A MODEL OF HOUSING INVESTMENT FOR THE MAJOR OECD ECONOMIES

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CONTENTS

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INTRODUCTION

This paper describes a recent empirical study of housing investment for the seven largest OECD economies. It was carried out both to provide a better understanding of the relevant determinants of investment and as a contribution to the OECD's world macroeconomic model INTERLINK[1]. Within this multi-country context, an important feature of the work is the development of a common framework of analysis and estimation, providing a more systematic basis for inter-country comparisons[2].

Residential construction accounts for a relatively small share of national income; one which has declined in a number of countries during the 1980s (Table 1). Housing's economic importance is, however, disproportionate to its GDP share, largely because it tends to be one of the most cyclical components of aggregate demand. In the United States, for example, the average peak-to-trough decline in housing construction since the 1950s has been 45 per cent, compared with declines of 10-15 per cent in industrial production and less than 10 per cent in overall output. Housing starts are also quite commonly used as leading indicators of changes in macroeconomic activity (OECD, 1987).

Table 1. Residential investment as a percentage of GDP

	Average			
	1960-67	1968-73	1974-79	1980-87
United States	4.8	4.8	4.9	4.5
Japan	5.2	7.2	7.6	5.6
Germany	7.3	7.2	6.1	6.1
France	7.1	8.1	8.0	6.1
United Kingdom	3.5	4.0	4.1	3.5
Italy	7.9	8.0	7.0	6.3
Canada	5.2	5.8	6.7	5.7
Total of above countries	5.3	5.8	5.9	5.1

Source: OECD, *Economic Outlook Historical Statistics 1960-1987,* Paris 1989.

The timing and amplitude of housing cycles can be associated with a number of factors which are particularly important for the housing market.

The ***durability*** of housing[3] and its role as a capital good, makes the distinctions between the investment flow, the physical stock of dwellings and the associated flow of housing services of significance to the dynamics of the investment process. House owners act as both consumers of housing services and investors in a durable asset, with the joint consumption/investment choice of owner occupation being affected by a variety of short- and long-term influences. These include income, house and land prices, operating costs, depreciation, mortgage interest rates, tax rates and expected capital gains. The dynamics of house purchases are also affected by past household saving rates, since relatively large down-payments from personal savings have traditionally been required prior to purchase, and also by expectations of future income in relation to mortgage repayment commitments.

The ***heterogeneity*** of housing also gives rise to information costs. The wide variety of search and transactions costs (brokers' fees, legal costs, stamp duties, moving costs) make it expensive for households to adjust the quantity of housing services consumed. Renovation and maintenance are also a significant part of housing expenditures.

The supply and demand of housing are particularly sensitive to ***financial market conditions,*** in particular the variability of the supply and cost of credit over the cycle and the roles of interest rates and credit controls as instruments of monetary policy. In many countries, institutional arrangements for the provision of finance for house purchase have from time to time tended to constrain the supply of mortgage credit, with the mortgage interest rate not clearing the market. In a number of OECD countries financial deregulation during the 1980s has been accompanied by a more competitive environment for housing finance, *so* that mortgage interest rates are now more closely determined by financial market conditions and credit availability may have become less of a constraint.

In addition to their influence on credit conditions, governments exert direct influence on housing markets, for instance through tax concessions on mortgage interest payments, the subsidisation of construction, and the control of rent and land prices. Housing development is also influenced by building codes and zoning laws and government-owned dwellings constitute an important part of the housing stock in many OECD countries. The list of special factors influencing housing is potentially long and very much beyond the scope of the present empirical study[4].

The development of disaggregated and complex housing models is a natural reflection of the heterogeneity of dwellings and the interplay between the housing market, the financial sector and government intervention. Large empirical models of the housing sector which can analyse the effects of specific public housing programmes and policies, have also been developed[5] but they are in general too complex for empirical macroeconomic models, such as INTERLINK, which are largely concerned with the development of the main macroeconomic aggregates.

In order to provide a focus for comparative study, a broad theoretical framework has been adopted within which aggregate investment in housing might be analysed empirically. Such a framework is described in Section I. This necessarily excludes consideration of many specific factors, in particular the explicit influence of governments in the housing market. Within this general framework, it is, however, possible to examine many of the main determinants of housing investment. The rest of Section I provides a survey of these factors as identified in a range of recent empirical studies for the largest OECD countries.

Section II then presents a set of estimation results for the seven major OECD countries based on a stock-adjustment approach. This contrasts with earlier versions of INTERLINK and many of the macroeconomic models surveyed, which have typically used housing equations specified and estimated in terms of investment flows. Stock-adjustment equation estimates are found to be reasonably robust and permit a number of interesting comparisons across the major OECD economies.

I. EMPIRICAL APPROACHES TO MODELLING AGGREGATE HOUSING INVESTMENT

This section reviews a number of alternative approaches which have commonly been adopted in aggregate models of the housing sector and recent empirical evidence on the influence of key explanatory variables for the major OECD economies. It is useful first, though, to consider a broad theoretical framework within which most of these studies can be classified.

A. A theoretical framework

Under the assumption that housing service flows are proportional to the stock of houses, equation [I] below can be used to represent a demand function for housing services:

$$K(t) = \alpha^{*}U(t) + X(t) \qquad [1]$$

Here $K(t)$ denotes the net stock of dwellings at time t, and $U(t)$ the implicit rental price per unit of dwelling stock – the so-called "user cost of housing." The parameter α represents the slope of the demand curve with respect to the user cost, and $X(t)$ a vector of exogenous determinants of the demand for housing services. The latter might typically include real per capita income, demographic variables and operating and maintenance expenditures.

With respect to the supply of new housing units, $P(t)$ is used to represent the price per unit and $f(I(t), C(t))$ the cost function of a representative builder producing $f(t)$ gross additions to the housing stock. $C(t)$ is a vector of cost determinants – the price of materials and labour, supply conditions of scarce inputs and the costs of borrowing to construction firms. Assuming construction output decisions to be based on marginal cost pricing, a linear approximation of the marginal cost condition implies a supply function of the following form:

$$I(t) = \beta^*P(t) - C(t) \qquad [2]$$

where $\beta > 0$ is the slope of the supply curve with respect to prices.

By definition, the flow of new residential investment is equal to the change in the net stock of dwellings plus depreciation:

$$I(t) = \Delta K(t) + \delta K(t\text{-}1) \qquad [3]$$

where 6 is the rate of depreciation and A denotes the first difference operator.

The model can be closed through an equation relating stock and flow prices, by assuming that the imputed flow price of a unit of housing is equal to the amortised stock price, thus:

$$U(t) = [r + \delta - \dot{P}^e(t)]^*P(t) \qquad [4]$$

where r is the rate of interest and $\dot{P}^e(t)$ the expected capital gain.

Substituting equation [4] into equation [1] yields:

$$K(t) = \alpha^*(r + \delta - \dot{P}^e(t))^*P(t) + X(t) \qquad [5]$$

Combining equations [2] and [3] also gives:

$$\Delta K(t) + 6\,K(t\text{-}1) = \beta\,P(t) - C(t) \qquad [6]$$

For given values of the initial stock of houses and a boundary condition for future interest costs, equations [5] and [6] can be solved to give general expressions for the time paths of housing stocks and market-clearing prices. In such a generalised system, the equilibria for $K(t)$ and $P(t)$ depend upon both exogenous supply and demand factors, the rate of interest and depreciation, thus:

$$K(t) = g(X(t), C(t), \delta, r) \qquad [7]$$

$$P(t) = h(X(t), C(t), S, r) \qquad [8]$$

Most analysts of aggregate housing sector behaviour have adapted this type of framework in a variety of ways – notably with respect to the inclusion of individual supply- and demand-side elements, the modelling of flows of investment as opposed to the stock of houses, the treatment of price formation and explicit assumptions with respect to the functional forms of equations. The rest of this section considers these issues in the context of a range of published empirical studies related to housing investment. For reference purposes, the general features and results of these studies are summarised in Table A in the Appendix. A more general investigation of the role of financial variables in a wider context is given in Chouraqui et al. (1988).

B. General specification issues and dynamics

Given housing's special characteristics, Stahl (1985) argues that there seems to be no universally accepted concept of either housing market behaviour or an appropriate model for residential investment. Indeed, the empirical literature offers housing investment equations and aggregate housing models which employ a wide range of different specifications, simplifying assumptions and explanatory variables.

Fundamental choices for modellers are whether to model the stock of houses or the flow of new investment and how the underlying market process is assumed to influence aggregate dynamic behaviour. Consistent with the framework outlined previously, studies of housing supply commonly model the flow of new construction rather than the stock of dwellings[6]. When housing demand is analysed, there is a corresponding – though less pronounced – tendency to use a stock' approach or at least to take the existing stock of houses directly into consideration.

Most aggregate studies of housing focus on one side of the market and do not attempt to model the simultaneous influence of demand and supply on the dwelling stock and house prices'. Exclusion of the supply side is usually based on the assumption that the supply of houses in the long run adapts to demand in a perfectly elastic manner. In the short run, price changes are assumed to adjust the demand side, with the supply of housing assumed to be price-inelastic, whilst, in the long run, prices are commonly assumed to reflect construction costs.

Many studies of housing subscribe to this characterisation of the market. Poterba (1984) and Rosen and Topel (1986) argue that the long-run production possibility frontier between houses and other goods is not flat, because some production factors in the construction industry are in limited supply. Wiesmeth (1985) and Goodwin (1986) question the capability of prices to rapidly clear the market in the short run, claiming that prices are rigid. To incorporate the rigidity of prices, Wiesmeth op. *cit.* employs the notion of fix-price equilibria, as developed by Benassy (1975) and Drèze (1975), to describe the housing market in the short run. Goodwin op. *cit.* develops an aggregate empirical macroeconomic two-market (housing and credit) model, with rationing and spill-over effects across markets. De Rosa (1978), Hendershott (1980) and Behring and Goldrian (1985) maintain that the short-run housing market should be modelled as a market in disequilibrium, mainly as a result of credit rationing.

Many authors use a stock-adjustment framework – in most cases without explicitly stating the assumptions underlying the market mechanism. Such models commonly specify the dynamics using a partial adjustment process, with the dwelling stock adjusting to long-run demand. A flexible adjustment approach may be appropriate, given that demand may react slowly to changes in underlying economic forces, and that supply can be expected to adjust slowly to anticipated changes in demand. A further refinement is to model the speed of adjustment as a function of short-run factors, including supply-side pressures[8].

Equations for residential investment in the ***macroeconomic models*** referred to in Table A use a wide variety of specifications, often with demand and supply determinants included together in the same hybrid equation.

Most of these models incorporate an adjustment mechanism, either in terms of the stock of houses or the flow of new investment. Some use a stock-adjustment approach, others include the dwelling stock in flow equations to proxy renovations and maintenance. But pure flow adjustment equations are also relatively common. For the United Kingdom, three out of the four macro-models surveyed use a flow approach without taking the stock of houses into consideration. The remaining UK model incorporates a stock/flow system, with stock demands and supplies affecting house prices, which in turn influence the flow supply of new investment. For France, on the other hand, housing equations in most of the large macro models are based on the stock-adjustment approach.

There also seems to be little consensus within countries concerning the representation of housing markets in macroeconomic models. The Canadian models surveyed illustrate how specifications typically vary. In three cases housing starts are related directly to mortgage approvals. In one model, housing investment is determined from the demand side only, while three others determine housing starts through supply-side equations, with demand affecting the price of houses. Only in one model is the housing equation based upon a stock-adjustment mechanism, although the stock of houses is often used in the other models as a determinant of investment in renovations and maintenance.

Stock-adjustment models introduce a distinction between net investment (additions to the stock) and gross investment (additions and maintenance). In the short run, investment is assumed to be influenced by the desire to change the level of stocks; in long-run equilibrium, investment will be equal to the level of replacements necessary to maintain the optimal stock. Since the flow of new investment during a year is small compared to the initial stock, shifts in the long-run desired stock of houses can therefore bring about rather large fluctuations in investment. In some macroeconomic models, these dynamic properties are approximated by adding accelerator terms to investment flow equations. Goux op. *cit.,* however, suggests that in distinguishing between short- and long-term effects, the stock-adjustment framework appears theoretically superior to one of flow-adjustment.

C. The choice of explanatory variables

Empirical studies and macroeconomic models commonly focus only on the demand side of the housing market, reflecting the implicit assumption that the supply of dwellings is perfectly price-elastic in the long run. The range of factors most often analysed are discussed below, with some reference to the empirical evidence of their importance reported in Table A in the Appendix. Numerical comparisons are, however, limited, given wide differences in the definitions of housing investment, stocks and the explanatory variables involved. Further detailed references can be found in Smith ***et al.*** (1988), and the surveys mentioned therein.

1. Demographic factors

Demographic factors constitute an important determinant of demand for housing, especially in the long run. Burch ***et al.*** (1986) identify the housing sector as being the most sensitive to changes in population trends. Hendershott (1987), for the United States, and Dicks (1988), for the United Kingdom, also suggest that demographic factors have been one of the major sources of changes in housing demand over the last few decades.

The need for dwelling units is closely linked to the number of households, which in turn can be explained by the size of the population, its age distribution and age-specific headship rates (the ratio of heads of households to population by age group). Changes in headship rates are influenced by changing social patterns, but most investigators find that economic explanations dominate. The growth in the number of households, expressed in terms of changes in the size and age distribution of the population at unchanged headship rates, can be thought of as the basic demographic factor driving long-term trends in housing demand[9].

To the extent that shifts in age-specific headship rates are themselves attributable to economic developments, such factors may also explain the pattern of headship and owner-occupancy rates across age groups. Haurin ***et al.*** (1987) suggest that increases in income and wealth over the life cycle can be used to explain a large part of the observed rise in ownership rates with age. It may thus be difficult to establish how demographic trends, at unchanged income levels, influence the real value of housing demand at the aggregate level.

Macroeconomic models which use a stock approach generally take demographic factors into account by specifying the demand for housing stock in ***per capita*** terms, including income per capita as an explanatory variable. The elasticity of housing stock with respect to the population is thus assumed to be unity for unchanged ***per capita*** income. Unlike more detailed housing studies, such models do not explicitly consider the influence of age distribution on housing markets. Frequently, however, the population variables involved may exclude some part of the population expected to exert only a minor influence on housing demand.

2. Household income and wealth

Housing demand can be analysed as an investment good using the portfolio balance sheet approach, as developed by Brainard and Tobin (1968), with asset demand expressed as a function of both household wealth and the rates of return on assets and liabilities in the household balance sheet. De Rosa op. ***cit.*** uses a portfolio approach to model housing stock demand, but explicit wealth variables are not frequently included in empirical studies or in the housing sectors of macroeconomic models. This reflects both a lack of readily usable wealth series and, in the case of macroeconomic models, the additional complexity of modelling household wealth.

In contrast, real disposable household income is commonly used as a key variable explaining housing demand. Real income variables often enter in a distributed lag form as a proxy for permanent income or wealth, but changes in income are also used to explain short-term cyclical swings. The majority of empirical models which incorporate a permanent income term, embody long-run elasticities with respect to either permanent household income or income ***per capita*** in the vicinity of unity. A unit elasticity is intuitively reasonable and may also be desirable for long-run model properties.

3. House prices and inflation

Increases in house prices relative to those for other goods should in theory induce substitution away from houses, thereby lowering demand. Anticipated house price inflation, however, may increase the demand for dwellings as an investment good. Both of these channels of influence can be captured by measures of the user cost of housing, although the two effects are often separated by splitting the user cost into relative price and real interest rate terms.

Given the heterogeneity of dwellings, the correct measurement of unit prices poses an important problem[10] and is often seen as a reason for not including house price indices. The argument that house prices in the long run reflect only construction costs has a similar implication. It is therefore not uncommon for house price indices to be replaced by the more supply-orientated investment deflators, but prices are often included only through the use of real, as opposed to nominal, interest rates.

There are some important differences in evidence concerning the overall effects of inflation on housing demand. Poterba ***op. cit.***, for example, argues that interest payments are normally tax-deductible and capital gains normally untaxed, so that inflation reduces the effective cost of homeownership independently of real interest rates. In support of this view, he presents evidence that higher inflation substantially raises housing investment. Kearl (1979), however, examining the so-called "tilt" problem provides estimates which support the opposite view. This problem arises because higher inflation and nominal mortgage interest rates increase the initial real burden of debt service for a mortgage with fixed nominal repayments. Only in the future will higher nominal income reduce the debt burden. If real interest rates are unchanged, the present value of total mortgage payments is unaffected, and the tilt effect may only reduce demand for houses because of capital market imperfections.

A final consideration is that individuals observing past price increases may increase their subjective uncertainty concerning future price developments. Rosen et al. (1984) provide evidence that by increasing the user cost to risk-averse consumers, price uncertainty may substantially discourage people from becoming homeowners.

4. Financial variables, taxes and consumer confidence

Housing investment is generally acknowledged as one of the most interest-rate-sensitive demand components in macroeconomic models,

A variety of interest rates are used in empirical studies. Long-term rates are normally thought to influence the demand side, given the long-term perspective of the house purchase decision. These are often measured by either the mortgage rate, as the cost variable, or by the long-term bond rate, acting as an indicator of the return to alternative assets. Models of housing supply, on the other hand, tend to include short-term interest rates, reflecting the borrowing costs for house builders.

In practice, there seems to be a tendency towards lower long run real interest rate/user cost elasticity estimates when these are obtained in a stock, as opposed to flow, model specification. This finding may largely reflect the difference in dynamics of stock versus flow models. In a stock-adjustment model, changes in real interest rates may affect the flow of new investment more in the short run, as the stock of houses adjusts to a new optimum, than in the long run. For example, in the stock-adjustment equation of a recent version of the U.S. Federal Reserve MPS model, the elasticity of housing expenditure with respect to the cost of capital is −1.3 in the short run compared with −0.7 in the long run.

Although the availability of mortgage credit is considered to be an important determinant, the analysis of credit rationing is troublesome because of the lack of theory as to why mortgage rates fail to clear the market for housing credit. Goodwin op. *cit.*, using multimarket disequilibrium econometrics, concludes that non-price credit rationing in the mortgage market has had profound short-term spillover effects on demand and supply in the U.S. housing market. Arcelus and Meltzer (1973) find a negative correlation between credit measures and housing investment. They explain this correlation in terms of the stock of mortgages being inversely related to the value of owner's equity in a given stock of houses. They conclude that there is no causal relationship independent of the mortgage interest rate, a conclusion also supported by de Rosa op. *cit.*

The empirical evidence for the inclusion of credit rationing variables is mixed. Some of the models surveyed adopt an extreme approach, with housing investment related directly to mortgage approvals. Other models include credit rationing variables alongside population, permanent income and real rates of interest, but many consider only the price of credit and not the amount. Explicit inclusion of credit variables or non-price terms related to mortgage availability also requires the addition of complicated structures in the model, to secure reliable simulation properties. The costs of such complications often outweigh the potential gains, especially if credit squeezes are infrequent or expected to be of relatively short duration.

Many detailed studies and some macroeconomic models correct for the influence of taxes when calculating user costs, but quite often the implicit cost of housing services is proxied by some real pre-tax interest rate. Tax rate effects are commonly excluded because of difficulties in analysing the specific channels of influence of complex tax systems. Measurement problems are also a major deterrent.

A further variable often found in empirical work on housing demand is the rate of unemployment. The underlying rationale is that changes in unemployment capture "consumer confidence" or "uncertainty" effects, and are therefore expected to influence the demand for houses negatively in the short run. When included, the short-run effects of changes in unemployment rates are often estimated to be both significant and substantial.

D. Summary of empirical findings

Given the complexities of housing markets, it is hardly surprising that studies of aggregate housing have used a wide range of different models. Some broad findings nevertheless stand out from a survey of the empirical literature.

Modellers commonly assume that the supply of dwellings adjusts fully to demand in the long run and that abnormal profits exist only in the short run, when the supply of new units is rigid. In models where medium-term properties rather than short-term fluctuations are emphasised, the dynamics of supply-side rigidities are often included in a relatively simplified fashion and the main emphasis is directed towards modelling the demand side of the housing market.

Demographic trends and household income are commonly found to be important determinants of the demand for houses, and the long-run elasticity with respect to real permanent income *per capita* is in many cases estimated as being close to unity. Furthermore, most studies find that the demand for dwellings is sensitive to developments in the financial sector, reflected in significant real interest-rate terms and, less commonly, in the inclusion of flows of mortgage credit. However, there is considerable variation across models in the quantitative importance of financial variables.

II. ESTIMATING HOUSING INVESTMENT EQUATIONS FOR THE SEVEN MAJOR OECD COUNTRY MODELS IN INTERLINK

A. A *stock-adjustment specification*

In the present study, which is based on semi-annual data, the actual stock of houses, KHV, is assumed to adjust gradually towards a desired stock, KHV*, through a second-order adjustment process of the following form:

$$(KHV(t)/KHV(t-1)) = [(KHV^*(t)/KHV(t-1))^{**\tau_1}]^* [(KHV(t-1)/KHV(t-2))]^{**\tau_2} \quad [9]$$

where τ_1 and τ_2 are adjustment parameters.

Whereas a simple first-order adjustment model portrays a gradually declining adjustment to changes in the desired housing stock through time, the inclusion of a positive second-order term allows for a "reaction period", with the largest adjustments possibly taking place some time after the initial shock. For values of τ_2 less than zero, cycles in the adjustment process appear, whereas values of τ_2 close to unity normally imply some overshooting.

Semi-annual values of residential investment, IHV, expressed at annual levels, can in turn be linked to the net stock of dwellings, KHV, through the identity:

$$KHV(t) = IHV(t)/2 + KHV(t-1)^*(1\text{-}RSCRH(t)/200) \quad [10]$$

where RSCRH represents the annualised rate of depreciation of the net housing stock.

To allow for the effects of demographic trends on housing demand, the desired stock of houses is specified in *per capita* of the working age population, POPT". *Per capita* demand for dwelling stock is in turn linked to real permanent income *per capita,* which ensures a unit elasticity of housing demand with respect to population for unchanged income *per capita.*

The link between housing investment and financial conditions is modelled by including the expected real long-term interest rate as a determinant of the desired dwelling stock ***per capita.*** Both the mortgage rate, IRM, which affects the specific costs of borrowing for house purchases, and a "typical" long-term interest rate, IRL, representing an indicator of returns to alternative assets, were considered in estimation. Depending on the nature of the financial sector in each country, the mortgage rate is often closely related to long-term rates charged elsewhere in the financial system. Hence, estimates including either IRM or IRL may differ only slightly. In allowing for expected capital gains from increases in house prices, changes in both the price of new investment and the price of privately consumed housing services have been examined as proxies for future capital gains in the market.

No attempt has been made to model credit rationing explicitly. First, the existing empirical evidence as to the importance of credit rationing is inconclusive. Secondly, since the INTERLINK model does not include the flow of financial resources between sectors in any detail, mortgage credit flows cannot be easily endogenised. Finally, although credit rationing variables may be helpful to explain past fluctuations in housing investment, it is probably inappropriate to maintain these for projections in a more deregulated environment.

For the United States and the United Kingdom, however, dummy variables were found to be necessary to capture the effects of recognised historical credit crunches.

For the United States, interest rate ceilings and other institutional rigidities caused periodic outflows of deposits from savings and loans associations into other financial assets until the mid- to late-1970s. Savings and loans associations, the largest source of mortgage credit, reacted by rationing mortgage credit through a variety of non-interest-rate methods (Gabriel, 1987). Although this practice has disappeared, it was taken into account in estimation by the inclusion of a dummy variable[12].

Historically, the flow of finance in the UK housing market has been dominated by the building societies, which have frequently rationed the demand for new mortgage credit in order to protect existing borrowers from the full effect of higher interest rates. In more recent years – especially after the large-scale entry of commercial banks into the housing finance market in 1981-82 – building societies appear to have shifted emphasis from credit rationing to using the interest rate to meet competition (Drayson, 1987). To examine how changes in the supply of rationed credit may have influenced the estimates, a credit dummy, CRE, was added to the UK equation assuming that the growth rate of the capital stock of houses was temporarily reduced in periods with tight credit[13].

The specification of the desired stock of houses ***per capita,*** KHV*/POPT, finally includes both the real price of new investment, as a proxy for trends in the relative price of houses, and the ratio of the deflator for private consumption of housing services to the overall consumer price index. Whereas increases in the real price of new investment are expected to reduce demand for dwellings, the real price of housing services is expected to enter the equation with a positive sign, representing the opportunity cost of not investing in a dwelling.

Expressed in logarithmic form, the general equation used to represent the desired stock of houses is:

$$\begin{aligned} \ln(KHV^*(t)/POPT(t)) = \varnothing_0 &+ \varnothing_1 * \ln[M(YDRH(t)/POPT(t))] \\ &+ \varnothing_2 * [M(IR(t)) - [M(\dot{P}^e(t))] \\ &+ \varnothing_3 * \ln[M(PCPH(t)/PCP(t))] \\ &+ \varnothing_4 * \ln[M(PIH(t)/PCP(t))] \end{aligned} \quad [11]$$

where M(z) represents a moving average process.

Real permanent income ***per capita*** is defined as a moving average of current real disposable household income divided by the working-age population, YDRH/POPT, with the formation of expectations simplified to moving average function of current and past values. $M(\dot{P}^e)$ represents expected inflation in the housing market, PCP is the consumer price deflator, PCPH the deflator for private consumption of housing services, PIH the residential investment deflator and IR the long-term interest rate.

Adding short-term fluctuations in the rate of unemployment to equation [9] as a proxy for consumer confidence, and substituting equation [11] gives the final estimation form:

$$\begin{aligned} \Delta\ln(KHV(t)) = \psi_0 &+ \psi_1 * \ln[M(YDRH(t)/POPT(t))] \\ &+ \psi_2 * [M(IR(t)) - M(\dot{P}^e(t))] \\ &+ \psi_3 * \ln[M(PCPH(t)/PCP(t))] + \psi_4 * \ln[(MPIH(t)/PCP(t))] \\ &- \tau_1 * \ln[KHV(t-1)/POPT(t)] + \tau_2 * \ln[KHV(t-1)/KHV(t-2)] \\ &+ \upsilon_1 * UNR(t) \end{aligned} \quad [12]$$

Given the broad framework of equation [12], estimates for each country were obtained, allowing for some flexibility in the inclusion of explanatory variables and in the specification of lags used to determine real permanent ***per capita*** income and the expectations of prices and real interest rates. For housing stocks, it was only possible to use unmodified stocks statistics from national sources for the United States and Japan. A major concern for the other countries examined was to establish data for stocks consistent with the specific national income accounts conventions of housing investment, as used in the INTERLINK model, whilst using as much information as possible contained in available housing stock data found in national sources. A detailed account of the data sources and methods used in measuring housing stocks and other variables for this study is given in Egebo and Lienert ***op. cit.***

B. Model estimation and validation

1. Comparative analysis of estimation results

Table 2 presents estimates of equation [12] for each of the major seven economies, selected from a range of wider results for inclusion in INTERLINK on the basis of goodness-of-fit and the plausibility of long-term properties. The corresponding long-run housing stock elasticities are summarised in Table 3.

Permanent income ***per capita*** is found to be highly significant for all seven countries. The estimates show long-run income elasticities clustered around unity, with relatively little variance across countries. This result appears to be robust across a range of specifications. Only the estimate for the United Kingdom, at 1.4, seems to be somewhat of an outlier, although it does not contradict previous empirical evidence for the United Kingdom.

Although correctly signed for all countries, there is more variability in the estimates of real interest rate sensitivity, with semi-elasticities ranging from 2.4 for Japan to just above unity for Canada, the United States and Germany, and less than 0.5 for France, Italy and the United Kingdom. This result may reflect structural differences. For example, since interest payments are not tax-deductible in Canada, changes in interest rates can be expected to have a larger-than-average influence on the Canadian housing market. The estimates of short-run real interest rate effects are significant at the 99 per cent level for Japan, Canada and the United States, at the 95 per cent level for the United Kingdom and Italy, at the 90 per cent level for France and at the 80 per cent level for Germany.

The weakness of the interest rate result for France is consistent with numerous studies of the French housing sector, which find either no interest rate influence or one present only in the short run. Introducing arbitrary dummies for periods where the largest residuals are observed and using longer moving averages in the income and current inflation terms, tends to give marginally larger estimates but the overall goodness-of-fit is reduced. An alternative series for the housing credit interest rate charged by banks was also tested, but proved inferior to the public sector bond rate. Similarly, for Germany, an alternative mortgage bond rate was highly correlated with the long-term interest rate used, and did not change the overall results for that county.

The cross-country average of long-run interest rate semi-elasticities is somewhat lower than found in most investigations using a flow equation approach, reflecting the differences in dynamics. However, a small change in the desired housing stock may nevertheless have a substantial effect on investment in the short run, as the actual stock of dwellings adjusts towards its new equilibrium. Given the overall specification, the short-run semi-elasticity of investment flows with respect to the real rate of interest varies positively with the speed of adjustment and negatively with the ratio of investment to stocks. Calculations

Table 2. Preferred stock adjustment equations

$$\Delta \ln(KHV) = \psi_0 + \psi_1 \bullet \ln(M_h(YDRH/POPT)) + \psi_2 \bullet (M_j(<IR>) - M_k(\dot{P}^e)) + \psi_3 * \ln(M_m(PCPH/PCP)) + \psi_4 \bullet \ln(M_n(PIH/PCP)) - \tau_1 * \ln(KHV(-1)/POPT) + \tau_2 \bullet \ln(KHV(-1)/KHV(-2)) + \upsilon_1 \bullet AUNR$$

	United States[a]	Japan	Germany	France	United Kingdom[b]	Italy[c]	Canada
ψ_0	0.3024	−0.1626	0.0458	0.0146	−0.1445	0.0019	0.0558
	(8.01)	(0.71)	(1.62)	(0.42)	(3.93)	(0.02)	(1.50)
ψ_1	0.1187	0.0949	0.0232	0.0514	0.0639	0.0316	0.0583
	(7.37)	(3.56)	(4.29)	(5.48)	(14.79)	(6.44)	(2.66)
	h=8	h−2	h=8	h=5	h=3	h=6	h=8
ψ_2	−0.00170	−0.00206	−0.00029	−0.00021	−0.00012	−0.00010	−0.00072
	(4.95)	(6.65)	(1.45)	(1.72)	(2.63)	(2.53)	(4.32)
	j=2, k=10	j=2, k−6	j=2, k=10	j=2, k=4	j=2, k=3	j=2, k=9	j=2, k−6
ψ_3	0.0757	0.0334		0.0173			0.0513
	(7.44)	(2.82)		(3.45)			(4.24)
	m=4	m=2		m−4			m=2
ψ_4				−0.0218	−0.0256	−0.0135	−0.0361
				(2.3)	(5.38)	(3.58)	(2.31)
				n=2	n=1	n=4	n=3
τ_1	0.1446	0.0844	0.0251	0.0485	0.0454	0.0310	0.0602
	(7.91)	(5.56)	(4.93)	(5.88)	(6.26)	(3.21)	(2.80)
τ_2	0.306	0.349	0.535	0.285		0.569	0.415
	(4.41)	(3.77)	(7.36)	(2.36)		(8.89)	(3.36)
υ_1	−0.00079		−0.00120		−0.00135	−0.00086	−0.00104
	(2.85)		(4.80)		(3.82)	(2.86)	(3.15)
Sample	651-8611	7011-8611	7311-8611	6611-8611	641-8611	701-8611	651-8611
SEE[d]	3.04	4.00	2.44	2.20	4.31	1.76	4.06
R^2-adj.	0.966	0.991	0.967	0.985	0.925	0.991	0.861
Durbin Watson	1.92	2.05	2.10	2.19	2.02	1.93	2.05
H-statistics	−0.01	-0.18	-0.30	−1.00		−0.09	−0.67
RHO,	0.549						0.239
	(3.55)						(1.65)
RHO,	−0.184					−0.509	
	(1.50)					(4.17)	
Mean lag (semesters)	3.80	6.71	17.56	13.76	21.04	12.92	8.72
Median lag (semesters)	2.30	4.30	12.01	9.04	13.93	8.97	5.76

a) A credit dummy is included, with an estimated coefficient of −0.00319 (4.42).
b) Estimated with a credit variable included (coefficient 0.358 (5.29)), and a dummy equal to 1 in 6811 with coefficient 0.00378 (3.54).
c) Estimated with a dummy equal to 1 in 751 with coefficient 0.0020 (4.07).
d) Percentage standard error of predicted investment.

Table 3. Longrun housing stock elasticities

	United States	Japan	Germany	France	United Kingdom	Italy	Canada
Permanent income *per capita*, ϕ_1	0.82	1.12	0.93	1.06	1.41	1.02	0.97
Real rate of interest, ϕ_2[a]	–1.18	**–2.44**	–1.17	–0.43	–0.25	–0.33	–1.19
Relative price of housing services, ϕ_3	0.52	**0.40**		0.36			0.85
Relative price of housing investment, ϕ_4				–0.45	–0.56	–0.44	–0.60

a) Longrun semi-elasticities.

using sample-period averages show that for the United States, where the speed of adjustment is relatively high, the short-run real interest rate elasticity is more than four times the long-run value. For the United Kingdom – the country with the slowest adjustment speed – the short-run response is twice that of the long run.

There was overwhelming evidence in favour of the mortgage lending rate only for the United States. For the other countries, long-term market rates were found to perform as welt or, in some cases, better than mortgage rates. Besides reflecting the fact that the two interest rates are often highly correlated, this result may indicate the importance of returns to alternative assets. For Canada, the average Federal government long-term bond rate used in the preferred equation produces results superior to those obtained with a five-year bank mortgage rate. Using the mortgage rate gives a higher long-term interest rate elasticity estimate but the equation fit deteriorates and the long-run income elasticity drops to values below 0.9.

For Japan, the Housing Loan Corporation and, to some extent, ordinary banks have historically charged relatively stable "administered" mortgage rates which do not mirror movements in the rates charged elsewhere in the financial system. However, the substitution of a market-determined long-term rate by an actual mortgage rate[14] only yields a marginal change in the standard error of estimate, with only marginal differences in coefficients. The significance of the market-based real interest rate could be interpreted as indicating the importance to Japanese households of alternative returns on financial assets.

The preferred equation for the United Kingdom in Table 2 includes a credit dummy, which proved to be highly significant, with a coefficient of 0.36 (see footnote 13). Estimates excluding this term tended to produce much slower speeds of adjustment and even higher long-run income elasticities. This equation also includes a ten-year government bond rate, which was found to give better overall results than the actual building society mortgage rate.

Neither of the relative price effects is significant for Germany, whereas both terms enter the estimated equations significantly and correctly-signed for France and Canada. For the remaining four countries, only one relative price term is found to be significant in each case – the relative price of housing services being preferred for the United States and Japan, and the relative price of housing investment being preferred in the equations for the United Kingdom and Italy. The estimated long-run price elasticities are centred around one-half. The observed variation in the significance of relative price terms across countries may reflect differences in methods of measuring the housing services deflator, PCPH, especially with respect to the treatment of imputed rent. The evidence concerning the most appropriate representation of expected inflation in the housing market is also mixed but, with the exception of Canada, the rate of change in the housing services deflator performs better than the rate of change in the investment deflator in countries where the relative price term is significant (the United States, Japan and France).

The short-run changes in the unemployment rate enter the estimated equations correctly-signed and with highly significant coefficients for all countries, except France and Japan. In the latter case, the rate of unemployment may not be a particularly good indicator of household uncertainty, its stability over economic cycles being a special feature of the Japanese labour market.

The different dynamic properties of the estimated equations are illustrated in Chart A. As can be seen in Table 2, the second-order adjustment term, τ_2, is found to be positive and significant for all countries, except the United Kingdom, implying that the largest stock adjustments in most cases lag somewhat behind changes in the desired stock. This result is consistent with the presence of short-run supply-side rigidities. Some diversity is observed for the overall speeds of adjustment. Mean and median lags for the adjustment of actual to desired stocks are relatively short for the non-European countries and full adjustment is accomplished fairly quickly, as can be seen in Chart A. Much slower adjustment speeds are estimated for the four European economies[15]. To the extent that these reveal something about the flexibility of housing markets and the adaptability of flows of financial resources, the result might also shed some light on the diversity of long-run real interest rate responses. In this respect, it is interesting to note that – with the exception of Germany – the results suggest that the fastest-adjusting countries also display the most interest-rate-sensitive demand for dwellings.

The overall tracking performance measured in terms of the flows of housing investment, but based on the preferred stock equation estimates of Table 2, are shown in Chart B. Given the relative simplicity of these specifications, the estimates track the actual path of residential investment rather well, although there is

CHART A

ESTIMATED DYNAMIC ADJUSTMENT OF THE HOUSING STOCK

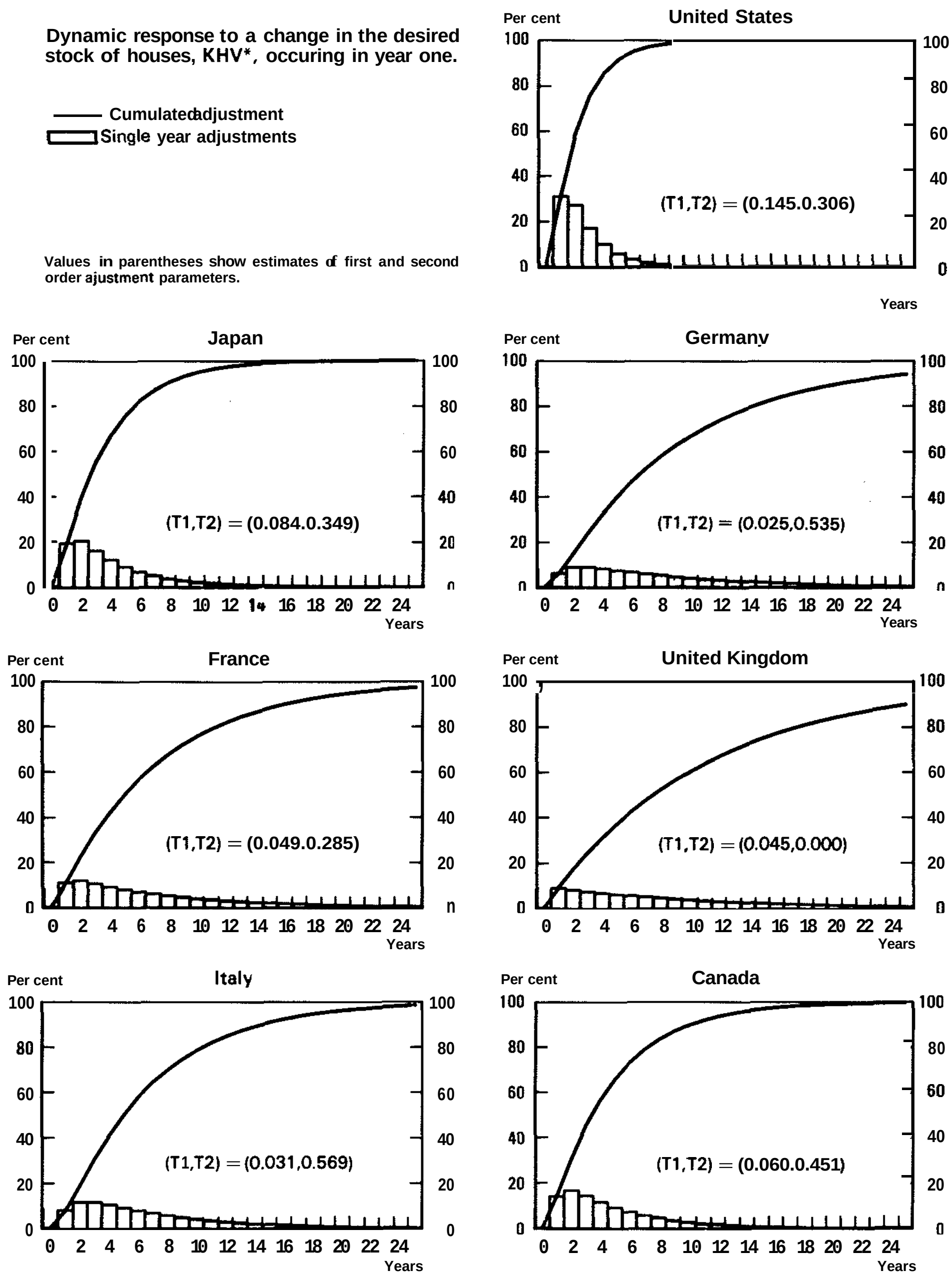
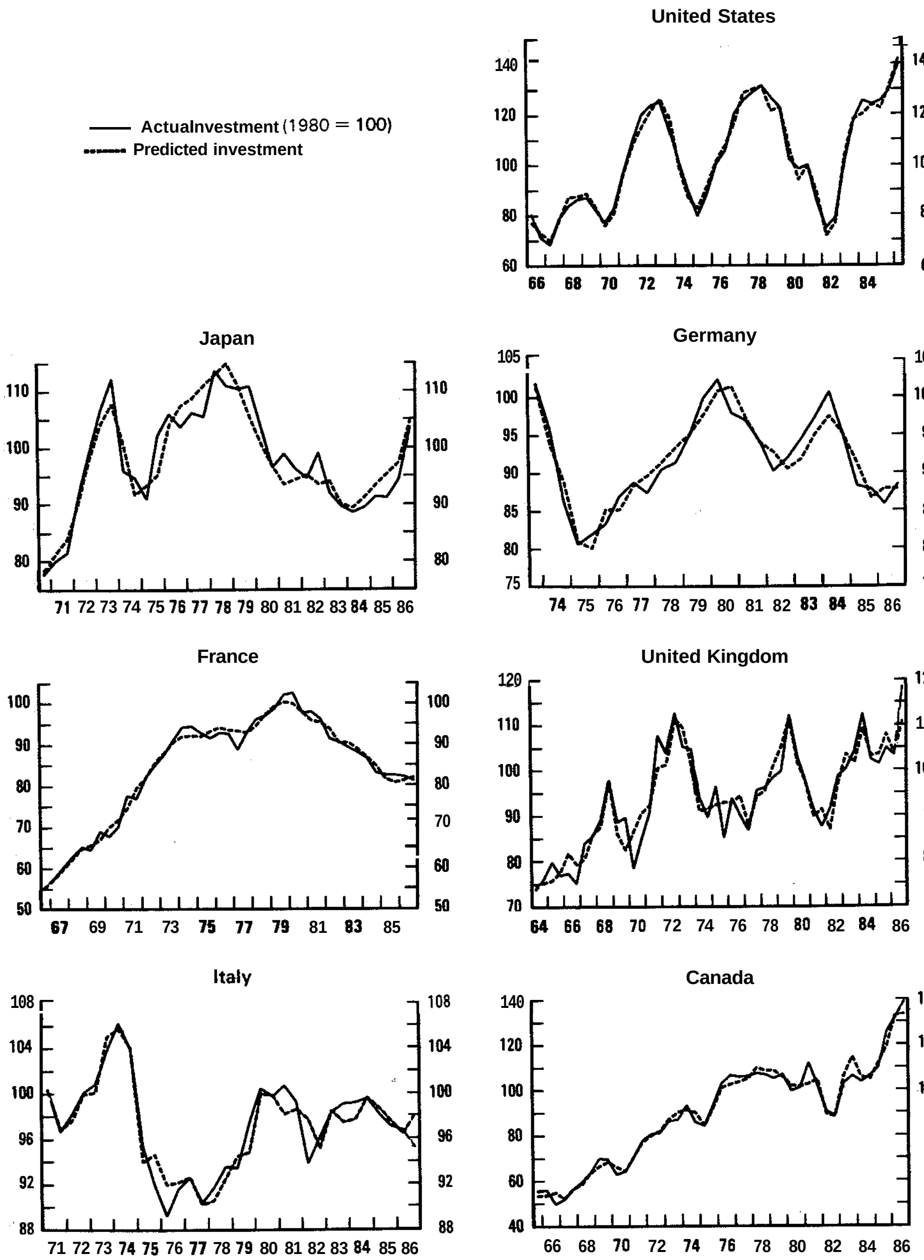


CHART B

HOUSING INVESTMENT EQUATIONS: STATIC TRACKING PERFORMANCE



some slight underestimation of peaks and troughs in a few short-run investment cycles.

2. Equation stability analysis

In examining equation stability, Table 4 reports a number of test statistics for the set of preferred **equations**[16]**.** For the United States, Germany, Italy and Canada stability cannot be rejected, even at the 90 per cent level. However, the chosen equations for Germany and Italy are estimated over relatively short samples.

	Degrees of freedom	Cusum		Cusum of squares	
		Backward	Forward	Backward	Forward
United States	34	0.7200	0.41 71	0.0808	0.1390
Japan	27	0.4201	0.8887''	0.3330'''	0.2674''
Germany	21	0.8031	0.63 18	0.1250	0.1256
France	34	0.2885	0.5207	0.2953'''	0.2595'''
United Kingdom	38	0.3801	0.8720''	0.2222''	0.3228'''''
Italy	25	0.6425	0.7424	0.1613	0.1955
Canada	**35**	0.4006	0.4289	0.1670	0.1803

The preferred equation for Germany was estimated on the basis of 27 observations, from the second half of 1973 to the second half of 1986. The same specification appears to be unstable when estimated over a longer sample period. There is evidence of a structural shift during 1973, and a standard Chow test rejects the hypothesis of stability over the subperiods 1964-73 and 1973-86 with a high probability. An equation which explains the growth of the housing stock in the latter subperiod underestimates growth in the **1964-73** period but there appears to be no satisfactory explanation of this shift.

The sample period for the preferred equation for Italy begins in **1970.** Data are available starting in **1965,** but if the equation is estimated over the full sample, very large residuals are observed in the period **1968-69** and the overall goodness-of-fit is substantially reduced.

For Japan and France, stability is rejected at the **95** per cent level, and for the United Kingdom, at the **99** per cent level. An examination of the estimated coefficients using recursive regressions reveals that the instability of the Japanese equation is largely associated with the speed of adjustment of the actual to desired housing stock, which tends to fall over time. Although the stability of the Japanese equation can be improved by adding a time trend in the adjustment process, this is unsatisfactory in the absence of a plausible underlying explanation.

For France it is the estimated adjustment profile – determined by the interaction of the adjustment parameters τ_1 and τ_2 – rather than the speed of adjustment which fluctuates in recursive regressions. The estimates of real interest rate and relative price terms do not seem to fluctuate any more than for other countries where stability is not rejected.

Eliminating the unemployment term, the equation for the United Kingdom seems stable, although the instability of the preferred equation does not appear to originate in the unemployment term. Rather, the main source of variation over time is in the interest rate term, independent of whether the unemployment rate is included or not. There is some tendency towards higher speeds of adjustment when beginning- or end-sample observations only are used. Chow-test statistics for all possible break points in the sample period do not, however, reject the hypothesis of stability across break points. This suggests that the results for the United Kingdom should be treated with some care.

Taken together, the stability performance of the estimates is not satisfying in a majority of countries, but, given the complexity of housing markets and the notorious difficulties in modelling aggregate housing in a similar way across countries, this result is not surprising.

3. Model properties

A further important stage of diagnostic testing for the set of estimated equations concerns their implications for overall model properties. To evaluate these effects, the relevant set of relationships was implemented in a test version of the INTERLINK system and a series of diagnostic simulation shocks were carried out and compared with standard model responses.

Full details of these tests are reported in Egebo and Lienert ***op. cit***. Apart from the significant improvement in goodness of fit, the principal results show little overall changes in short and medium-term model properties at the aggregate level for fiscal and monetary shocks – largely reflecting housing's relatively low GNP weight. On the other hand, for simulated changes in long-term interest rates these new equations were generally found to give a more uniform set of responses across the major economies.

III. CONCLUDING REMARKS

Due to special features of the housing sector, residential investment is one of the most difficult expenditure components to model. There appears to be little consensus on the exact functioning of housing markets or the most appropriate model specifications for aggregate residential investment. In practice, a wide range of approaches and specifications coexist, with empirical models often focusing on the demand side of the market, usually under the assumption of perfectly elastic supply in the long run. Thus, it is found that household income, population, real house prices and interest rates are commonly used explanatory variables. Household wealth, credit rationing variables and the unemployment rate are also included by some researchers.

The empirical results presented in this paper for the seven major OECD economies relate to the determination of housing stocks, an approach which is considered to be superior on theoretical grounds, with long-term properties being more transparent. Using a second-order stock-adjustment model, the empirical estimates confirm the findings of many other researchers – that real after-tax income is a key determinant of residential investment, with the estimated long-run elasticities for real housing stock demand being relatively close to unity for most of the countries considered.

Financial market influences were also found to have an important impact on housing activity, as indicated by the significance of real interest rate estimates obtained for most countries. No attempt, however, was made to incorporate the effects of tax concessions on mortgage interest rates and, with the exception of the United States, it did not prove necessary to introduce mortgage lending rates as opposed to long-term bond rates into the equations. The reported significance of real interest rates contrasts with the results in the previous flow equations in INTERLINK, where robust estimates of interest rate effects could not be obtained for many countries. Averaged across countries, the revised long-run interest rate sensitivity is nonetheless relatively low, possibly reflecting important differences in dynamics introduced with the stock specification.

The estimated interest rate elasticities also vary widely across countries, possibly due to the differing institutional arrangements. Given the effects of historical credit squeezes on the availability of mortgage finance, credit dummies were introduced and found to be significant for the United States and the United Kingdom.

Significant relative price terms appear in the equations for all countries except Germany. The deflator of residential investment relative to consumer prices proved to be significant in four countries, with little dispersion in the long-term elasticities. Greater dispersion across countries is observed for the elasticity of housing demand with respect to the price of housing services relative to consumer prices, which again proved to be significant in four countries.

The overall tracking performance of the new equations was found to be generally satisfactory, given the relatively sharp fluctuations in housing investment in some countries. This may in part be due to richer dynamics incorporated in the stock adjustment mechanism, which may be sufficient to capture the most important short-term supply-side developments. Additional short-term effects associated with household uncertainty, proxied by changes in the unemployment rate, are also identified in the equations. The equation estimates are, however, found to be somewhat unstable for a number of countries, possibly reflecting the non-homogeneous nature of the housing market and institutional changes in credit markets during the estimation period.

At an aggregate level, short to medium-term model properties with respect to fiscal and monetary policy shocks were found to change only marginally with the introduction of the new equations into the INTERLINK model – an unsurprising result given housing's relatively low weight in GNP. An exception to this general finding concerns long-term interest rate simulations, which now give more uniform results across countries.

Overall, this paper suggests that reasonable estimates can be obtained by applying a common stock-adjustment approach to housing in the seven major OECD countries, even though there have been widely different institutional features supporting each country's housing market.

NOTES

1. Richardson (1988) summarises the principal features of the OECD INTERLINK model. A detailed guide to recent developments in the overall structure and simulation properties of INTERLINK is given by Richardson (1987a, 1987b). Llewellyn *et al.* (1985) discuss the general background, role and functions of INTERLINK in OECD work.
2. A more detailed account of this project is given by Egebo and Lienert (1988).
3. The service lives of dwellings are typically assumed in National Accounts, to be between 50 and 100 years (see Blades 1983, Table 5) and, for most countries, housing investment in any given year adds little more than 1 per cent to the existing stock.
4. A wide range of such factors is discussed in a recent survey article by Smith *et al.* (1988).
5. The French models SABINE (180 equations, 140 estimated) and FANIE (56 equations, 38 estimated) are typical examples (Lefebvre and Mouillart, 1986).
6. The existing stock of houses may be included, for instance as a scaling factor for other explanatory variables in the supply equation (Jaffee and Rosen, 1979).
7. Explanatory variables such as interest rates may nonetheless be perceived as representing both a demand- and a supply-side influence. Hendry (1984), for example, specifies a house price equation incorporating both demand- and supply-side effects.
8. Goux (1983), for example, develops a stock-adjustment model with endogenous speed of adjustment, but incorporating mainly demand-side influences.
9. This distinction is used by Hendershott (1980 and 1987) and Dicks (*op. cit.*). In a model of the demand for owner-occupied housing units in the United States, Jaffee and Rosen (*op. cit.*) also control for the number of owner-occupied units which would have resulted from unchanged age-specific rates of owner occupancy.
10. One approach is to estimate prices of dwelling characteristics (so-called "hedonic" prices) and use these to generate house price indices (Rosen, 1984). There is some uncertainty, however, about the content and correctness of such measures.
11. Males and females in the age group of 15 to 64 years. The demographic influence is represented by the working age population, because developments in household formation are considered to be more closely linked to the active work force than to total population growth.
12. The dummy variable is based on a quarterly variable, set to unity in quarters when deposits at savings and loans associations fell and zero otherwise. It is assumed that credit rationing ceased in the late 1970s, with the dummy variable set to zero thereafter.
13. The UK credit dummy is based on the C.S.O. quarterly series for the real value of building society loans. Expressed at semi-annual rates, the loan variable was normalised by the lagged stock and the real value of loans in the first half of 1983 was deducted, assuming

no credit rationing to have occurred thereafter. Positive values before 1983 were set to zero. A credit dummy similar to that used in the estimation for the US equation was also tested without success.

In estimation an alternative equation of the following form was used:

$$(KHV(t)/KHV(t-1)) = [(KHV*(t)/KHV(t-1))**\tau_1]*[(KHV(t-1)/KHV(t-2))**\tau_2]*EXP(v_1*\Delta UNR(t)) + v_2*(CRE(t)/KHV(t-1))$$

where CRE represents the credit dummy.

14. The mortgage interest rate used for Japan is a weighted average of the Housing Loan Corporations rate and the City Bank housing loan rate, using weights reflecting the sample average period of flow of funds for housing purchase from these two institutions.
15. The speed of adjustment of the desired capital stock of houses, KHV*, to changes in individual explanatory variables also differs across countries.
16. Further details on the calculation of recursive residuals and associated test statistics are given by Johnston (1985,. pp. 384-92) and the references therein.

Annex

A SUMMARY OF KEY FEATURES OF EMPIRICAL STUDIES OF HOUSING INVESTMENT

The following table summarises key features of housing investment equations in recent empirical studies for the seven major OECD economies. The studies and models cited are listed in the bibliography to the main text.

General Notes

Numerical values in brackets refer to long-run elasticity estimates, where these are clearly identified.

Flow/stock indicates that the housing stock either enters as an explanatory variable in the flow equation or influences housing investment through a house price equation in the overall model.

Equations are labelled as stock when based on a stock-adjustment model although the dependent variable may sometimes be the flow variable.

Demand/supply refers to the housing market model, rather than associated financial markets.

Demographic factors normally enter housing equations through the specification of other variables in per capita terms. Where the demographic variable enters separately, a sign/elasticity is reported in the table.

Current/permanent means that income enters in a distributed lag form, although it is often unclear whether such terms should be interpreted as representing permanent income.

n.s. indicates that coefficient values were reported as being statistically insignificant.

Table A. Key features of housing investment equations in recent empirical studies for the major seven OEGD economies

Study/Model	Type of housing equation(s)	Demographic factors	Household income	Prices	Financial factors	Other factors
USA						
Arcelus and Meltzer (1973)	Flow (services) Demand	None	Permanent (0.94)	Rent index (-0.51) GNP deflator (0.91)	None	Real base money (n.s.) Real government debt (−0.15)
	Flow (starts) Supply	None	Indirectly, through services	Rent index (3.68) House price (0.29)	Nominal bond rate (-2.05)	Real labour cost of construction (-0.95)
	Flow (starts) Demand	None	Indirectly, through services	Rent index (4.35) House price (-0.40)	Nominal bond rate (-1.75) Real mortgage stock (−0.69)	Real base money (0.71) Real government debt (−0.24) Expected demand for housing services (0.66)
De Rosa (1978)	Stock Demand Portfolio adjustment model	None	Current (+)	Real house price (−) Real price of consumer durables (+)	Nominal time and savings rates (−) Nominal bond rate (−) Nominal mortgage rate (−)	Savings, capital gains and excess demand for other assets
Jaffee and Rosen (1979)	Stock (number of owner-occup. houses) Demand Stock adjustment	Age-distributed population	None	Price of home ownership rel. to rent index (−)	Real credit flows (+)	Unemployment rate (−)
	Flowlstock (single-family starts) Demand	Age-distributed population	None	Credit variables deflated by house price	Nom. mortgage rate (−) Real credit flows (+)	Demand for owner-occup. houses (+) Stock of single-family houses (+)
	Flowlstock (multi-family starts) Supply	None	None	Real rent index (+)	Real mortgage rate (−) Real credit flows (+)	Vacancy rate (−) Stock of multi-family houses (−)
Kearl[1] (1979)	Flowlstock Demand/supply	Number of house-holds	Permanent, per household (1.29)[2]	Through interest term	Real after-tax mortgage rate (−)	Initial mortgage payment (−1.70)[2] Owner's equity per household (1.03)[2] Housing stock per household (-8.76)

Hendershott (1980)	Rate of owner. occup. Demand	Age-distributed population Number of households	Current, per household (n.s)	Rent index (see "financial factors")	Real after-tax mortgage rate rel. to rent index (−)	
	Flow (one-to four-family starts) Demand	Indirectly	None	Indirectly	Credit flows (+) Mortgage rate (indirectly)	Number of homeowners (+)
	Flow (quality of starts)	Number of households	Current, per household (0.36. 0.68)	Interest term scaled by real house price	Real after-tax mortgage rate (-0.10. –0.22)	Mortgage payment constraint (-0.16. -0.43)
Poterba[3] (1984)	Flown (onefamily only) **Supply**	None	None	Real house price (0.52-2.92) Non-residential construction deflator (-0.93. -3.13)	Credit flows (0.38- 0.48) Credit dummy (mixed signs)	Real construction wage (mixed signs)
Henderson and Ioannides[1] (1986)	Flow (services) Demand	Household survey data	Current (0.38. 0.45)	Rent index (0.33. 0.45)	Real rate of interest (−0.81)	
Goodwin (1986)	Flow (number of one-family houses sold) **Supply**	None	None	House price rel. to cost index (−)[4]	4-6 mo. rate on prime commercial paper (+)[4]	Average sales period (−) Vacancy rate (−)
	Stock (number of one-family houses sold is modelled) Demand Stock adiustment	Number of households (+)	Permanent (+)	Real house price (+)[4]	Nominal mortgage rate (−)[7]	Marginal income tax rate (+)
Charpin[5] (1987)	Stock (per capita) Demand Stock adiustment	Total population	Permanent, per capita (0.85)	Real investment deflator (n.s.)	Real mortgage rate (−0.21)[7]	Unemployment rate (−1.01)[6]
MPS model Brayton and Mauskopf (1985)	Stock (inv. per capita is modelled) Demand Stock adiustment	Total population	Permanent, per capita (0.84)	Interest term scaled by real house price	Weighted nominal and real after-tax mortgage rate (−0.69) Credit flows in dummv	Unemployment rate (−7.28)[6, 7]

Table A *(Cont'd)*. Key features of housing investment equations in recent empirical studies for the major seven OECD economies

Study/Model	Type of housing equation(s)	Demographic factors	Household income	Prices	Financial factors	Other factors
MCM model[5] Edison et al. (1987)	Flow/stock (net) Demand Flow adjustment	None	Current (>1)	Through interest term	Real after-tax mortgage rate (–)	A fraction of the lagged housing stock deducted from gross investment
EPA world model[5] (1987)	Stock (net investment is modelled) Demand Stock adjustment	None	Current $(\simeq 1)$	Interest term scaled by real investment deflator	Real mortgage rate (–)	
JAPAN						
Charpin[5] (1987)	Stock (per capita) Demand Stock adjustment	Total population (1.56)	Permanent, per capita (0.45)	Income scaled by real investment deflator	Real mortgage rate (n.s.)	Unemployment rate (n.s.)[6]
EPA world model[5] (1987)	Stock (net housing is modelled) Demand Stock adjustment	None	Current $(=0.8)$	Income deflated by investment deflator	Real mortgage rate $(\simeq 0.7)$[7]	
MCM model[5] Edison et al. (1986)	Flow/stock (net) Demand Flow adjustment Accelerator term	None	Current/permanent Accelerator term (+)[6]	Through interest term	Real after-tax mortgage rate $(\gg -1)$[7]	Real net wealth (+) Housing stock[8]
GERMANY						
Charpin[5] (1987)	Stock (per capita) Demand	Total population (0.91)[6]	Permanent (0.30)[6]	Real investment deflator (-0.15)[6]	Real interest rate (n.s.)[6]	Unemployment rate (n.s.)[6]
SYSIFO model Univ. of Hamburg (1982)	Flow/stock Demand/supply Flow adjustment	Total population	Current/permanent per capita[5]	Through interest term	Real after-tax interest rate rel. to consumer deflator[9]	Housing stock per capita[9]
Deutsche Bundesbank Model (1988)	flow/stock Demand/supply Flow adjustment	None	Current (0.20)[6]	Interest term scaled by real investment deflator	Real after-tax bond rate (–0.20)[6]	Rate of indirect taxes to final demand (–)[6] Housing stock (–)[6]
EPA world model[5] (1987)	Stock (investment is modelled) Demand Stock adjustment	None	Current/permanent (0.89)	Through interest term	Real mortgage rate (–1.15)[7]	Real financial net worth (0.10)

MCM model[5] Edison *et al.* (1986)	Flow/stock (net) Demand Flow adjustment Accelerator term	None	Current/permanent (+)[6]	Through interest term	Real after-tax interest rate (≫ −1)[7]	Housing stock[8]
FRANCE						
Goux (1983)	Stock (per capita) Demand/supply Stock adjustment with endogenous soeed	Population, 20-65 yrs. of age No. of marriages (+)[6]	Permanent per capita (0.81 . 0.83)	Independent inflation term (+)[6] Interest term influenced by house price	Real interest rate (−)[6] Nominal bond rate (n.s.)[6] Credit variables (n.s.)[6]	Unemployment rate (n.s.)[6] Temporary income (n.s.)[6]
MELO model Mouillart and Salmon (1987)	Flow (non-subsidised starts for rent) Supply Flow adjustment	None	None	None	Nominal bond rate (≫ −1)[7]	
	Flow (non subsidised starts for purchase) Demand	Total population	Current, per capita (+)	Income deflated by cost index	Real bond rate (≫ − 1)[7]	Unemployment rate (≫ − 1)[7]
Charpin[5] (1987)	Stock (per capita) Demand Stock adjustment	Total population	Permanent, per capita (0.89)	Real investment deflator (−0.47)	Real mortgage rate (−0.10)[7]	Unemployment rate (n.s.)[6]
METRIC model Artus *et al.* (1981)	Stock (non-HLM starts per capita is modelled) Stock adjustment	Total population	Permanent, per capita (salary income: 0.87 . 1.01; non-salary income: 1.73 . 2.01)	Real house price (−0.91)[7]; −2.80[6, 7]) Independ. inflation term (1.64 . 1.71)[7]	Nominal or real mortgage rate (n.s.) Subsidies (+) Credit ceiling rate (+)	
COPAIN model Dehove (1981)	Stock Demand Stock adjustment with endogenous speed	Population, more than 20 yrs. of age (1, imposed)	Permanent, per capita (0.72)	Income and liquidity deflated by investment deflator	Real liquidity (+)[6]	
DMS-4 INSEE (1987)	Stock (non-HLM) Demand Stock adjustment	Population, more than 20 yrs. of age (1, imposed) Population growth (+)[6]	Permanent, per capita (0.97)	Income defl. by house price Indep. inflation term is signif. (+)[6], but is left out	Real interest rate (n.s.)	

Table A *(Cont'd)*. Key features of housing investment equations in recent empirical studies for the major seven OECD economies

Study/Model	Type of housing equation(s)	Demographic factors	Household income	Prices	Financial factors	Other factors
UNITED KINGDOM						
Hendry (1984)	Stock (no. of owner-occupied houses) Demand Derived from house price equation[3]	Number of households (1, imposed)	Current, per household (1, imposed)	Real house price (−0.27) Indep. inflation term (0.7)[7]	Nominal after-tax market rate (−0.4)[7] Mortgage stock rel. to income (0.27)	
Naticnal Institute model-7 (1984) Easton and Patterson (1987)	Flow[10] Demand Flow ajustment	None	None	Interest term scaled by real house price House price inflation rel. to interest rate on local authority debt (0.4)[7]	Real after-tax mortgage rate (≃ 1.7)[7] Real credit flows (+)	
HM Treasury model (1984) Easton and Patterson (1987)	Flow (net of local authority capital grants)[10] Demandlsupply Flow adjustment	None	None	Real house price (≃ 3.7)	Nominal interest rate (≃ 1.1)[7]	
LBS model (1984) Easton and Patterson (1987)	Flow Demandlsupply Flow adjustment	None	Current (0.42)	Real house price (0.57)[6]	Nominal clearing bank base rate (−8.68)[7]	
Bank of England model Patterson et al. (1987)	Flow/stock[10] Demand Flow adjustment	None	Current (+)	Real house price (−)	Real after-tax bond rate (−) Real credit flows (+)	Net liquid assets to income ratio (+) Housing stock through house price equation[3]
MCM model[5] Edison et al. (1986)	Flowlstock (net) Demand	None	Currentlpermanent (> 1)	Indep. inflation term (≫ 1)[7]	Real after-tax mortgage rate (≫ −1)[7]	Housing stock[8]
ITALY						
Banca d'Italia model (1986)	Flowlstock (inv. is modelled) Demandlsupply Flow adjustment	Total population	None	Demand pressure minus investment inflation (+)	Real bank interest rate (−)	Housing stock per capita (−) Demand pressure divided by housing stock (+)

	Stock Demand Stock adjustment	Total population	None	None	Yield on houses rel. to financial investments (+) Credit rationing	Housing stock per capita (+) Household wealth (+)
Charpin[5] (1987)	Stock (per capital Demand	Total population (1.20)[6]	Permanent per capita (0.27)[6]	Income term scaled by the real invest. deflator	Real interest rate (n.s.)[6]	Unemployment rate (n.s.)[6]
CANADA						
RDX2 model'' (1976)	Flowlstock (starts) (Demand/supply)[12, 13]	None	None	Credit flows defl. by investment defl.	Real credit flows (+)	
CANDIDE model[11] (1979)	Flow (single-family starts)[12, 13] Demandlsupply	Population, 30-34 yrs. of age (+)[6]	None	Cost of home ownership rel. to rent index (+) Credit flow deflat. by invest. deflat.	Real credit flows (+)	
	Flow (multi-family starts)[12, 13] Demand Flow adiustment	Population, 25-29 yrs. of age (+)[6]	None	Credit flow deflat. by invest. deflat.	Real credit flows (+)	
FOCUS model'' (1982)	Flowlstock (starts)[12, 13] (Demand/supplv)	None	None	Credit flow deflat. by invest. deflat.	Real credit flows (+)	
DRI model[11] (1983)	Flowlstock[13] (starts per capita) Demand/supplv	Population, more than 15 yrs. of age (1, imposed)	Current[9]	House price[9] Real rent index[9]	Nominal mortgage rate[9] Real credit stock[9]	Stock of houses[9]
RDXF model[11] (1983)	Flowlstock (starts)[13] Supplv	None	None	House price (1.28) Cost index (−0.94)	Nominal chartered bank prime lending rate (−7.98)[7]	Stock of houses through house price equation[3]
TIM model[11] (1984)	Flowlstock (starts)[13] Demand	Number of one-person households Number of multi-family households	Currentlpermanent	House and land prices in mortgage payment	Nominal mortgage rate in mortgage payment Real commercial paper interest rates (long)[9]	

Table A (Cont'd). Key features of housing investment equations in recent empirical studies for the major seven OECD economies

Study/Model	Type of housing equation(s)	Demographic factors	Household income	Prices	Financial factors	Other factors
CHASE model[11] (1984)	Flowlstock (starts per capita)[13] Demandlsupply Stock adjustment	Population, more than 15 yrs. of age	Current, per capita (2.18)[2]	House price rel. to cost index (0.35)[2]	Nominal mortgage rate (−6.07)[2, 7] Stock of houses through house price equation[3]	Housing stock per capita (−3.45)
MTFM model[11] (1984)	Flowlstock (single-family starts)[13] **Supply**	None	None	House price[9] Cost index[9] Indep. inflation term[9]	Chartered bank prime lending rate[9]	Unemployment rate[6, 9] Stock of houses through house price equation[3]
	Flowlstock (multi-family starts)[13] **Supply**	None	None	Rent index rel. to user cost of rental houses[9] House price rel. to cost index[9]	Real after-tax interest rate in user cost for rental houses Nominal mortgage rate[9]	Stock of houses through house price equation3
CEFM model Stokes (1987)	Flowlstock (single-family starts)[13] **Supply**	None	None	House price[9] Cost index[9]	Real chartered bank prime lending rate[9] Credit availability[9]	Unemployment rate[6, 9] Stock of houses through house price equation[3]
	Flowlstock (multi-family starts)[13] **Supply**	None	None	Rent index[9] Interest term scaled by cost index	Real after-tax interest rate charged to business companies[9] Real chartered bank prime lending rate[9] Credit availability[9]	Stock of houses through house price equation[3]
MCM model[5] Edison et al. (1987)	Flowlstock Demand Accelerator term	None	Currentlpermanent (+)[6]	Through interest term	Real bond rate (< −1)[7]	Housing stock (+)

1. Estimates using alternative specifications are reported. The results shown in the table refer either to the equation explicitly preferred by the author(s) or the equation used as the basis for numerical conclusions in the study under consideration.
2. Short-term elasticities, disregarding the specified interaction between housing investment and the housing stock term in the equation.
3. The house price equation is important in this study model. The price of houses is usually determined by a conventional Walrasian priceadjustment equation as a function of excess demand for houses, where demand in general is explained by population, income, prices and interest rates, and supply by the existing stock of houses.
4. Recognised to be contrary to theory.
5. Multi-country study/model.
6. Short-term (impact) elasticity; effect only present in the short run.
7. Semi-elasticity.
8. See "other factors" under the MCM model for the United States.
9. The sign of the estimated coefficient is not published.
10. The equation for housing investment/housing starts interacts with equations for the price of houses interest rates and flow of funds between institutional sectors.
11. See Grady Economics and Associates (1985).
12. Housing investment in RDX2, CANDIDE and FOCUS is very closely linked to the flow of credit. Explanatory variables, such as household income, prices and interest rates in general, affect the flow of credit and thereby housing investment.
13. Housing investment is determined as a function of starts and in general also real estate commissions plus renovations/repairs. The stock of houses influences the renovations/repairs component.

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