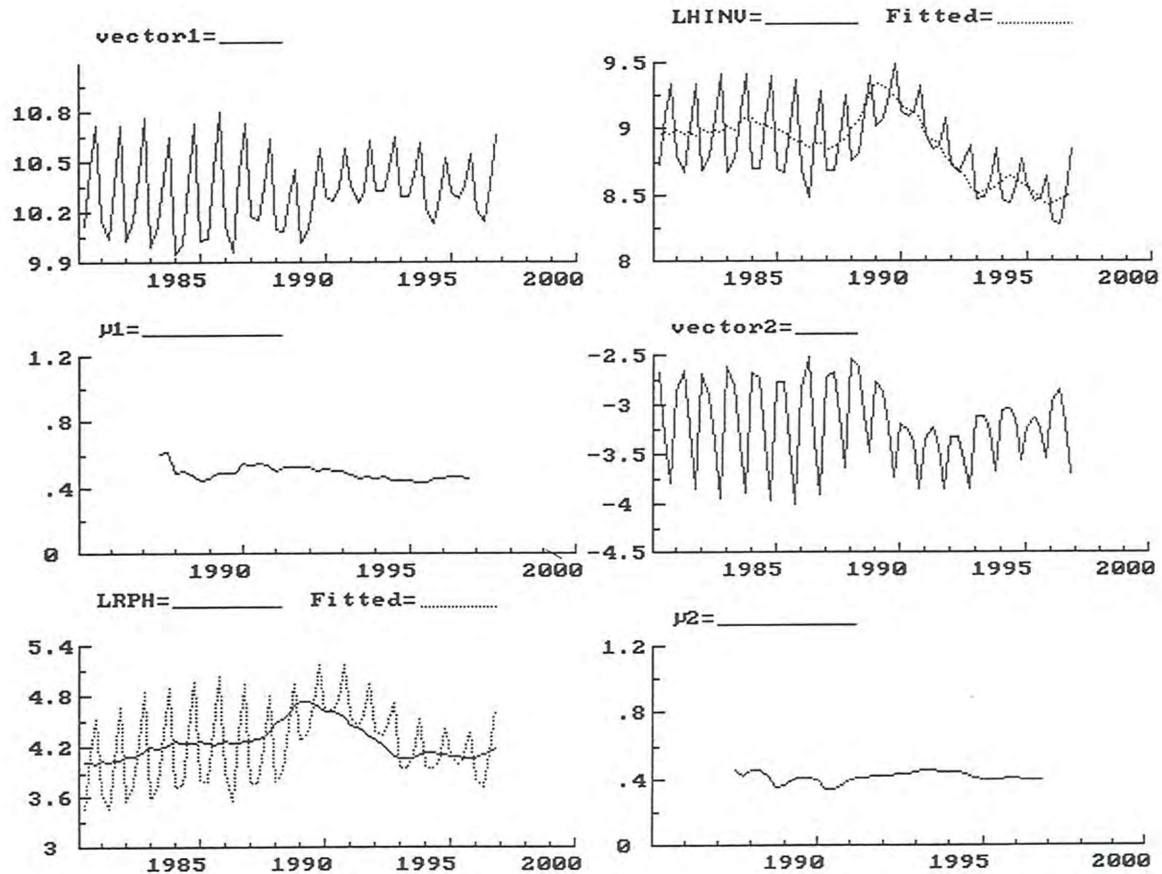
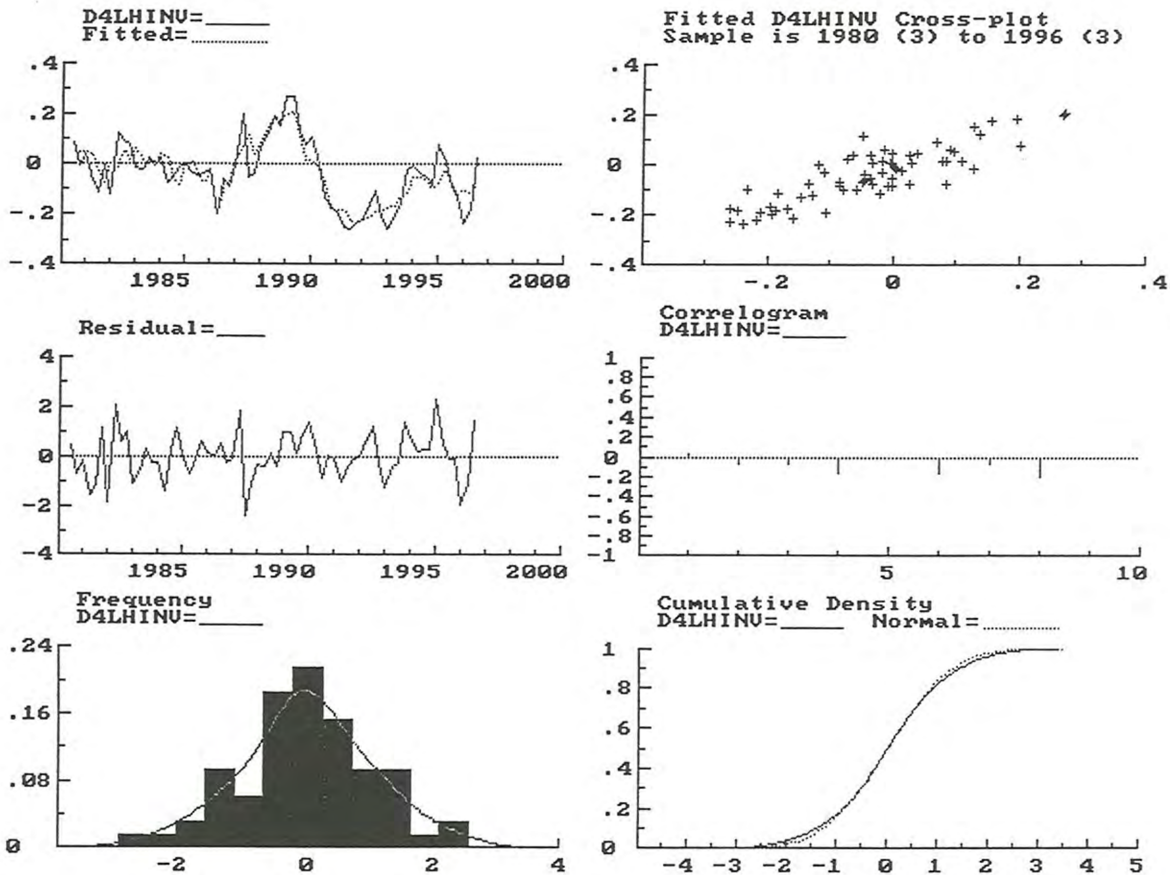

vector1=
LHINV=
Fitted=
μ1=
vector2=
LRPH=
Fitted=
μ2=
1985
1990
1995
2000

Figure 7.


D4LHINV=
Fitted=
.4
.2
0
-.2
-.4
1985
1990
1995
2000
Fitted D4LHINV Cross-plot
Sample is 1980 (3) to 1996 (3)
.4
.2
0
-.2
-.4
-.2
0
.2
.4
Residual=
4
2
0
-2
-4
1985
1990
1995
2000
Correlogram
D4LHINV=
1
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1
5
10
Frequency
D4LHINV=
.24
.16
.08
0
-2
0
2
4
Cumulative Density
D4LHINV=
Normal=
1
.8
.6
.4
.2
0
-4
-3
-2
-1
0
1
2
3
4
5