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by

M J Dicks

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The object of this series is to give a wider circulation to research being undertaken in the Bank and to invite comment upon it; and any comments should be sent to the author at the address given below.

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Contents

Abstract

This paper brings together previous work by Hendry (1984 and 1986) and Ericsson and Hendry (1985) on the UK housing market and re-estimates their models of house-prices (for both new and second-hand dwellings) and housing investment (for both housing completions and the uncompleted stock of dwellings). As a first step in testing the adequacy of these models they are re-estimated using more up-to-date data. Next several (minor) extensions to these models are considered, to take into account recent developments in the mortgage market and other influences ignored in previous research — namely demographics on the demand-side of the market and land prices on the supply-side. In addition, mention is made of the potential importance of changes in the number of completed but unsold dwellings as an indicator of disequilibrium. The resulting models perform well both in terms of explaining developments in the housing market which occurred during the first half of the 1980s and forecasting the following two years accurately. Nevertheless, further work is still needed to discover whether or not a model with a more rigorously defined theoretical structure performs better.

A Simple Model of The Housing Market

It has been contended that an acceleration of house prices causes inflation to worsen and that even if there is no causal link, an acceleration of the rate of increase in house prices is a harbinger of worsening inflation. [Furthermore] ... it is evident that the case rests essentially on the booms in house prices in 1971-72 and 1978-9 being followed by surges of inflation in 1973-75 and 1979-80 Neither [of the surges in inflation] had anything to do with British house prices. No means suggests itself whereby the rise in house prices could have caused either the 'Yom Kippur war' or the revolution in Iran, let alone both.

Taken from Holmans (1988)

Section 1: Introduction

Interest in the housing market is currently running high — not so much because the fast rate of increase of house prices which occurred in 1988 and early 1989 led economists to speculate that there would be another crisis in the Middle East, but because some people felt that the increases in wealth which resulted from house prices rising quickly would fuel consumption and, perhaps too, increase the upward pressure on wage settlements because of their deleterious effects on first-time buyers' ability-to-buy. The aim of this paper is to try and improve our understanding of what causes house prices to rise and the housing stock to change by bringing together previous research on the UK housing market and seeing how well it explains recent developments. In order to do this some slight extensions of the Hendry models are considered.

In Section 2 the model of the housing market developed by Hendry (1984), Hendry (1986) and Ericsson and Hendry (1985) is set out. Section 3 contains a sketch of the model used by Anderson and Hendry (1984) to explain the activities of building societies in the mortgage market and show how this was extended by Wilcox (1985) (thus enabling one to gauge the degree of rationing which sometimes occurred in the mortgage market during the 1960s and 1970s). The disequilibrium model used by Hall and Urwin (1989), which provides slightly different measures of mortgage rationing, is also mentioned. Section 4 shows how the Hendry housing market model can be extended to take into account both developments in the mortgage market and other influences ignored in previous research — namely demographics on the demand-side of the market, and land prices on the supply-side. Empirical results are contained in Section 5, where, in addition to presenting the results previously obtained by Hendry and Ericsson and Hendry, we report our attempts to replicate their work. This forms the basis of our (slightly) extended model, which we report in detail in Section 6. Section 7 contains some conclusions.

Section 2: Previous Models of the Housing Market

The aim of this section is fairly modest — simply bringing together previous research so as to emphasise the importance of trying to maintain consistency between empirical work and a coherent model. One could, of course, posit a very different model from that used as the basis of Hendry's previous research — indeed, one might wish to go as far as testing between the different theories and gauging the lessons for policy that one can learn from such an exercise. However, this paper does not attempt such an analysis. Rather it takes the existing theoretical structure (as developed by Hendry) as given and considers only minor extensions to allow for some of those factors, such as demographics and mortgage rationing, not previously considered - extensions which involve, in a theoretical sense, only minor departures from previous work. Before considering the Hendry model of the housing market in detail, however, it should be noted that there are problems with the model on which it is based. It is hoped that future work will address the question of whether or not a model with a more rigorously defined theoretical structure would perform better than the Hendry model.[1] Nevertheless, as a first step in testing the latter it seemed worthwhile seeing how well it performs when confronted with new data.

The Hendry Model of the Housing Market

The rest of this section aims to bring together the models presented in Ericsson and Hendry (1985), Hendry (1984), and Hendry (1986). First we consider the market for new dwellings, as in Ericsson and Hendry (1985).

The Supply of New Housing

Ericsson and Hendry suggest that housebuilders are small in terms of the markets they supply (housing) and from which they demand inputs (labour, capital, land, materials and fuel) in which case, in the longer run at least, competitive forces might be expected to ensure that only normal profits are earned. In addition, however, they recognise that builders may have some element of monopolistic power and so be able to influence sales to some degree by (say) advertising. Thus Ericsson and Hendry suggest that, 'in the medium term, they [builders] can determine the volume or the price of their new construction (or possibly some combination thereof); usually, their supply schedule reflects a willingness to supply more houses with higher profitability of construction'. In a 'schematic' formulation of this process it is suggested that the number of completions of new houses in period t (denoted C_t) depends upon the stock of uncompleted dwellings (U_{t-1}), with variations in the rate of completions depending upon new house prices (PN_t) and construction costs (CC_t). Ericsson and Hendry choose a log-linear representation;

$$c_t^s = \beta_0 + \beta_1 u_{t-1} - \beta_2 cc_t + \beta_3 pn_t \tag{1}$$

where each parameter is assumed to be greater than or equal to zero. Lowercase letters denotes logs[2] and the superscript denotes supply.

The stock of uncompleted dwellings (U_t) must evolve according to the simple rule;

$$U_t \equiv U_{t-1} + S_t - C_t \tag{2}$$

where S_t is the number of starts of new dwellings. Ericsson and Hendry suggest that one can think of stock-flow ratios, such as $\frac{U_t}{C_t}$ or $\frac{U_t}{S_t}$, as crude measures of the average lag between starting and ending construction. In equilibrium they assume that builders seek to keep such ratios constant; in the case corresponding to $C = KU$ this would imply that $\beta_1 \approx 1$. Of course, (2) implies that in

(1) In that such a model would need to confront the problems involved with modelling a market in which both expectations and rationing are important - see, for example, Precious (1987) - it is perhaps best to consider the Hendry model as a 'simple' model. Hence the title of this paper.

(2) This convention is maintained throughout. Appendix 1 gives details of the notation used.

equilibrium $S = C$, in which case the average lag between starting and ending construction will be constant. Thus Ericsson and Hendry interpret the role of cc_t and pn_t in (1) to be one of altering the average lag (between starting and ending construction) around $e^{-\beta_0}$, whilst the main impact of changes in long-run profitability feed through to c_t^s via the term u_{t-1}. Of course, if it is profitability which matters, then one would expect β_2 and β_3 to be of equal magnitude.

The Demand for New Housing

The demand for new housing is posited to depend upon population, income, interest rates and the relative price of new to second-hand housing. Again a log-linear expression is used;

$$c_t^d = \gamma_0 + \gamma_1 (y-n)_t + \gamma_2 n_t - \gamma_3 (pn-ph)_t - \gamma_4 RM_t \tag{3}$$

where the superscript refers to demand, n_t is a demographic variable,(1) Y_t is real personal disposable income, PH_t is the price of existing dwellings and RM_t is the (nominal) mortgage rate.(2) Although recognising that demographic factors may have a role to play Ericsson and Hendry assume in their empirical work that $\gamma_1 \approx \gamma_2 \approx 1$ so that n_t can be dropped. Hence, y_t is left to capture both scale changes (via changes in n) and movements in $(y\text{-}n)$. They also emphasise that a large value of γ_3 might be anticipated, reflecting a willingness to switch freely between otherwise identical new and existing dwellings when prices change. Nevertheless, they also recognise that their analysis has assumed homogenous housing units and that it would be desirable to allow for changes in housing attributes and composition. It should also be noted that it is very difficult interpreting (3) in terms of a standard intertemporal model of the housing market (as presented in say, Poterba (1984) or Mankiw and Weil (1988)), for to do so requires very strong assumptions. (For example, capital gains are ignored in the Hendry model.) Moreover, there are also problems with the price term used in (3)— Ericsson and Hendry argued that, since the demand for completions is a demand for new housing (over and above the existing housing stock) then it is the price of new houses relative to that of existing houses which is relevant. However, it would seem more natural to augment (3) with a weighted average of pn and ph (measured relative to consumer prices). Otherwise in equilibrium, with $pn = ph$, it would appear that demand is not a function of price. Even doing this, however, is inadequate since demand ought too to depend upon the (expected) supply response (and the resulting price changes).

The Price of Existing Dwellings

Next we consider the overall demand for housing (ie of new and secondhand dwellings) relating to the national stock (H_t). Ericsson and Hendry assume that the total demand for housing is a function of incomes, real house prices and interest rates, although in Hendry (1984) the model is extended slightly to permit a role for the real rental rate (R), the stock of mortgages (M), the number of families (N) and average family size (F);

$$h_t^d = \lambda_0 + \lambda_1 (y-n)_t - \lambda_2 (ph-pc)_t - \lambda_3 RM_t - \lambda_4 R_t + \lambda_5 m_t + \lambda_6 n_t \pm \lambda_7 f_t \tag{4}$$

where pc is the overall price level of goods and services. Note that it is hard to anticipate the sign of the partial derivative with respect to family size,(3) and that once one decides to use demographic variables it seems natural to use income per family/household rather than an aggregate measure. Note also that it is again difficult interpreting (4) in terms of the standard

(1) Ericsson and Hendry actually use the term 'families' (by which they probably mean households?) but they later suggest that (y-n) is income per capita. We discuss demographics in more detail below (Section 4).

(2) Ericsson and Hendry, in their data appendix, define RM_t as the minimum lending rate or the mortgage rate. We assume that the latter is more likely to be relevant here. One might also think a real interest rate is more appropriate (see below).

(3) Not that it really matters since neither the real rental rate nor the demographic terms were actually used in empirical work by Hendry.

theoretical model. To do so requires not only (again) an assumption that capital gains can be ignored (say because of 'naive' expectations) but a justification for a number of new variables being relevant. One might imagine that the most plausible justification for using (4) is that rationing in the mortgage market means that expectations of capital gains can be ignored (from an econometric point of view) if mortgage finance is supply-determined and factors which determine how much lending takes place are entered in the equation instead. In fact, however, this amounts to making very strong restrictions regarding the precise nature of rationing — it requires (at minimum) an assumption that rationing is expected to occur throughout future periods and that agents cannot anticipate changes in the degree of rationing. If these assumptions do not hold (as seems likely) then more complex models than (4) are needed — see, for example, Precious (1987). Moreover, even if (4) is accepted as adequate it seems more natural to use the price of all houses rather than *ph*. (If one were interested in testing whether a distinction between new and existing houses is significant one could always run regressions to see if the share of houses which are new is related to (*pn-ph*)).

Since completions (C_t) will only be a very small fraction of the housing stock, so Ericsson and Hendry maintain that the average price of existing dwellings (PH_t) will be determined largely by the demand for housing relative to the pre-existing stock, H_{t-1}. Thus (4) can be thought of as the house price equation (for *PH*). Given PH_t (3) then determines the demand for new houses (C_t^d), which is confronted with the supply C_t^s. The problem with this approach is that it ignores the effect on demand of the expectations of price changes generated by additions to supply. If demand is inelastic small increments to the stock might set up significant price movements with, if anticipated, significant effects on demand. In general, Ericsson and Hendry suggest that one would *not* expect to see supply equal to demand, with builders either failing to satisfy demand or being left with unsold (but completed) houses. This necessitates their adjusting output and/or price. If γ_3 is large disequilibrium will persist until *PN* is fully adjusted to *PH*. However, simultaneously H_t must be evolving, given that;

$$H_t = (1-\delta_t)H_{t-1} + C_t + O_t \tag{5}$$

where δ_t is the rate of destruction of houses and O_t is other net sources of housing supply (eg from the government and rental sectors). The system will evolve until a new equilibrium is reached. In the static equilibrium, where $C_t^d = C_t^s$ then, provided we assume $O_t = 0$, (5) implies that;

$$c = \ln\delta + h \tag{6}$$

The Uncompleted Stock and the Number of Completions

Although we have considered housebuilders' supply of new housing (in the form of the number of completions), we also need to consider an equation which determines either the number of starts which occur or the volume of work in progress (then (2) can be used to derive the third variable). Ericsson and Hendry choose a very simple formulation for their uncompleted stock equation;

$$u_t = \psi_0 + \psi_1(pn-cc)_t + \psi_2 z_t \tag{7}$$

where z_t denotes other exogenous influences such as technology.

Taking together (1), (3), (4) and (7) with the two identities (2) and (6) we now have a system of equations with which we can determine c, h, u, pn and ph in terms of y, δ, pc, RM, cc, R, m, n, t and z [1] provided one makes one further assumption — that builders wish to maintain a constant mean lag in equilibrium ($C/U = K$). Hendry (1985) admits that it is difficult to embed in an optimisation framework the desire for builders to do this. Anyway, in practice Hendry does not choose to follow the approach of using the simple model set out above. Rather he formulates a decision problem which yields models for U_t and K_t (defined as $\frac{C_t}{U_{t-1}}$) — the latter modification being necessary because of heteroscedasticity — based on builders maximising profit per house and wanting to hold $C = KU$ in equilibrium (and being subject to costs from failing to do so). It is also assumed that they face adjustment costs if they change U_t and that there are costs of holding inventories or from selling completed dwellings. Solving this maximisation problem gives an optimal plan of the form;

$$\Delta u_t = \alpha_0 + \alpha_1 \Delta u_{t-1} - \alpha_2 u_{t-1} + \alpha_3 c_t^d - \alpha_4 RB_t \tag{8}$$

where RB_t is an interest rate associated with holding an inventory of unsold houses and where c_t^d can be eliminated by substituting in the determinants of the demand for completions (3). The equation for completions is given by;

$$K_t = \varphi_0 + \varphi_1 (pn - cc)_t + \varphi_2 \left(\frac{c_t^d}{U_{t-1}} \right) \tag{9}$$

where again c_t^d can be substituted out for empirical purposes. Note, however, that both (8) and (9) are regarded as 'suggestive, not as obligatory, especially for the lag reaction profiles' by Hendry. Hence his final 'preferred' models for u and K do not accord precisely with the theoretical specifications.

One might argue that using (8) and (9) as the basis for the U_t and C_t models seems rather ad hoc, especially since Hendry has already set out a system of equations which could be solved to give models which would then be consistent with the remaining equations. The simplest means of deriving such a model for u_t in terms of pn_t and cc_t would be to estimate (7) directly.[2] If, however, one wants to retain factors relevant to C_t^d one might prefer to equate (2) and (3) and then use (7) to substitute for cc_t giving:

$$u_t = (A_0) \left(A_1 + \alpha_1 y_t - \alpha_3 (pn - ph)_t - \alpha_4 RM_t + (\beta_2 - \beta_3) pn_t \right) \tag{10}$$

where $A_0 = \left(\dfrac{\psi_1}{\beta_1 \psi_1 + \beta_2} \right)$

and $A_1 = \left(\alpha_0 - \beta_0 + \dfrac{\psi_0 \beta_2}{\psi_1} \right)$

As regards completions, if one wishes to estimate an equation with both 'profitability' and 'demand' factors then again one can use the simple model to derive a broadly-similar equation to (9) which is consistent with the rest of the housing model. First one takes the equilibrium condition $c = k + u$ and substitutes for u using (1) and for c using (3). After re-arranging this gives;

(1) Appendix 2 gives details.

(2) Assuming, that is, that one does not want to solve the system for U_t in terms of exogenous variables alone.

$$c_t = (B_0) + \beta_3 pn_t - \beta_2 cc_t + \alpha_1 \beta_1 y_t - \alpha_3 \beta_1 (pn - ph)_t - \alpha_4 \beta_1 RM_t \quad (11)$$

where $B_0 = (\beta_0 + \alpha_0 \beta_1 - k)$.

Once again it is worth asking if (8) to (11) are consistent with a 'standard' intertemporal model of the housing market. Although one would clearly need to extend the models outlined in, say, Poterba (1984) it is clear that such extensions would not involve making very strong assumptions.

The Price of New Dwellings

Finally, we consider the price of new dwellings. In the model *pn* is determined by *cc* and other factors affecting profitability, which might suggest trying to 'explain' pn_t by conditioning on cc_{t-i}, $(i = 0, 1, ...)$. However, Ericsson and Hendry suggest that a more natural method of proceeding is to equate (1) and (3), in which case one finds that;

$$pn_t = (\gamma_3 + \beta_3)^{-1}\left((\gamma_0 + \beta_0) + \gamma_3 ph_t + \beta_2 cc_t + \gamma_1 y_t - \beta_1 u_{t-1} - \gamma_4 RM_t\right) \quad (12)$$

Note, however, that if one is to estimate a price equation with (12) as its long-run solution and equations for the uncompleted stock and completions with (10) and (11) as their long-run solutions then many of the parameters are common to more than just one of the equations. Since, like Hendry, we choose to estimate each equation in isolation (using ordinary least squares) then this provides a useful means of checking whether the results obtained are reasonable.

Of course, it is important to recognise that, since $c^s_t \neq c^d_t$ in general, it is only required that a model reproduces (12) in equilibrium.[1] One justification for this approach to modelling pn_t is that the stock of unsold completions varies considerably. Ericsson and Hendry try modelling this series, finding that the stock of unsold (but completed) dwellings (*UD*) appears to depend upon the same variables that enter the housing demand and supply model interest rates, incomes and house prices.

Section 3: The Mortgage Market

In Hendry's model of the housing market it was assumed that housing demand depends upon, *inter alia*, the mortgage stock (M). Implicit in this relationship is the realisation that the mortgage and housing markets cannot be treated in isolation. One of the main reasons for this is that throughout much of the 1960s and 1970s the demand for mortgages was rationed. Hence one cannot simply substitute for M in the housing demand equation in terms of the determinants of mortgage demand (real personal disposable income, interest rates, house prices etc). Instead one needs to consider both how the building societies (and other lenders) supply and the personal sector demand mortgages. Anderson and Hendry (1984) have developed this type of model, although they chose to consider just the role of the building societies on the supply-side.

The Anderson-Hendry model envisages societies acting not as profit-maximisers but choosing instead to attempt to meet mortgage demand at a 'reasonable' cost. However, the cost function they use means that mortgage demand remains a latent variable (ie its values cannot be identified from the mortgage supply rule they adopt). This means that it is not possible to derive from their model a

(1) Note also that (12) can be justified by considering a model in which builders maximise the profits from constructing dwellings, subject to a Cobb-Douglas production function in a situation where they have some element of monopolistic power. Ericsson and Hendry give details.

measure of the excess demand for mortgages — this being necessary if one is to test whether or not the influence of mortgage supply on the housing market has declined during the 1980s as mortgage rationing has declined, which is one of the extensions which we make to the Hendry model of the housing market (see Section 4 below). Fortunately, however, there have been several attempts at estimating a similar model which does permit one to do this; Meen (1985), for example, derives an explicit measure of rationing by assuming that the building societies' cost function includes the change in mortgage demand relative to the *change* in mortgage supply, but *not* the difference between mortgage demand and planned supply. Given that the former can be thought of as reflecting whether building societies are lengthening or shortening their mortgage queues, whilst the latter can be thought of as the length of the queue, then one might argue that such a measure will be unlikely to reflect queue length, so much as queue lengthening. For this reason these estimates of the degree of mortgage rationing are probably unlikely to be very accurate measures of 'true' excess demand. Hence, we have not followed his approach in attempting to gauge the severity of rationing.

Fortunately, Wilcox (1985) has also extended the Anderson-Hendry model of the mortgage market in such a way as to provide explicit measures of excess demand which do not suffer from the same problem, since he includes an explicit measure of rationing — the loan-to-value ratio for first-time buyers — in the mortgage demand function. Building societies are viewed as setting this ratio according to their liquidity position, although with some households being permitted to meet their optimal ratios. As regards gauging unrationed mortgage demand, Wilcox suggests that one should use the highest actual value of the loan-to-value ratio which has occurred as an estimate of the level of the ratio which would be necessary for there to be *no* rationing. This value can then be substituted in the long-run static equilibrium of the mortgage equation to gauge long-run excess demand, or it can be used dynamically by comparing forecasts from the mortgage equation using first actual and then 'market clearing' levels of the ratio. Nevertheless, it is important to realise that neither of these measures will pick-up a second (perhaps important) type of rationing, which results from the fact that an individual's mortgage debt is set in nominal terms and generally (in the past, at least) has not been easy to increase unless the individual has moved house. Since however, the higher the inflation rate is then the greater will be the rationing due to this 'front-end' loading it might be possible to use this to develop other proxies for use in an extended model.

A second piece of research which provides explicit measures of mortgage rationing is that by Hall and Urwin (1989). They estimate the demand for and supply of mortgages within an explicit disequilibrium framework.(1) In their model the demand for mortgage borrowing (per owner-occupied dwelling) is posited to depend upon disposable incomes, house prices, interest rates and consumer prices, with lagged values being necessary due to the existence of adjustment costs. The effect of new lenders entering the mortgage market is captured by entering the amount of mortgage lending other than by building societies explicitly in the demand function.(2) The supply of mortgage lending is deemed to depend upon the supply of building society shares and deposits and the amount of wholesale borrowing which takes place (the latter being treated as exogenous). Deposits are presumed to depend upon relative interest rates and disposable incomes in much the same way as in the Anderson-Hendry and Wilcox models. Mortgage supply is then assumed to be a function of deposits plus wholesale borrowing, with this function depending upon both loan-to-value and loan-to-income multiples. To close the model Hall and Urwin use an interest rate adjustment equation involving changes in competing interest rates, the excess demand for mortgages and a lagged dependent variable.

Hall and Urwin find that both the nature and extent of disequilibrium are related to the institutional structure of the market — in periods of little competition the building societies typically did not, in the past, meet the demand for mortgages in full or alter interest

(1) Although the model they use incorporates a notion of equilibrium (one in which there is no pressure from within the market for a change in real interest rates at an equilibrium point) such that their system will on average be in equilibrium, thus conflicting with the view that mortgage demand is always rationed. For a discussion of this issue see Hall and Urwin (1989), page 14.

(2) Of course, this implies that bank lending for house purchase is treated as pre-determined.

rates by enough to eliminate excess demand. However, once the banks entered the mortgage market building societies responded by meeting demand in full. Indeed, during the early 1980s (when the banks first began competing strongly) Hall and Urwin's results suggest that there was an excess supply of mortgages from the building societies. Thus their measure of mortgage rationing fell sharply around this time. It has remained close to zero since then. Interestingly, this is much the same profile as has been followed by the proxy for rationing based on the Wilcox model.

Section 4: Extending the Hendry Model of the Housing Market

Since the main aim of this paper is to re-estimate the Hendry model of the housing market on more up-to-date data only minor extensions to the basic model are examined. In this section three extensions to the Hendry model of the housing market are considered. First, the demand for housing is re-examined (including taking into account the influence of demographic factors and changes in the distribution of income). Second, those supply factors which have been omitted from the Hendry model are considered. These include labour costs and the price of land. Finally, it is suggested that one should test whether or not (and, if so, how) rationing in the mortgage market affects the housing market.

(i) The Demand for Housing

Demographic Factors

In Section 2 a model of the housing market was presented which treated demographic factors as being of little importance. Hence, although the demand for completions of new dwellings was posited to depend upon 'the total number of families in the relevant geographical region' and income per family (see equation (3) and Ericsson and Hendry, page 263), in practice only the number of dwellings was used in empirical work (to proxy the number of households) when modelling completions (see section 5 below). Similarly, although in Hendry (1984) both the number of families and average family size entered the housing demand equation (see equation (4)), it was then assumed that the coefficients on income per family and the number of families were similar in size, thus implying that it was only necessary to include aggregate income in empirical work. Clearly this assumption should be tested. First, though, it is perhaps worthwhile attempting to clarify how demographic factors might play a role.

Obviously the size of the population is relevant to the demand for housing, suggesting that one could simply substitute 'population' for 'family' in the Hendry model. Probably a more appropriate measure of demand, however, is likely to be the total number of households.[1] Since average household size has fallen dramatically during the period since the Second World War (ie the headship rate— the proportion of the population who are heads of households — has risen)[2] then clearly a model which uses the total number of households to gauge housing demand would anticipate housing demand rising much faster than one which uses total population. Testing which model is best by including average household income (*y-ho*) and total number of households (*ho*) in a model and comparing its results with those based on using population- based variables ((*y-pop*) and *pop*) instead is one of the extensions considered below.[3]

(1) Note that this is a very different concept from that of family, the term used by Hendry.
(2) See, for example, Wall (1987).
(3) Although one might argue that since household formation is likely to be endogenous an extended model is necessary to test such a proposition.

Even this approach, however, is likely to ignore some potentially important factors. The process of household formation and dissolution appears to be one which is fairly age-specific (although, of course, social and economic factors are also significant factors in explaining the rise in the aggregate headship rate which has occurred during the last two decades — see Dicks (1988a) for an explanation of British household formation over this period or Hendershott and Smith (1985) for evidence in the United States). The usual explanation given for this is that most individuals are assumed to have a fairly age-specific family 'life-cycle' — in the sense that the pattern of pre-marriage period, marriage, pre-child period, child rearing period and 'empty-nest' period is sufficiently general that much of the change in the total number of households which occurs can be predicted by examining changes in the age distribution of the population (and assuming that age-specific headship rates remain unchanged over time). It could be the case that housing demand follows an age-specific process too, in which case changes in the age distribution of the population might be an important determinant of the demand for housing. Hendershott (1987) has used this approach (using US data) with some success finding that broadly one-half of the rise in the number of owners during the 1960s and 1970s was due to population growth combined with changes in its age structure and changes in household composition.(1)

To some extent these results may in part reflect the closer correspondence between the concepts of household and dwelling used in the United States. (Thus, for example, in the United States two households cannot share a dwelling, whereas this is possible using the British definition of household.) Despite this caveat there does appear to be fairly convincing evidence that changes in the age-distribution are important to housing demand. A related factor is likely to be changes in household size. Rudel (1987) has suggested that these factors are important because, paralleling the family life-cycle, there is a housing cycle with changes in the former triggering changes in the latter. Comparing cross-sectional data from the mid and late-1970s he finds that income and household demographic variables provide a fairly good explanation of US tenure choice. In particular, household size is found to have a positive impact on the likelihood of moving from rented to owner-occupied housing. One way of testing whether or not the same result holds for the UK is by adding to our housing demand equation an average household size variable (*pop-ho*) (although again the problem of endogeneity means that a more thorough analysis is really necessary). In addition, however, it would seem worthwhile testing for the effects of changes in the age-distribution of the population by including age-specific terms. Two such variables are tried in our empirical work; first, the proportion of the population between the ages of 25 and 34 and, second, that comprising those aged over 60. The first variable (denoted *SY*) is used simply because ownership rates (ie the proportion of households who are owner-occupiers) tend to be highest for those households whose heads are in their late 20s or early 30s — these being the prime household formation years.(2) The second group (denoted *SO*) has been picked because of the sharp rise in its headship rate during the 1960s and 1970s. This reflects, in part, the growth in the number of single person households. Whether this development is due to demand shifting is questionable.(3) A more comprehensive means of weighting the different age categories of the population to ascertain total housing demand might be to use, for each year, the previous year's headship rates to calculate the number of households one would expect to see if one assumed that age-specific headship rates remained unchanged allowing, however, for changes in the population and its age structure.(4) In Dicks (1988a) we have used this approach to gauge how much of the increase in the total number of households over the past two decades has been due to demographic factors and how much has occurred because of the rise in age-specific headship rates. Since most of the latter is likely to be due to social and

(1) Mankiw and Weil (1988) too have had some success using this approach to explain changes in US house prices.

(2) Moreover, it is evident that ownership rates for these groups have risen significantly faster than trend during the 1980s (see Dicks (1988a), Section 8). Of course, this development may simply be due to changes in the supply of housing finance (rather than increased demand), in which case one would not expect this variable to play a significant role.

(3) Although it could be the case that higher living standards enables more older households to live alone whereas previously they were forced to live with relatives. Certainly Hendershott and Smith (1985) find it necessary to allow for a shift in tastes in order to explain the increase in the number of households in recent years in the United States.

(4) Buckley and Ermisch (1982) have had some success with using a similar variable in modelling UK house prices.

economic factors such as higher real incomes (which may be picked up by other terms in our housing demand equation), this rather suggests that the 'demographic' element could be included as an additional exogenous factor determining housing demand.[1] Of course, if one has not already included the relevant economic and social variables too, then these will need to be added to the housing demand equations. Possible candidates in this respect are the number of divorces and marriages, although there is fairly strong evidence to suggest that these variables depend too on many of the economic factors already included (such as income growth) — see, for an early such study, Yule (1906). Note, however, that whatever the reason for a new household forming it will be the total number of households which is relevant to the long-run equilibrium. For this reason one might expect only changes in the number of households due to demographic factors (denoted Δhod) to enter the relevant demand equations, but levels of the total number of households variable.

The Distribution of Income

One potential problem with using an aggregate measure of real personal disposable income to gauge housing demand is that such a measure is unlikely to pick up changes in the distribution of income. In recent years there has been a significant shift in this distribution towards those people who, traditionally, have been more likely to buy their own homes. This reflects not only changes in the tax and social security systems — both in terms of reductions in tax rates and the differential between the highest and standard rates of tax and changes in indexation rules and entitlements to benefits — but also changes in the composition of income and employment. Unemployment, too, has been higher than in the past (both in absolute terms and as a proportion of the working population). Moreover, within the category of employed workers there has been a shift towards those most likely to be home-buyers. Thus, Holmans (1988) has shown that non-manual employees have experienced an increase in real average pre-tax earnings of nearly 28% between 1979 and 1986 — a period over which the pay of manual workers rose by less than 8%. The problem is not just that income growth has been concentrated amongst certain types of household. In addition, incomes have grown faster in some regions (notably London and the South East) than in others.[2] Since the supply of housing is more strictly controlled in those regions experiencing the faster than average rise in housing demand (because of 'Green Belt' policies, for example), one might expect to see a faster rate of aggregate house price increases for a given rise in total demand than one would have witnessed had income growth been more evenly balanced across the regions (ie an 'uneven' increase in demand causes the national average level of house prices to rise faster than with an 'even' increase). Of course, also relevant would be the regional pattern of increases in households, growth of the workforce and unemployment rates.

For these reasons it may be worth argumenting the housing demand equations with a number of variables designed to capture these effects, such as the unemployment rate (UR), the differential between the standard rate of income tax and the highest rate ($DTAX$), the differential between average earnings in manufacturing and services ($DEARN$), the proportion of total personal income from sources other than wages and salaries (POY) and the ratio of average earnings in the South East to those in the rest of the United Kingdom (RSE). Including both these and the various demographic variables mentioned above gives housing demand equations of the form;

(1) Although even this one might not want to call exogenous. Becker (1988) stresses, for example, that 'family behaviour is active, not passive, and endogenous not exogenous'.

(2) Of course, this is neither a new phenomenon, nor one which is exceptional to Britain. For example, according to Schofield (1965) the value of London's assessed wealth rose fifteenfold between 1334 and 1515, raising its share of national wealth from 2 to 9%. Interestingly though, it is only recently that evidence has emerged to suggest that differential rates of regional house price increase affect the labour market (see, for example, Bover, Muellbauer and Murphy (1988)).

$$c_t^d = \gamma_0 + \gamma_1(y-ho)_t + \gamma_2 ho_t + \gamma_3(\Delta hod)_t - \gamma_4(pn-ph)_t - \gamma_5 RM_t + \gamma_6 UR_t + \gamma_7 DTAX_t + \gamma_8 DEARN_t + \gamma_9 POY_t + \gamma_{10} RSE_t \qquad (3)'$$

and

$$h_t^d = \lambda_0 + \lambda_1(y-ho)_t + \lambda_2 ho_t + \lambda_3(\Delta hod)_t - \lambda_4(ph-pc)_t - \lambda_5 RM_t + \lambda_6 m_t + \lambda_7 UR_t + \lambda_8 DTAX_t + \lambda_9 DEARN_t + \lambda_{10} POY_t + \lambda_{11} RSE_t \qquad (4)'$$

Note that the coefficient relating to unemployment could turn out to be positive or negative since, although higher unemployment could raise the demand for housing (for a given level of total personal disposable income) because of the associated distributional effects, it might also reduce demand because households lower their expectations regarding future (permanent) income.

(ii) The Supply of Housing

Land Prices and Construction Costs

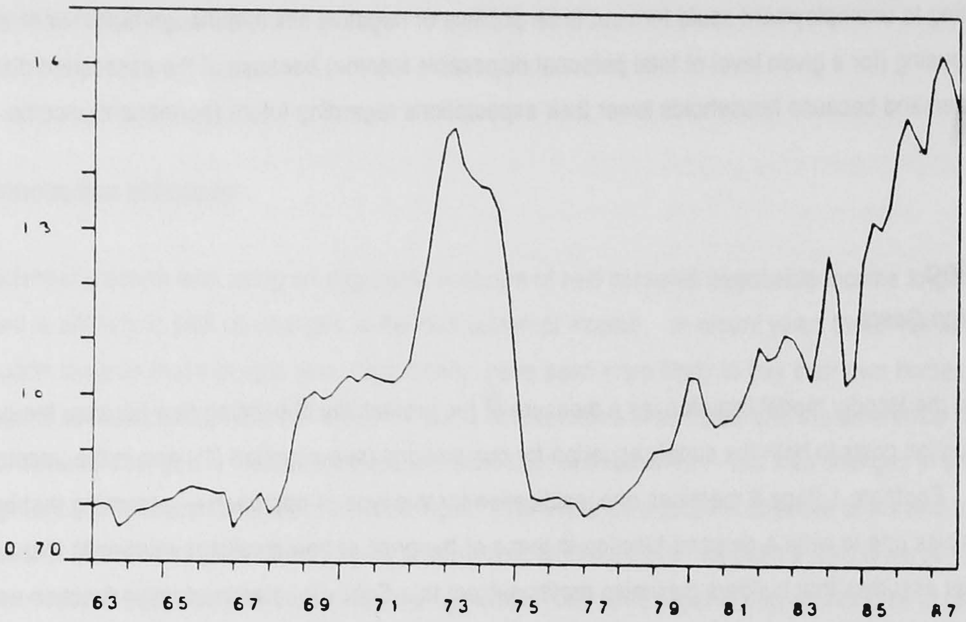
In Section 2 it was shown that the Hendry model includes, as a measure of the profitability of building new houses, the gap between new house prices and construction costs in both the supply equation for completions (see equation (1)) and in the uncompleted stock equation (see equation (12)). Footnote 1 Page 6 mentions one justification for this type of approach — assuming that builders have some monopolistic power enables one to write a demand function in terms of the price of new dwellings relative to that of existing dwellings. Then, if one further assumes that builders maximise profits subject to a Cobb-Douglas production function and this demand function, it turns out that *pn* will be a weighted average of *ph*, *cc* and *pl* (the latter being the price per plot of land). Here 'construction costs' covers the cost of both workers and building materials (measured per dwelling unit). Hendry then points out that if constant returns prevail *pn* will depend only on *pl* and *cc*, in which case, '*ph* would then proxy *pl*, since any increase in land prices would be reflected in increased prices for existing houses'. He thus assumes that *ph* will be a good proxy for *pl* and thus drops the latter from the model. His assumption may well have been true throughout much of the 1960s, but is certainly an unrealistic assumption to have made in the more recent times. Thus, if we compare the price of land to that of existing dwellings (on the basis that 1980=1) we find a ratio of close to 0.7 towards the end of 1975 but nearer 1.6 in 1986. Moreover, between these years the ratio fluctuates considerably (see Chart 1). This suggests that adding land prices to our model could be worth investigating.

This, in turn, raises some problems, since comparing land prices with new house prices in the same period amounts to our assuming that profits arise from housebuilding, whereas in practice developers may speculate on land prices rising and hence choose to hold land for a period.[(1)] Holmans (1988) includes anecdotal evidence which suggests that developers may hold considerable 'land banks' and for quite lengthy periods. He also shows, however, that although it is often asserted that it is only the increase in land values over the time it takes to build a house which produces a profit — the price of the building merely covering its costs — this view rather exaggerates the truth; indeed profit margins may have been wider last year than in the peak of 1973. Obviously the gap

(1) Of course, the problem in modelling this type of behaviour is that it is hard to gauge what elements of speculators' information sets is not common knowledge (or, at least is not available to those who lose out from the speculation). For example, suppose builders suddenly expect land prices to rise in the future and raise their demand for land. What stops existing landowners from realising this is going to happen and hence realising the gains themselves? The problem is one acknowledged by Thomson (1983) in his efforts to calculate the impact of the Anglo-French wars on land prices in England in the fifteenth century, for he writes, 'The fact that lands were available for purchase presupposes that there were sellers as well as buyers, and much less is well known about who these were, and why they were selling, than is known about the purchasers.'

between house and land prices will affect profitability. Nevertheless, the direction of causality is less clear cut. Holmans suggests that, since the supply of land is pretty much fixed, it is house prices which push up land prices, arguing that, although it is true that to the individual housebuilder the market price of land can be taken as given, for the housebuilding industry as a whole the price of land will be demand determined.

Chart 1
The price of land relative to the price of existing dwellings (1980 = 1)



Ignoring expectations we can easily tell a story consistent with the 'stylised facts', which we can test more fully below. Suppose the demand for housing increases (due say to a rise in incomes increasing the rate of household formation). In the short-run the supply of houses can be treated as fixed — in which case all the increase in demand feeds through to the price of existing houses (although of course such a story is open to the objections mentioned above). This raises profitability from building new houses (given existing costs, including that of land) which stimulates supply. In order to build new houses, however, either more land needs to be developed or existing land must be used more intensively — ie the demand for land rises. But again it seems likely that the supply of land is fixed in the short run. Hence, if land were the only factor of production (houses, say, comprising solely 'open space') then obviously all of the increase in demand for land would feed through to prices. The new equilibrium would then simply involve higher house and land prices. However, expectations may well be important and other costs do in practice comprise a large proportion of total housebuilding costs, so that land prices would need to rise much faster than house prices in order to choke off the increased profitability of housebuilding. This could only occur if the supply of land is much more inelastic than that of housing. In fact, we know that land prices have fluctuated more widely than those of houses and so it seems reasonable to speculate that the former must be more inelastic but, since housing supply has risen too, it is clear that not all of the rise in housing demand has been choked off. Of course, if this is true then, if demand continues rising over a long period,(1) one would expect to see rising land to house prices ratios and hence an increase in land prices as a fraction of *total* costs of housebuilding. Although we do not have a very long run of

(1) As one would expect if the population keeps rising.

relevant data, Chart 1 is certainly consistent with such a story. It should be added, however, that if land prices are endogenous then simply adding pl to the model may not be of much help and a more complex model is needed (see, for example, the Appendix in Poterba (1984)).

The easiest way of extending the Hendry model to include land prices explicitly is to include land prices in our equations for completions and work in progress. This gives equations of the form;

$$c_t^s = \beta_0 + \beta_1 u_{t-1} - \beta_2 cc_t + \beta_3 pn_t - \beta_4 pl_t \tag{1}^*$$

and;

$$u_t = \psi_0 + \psi_1 pn_t - \psi_2 cc_t - \psi_3 pl_t + \psi_4 z_t \tag{7}^*$$

The demand for land for the purposes of constructing houses will be determined by the profitability of building new houses;

$$l_t^d = a_0 + a_1 pn_t - a_2 cc_t - a_3 pl_t \tag{13}$$

whilst the total supply of land can be treated as fixed. Nevertheless, the supply available for building purposes will rise if the price of land rises compared to the profits which can be obtained from its being used for alternative purposes (say agriculture). In practice, of course, land supply will depend to a large extent on government policy, since it can only be used for building purposes if planning permission is granted. We assume that;

$$l_t^s = b_0 + b_1 (pl - plo)_t \tag{14}$$

where plo is the price of land used for purposes other than building. Of course, adding (13) and (14) to our existing model still gives a unique static equilibrium.

Finally in this section we point out a small problem with the construction cost index used by Ericsson and Hendry. This covers only materials (the largest elements of which are imported softwood, paints and preservatives, copper tubes and ready-mixed concrete). The housebuilding materials index is probably preferable(1) (although in practice the two series have moved fairly closely together) but, more importantly, we also need to take into account labour costs. For this reason in our work we have also included an index of average earnings in the construction industry, denoted w, augmenting (1)* and (7)* as necessary.

(iii) Rationing in the Mortgage Market

If households are rationed in the credit market (in the sense of either being unable to borrow or, if they are, being able to borrow less than they would like given current rates of interest) then obviously their consumption will be affected. Artle and Varaiya (1978), for example, present an analysis of the effects of tenure choice in the presence of liquidity constraints upon the shape of the optimal

(1) Even this, however, has surprisingly low weights on some items (for example, only 4% on common bricks) and high weights on others (for example, 2% on locks, latches and keys).

profile of consumption over the life-cycle.[1] This might suggest that it would be more appropriate to condition housing demand on mortgage supply rather than enter the determinants of mortgage demand in the housing demand equation direct. If we do this, however, we run the risk of ignoring the possibility that some households who are refused loans may still have recourse to other sources of finance or may be able to run-down other assets.[2]

Such behaviour is perhaps more likely to be practicable if the constraint binding on the household is a fairly weak one — for example, a minimum deposit requirement. However, on occasion the incentive to carry out such a policy may be very strong. For example, during the two house price 'booms' (in the early and late 1970s) the rate of house price increase rose very sharply so that potential first-time buyers would have found that even if borrowing requirements (in the form of the deposit as a percentage of house price) had remained constant and their earnings risen at the same rate as average earnings then still they would have needed to save an increasing fraction of their incomes in order to get closer to meeting the deposit. Delaying purchase in these circumstances may prove to be very costly, in the sense that at the end of the 'waiting' period a borrower may still find him/herself unable to afford the house he/she wished to buy (since savings would still fall short of meeting the required deposit).[3]

This rather suggests that in situations where house prices are expected to rise rapidly potential borrowers who are rationed may well choose to (temporarily) devote a larger fraction of their income to house purchase than they would were they not rationed. If they do adopt such a strategy then it is not just mortgage supply which is relevant to housing demand, but also this temporary saving. In the case of meeting 'unusually high' deposit requirements, for example, one might use as an additional measure of housing demand the differential between actual loan-to-value ratios of first-time buyers with the unrationed loan-to-value ratios (which could perhaps be as high as one?), this measure being weighted by the average first-time buyers' house price. In the situation where suppliers of mortgage funds simply refuse to make loans it is more difficult gauging how high demand would be were they to end credit rationing, particularly as there may be good reasons for their choosing to ration some groups of people (see, for example, Stiglitz and Weiss (1981) and (1987)). We can, however, try using the measures of rationing devised by Wilcox (1985) and by Hall and Urwin (1989) to gauge these effects. This is the approach we have adopted below; a measure of the change in mortgage rationing (MR) is added to both of our housing demand equations (3)* and (4)*. The change, rather than the level of, the variable is used, since we feel that households will generally anticipate rationing as being only a temporary rather than a equilibrium phenomenon. Such an interpretation is certainly open to question, however, [4] and so is tested by including a levels term in the equations too. (This it turned out was insignificant.)

Section 5: Empirical Results: The Housing Market

This section begins by considering single equation estimates for *PN, PH, U* and *HC*, in much the same way as Ericsson and Hendry (1985), Hendry (1984) and Hendry (1986) have done, using wherever possible the same sample periods. However, results are also

(1) In particular they show that if owners are prevented from borrowing against the equity in their homes then discontinuities (at the time of sale) are introduced in their consumption profiles; ie they engage in 'forced' saving during their homeownership period.

(2) It is even possible that in recent years some borrowers have not realised just how much they can borrow and have asked for less than they actually require, making up the shortfall from other assets. Hence, the Abbey National claimed last year, when introducing score cards designed to raise the quality of their loans, that, although these may lead them to lend less to some applicants, 'on the other hand, there may be people who could borrow more than they do' (see Sunday Times (1988)).

(3) Of course, some would-be purchasers will simply buy a smaller (cheaper) dwelling. For many first-time buyers, however (who will tend to be buying the cheapest homes available) this is not feasible.

(4) Precious (1987), for example, has examined the effects of changes in rationing (both as regards the length of the constraint period and the severity of the constraint) on the behaviour of agents who have rational expectations.

presented based on a common sample period (running from 1965 Q1 to 1985 Q4) with more recent data being retained in order to measure the ability of the equations to forecast accurately.

(i) The Price of New Dwellings (PN)

First we try estimating a model of *PN* (given *PH*) along the same lines as has Ericsson and Hendry (see, in particular, pages 267-279). This should aim to replicate equation (12) in equilibrium. Table 1 shows in column A Ericsson and Hendry's equation (4.4), which they felt illustrated 'the relative roles of all the potential explanatory factors', together with our attempt to reproduce a similar equation using the same sample period (column B). Note, however, that our model has been estimated using an approvals-based rather than a completions-based house price series (this being necessary since the series used by Ericsson and Hendry is no longer published, and we wish to extend the sample period in subsequent work to include more recent data).[1] At first blush, our results suggest that the Hendry model suffers from a number of problems with some terms being insignificant or wrongly signed. Moreover, despite its high standard error, the re-estimated equation fails the parameter stability ('forecast') test. On a more positive note, however, the long-run static solutions do have fairly similar properties, with the equilibrium in Ericsson and Hendry's model being given by:

$$pn - ph = -0.11(ph - pc) + 0.52(cc - pc) - 0.09(u - y) - 0.89RM(1 - T) - 0.30 \qquad (15)$$

whereas our results suggest a long-run solution of the form;

$$pn - ph = -0.09(ph - pc) + 0.36(cc - pc) - 0.02(u - y) - 0.003RM(1 - T) + 0.08 \qquad (16)$$

Not only are all terms correctly signed in (16), but the elasticities (with the exception of the interest rate term) are of broadly similar magnitude. This rather hints that it is simply the *dynamics* of the model which have broken down in our re-estimation exercise. This is hardly surprising given that we have interchanged an approvals-based house price series for a completions-based one, since there is normally a lag of some two to three months between the two events (and sometimes much longer). Comparing (16) with (12) does raise a number of issues, however, regarding the consistency of the empirical results obtained with the theoretical model. First, one notices that both of the terms in house prices (of existing dwellings) and costs in (16) are in real terms — whereas in (12) nominal variables were used. This, it turns out, is not such a big problem, however, since one can easily write the supply of completions equation (1) in real rather than nominal terms. If $\beta_2 = \beta_3$ (which one would expect to hold) then the two equations are identical. In practice, however, estimates of β_2 and β_3 do differ. Second, it should be noted that in (16) the coefficients on *u* and *y* have been restricted to be equal in absolute terms. This, it turns out, makes some difference to the other parameters in the model.[2]

(ii) The Price of Existing Dwellings (*PH*)

The basis for Hendry's equation for the price of existing dwellings is that, conditional on H_{t-1}, the housing demand equation (4) determines *PH*. However, since the market is deemed to be sometimes out of equilibrium it is only necessary that the model for *PH* solves to give the demand equation in the long run. Hendry's research suggests that the use of a cubed lagged dependent variable

(1) In fact Professor Hendry has been kind enough to supply me with the data used to estimate the Ericsson and Hendry new house price equation. Using this we have been able to replicate their results perfectly. It should be noted that, in order to maintain consistency throughout our work, we have chosen to use the mortgage rate in each equation rather than minimum lending rate/base rates (as used by Hendry some of the time). This too helps explain the differences between the two sets of estimates.

(2) For example, estimates of γ_3 tend to be much bigger in the restricted model.

in the equation is needed if we are to explain the two house price 'booms' which occurred during 1971 to 1973 and 1978 to 1979 (see Hendry (1984) pages 229-247). Table 2, column A, shows his preferred choice 'for practical modelling'[1] (ie equation (18) on page 237) together with our attempt to replicate his results (column B).[2] Clearly our results are broadly similar to those Hendry obtained (although the standard error has risen some 20%). There are, however, a number of problems. The first (which is common to the original Hendry equation) concerns normality of the residuals. We find there is evidence of both skewness and kurtosis, partly as a result of the very large (positive) residual in 1972 Q3 (equal to 3.5 $\hat{\sigma}$). The second 'boom' is similarly poorly explained by the model, since there are five consecutive positive residuals between the third quarters of 1978 and 1979, each of which is of magnitude $\hat{\sigma}$ to $2\hat{\sigma}$. A second problem with the model concerns the interest rate effects which we found were incorrectly signed. The long-run static solution of Hendry's model is given by;

$$\left(\frac{PH.H}{PC.Y}\right) = K_0\left(\frac{M}{PC.Y}\right)\left(\frac{Y}{H}\right)^{2.65}\exp\left(-1.3\,RM^0 + 2.4\,\dot{pc}_a\right) \qquad (1$$

where $k_0 = \exp(-1.7 + \Sigma\hat{\beta}_j Q_j)$ (the Q_j being quarterly dummies) and $\dot{pc}_a$ is the annual rate of inflation.

This compares with our model's solution of;

$$\left(\frac{Ph.H}{PC.Y}\right) = K_1\left(\frac{M}{PC.Y}\right)\left(\frac{Y}{H}\right)^{1.6}\exp\left(2.7\,RM^0 + 2.6\,\dot{pc}_a\right) \qquad (1$$

where $K_1 = \exp(0.6) + \Sigma\hat{\beta}_j Q_j$).

Clearly our positive (though insignificant) effect from interest rates means that if we were to re-write (18) in terms of our housing demand equation we would find that our empirical results are inconsistent with our theory. Comparing (17) with (4) one notices that the former includes a number of restrictions which are perhaps worth testing. Apart from those related to demographics already mentioned (that $\lambda_1 = \lambda_6$ and $\lambda_7 = 0$) it is also the case that $\lambda_2 = \lambda_5$. Moreover, (17) and (4) are inconsistent regarding their price effects, since by inverting (4) it is clear that *ph* should be homogeneous of degree one in prices. In (17), however, *ph* is homogeneous of degree zero. Clearly this inconsistency has arisen because Hendry has chosen to use not m but (*m-pc-y*) in (4). One might argue, however, that a more natural choice to have made would have been to use real variables throughout (ie.(*ph-pc*), (*RM-pc*) and (*m-pc*)).[3]

Other statistical problems evident from column B are the possibility of autocorrelation (for, although the Ljung-Box test is passed, the F-test is close to the 95% significance level and the unmodified LM test above the critical value), a strong suggestion of parameter instability (21 out of the 22 forecasts being overpredictions) and evidence of heteroscedasticity (the squared residuals being strongly correlated with our income term). Re-estimating the equation on more recent data (column C) does little to improve the model,

(1) We do not consider his cubic excess demand and cubic difference models.

(2) Again thanks to Professor Hendry providing us with the dataset he used to estimate A we were able to replicate his results exactly. The differences between A and B arise because we have chosen to let our mortgage stock variable (m) include not just building society mortgages but also those made by other institutions. In addition, we have used the mortgage rate rather than a market rate (minimum lending rate or base rate).

(3) Dicks (1989) includes an examination of this choice. Unfortunately, however, in doing so it is also necessary to consider a number of other issues, making their discussion in this paper impracticable.

although the parameter constancy test is now just passed (despite the fact that the model still overpredicts in seven out of the eight quarters).[1]

(iii) The Uncompleted Stock of Dwellings (U)

The basis for Hendry's (1986) equation is (8), in which the determinants of c_t^d have first been substituted using (2), although, as was mentioned earlier, a more natural theoretical model to use is perhaps (10). Table 3 shows Hendry's preferred equation (see (34) on page 32 of Hendry (1985)), which differs from his theoretical formulation (8) in that it is dependent on the level of real construction costs and finds no role for Δ_y, h or $(pn - pc)$ even though these terms might contribute to c^d. Table 3 also shows our attempt to replicate Hendry's equation (again using the approvals-based series for pn). Our results indicate that all of the regressors are significant (at the 95% significance level) with the exceptions of the real cost term, two of the quarterly dummies and (although only just) the term measuring the difference between new and existing house prices. Since the weather variable should pick up seasonal factors pretty well (despite the fairly widely-held view that there is no such thing as a British summer), this may reduce (if not eliminate) the need for seasonal dummies.

Again there are a number of problems evident with the model. Hence, despite the similarity in size and significance of the coefficients in the two models shown in columns A and B of Table 3, the goodness-of-fit of the latter is some two-thirds worse (in terms of the standard error of the equation). Moreover, the equation in column B suffers from autocorrelated errors. Given that we have used an approvals rather than a completions-based series for pn, however, this is perhaps not too surprising. Finally, it should be noted that the equation in column B fails the Breusch-Pagan test for heteroscedasticity (again despite having passed the ARCH test used by Hendry) and that it tends to underpredict (although comfortably passing the Hendry forecast test, 18 of the 22 forecast errors are positive suggesting that in dynamic forecasts it might not perform so well).

The static solution of Hendry's model (column A) is given by;

$$U = \gamma Y \left(\frac{PN}{PH}\right)^{-2.6} \left(\frac{CC}{PC}\right)^{1.3} RM^{-0.6} \tag{19}$$

where γ varies seasonally. This compares with our results (from column B);

$$U = \gamma Y \left(\frac{PN}{PH}\right)^{-2.7} \left(\frac{CC}{PC}\right)^{-0.5} RM^{-0.5} \tag{20}$$

where it should be remembered that the cost term was insignificant. Nevertheless, the two equations give very similar long-run effects from house prices and interest rates.

It is interesting to note that when the model is re-estimated using more recent data (column C) the standard error falls significantly from that obtained when using the same sample period as Hendry. However, fewer terms are now significant and the ratio of the uncompleted stock to income plays a much stronger role in the model than was previously found to be the case. This, coupled with the falling coefficient (in absolute terms) on the relative house price term, implies a very different long-run elasticity (around 30% that of our other models). In other respects the model in column C is similar to that in column B, with there being strong evidence of

(1) This rather suggests that when run dynamically (ie using forecast values of the lagged dependent variable) the equation would perform very poorly. In other words the equation is probably of little use in 'practical' forecasting. Note that this property does not depend on our having used a broader measure of mortgage stock than did Hendry - Model A has the same problem when used to forecast recent developments.

autocorrelation but none of non-normality. In addition, however, the parameter stability test is now failed. The model has a tendency to underpredict (doing so in six out of the eight quarters), and has errors more than twice the standard error of the equation on three occasions. It should be noted, however, that revisions to both housing starts and completions can be substantial, so that we should not necessarily put very much weight on recent years' 'data'.

(iv) Housing Completions (C)

We follow Hendry's advice in modelling $K_t \left(= \frac{C_t}{U_{t-1}}\right)$ rather than C_t, because of heteroscedasticity. Table 4 shows both Hendry's simplified specification (see (32) on page 31 of Hendry (1986)) and our replication of this model (based on (9) and (3) from Section 2 although again it should be noted that perhaps a more natural theoretical model to consider might be to use (11)) — again with our having used the approvals-based series for *pn*. All of the coefficients in column B are correctly signed with the exception of that relating to the change in real costs. We have not, however, tried including the level of costs as a regressor (even though theory suggests that it should play a role [1]), which may explain this result. Other variables we found to be insignificant were the relative house price term, the change in the real price of new dwellings, the dummy variable, the constant and one of the quarterly dummies. In the case of the two dummies we should not be too surprised to find that the weather variable is picking up these effects, although there is a large residual in 1963 Q1 suggesting that Hendry's 'Bad Winter' dummy ought to have been defined as -1 in 1962 Q4 and +1 in 1963 Q1.[2] Replacing Hendry's dummy with such a variable one finds a significant coefficient on the new dummy (the relevant t-statistic being 4.6) with the result that the standard error of the equation falls to 1.56% (still around 46% greater than that of the original Hendry model) although none of the other coefficients change significantly. A second point to note is that we have used the change in real new house prices lagged one quarter rather than the level (as reported by Hendry). This is because there is an inconsistency between equation (32) reported in Hendry (1986) (page 31) and the derived static solution ((33) on page 32). The two equations are reconciled if we assume it is (32) which is wrong — although in practice we found that neither the level or the differenced variable was significant.

The only other problem evident from column B is the result of our parameter stability test. The model tends to underpredict (with around three-quarters of the forecast errors being positive), with particularly large falls expected in the first quarter of each year between 1984 and 1987 (inclusive). We guessed that this may in part be the result of our having initially used the Hendry (wrong) 'bad winter' dummy variable (resulting in a large coefficient on our weather variable). If we use the correct variable the coefficient on WT falls to 0.83 and the model predicts slightly more accurately (ε_3 (22) = 46.8). Nevertheless, there is still evidence of significant underprediction, and still mainly in the first quarters. Using more recent data to re- estimate the model (as in column C) suggests a changing seasonal pattern with coefficients on both the dummies and the weather variable closer to those estimated by Hendry. The resulting equation predicts rather more satisfactorily too.

Next, we consider the long-run static solutions to the model. Hendry's estimates give;

$$\left(\frac{C}{U}\right) = \left\{K + 0.5\ (y - h) - 0.025\,rm - 0.27\,(pn - pc) - 0.36\,(pn - ph)\right\} + 0.26\left(\frac{H}{U}\right) \quad (21$$

where K depends upon the season, weather etc ..., whereas the model in column B gives ;

(1) Hendry finds that only the differenced (real) cost variable attracts a significant coefficient.

(2) We have checked that this is more appropriate by examining monthly temperature data. In January and February of 1963 the average daily temperature was $9\frac{1}{2}^{\circ}$ F and 8° F below the corresponding monthly averages measured over the period 1931-60. In 1964, however, the differences were only $-\frac{1}{2}^{\circ}$ F and 1° F suggesting that it was a 'fairly average' winter. My *mother* agrees, for she remembers that it was 1962-63 and not 1963-64 when the sea froze in Swanage Bay.

$$\left(\frac{C}{U}\right) = \{K + 0.35\,(y-h) - 0.20\,rm - 0.09\,(pn-pc) - 0.24\,(pn-ph)\} + 0.35\left(\frac{H}{U}\right) \quad (22)$$

Most of the elasticities are of broadly similar magnitude, although that on interest rates has risen sharply. One of the reasons for this is that we have used the mortgage rate when estimating our equation for K (since the justification for including interest rates in our simple model (11) is that they affect households' demand for housing, rather than there being a cost to builders), whereas Hendry used the minimum lending rate. (This is because he is using (8) and (9) as a theoretical basis which permits a role for both RM and RB). When we tried using the latter we did find smaller effects. Finally, it should be noted in comparing (21) with (9), having first substituted for C_t^d using (3), that Hendry is assuming that h is a good proxy for ho (the number of households), rather than simply assuming that $\gamma_1 = \gamma_2$ (as has been done up till now).

Section 6: Empirical Results - Extending the Hendry Model

Given that Section 5 has showed that all of the Hendry equations suffer from one or more problems when re-estimated using more up-to-date data, this Section reports the results obtained from re-estimating the model using the general-to-specific testing down procedure. The only extensions to the models considered are those outlined in Section 4, although it is hoped that future work will examine a model based on a more rigorously defined theoretical structure.

(i) The Price of New Dwellings (PN)

The Hendry equation models new house prices, given the price of existing dwellings, in terms of costs, the uncompleted stock of dwelling, real incomes and interest rates. In estimating a new equation for PN we hoped not only to remedy the (econometric) problems we had found with the Hendry model (outlined in Section 5(i)) but also to check whether or not there was a role for land prices and labour costs. In practice, however, when three separate cost terms were included in the model (for land, labour and materials) we discovered that neither the land price nor the wage terms were significant at the 95% level (no matter what lag length was tried) and that the land price term was generally incorrectly signed.[1]

One reason for these results may be the high correlation between real labour costs and real incomes (the latter also having a long-run positive impact on new house prices through their effect on the demand for completions). Unfortunately, using a relative labour cost term (w-y) does not give any better results. The failure to identify a role for land prices is perhaps a little more surprising.[2] One possible explanation which has been suggested is that it is house prices which 'cause' land prices since most of the large housebuilders use house prices to guide them in judging what price to bid for land that becomes available for new building. Hence, after subtracting costs (plus a mark-up to cover profits) from what they gauge to be current new house prices they are left with an amount which they are willing to pay for the land. There are several problems with this 'explanation', however. First, it is hard to imagine that builders would always use such a simple rule. Most will be aware, for example, that house prices will respond to excess demand. For example, if it is anticipated that demand will rise faster than supply over the period it takes to build new dwellings on land it is currently buying, then a firm may be willing to bid more for land than its simple house price minus costs formula suggests (ie the mark-up will not be constant over time). Hence, different builders may have different views about the increase in the house price

(1) We found the same results whether or not we included real or nominal cost terms. Moreover, we found our results were insensitive to whether levels and/or changes were used.

(2) Of course it is important to remember both the endogeneity problem mentioned earlier and that the data relating to land prices is of fairly poor quality (and only available bi-annually). See Appendix 3 for details.

there will be by the time the houses are for sale and about how quickly the houses will sell (and hence the financing costs if any). Bargaining skills of builders/developers relative to sellers of land could also be relevant. Second, even if such a simple rule were used by those bidding for land, then changes in land prices would still affect the supply of land available for new buildings, as well as demand. This may only occur slowly (for example, because of the need to obtain changes in planning permission for some of the new land) — indeed, the lags in the process may be long and variable and so prove to be hard to pick up in our data. Moreover, one would really need *relative* land prices to tell this type of story (otherwise one has to ***assume*** that the price of agricultural land is constant, which of course it is not). Nevertheless, even if one cannot identify a significant role for land prices one might wish to constrain the model (say for simulation purposes) to ensure that it gives one. One possible solution to this problem is to try weighting up the three cost terms to give a 'total cost' variable. A difficulty with this approach arises, however, in defining the weights to use—- obviously one would not be successful if either the wrong weights are chosen or if the true weights vary over time. Since the latter are not published we have tried using 'sensible' weights, but allowed for the possibility that they might be wrong by both trying a number of different total cost variables (based on different weights) and by including land prices and wage costs as additional regressors. For purposes of comparison we also report our best equation based on using just the materials cost term.

As a first step it was decided to try using equal weights for land, labour and materials in constructing the total costs variable (denoted TC). It has been suggested by those in the construction industry that this may well have been broadly true during the 1960s and 1970s, but that more recently weights have varied considerably, so that this approach may not prove successful.

Research carried out by NEDO confirms that when they examined the question in 1986 it was the case that labour and material costs were of broadly similar magnitude, but Whitehead (1974) reports that the Building Research Establishment then estimated that land prices accounted for just 20% of total costs. We have therefore also tried using a total costs variable with weights of 40% on each of labour and materials costs, land comprising the remainder. This we denote TC2.Typical equations are shown in Table 5. Column A shows a model in which all three cost terms have been included. This illustrates the problems we had in finding significant land price effects. Next, in column B, is shown the results of using the total cost term which gives land a lower weight, rather than all three cost terms (this worked slightly better than the equal-weights measure). Column C retains a measure of total costs but includes additional terms in land prices and labour costs whilst, finally, column D shows the best results obtained using just the materials cost term.

Before considering the results in detail it is worth noting that all of the equations reported have used income per household (rather than aggregate income as in Hendry). This gave slightly better results than if demographics were ignored, although we could not find a significant term in the level or change in the total number of households. We have also had difficulty identifying significant interest rate effects in some of the models (although, interestingly, when estimating a similar model using the two-step Engle-Granger estimation procedure it was discovered that interest rates did have a significant long-run effect). This was true whether we used a mortgage rate term (justified as having a negative impact on the demand for completions) or a short-term market rate (which might proxy builder's costs). We also tried using a before-tax rate, a 'real' rate,(1) taking logs of the interest rate terms and using household sector income gearing (both gross and net of tax, the latter taking into account mortgage interest relief). None of these terms proved to be much better than any other. However, since we have used a backward-looking measure of the 'real' rate it may be the case that we have failed to measure expected inflation correctly and that it is this failure which is giving us these results.

(1) Where for our purposes the 'real' rate was defined as the nominal rate minus the annual rate of increase of consumer prices.

Time constraints have prevented us from examining whether or not including a more sophisticated measure of expected inflation could improve our model in this respect.[1] A third feature of our model which contrasts with that estimated by Hendry is that we have included as a regressor the stock of unsold but completed dwellings. Generally one might expect that the higher this stock the lower the demand for new dwellings relative to that which builders' anticipated. Hence, we would expect to find a negative coefficient on this term.

Column A of Table 5 highlights the poor results obtained by using three separate cost terms — only the materials cost is significant at the 95% level. Otherwise all the regressors, with the exception of the interest rate term, have correctly signed coefficients which are significant. Column B shows what happens if just total costs are used — the positive effect is what one would anticipate but the t-value is only just above one. Adding long lags in land prices and labour costs improves the model's fit, but with both these terms having a negative impact (column C). Here, the total cost term has equal weights on the three components, which implies that one could interpret the model as providing evidence that the true weights on land and labour costs are each less than one-third. One cannot measure the elasticities in model C, however, since we have taken logarithms of the total cost term. Re-running the equation but using the levels of the cost terms suggests long- run effects from each of the land and wage components which are very close to zero. This implies that a model like that shown in column D, which allows a role *only* for the cost of materials, cannot be rejected by the data.[2]

It is interesting to note that none of the models shown in Table 5 forecast particularly well over the past two years. One reason for this might be the increased competition in the mortgage market in recent years. This may bias the new house price data, which is based solely on mortgages from the building societies (rather than total mortgage lending) because the banks and other new lenders may make larger-than-average loans to buy dwellings which are more expensive than those bought with building society mortgages. This was the justification used by Hendry for including a dummy variable in his model (denoted dummy 1 in Table 5), although his choice of values for this variable were chosen by examining the residuals from his autoregression and bi-variate model of *pn*. Since our new equations have a tendency to underpredict at a time when other lenders have been taking a large share of total lending (around one-half last year), so we have tried improving our model by replacing dummy 1 with a variable which takes the value 1 when 'other' lenders (ie non- building society lenders) are re-entering the market and have succeeded in capturing more than 25% of total lending. In practice this turns out to be just six quarters — the second half of 1981, the second and third quarters of 1982 and the second half of 1984. Substituting this dummy for dummy 1 does, however, give significantly better results. Thus the revised version of model C has a standard error of 1.39% (15% lower than that of the re-estimated Hendry model) and a forecast test value of 18.3 (only slightly higher than the critical value of 15.5). Despite the improvement, the model still has a tendency to underpredict recent rates of growth of new house prices. A revised version of model D, however, performs still better,[3] passing the relevant forecast test (the value of the Hendry test being 13.1). All of the regressors are still significant and correctly signed and the standard error of the equation (at 1.42%) is smaller than that of model D in Table 5, although larger than that of the revised model C.[4] Table 6 (column A) gives details.

(1) Obviously, the failure to distinguish between anticipated and unanticipated changes in interest rates may well have important policy implications too. For a discussion of these issues as regards the effect of interest rates on consumers' expenditure see Dicks (1988b).

(2) Note, however, that the standard errors of the models shown in columns C and D are much the same. Each is close to one-tenth smaller than that of the re-estimated Hendry model (column C in Table 1).

(3) In fact it even overpredicts in two out of eight quarters considered!

(4) It should be noted that this does not imply that the revised model C forecasts as well as does the revised model D (and that the only reason the latter passes the forecast test is because of its larger standard error). The relevant root mean squared percentage errors are 41 and 34 respectively.

One interesting feature of the new model is its sensitivity to the interest rate term we choose to employ. Whether we use the level or logarithm of the after-tax rate made little difference to the specification, but when income gearing was used the equation was found to have a somewhat smaller standard error (of just 1.38%). Column B of Table 6 shows such a model. At first glance the model appears fairly similar to that which is reported in column A, with no problem of autocorrelation, non-normality etc. One finds, however, that the model forecasts very inaccurately (underpredicting throughout 1986 and 1987 and with a root mean squared percentage error of 71). One might infer from these results that the high levels of gearing in recent years may not be reducing demand by as much as they would have done in the past (ie people are more willing to take on debt despite the high costs of servicing it). The fact that using interest rates does not give the same problem of underprediction rather suggests, however, that it is the fact that income enters the denominator of income gearing which is causing the problem.(1) The increase in the personal sector balancing item which has occurred in recent years suggests that income has been under-recorded by the CSO during the forecast period — were we to correct for this factor then the equation would not be underpredicting to anything like the extent suggested by the parameter stability tests shown in Table 6.

One final set of tests that have been carried out on our model were designed to see if it is sensitive to the use of the dummy variable. This was done by redefining the house price terms to take account of new lenders entering the mortgage market. Holmans (1988) provides estimates of the effects on the building society measure of house prices of increased bank lending during the 1980s, although his figures pertain to the *all* dwellings index (and not to the new dwellings series and existing dwellings series separately). We assume that each series has been affected to the same extent and re-estimate our model shown in column D of Table 5 using the new data but dropping the dummy. Our results give a somewhat poorer explanation of past changes in new house prices using this measure (the standard error of the equation rising to 1.55%) — with a tendency to overpredict throughout much of 1984 and 1985 — but the forecast tests are now passed. However, without further knowledge of the split of bank mortgage lending between loans for the purchase of new dwellings and loans for the purchase of existing dwellings it is difficult to gauge whether this is anything more than a statistical fluke. For this reason we prefer to think of the models shown in Table 6 as our best specifications. Chart 2 illustrates both the goodness-of-fit and the forecast performance of the model shown in column A. The long-run solution of this model is given by;

$$pn - ph = 0.34(cc - pc) - 0.21(u - y) - 0.007RM(1 - T) - 0.002ud + 1.27 \qquad (23)$$

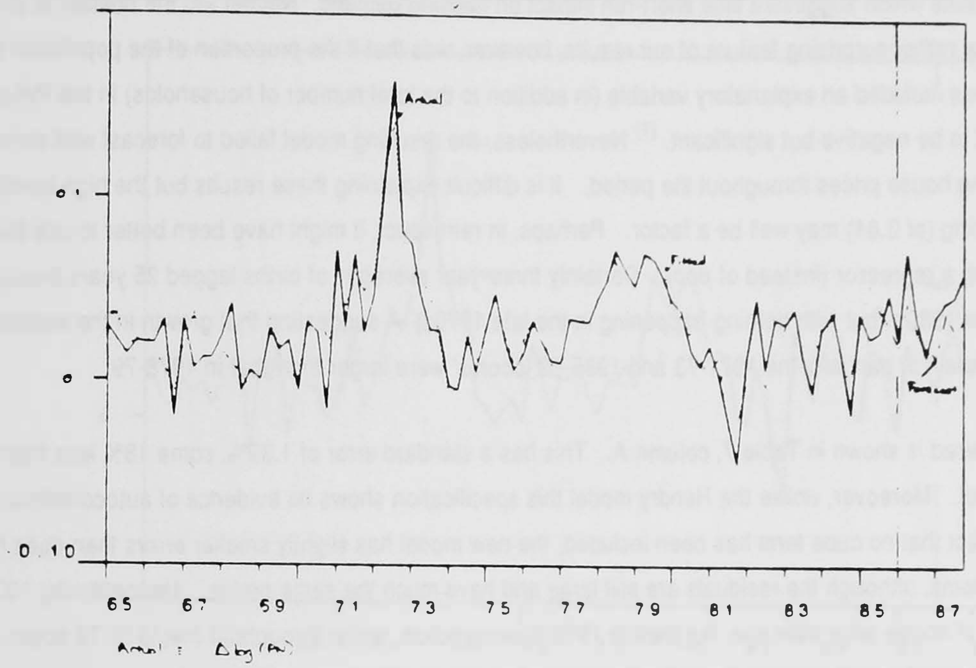
This has a similar long-run elasticity with respect to real costs as had the re-estimated Hendry model (which is, however, somewhat smaller than that originally reported in Ericsson and Hendry), a stronger (ie more negative) effect from the ratio of the uncompleted stock to income, a very small interest rate elasticity (but which is at least correctly signed now!) and a small effect from the stock of unsold (but completed) dwellings. We have also dropped the levels term in real house prices (of existing dwellings), which seems reasonable if we expect $pn=ph$ in the long run (which, of course, was not a property of the original Hendry model unless $ph=pc$ too).

Comparing (23) with our theoretical model (12), which was obtained by equating the demand for and supply of completions, it is clear that, although (23) is broadly in agreement with the theoretical structure, there are still some discrepancies. In particular it is noticeable that (23) still uses real, rather than nominal, costs. In addition, we have in (23) introduced a role for ud — something which could, of course, easily be justified in theoretical terms, but has not been done so formally. Finally, we note that (23) includes the constraints that the coefficient on ph is equal to one (thus implicitly ensuring that $\beta_3 = 0$) and that those relating to u and y are

(1) Further evidence that gearing effects are not connected with changes in rationing is that we could find no role for mortgage rationing in the equation.

equal in size. Relaxing these constraints gives a small coefficient on u (suggesting that the assumption that $C = KU$ in equilibrium may not hold in the data) and a coefficient on ph very slightly smaller than one (implying $\beta_3 \neq 0$). Although the F-test to restrict the coefficient to equal one is accepted, it should be noted that this restriction makes interpreting the model in terms of its theoretical structure rather difficult, especially if it turns out that $\beta_2 \neq 0$.

Chart 2
The price of new dwellings



(ii) The Price of Existing Houses (PH)

We next consider how to explain changes in the price of existing houses (ie secondhand) dwellings. The Hendry model uses information relating to personal incomes, mortgage stocks, interest rates, the number of owner-occupied houses and retail prices. An important feature of this model is its inclusion of a cubed lagged dependent variable. This is justified by claiming that one would expect 'very rapid adjustment of house prices to excess demand', although it is also suggested that a 'Catastrophe Theory' model might be applicable.[1] The term's contribution is close to zero throughout much of the last two decades, only becoming significant during the periods 1971 Q3 to 1973 Q3 and 1978 Q3 to 1980 Q1 (contributing on average 13% and 8% of the total predicted changes during these periods (and much more — 49%— in 1972 Q4). Nevertheless, as was shown in Section 5(ii), the re-estimated Hendry equation performs poorly in terms of explaining the house price 'booms'. In addition it suffers from first-order autocorrelation and predicts poorly. Taking the eight quarters covering 1986 and 1987 one finds that the model overpredicts the rate of house price growth on seven occasions (although it does just pass the relevant static forecast test) and this is despite the fact that incomes may have been under-recorded in the official statistics in recent years. All in all the root mean squared error as a percentage of the mean actual over the forecast period was 54%, falling only slightly (to 52%) if the contribution of the cube term is ignored.

(1) This would give a rather more complex model, however, since it would imply that there are multiple equilibria, there being three possible solutions of Δph_t given any particular value of excess demand. Prices could suddenly 'jump' between these solutions (which one might claim perhaps as being due to speculative behavior).

Table 7 shows two models which improve upon Hendry's specification. Both use real income per household (rather than real income per dwelling), income gearing (instead of an after-tax interest rate) which we denote *HIG* and a measure of mortgage rationing (denoted *MR*) in addition to the regressors used by Hendry. Perhaps rather surprisingly none of the variables that were used in order to pick up changes in the distribution of income proved to be significant regressors in the house price equations. This could simply point to the variables not really picking up the differential rise in incomes of the *house-buying* part of the population — certainly it would be a valuable extension of this work to try constructing a better measure of average net income of households in the house-buying population. As regards demographics, households turned out to give slightly better results then did population but no role for household size could be identified. Including regressors to proxy changes in demographic factors (such as the *hod* term — see page 9) gave results which suggested little short-run impact on housing demand. Neither did the number of divorces turn out to be significant. One rather surprising feature of our results, however, was that if the proportion of the population between the ages of 25 and 34 (*SY*) was included an explanatory variable (in addition to the total number of households) in the *PH* quation then its coefficient turned out to be negative but significant. [1] Nevertheless, the resulting model failed to forecast well during 1986 or 1987, severely underpredicting house prices throughout the period. It is difficult explaining these results but the high correlation between *SY* and income gearing (of 0.84) may well be a factor. Perhaps, in retrospect, it might have been better to use the absolute size of the 25-34 age group as a regressor (instead of *pop*). Certainly three-year averages of births lagged 25 years produce peaks in the early 1970s and the late 1980s (but with nothing happening in the late 1970s) — suggesting that growth in the number of households could perhaps explain in part why the 1971-73 and 1985-88 'booms' were larger than that in 1978-79.

The first model for *PH* considered is shown in Table 7, column A. This has a standard error of 1.32%, some 18% less than that of the re-estimated Hendry model. Moreover, unlike the Hendry model this specification shows no evidence of autocorrelation and forecasts well. Despite the fact that no cube term has been included, the new model has slightly smaller errors than does Hendry's during the two house price booms, although the residuals are still large and have much the same profile. Hence during 1972 the model underpredicts the rate of house price increase, but then in 1973 it overpredicts, whilst throughout the 1978-79 boom it underpredicts. Interestingly its relative performance (ie to the Hendry model) can be seen to improve significantly if the late 1970s boom is compared with that which occurred earlier in the decade — the mean (absolute) residual of the new equation is 82% that of the Hendry model during the 1971-73 but 66% during 1979-80. Nevertheless, the failure of the model to explain the booms results in its failing the tests for non-normality. Column B, however, offers an equation which solves this problem. Here a cube term has again been included — but this time it is the rate of change of income per household lagged one quarter which is cubed. This helps reduce the standard error of the equation to 1.26% (around 22% less than that of the Hendry model) and solves the problems of skewness and kurtosis identified in column A. Neither does the new model suffer from any new problems regarding autocorrelation, heteroscedasticity or parameter instability. Its long-run solution is given by;

$$\left(\frac{PH.H}{PC.Y}\right) = K_0\left(\frac{M}{PC.Y}\right)(HO)\left(\frac{Y}{HO}\right)^{1.35}\exp\left(-0.006\ HIG + 4.1\ \dot{pc}_a\right) \qquad (24)$$

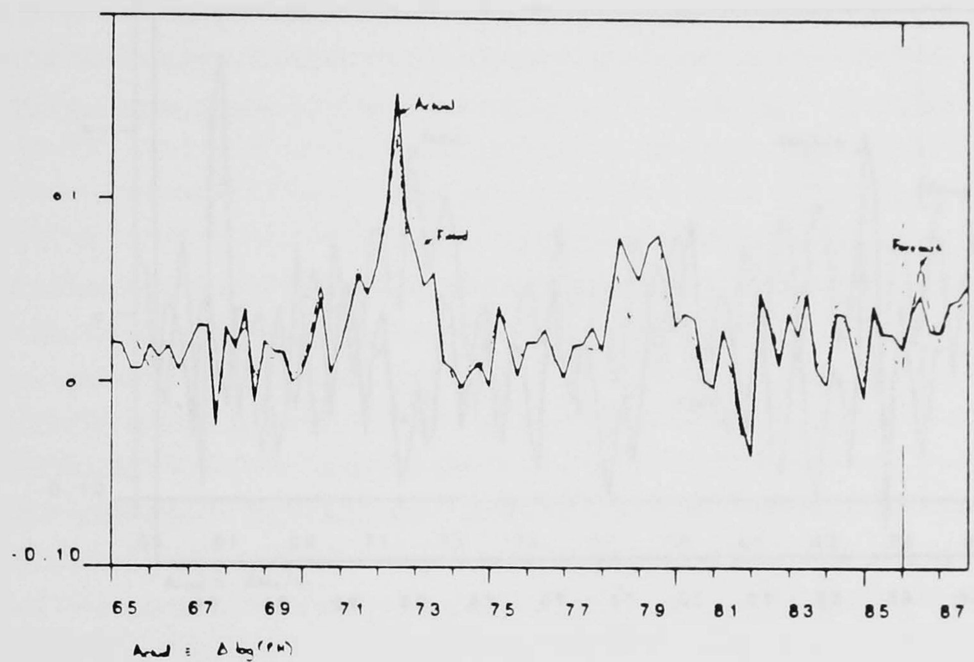
where $K^0 = \exp(\,11.9 + \Sigma\,\hat{\beta}_j\,Q_j\,)$ and $\dot{pc}_a$ is the annual rate of inflation.

Of course, one could substitute an approximation of the form HIG = (RM.M)/Y if one wanted to make a closer comparison with the steady-state of Hendry's model. It is clear, however, that the new specification has significantly smaller income and interest rate

(1) Perhaps one could argue that if these buyers comprise a large share of the market then, since they will tend to be buying cheaper dwellings, there could be a compositional effect on prices. This should be taken out,however, through the mix-adjustment process.

elasticities but a stronger role for inflation. In addition, unlike the Hendry model, it has a role for the number of households. One potential problem with (24), however, is the absence of a term in the level of prices, implying that we still have a *nominal* rather than a real house price equation (see the discussion on page 30). One might also question, however, why Hendry chose to use real income and real house prices in the housing demand but a nominal mortgage variable. Once one includes real mortgages, however, one finds that it is also necessary using real interest rates if the model is to have sensible coefficients.[1] Finally, as regards the model shown in Column B of Table 7, Chart 3 illustrates both its goodness-of-fit and its forecasting capabilities.

Chart 3
The price of existing dwellings



(iii) The Uncompleted Stock of Dwellings (*U*)

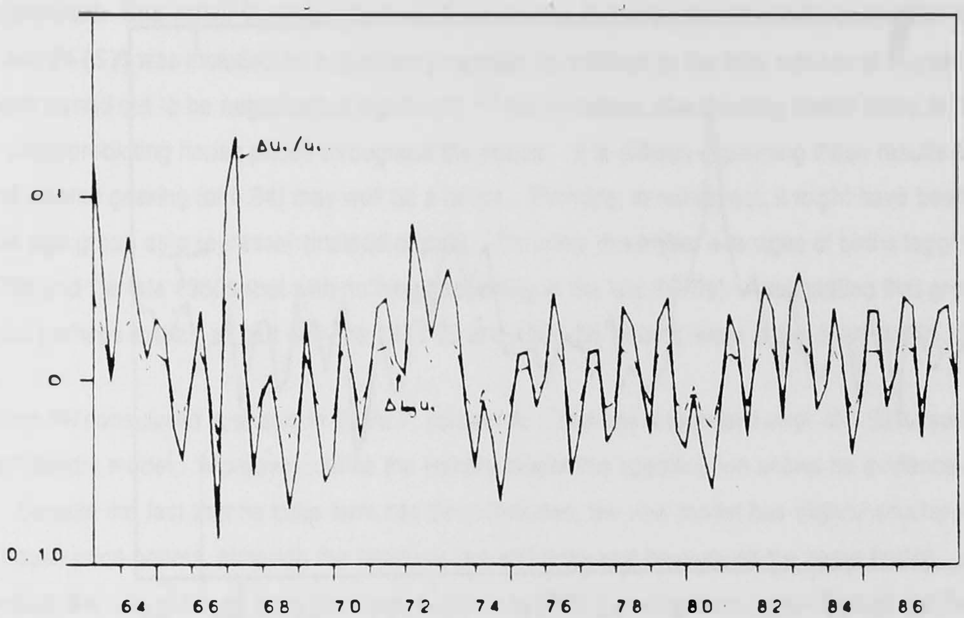
Hendry's model for the uncompleted stock of dwellings depends upon real incomes, the differential between the price of new and secondhand dwellings, and interest rates and real costs. It does not, however, include a long-run effect from the number of owner-occupied houses (Hendry's proxy for the number of households) even though it was expected that demographics would have a role to play. Moreover, the discovery that real costs have a long-run (positive) effect is somewhat surprising given that the inclusion of such a term is not justified by Hendry's theoretical model (ie his optimisation problem specified in Appendix A of Hendry (1986)).[2] In section 5 (iii) it was shown that, when using an approvals-based series for *pn*, the Hendry equation suffers from autocorrelated and heteroscedastic errors and, when estimated over the two decades to 1985, fails to pass parameter stability tests (underpredecting through much of the last two years). Worse still five out of the twelve estimated coefficients are insignificant at the 95 % level. It is hardly surprising therefore that the standard error of our re-estimated Hendry model is two-thirds as large again as that of the original equation (although only 30 % larger if we restrict the sample period to run from the mid-1960s to the mid-1980s).

(1) This is one of the issues examined by Dicks (1989)

(2) Interestingly, however, using just the equations set out in Section 2, or Appendix 2, one can justify a role for (nominal) costs, provided one is willing to accept that $\beta_2 = \beta_3$.

Hendry chose to use the approximation that $\frac{\Delta U_t}{U_{t-1}} = \Delta \log U_t$ (hence using the latter as the dependent variable in his modelling) although he recognised that 'in retrospect it may have been better to retain $\frac{(S_t - C_t)}{U_{t-1}}$, as this ensures data admissibility'. Chart 4 shows how the two terms have moved during the last two decades, illustrating that the logarithmic form has a slightly smaller variance. Nevertheless, if the Hendry model is re-estimated using $\frac{\Delta U_t}{U_{t-1}}$ as the dependent variable one finds that the standard error

Chart 4
Changes in the uncompleted stock of dwellings

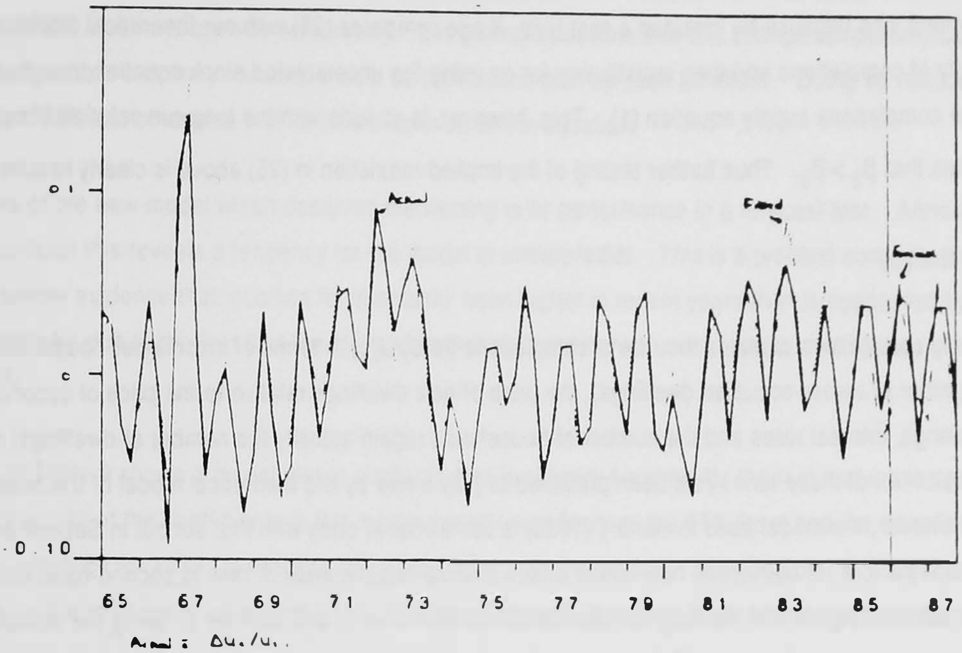


of the equation remains much the same as when the logarithm form was used (at just under 2%). We have therefore chosen to use this as our dependent variable. Table 8 illustrates our results. At first glance the new specifications look very similar to that suggested by Hendry. In fact, however, a couple of refinements have been made. First, the real costs term has been dropped, both because it was found to be insignificant and because it was not justified by our theoretical model. Second, we have included an (albeit minor) effect from the number of households — this coming through our income per household term. Finally, a dummy has been included for the change in the VAT base which occurred in 1984 (it then being extended to cover improvements, greenhouses etc).

The model shown in Column A includes seasonal dummies even though, as in the Hendry equation, two of the three are insignificant at the 95% level. Column B shows what happens if these are dropped, but a weather variable used instead (this is in addition to the change in the weather term, which is used in both specifications). There is very little to choose between the two models, as regards goodness-of-fit (both the equations representing an improvement of close to one-fifth compared with the Hendry model). Model B, however, forecasts somewhat better — with a root mean squared percentage error of close to 130 (which compares with 155 for model A). Nevertheless, it fails the Hendry forecast test at the 95% significance level, underpredicting through much of the last two years (and especially in the first quarters). This is despite the fact that the equation has a tendency to overpredict in recent years, as is shown by Chart 5.

One possible reason for the model's (apparent) instability is that future data revisions may turn out to be important. It has already been mentioned that the national accounts measure of real personal disposable income may be too low in recent years, perhaps by enough to affect the equation's performance. The estimates of starts and completions (and hence the uncompleted stock) also get revised fairly frequently (and sometimes by substantial amounts), so that this too could be a factor. It is worth noting that our 'data'

Chart 5
The uncompleted stock of dwellings



for the uncompleted stock of dwellings has been constructed using estimates of starts and completions [1] and so will change on each occasion that they are revised. It will also differ from figures published by the Department of the Environment for the total stock of uncompleted (private sector) dwellings since the latter also take into account transfers of dwellings between sectors and, although being calculated on the same cumulative basis, is revised from time to time after the authorities have carried out checks on the sites in their area and reported the actual number of dwellings under construction.[2] One might imagine that the errors which arise in our model because of these factors would be fairly small. Nevertheless, they could easily turn out to be sufficiently large to ensure that the parameter stability tests are passed — certainly revisions made to the starts and completions data during the first six months of 1989 were of sufficient magnitude to reduce the root mean squared percentage error of our preferred specification (model B) form around 145 to just 135.[3]

(1) See Appendix 3 for details of our data sources.

(2) Of course, the fact that corrections are needed to the under construction figures points to the fact that really the starts and completions figures re wrong (and hence they should be corrected too, for consistency). The Department of the Environment have suggested that there are several reasons for errors arising in the starts and completions data. For example, construction of some dwellings is suspended and, once re-started, may be reported as a start again. Also, some reporting of completions may be overlooked.

(3) In fact, when the model was recently re-estimated using more up-to-date data for starts and completions the forecast test was passed at the 95% significance level.

Finally, the long-run properties of model B are considered. Its static steady-state solution is given by;

$$U = \gamma \left(\frac{Y}{HO}\right)^{1.2} (Y) \left(\frac{PN}{PH}\right)^{-1.4} (RM(1-T))^{-0.6} \quad (25)$$

where γ varies seasonally. Compared with the Hendry model (25) has an additional term in income per household with an elasticity of 1.2 (this being in addition to the unit elasticity on aggregate income and so making the overall effect perhaps too big to believe?), a somewhat smaller relative price elasticity and an identical interest rate elasticity. Interestingly if the implied restriction on aggregate income is relaxed (ie $(u\text{-}y)_{t\text{-}4}$ replaced with $u_{t\text{-}4}$) then one still finds an income elasticity of 2.2. Presumably the main reason that Hendry found a smaller effect was because he included a cost term. If one compares (25) with our theoretical model, say by equating the demand for and supply of completions and then substituting for *pn* using the uncompleted stock equation, one finds that (25) implies that $\beta_2 = \beta_3$ in the completions supply equation (1). This, however, is at odds with the long-run solution of our new pn equation (23) which implies that $\beta_2 > \beta_3$. Thus further testing of the implied restriction in (25) above is clearly required.(1)

(iv) **Housing Completions (*C*)**

Hendry's model for housing completions explains the rate of completions (ie C_t/U_{t-1}) in terms of income per household (where the latter is proxied by the number of owner-occupied dwellings), the price of new dwellings relative to the price of second-hand houses, the real price of new dwellings, interest rates and the number of households (again actually the number of dwellings) relative to the (lagged) uncompleted stock. All of these terms had been predicted to play a role by the theoretical model of the housing market developed by Hendry. However, the model used in Hendry (1986) is somewhat at odds with that set out in Section 2 (or Appendix 2) of this paper, since it includes a role for both (real) new house prices *and* the relative price of new to second-hand house prices simultaneously. (In fact, substituting for *u* in the long-run equilibrium solution $C=K^*U$ and then for *C* using the demand for completions equation gives a long-run solution for *C* without a term in *h* and using *nominal* new house prices rather than a real variable. Alternatively, substituting for *ph* does give a solution with terms in real new house prices and *h*, but no term in the relative price of new to second-hand dwellings.) In addition, it should be noted that in the theoretical model costs were expected to be an important factor affecting completions, but in practice were found to have no long-run effect.

In Section 5(iv) we showed that it was fairly easily replicating the Hendry equation — although the standard error of our version of the model is considerably (around two-thirds) higher than that of Hendry's. It also fails to explain the post-sample period very well (1982 through 1987) although if its coefficients are up-dated it copes rather better.(2) In our modelling we have kept a very similar structure to that used by Hendry but replaced his proxy for the number of households with a better measure (based on survey evidence linked in with Census data). We have also allowed for the possibility that the reason Hendry could find no long-run effect from costs was because he only included materials costs. We have therefore tried using land prices and labour costs too. On the demand side we have proxied changes in the distribution of income by including such terms as the unemployment rate and the differential between earnings of non-manual and manual workers (as outlined in Section 4).

(1) Our own preliminary attempts, using co-integration analysis, hint that it is the price equation which is most likely to be mis-specified, since it is difficult finding a vector of variables which co-integrate.

(2) To some extent this is what one might expect, since (as Hendry notes) out of equilibrium the parameters in our model should not be thought of as 'fundamental constants', in which case they will alter with changes in technology, legislation etc. Probably the only solution to this problem will be to accept that, for practical purposes, it will be necessary to use techniques (such as a Kalman filter) which allow the parameters of the model to vary over time.

Table 9 column A shows an equation which includes roles for both land prices and materials costs (labour costs proving to be insignificant). In addition it includes small effects from the differential in (real) earnings of non-manual and manual workers and the unemployment rate. In addition to a (dynamic) effect from the number of households,[1] it was also found that increases in the number of households per dwelling raises completions (these variables were found to work slightly better than simply using population variables). The new model passes all the relevant tests and has a standard error around seven eighths that of the re-estimated Hendry model. Nevertheless, the relatively high values for skewness and kurtosis reflect, in part, a large (positive) residual (2.5 $\hat{\sigma}$) in 1979 Q4. Prior to mid-1979 the rate of development land tax was 66 2/3% for annual disposals with not more than 150,000 chargeable realised development value and 80% on the excess. After that date, however, a single rate of 60% applied (until March 1985 when the tax was withdrawn). It is perhaps possible that this change temporarily depressed completions and so one might argue that a dummy variable should be included to pick-up such an effect. Doing so reduces the standard error of the equation to 1.20% but otherwise makes little difference to the equation.

One feature of the new model which deserves mentioning is its performance in a forecast test. Although passed at the 95% significance level this reveals a tendency for the model to underpredict. This is a problem common to all of our models thus providing further evidence that incomes have actually been higher in recent years than is suggested by official statistics. Alternatively it could simply be due to the fact that the starts, completions (and hence uncompleted stocks) data are also subject to fairly extensive revisions.[2]

Column B of Table 9 shows a model that is similar to that in column A except for the fact that it uses a total costs measure (based on equal weights). All of the coefficients in this model are still significant at the 95% level and the equation performs well. Again the addition of a dummy for 1979 Q4 reduces the standard error of the equation considerably (to 1.23%) although at the cost of reducing the t-value on the total costs variable to 1.7. Both equations still, however, have a tendency to underpredict.

Despite the improvements upon the Hendry model made, both of the specifications shown in Table 9 can be improved still further in terms of goodness-of-fit, but at the expense of worsening their forecasting capabilities. One change which reduces the standard error of the equation significantly (to 1.21%) is to replace the actual unemployment rate with its logarithm. This, however, has the unfortunate consequence of raising the standard errors on both the real (new) house price and households per house terms. Moreover, the root mean squared percentage error of the static forecast test rises by more than 10% (although the test is still just passed at the 95% significance level). The problem arises because the three variables are very highly correlated, making it difficult to distinguish between their separate effects. It may be the case that one of the reasons for the equation underpredicting is that unemployment (as measured by the claimant count) has fallen sharply since mid-1986, but that this fall has had little impact on the distribution of income. Certainly research carried out by Dicks and Hatch (1989) suggests that one reason for the fall has been the introduction of more strict availability-for-work tests which, coupled with the Restart Programme, will have removed some people from the claimant count by placing them in other Special Employment Measures, employment or by stopping them from claiming.

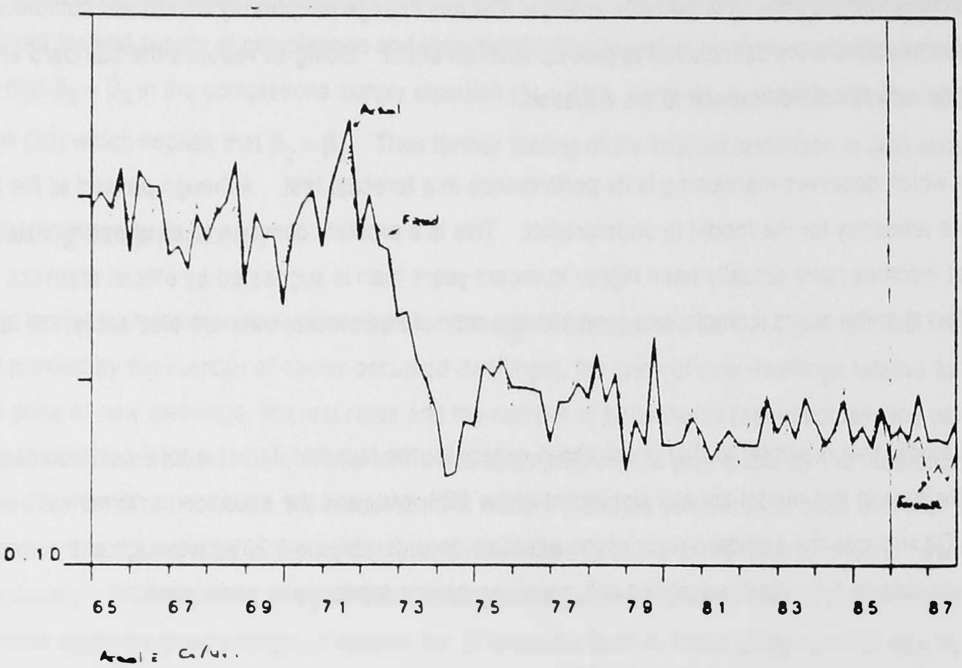
One other point to note as regards the new equations is the absence of interest rate effects. Here too the problem is one of high correlation (between the unemployment rate and nominal interest rates one finds a correlation coefficient of 0.83), so that on adding an interest rate term to the model one finds it has a t-value of just 1.1. This also causes problems as regards the significance of the

(1) Note that despite its large coeficct this term is actually doing very little work in explaining changes in K_t since Δho_t is generally very small.

(2) For example, it has been suggested to me that recent quarters estimates of the number of completions seem too low given the number of starts which have been recorded. (Since we have constructed our data for the uncompleted stock using starts and completions of course this also implies that U_t is too high.)

real (new) house price term. The best equation found which had a significant interest rate term used the actual unemployment rate (t-value of 1.7) and the logarithm of the nominal interest rate lagged two periods (t-value of 2.0). The model had a standard error of 1.24% and passed all the tests tried on it, with the exception of the parameter stability test. Here the root mean squared percentage error was 30% higher than that of our preferred model (in column A) leading it to fail the test at the 95% significance level. Clearly, however, more work needs to be done if we are to disentangle interest rate and other (distributional) effects from each other.

Chart 6
Housing completions



Because of the slight problem we had in identifying a strongly significant effect from total costs we consider model A to be our best specification. It has a long-run solution given by;

$$\left(\frac{C}{U}\right) = K + 0.35\,(y - ho) - 0.13\,(pn - pc) - 0.31\,(pn - ph) + 0.34\,(ho - h) - 0.006\,UR - 0.17\,(cc - pc) - 0.05\,(lp - pc) + 0.18\left(\frac{H}{U}\right) \tag{26}$$

where K depends upon the season, weather etc.

A comparison with the steady-state solution of Hendry's original equation reveals that the new model has a much smaller (perhaps implausibly so) income elasticity (substantiating our earlier finding in this respect — our re-estimated Hendry equation also had an elasticity close to one-third). One might speculate that one of the reasons for this result is that we have measured income relative to the number of households rather than the number of dwellings. However, (26) indicates an elasticity of close to one-third with regards to the number of households per dwelling, implying that we would have found very similar elasticities if we had used the same regressor as Hendry. Both of the price elasticities in the new model are closer to zero than in the Hendry model, with that relating to real new house prices only one-half the magnitude previously estimated. Much of this change is likely to be due to the fact that we have additional negative long-run effects from the cost variables — if margins are kept almost constant then obviously costs and new house prices will be very strongly correlated. Finally it is worth mentioning that the long-run elasticity relating to the stock of housing relative to the stock of work in progress on new housing is around three-quarters of that estimated by Hendry. Renormalising in terms of (C/H) we can use this coefficient to calculate the mean-life of a house. Hendry's model gives a figure of around 95 years but ours one of 135 years.(1) In this respect our model is perhaps less realistic, although it is of course more difficult to interpret given its additional regressors in the number of households relative to the housing stock.(2) Nevertheless, the new model clearly has a reasonably good tracking performance and (so far at least) has forecast adequately, as is shown by Chart 6. Of course, as has been mentioned elsewhere,(3) 'genuine evaluation of such equations must await new data'.

Section 7 Conclusions

In this paper we have first summarised the best of the existing econometric literature on the UK housing market and then tried re-estimating these models using more up-to-date data. Since such an exercise revealed a number of problems with them we next tried extending these models to take into account demographic factors, changes in the distribution of income, additional cost terms (which might affect the profitability of building new houses) and rationing in the mortgage market. Despite our starting with models which have fairly small standard errors our empirical work shows that it is possible to improve upon previous research. We thus now have a slightly better understanding of what causes house prices and the housing stock to change. Nevertheless, the problems outlined earlier with the theoretical basis of the Hendry model suggest that future work should concentrate on trying to estimate equations with a more rigorous intertemporal theoretical foundation. In addition, there are still several potentially important factors which we have yet to try taking into account. These include;

(1) modelling the housing and mortgage markets jointly;

(2) allowing for the possibility of interaction between dwellings which are rented and those which are owned (for example, neither rents nor council house sales have a role in our model)(4) and,

(3) analysing more carefully whether or not 'speculative bubbles' occur. Why, for example, do we need a cube term in the house price equation? Clearly, to answer this type of equation we may need to model expectations explicitly.

In conclusion, however, we feel (as do Hendry and Ericsson) that the problems that do remain should be regarded as 'a future stimulus [to more work] rather than a major drawback'.

(1) In calculating this figure we assume that, in the long run, the number of households equals the number of dwellings, so that we can ignore the coefficient pertaining to (ho-h).

(2) Again we have tried investigating the long-run properties of the equation using co-integration techniques. It turns out that including the land price term is crucial if we are to find a co-integrating vector.

(3) See Hendry (1985), page 32.

(4) Although Hendry (1984) reports that the former were insignificant when added to the house price equation. Minford, Peel and Ashton (1987), however, suggest that these factors may have been important.

Table 1: House Prices (new dwellings)

Dependent Variable: Δpn_t

Explanatory Variable	A Ericsson and Hendry		B Our Estimates		C	
$A_4\ (\Delta ph_t)$	0.67	(0.06)	1.08	(0.10)	1.25	(0.12)
$\Delta_2\ pn_{t-2}$	0.19	(0.05)	0.06	(0.07)	-0.03	(0.07)
$\Delta_3\ (cc - pc)_t$	0.11	(0.04)	-0.05	(0.07)	0.06	(0.08)
$\Delta\ u_{t-2}$	-0.17	(0.03)	-0.19	(0.05)	-0.23	(0.06)
$\Delta_2\ y_{t-1}$	0.09	(0.04)	0.16	(0.07)	0.09	(0.08)
Dummy 1	-0.019	(0.005)	-0.038	(0.009)	-0.026	(0.009)
$(pn - ph)_{t-1}$	-0.26	(0.06)	-0.36	(0.09)	-0.48	(0.11)
$(ph - pc)_{t-1}$	-0.027	(0.015)	-0.032	(0.020)	-0.070	(0.024)
$(cc - pc)_{t-4}$	0.13	(0.03)	0.13	(0.04)	0.16	(0.04)
$(u - y)_{t-1}$	-0.023	(0.012)	-0.007	(0.015)	-0.040	(0.022)
$(RM\ (1 - T))_{t-1}$	-0.23	(0.13)	-0.001	(0.003)	-0.002	(0.002)
Constant	-0.077	(0.05)	0.03	(0.07)	-0.152	(0.122)
Sample Period	1959.1-1982.2		1959.1 - 1982.2		1965.1 - 1985.4	
R^2	0.86		0.75		0.73	
$\hat{\sigma}$	0.94%		1.50%		1.62%	
	$\eta_1(6, 76) = 0.9$		$\eta_1(4, 78) = 0.66$		$\eta_1(4, 68) = 0.32$	
	$\eta_3\ (2, 80)^{(b)} = 0.9$		$\xi_1\ (4) = 3.06$		$\xi_1\ (4) = 1.57$	
	$\xi_4^*\ (1) = 0.2$		$\xi_1^*\ (4) = 1.92$		$\xi_1^*\ (4) = 0.97$	
	$\xi_5\ (2) = 1.5$		$\xi_3\ (22) = 43.48$		$\xi_3\ (8) = 16.17$	
			$\xi_4\ (1) = 8.59$		$\xi_4\ (1) = 0.06$	
			$\phi_7\ [0.96] = 0.96$		$\phi_7[0.96] = 0.98$	
			$\phi_8\ [\pm 0.5] = 0.67$		$\phi_8[\pm 0.53] = -0.44$	
			$\phi_9\ [1.99, 4.0] = 3.7$		$\phi_9[1.93,\ 4.07] = 3.22$	

where $$A_n(x_t) = \frac{2}{n\,(n+1)} \sum_{i=0}^{n} (n - i)\, x_{t-i}$$

and Dummy 1 takes the value 1 in 1981 Q3 and Q4, -1 in 1982 Q2 and Q3 and 0 elsewhere.

$\hat{\sigma}$ refers to the residual standard deviation, whilst standard errors are shown in brackets.

The η_i, ξ_i and ϕ_i are test statistics, defined in Appendix 4.

Table 2: **House Prices (existing dwellings)**

Dependent Variable: Δph_t

	A		B		C	
	Hendry		Our Estimates			
Explanatory Variable						
Δph_{t-2}	0.22	(0.07)	0.42	(0.10)	0.52	(0.10)
$(\Delta ph_{t-1})^3$	14.0	(4.9)	13.5	(5.1)	14.3	(4.8)
$A_2\ (\Delta y_t)$	0.42	(0.07)	0.41	(0.13)	0.54	(0.15)
$(m - ph - h)_{t-1}$	0.178	(0.027)	0.200	(0.040)	0.188	(0.038)
$(y-h)_{t-1}$	0.47	(0.08)	0.32	(0.09)	0.41	(0.10)
$F_{13}\ (pc)$	0.85	(0.12)	1.02	(0.24)	0.67	(0.24)
$F_{13}\ (m-pc)$	0.54	(0.11)	0.82	(0.21)	0.39	(0.20)
$\overline{(RM(1 - T))}^{o}_{t-3}$	-0.22	(0.09)	0.53	(2.42)	0.39	(0.21)
$\Delta(RM(1 - T))^{o}_{t-1}$	-0.50	(0.20)	0.17	(5.91)	-0.28	(0.44)
Constant	-0.30	(0.05)	0.11	(0.09)	-0.02	(0.08)
Dummy 2^{o}	-3.5	(0.4)	-3.9	(0.6)	-2.7	(0.9)
Dummy 3^{o}	-2.1	(0.3)	-4.7	(1.7)	-4.3	(1.7)
Sample Period	1955.1 - 1982.2		1959.1 - 1982.2		1965.1 - 1985.4	
R^2	0.78		0.65		0.75	
$\hat{\sigma}$	1.43%		1.72%		1.60%	
	$\eta_1\ (6,\ 72) = 1.0$		$\eta_1\ (4,\ 75) = 2.35$		$\eta_1\ (4,\ 65) = 2.18$	
	$\eta_2\ (2,\ 76) = 0.2$		$\xi_1\ (4) = 10.48$		$\xi_1\ (4) = 9.92$	
	$\xi_4^*\ (1) = 0.01$		$\xi_1^*\ (4) = 6.86$		$\xi_1^*\ (4) = 7.27$	
	$\xi_5\ (2) = 117$		$\xi_3\ (22) = 91.45$		$\xi_3\ (8) = 14.75$	
			$\xi_4\ (1) = 5.87$		$\xi_4\ (1) = 2.78$	
			$\phi_7\ [0.96] = 0.96$		$\phi_7\ [0.96] = 0.97$	
			$\phi_8\ [\pm 0.51] = 0.82$		$\phi_8\ [\pm 0.53] = 0.81$	
			$\phi_9\ [1.99, 4.01] = 5.15$		$\phi_9\ [1.93, 4.07] = 5.10$	

where $F_{13}\ (x) = \Delta\ (x_{t-1} + x_{t-3})$,

$$\bar{x}_t = \frac{1}{2}\ (x_t + x_{t-1}),$$

$$x_t^{o} = x_t/100.$$

Quarterly dummies were also included in all the equations but are not reported. Dummy 2 takes the value 1 in 1967 Q4 and 0 elsewhere. Dummy 3 takes the value 1 in 1981 Q4 and 1982 Q1, -2 in 1982 Q2 and 0 elsewhere.

Table 3: The Uncompleted Stock of Dwellings

Dependent Variable: Δu_t

	A		B		C	
	Hendry		Our Estimates			
Explanatory Variable						
$\Delta^2 u_{t-1}$	0.23	(0.05)	0.30	(0.07)	0.26	(0.08)
$(u-y)_{t-4}$	-0.092	(0.012)	-0.083	(0.014)	-0.214	(0.025)
ΔWT	0.63	(0.15)	0.82	(0.24)	0.68	(0.20)
$(cc - pc)_{t-3}$	0.12	(0.03)	0.04	(0.07)	0.06	(0.05)
$(pn - ph)_t$	-0.24	(0.04)	-0.22	(0.12)	-0.18	(0.09)
rm_{t-1}	-0.056	(0.007)	-0.039	(0.015)	-0.084	(0.018)
$\Delta\ (pn - ph)_{t-1}$	-0.21	(0.09)	-0.35	(0.15)	-0.16	(0.13)
Dummy 4	0.08	(0.014)	0.08	(0.02)	0.09	(0.02)
Q1	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)
Q2	-0.02	(0.02)	-0.04	(0.03)	-0.02	(0.03)
Q3	-0.04	(0.02)	-0.06	(0.03)	-0.04	(0.03)
Constant	1.13	(0.15)	-0.30	(0.12)	-0.87	(0.13)
Sample Period	1958.1 - 1982.4		1958.1 - 1982.4		1965.1 - 1985.4	
R^2	0.88		0.78		0.82	
$\hat{\sigma}$	1.51%		2.50%		1.94%	
	η_1 (8, 78) = 0.8		η_1 (4, 84) = 2.31		η_1 (4, 68) = 2.06	
	η_3 (20, 66) = 0.7		ϵ_1 (4) = 9.93		ϵ_1 (4) = 9.07	
	η_3 (11, 75) = 1.8		ϵ_1^* (4) = 15.64		ϵ_1^* (4) = 13.57	
	η_4 (35, 54) = 0.6		ϵ_3 (20) = 24.54		ϵ_3 (8) = 26.49	
	η_4^* (8, 78) = 1.0		ϵ_4 (1) = 4.50		ϵ_4 (1) = 1.49	
	ϵ_5 (2) = 0.1		ϕ_7 [0.96] = 0.98		ϕ_7 [0.96] = 0.98	
			ϕ_8 [±0.49] = 0.05		ϕ_8 [±0.53] = 0.11	
			ϕ_9 [2.03, 3.98] = 2.46		ϕ_9 [1.93, 4.07] = 2.62	

where WT is an index of mean daily air temperature. Dummy 4 takes the value 1 in 1967 Q1 and 1967 Q2 and 0 elsewhere.

Table 4 Housing Completions

Dependent Variable: $R_t = C_t / U_{t-1}$

	A		B	C
	Hendry		Our Estimates	
Explanatory Variable				
ΔR_{t-1}	0.43	(0.08)	0.36 (0.08)	0.55 (0.10)
R_{t-2}	0.25	(0.09)	0.45 (0.07)	0.60 (0.08)
$\overline{(y - h)}_t$	0.37	(0.06)	0.19 (0.08)	0.11 (0.07)
$(pn - ph)_{t-2}$	-0.27	(0.05)	-0.13 (0.09)	-0.11 (0.07)
$(pn - pc)_{t-2}$	-0.20	(0.03)	-0.05 (0.02)	-0.05 (0.02)
$(H/U)_{t-1}$	0.19	(0.03)	0.19 (0.03)	0.09 (0.05)
$\Delta (cc - pc)_{t-1}$	0.19	(0.07)	-0.30 (0.16)	-0.36 (0.13)
$\Delta (pn - pc)_{t-1}$	-0.40	(0.05)	-0.07 (0.07)	-0.08 (0.06)
rm_{t-1}	-0.02	(0.01)	-0.11 (0.02)	-0.05 (0.02)
W	0.65	(0.12)	1.28 (0.23)	0.45 (0.22)
Dummy 5	0.05	(0.01)	0.06 (0.01)	-0.01 (0.02)
Q1	-0.02	(0.01)	-0.01 (0.01)	-0.03 (0.01)
Q2	-0.03	(0.01)	-0.06 (0.01)	-0.03 (0.01)
Q3	-0.07	(0.01)	-0.11 (0.02)	-0.06 (0.01)
Constant	0.50	(0.08)	-0.09 (0.13)	-0.07 (0.11)
Sample Period	1958.1 - 1982.2		1958.1 - 1982.2	1965.1 - 1985.4
R^2	0.98		0.98	0.95
$\hat{\sigma}$	1.07%		1.74%	1.43%
	$\eta_1(8, 75) = 0.7$		$\eta_1(4, 79) = 1.20$	$\eta_1(4, 69) = 0.62$
	$\eta_2(4, 79) = 0.7$		$\xi_1(4) = 5.60$	$\xi_1(4) = 3.08$
	$\eta_3(20, 63) = 1.6$		$\xi_1'(4) = 4.70$	$\xi_1'(4) = 1.22$
	$\eta_3(14, 69) = 1.6$		$\xi_3(22) = 51.82$	$\xi_3(8) = 12.72$
	$\eta_4(27, 55) = 0.6$		$\xi_4(1) = 0.67$	$\xi_4(1) = 0.01$
	$\eta_4'(4, 79) = 1.3$		$\phi_7[0.96] = 0.97$	$\phi_7[0.96] = 0.98$
	$\xi_5(2) = 0.1$		$\phi_8[\pm 0.49] = -0.70$	$\phi_8[\pm 0.52] = -0.07$
			$\phi_9[2.01, 3.99] = 4.04$	$\phi_9[1.96, 4.04] = 2.70$

The coefficient on $(H/U)_{t-1}$ has been scaled to ensure that its coefficient lies between 0.1 and 1.

Dummy 5 takes a value of -1 in 1963 Q4 and +1 in 1964 Q1 and is designed to take account of severe weather.

Table 5 **New House Prices**

Dependent Variable: Δpn_t

Explanatory Variable	A		B		C		D	
Δph_t	0.80	(0.09)	0.69	(0.08)	0.76	(0.08	0.70	(0.07)
Δu_{t-2}	-0.19	(0.06)	-0.16	(0.06)	-0.21	(0.05)	-0.20	(0.05)
$\Delta_2 (y-ho)_{t-1}$	0.17	(0.07)	0.18	(0.08)	0.15	(0.07)	0.14	(0.07)
Dummy 1	-0.014	(0.008)	-0.015	(0.009)	-0.019	(0.008)	-0.022	(0.008)
$(pn-ph)_{t-1}$	-0.56	(0.11)	-0.32	(0.09)	-0.62	(0.10)	-0.59	(0.10)
$(cc-pc)_{t-1}$	0.11	(0.05)	-		-		-	
$(cc-pc)_{t-4}$	-		-		-		0.21	(0.05)
$(w-pc)_{t-1}$	0.04	(0.05)	-		-		-	
$(w-pc)_{t-4}$	-		-		-0.14	(0.06)	-	
$(lp-pc)_{t-1}$	-0.02	(0.01)	-		-		-	
$(lp-pc)_{t-4}$	-		-		-0.12	(0.03)	-	
$(tc)_{t-4}$	-		-		0.44	(0.11)	-	
$(tc2)_{t-1}$	-		0.04	(0.04)	-		-	
$(RM(1-T))_{t-1}$	-0.001	(0.002)	-0.000	(0.002)	-0.002	(0.002)	-0.004	(0.002)
$(u-y-hc)_{t-6}$	-0.09	(0.03)	-0.07	(0.03)	-0.12	(0.03)	-0.11	(0.03
Bud_t	-0.001	(0.000)	-0.001	(0.000)	-0.001	(0.000)	-0.002	(0.000)
Constant	0.60	(0.17)	0.12	(0.17)	-1.13	(0.39)	0.70	(0.15)
Sample Period	1965.1 - 1985.4		1965.1 - 1985.1		1965.1 - 1985.4		1965.1 - 1985.4	
R^2	0.76		0.71		0.78		0.78	
$\hat{\sigma}$	1.55%		1.65%		1.48%		1.47%	
η_1 (4,68)	0.45		0.14		1.09		0.39	
ϕ_1 (4)	2.17		0.68		5.08		1.81	
ϕ_1^* (4)	1.91		0.74		3.78		1.69	
ϕ_3 (8)	27.48		11.19		21.69		19.80	
ϕ_4 (1)	1.99		1.05		3.28		2.87	
ϕ_7 [0.96]	0.97		0.97		0.99		0.99	
ϕ_8 [±0.53]	-0.34		-0.18		-0.11		-0.16	
ϕ_9 [1.93, 4.07]	2.71		2.33		2.79		3.07	

where $Bud_t = \frac{1}{4} \sum_{i=0}^{3} ud_{t-i}$

Table 6: New House Prices

Dependent Variable: Δpn_t

	A		B	
Explanatory Variable				
Δph_t	0.73	(0.07)	0.76	(0.07)
Δu_{t-2}	-0.19	(0.05)	-0.16	(0.05)
$\Delta_4(\Delta(y-ho)_{t-1})$	0.49	(0.20)	0.53	(0.19)
Dummy 6	-0.024	(0.007)	-0.020	(0.007)
$(pn-ph)_{t-1}$	-0.51	(0.09)	-0.59	(0.10)
$(cc-pc)_{t-4}$	0.17	(0.04)	0.21	(0.04)
$(RM(1-T))_{t-1}$	-0.004	(0.002)	-	
HIG_t	-		-0.005	(0.002)
$(u-y-ho)_{t-4}$	-0.10	(0.02)	-0.09	(0.02)
Bud_t	-0.001	(0.000)	-0.001	(0.001)
Constant	0.65	(0.14)	0.59	(0.12)
Sample Period	1965.1 -	1985.4	1965.1 -	1985.4
R^2	0.79		0.80	
$\hat{\sigma}$	1.42%		1.38%	
η_1 (4,70)	1.59		0.86	
ξ_1 (4)	6.98		3.92	
ξ_1^* (4)	6.38		3.63	
ξ_3 (8)	13.09		38.43	
ξ_4 (1)	0.32		0.38	
ϕ_7 [0.96]	0.98		0.99	
ϕ_8 [±0.53]	-0.02		0.14	
ϕ_9 [1.93, 4.07]	2.80		2.65	

where HIG is household sector income gearing (gross), and Dummy 6 takes the value 1 in 1981 Q3 and Q4, 1982 Q2 and Q3 and 1984 Q3 and Q4.

Table 7: **House prices (Existing Dwellings)**

Dependent Variable: $\Delta\, ph_t$

Explanatory Variable	A		B	
$\Delta\, ph_{t-2}$	0.18	(0.08)	0.22	(0.08)
$A_2\ (\Delta(y-ho)_t)$	0.31	(0.12)	0.31	(0.12)
$(\Delta(y-ho)_{t-1})^3$	-		0.61	(0.21)
$\Delta\, pc_t$	1.92	(0.33)	1.84	(0.31)
$\Delta(m-pc)_t$	1.56	(0.27)	1.44	(0.26)
$(m-ph-h-ho)_{t-4}$	0.129	(0.020)	0.112	(0.020)
$(y-ho)_{t-1}$	0.22	(0.06)	0.15	(0.07)
HIG_t	-0.009	(0.002)	-0.006	(0.002)
$\Delta_2\ MR_t$	0.012	(0.005)	0.011	(0.004)
Constant	1.51	(0.24)	1.33	(0.23)
Dummy 2[c]	-2.3	(0.7)	-2.4	(0.7)
Dummy 3[c]	-4.9	(1.4)	-4.9	(1.3)
Sample Period	1965.1 -	1985.4	1965.1 -	1985.4
R^2	0.83		0.85	
$\hat{\sigma}$	1.32%		1.26%	
η_1 (4,70)	0.95		1.07	
ξ_1 (4)	4.55		5.20	
ξ_1^* (4)	4.74		5.18	
ξ_3 (8)	3.93		3.64	
ξ_3^* (8)	3.26		2.98	
ξ_4 (1)	0.88		0.32	
ϕ_7 [0.96]	0.98		0.99	
ϕ_8 [$\pm$0.53]	0.54		0.00	
ϕ_9 [1.93, 4.97]	4.79		2.86	

where MR is the Hall and Urwin measure of mortgage rationing. Quarterly dummies were also included but are not reported.

Table 8: The Uncompleted Stock Of Dwellings

Dependent Variable: $\Delta U_t / U_{t-1}$

Explanatory Variable	A		B	
$\Delta^2 (U_{t-1}/U_{t-2})$	0.25	(0.06)	0.21	(0.06)
$(u-y)_{t-4}$	-0.22	(0.02)	-0.22	(0.02)
ΔW	0.007	(0.002)	0.003	(0.002)
$(pn-ph)_{t-1}$	-0.31	(0.07)	-0.30	(0.07)
$(rm(1-T))_{t-1}$	-0.14	(0.02)	-0.14	(0.02)
$B(y-ho)_t$	0.26	(0.05)	0.25	(0.05)
Dummy 4	0.11	(0.01)	0.11	(0.01)
Dummy 7	-0.03	(0.02)	-0.03	(0.02)
W_{-1}	-		-0.003	(0.001)
C1	0.003	(0.009)	-	
C2	-0.027	(0.024)	-	
C3	-0.038	(0.021)	-	
Constant	-1.00	(0.10)	-1.01	(0.10)
Sample Period	1965.1 - 1985.4		1965.1 - 1985.4	
R^2	0.88		0.88	
$\hat{\sigma}$	1.58%		1.60%	
$\eta_1(4,68)$ =	0.53		0.29	
$\xi_1(4)$ =	2.54		1.39	
$\xi_1^*(4)$ =	2.16		1.35	
$\xi_3(8)$ =	25.0		17.5	
$\xi_4(1)$ =	0.07		0.09	
$\xi_7[0.96]$ =	0.96		0.96	
$\xi_8[\pm 0.53]$	0.34		0.24	
$\xi_9[1.93, 4.07]$	2.32		2.17	

Dummy 7 takes the value 1 in 1984 Q2 and 0 elsewhere.

Table 9 Housing Completions

Dependent Variable: $K_t = C_t/U_{t-1}$

Explanatory Variable	A		B	
ΔK_{t-1}	0.27	(0.11)	0.32	(0.11)
K_{t-2}	0.27	(0.11)	0.31	(0.11)
$\Delta(y-ho)_t$	0.24	(0.08)	0.23	(0.08)
$(y-ho)_{t-1}$	0.25	(0.09)	0.21	(0.09)
$(pn-ph)_{t-4}$	-0.23	(0.08)	-0.23	(0.08)
$B(pn-pc)_{t-1}$	-0.09	(0.04)	-0.08	(0.04)
$(H/U)_{t-1}$	0.13	(0.04)	0.14	(0.04)
$B(\Delta ho)_t$	0.24	(0.07)	0.25	(0.07)
$(ho-h)_{t-4}$	0.25	(0.12)	0.25	(0.12)
$B(DEARN)_t$	0.002	(0.001)	0.002	(0.001)
UR_t	-0.005	(0.002)	-0.005	(0.002)
$(cc-pc)_{t-1}$	-0.13	(0.06)	-	
$(lp-pc)_{t-1}$	-0.04	(0.02)	-	
$(tc-pc)_{t-1}$	-		-0.11	(0.06)
Q1	-0.03	(0.01)	-0.03	(0.00)
Q2	-0.01	(0.00)	-0.01	(0.00)
Q3	-0.02	(0.00)	-0.02	(0.00)
Constant	-0.36	(0.14)	0.16	(0.31)
Sample Period	1965.1 - 1985.4		1965.1 - 1985.4	
R^2		0.96	0.96	
$\hat{\sigma}$		1.27%	1.30%	
η_1 (4, 68)		0.44	0.83	
ϵ_1 (4)		2.27	4.12	
ϵ_1^* (4)		1.73	1.87	
ϵ_3 (8)		10.52	11.95	
ϵ_4 (1)		0.40	0.05	
ϕ_7 [0.96]		0.96	0.97	
ϕ_8 [$\pm$0.53]		0.48	0.39	
ϕ_9 [1.93, 4.07]		3.21	2.97	

where $Bx = \frac{1}{4}\sum_{i=0}^{3} x_{t-i}$

and the coefficients on $(H/U)_{t-1}$ and $B(\Delta ho)_t$ have been scaled to lie between 0.1 and 1.0 in order to facilitate a closer comparison with the Hendry model.

Appendix 1: Notation

We use the following notation;

C Private sector completions.

CC Construction costs

δ Rate of destruction of housing

DEARN Differential between average earnings in manufacturing and services.

DTAX Differential between the highest rate of income tax and the standard rate.

F Average family size.

H Stock of owner-occupied housing.

HIG Household sector income gearing.

HO Number of households

HOD Number of households due to demographic factors (see text, page 22).

K Ratio of completions to the (lagged) stock of uncompleted dwellings.

M Stock of mortgages.

MR Measure of mortgage rationing.

N Demographic variable (see text).

NF Number of families.

O Sources of housing supply other than the private sector.

PC Consumer or retail prices

PH Price of second-hand houses (ie existing dwellings).

PL Price of land used for building.

PLO Price of land for uses other than building.

PN Price of new dwellings.

POP Population.

POY Proportion of total personal income from sources other than wages and salaries.

R Real rental rate.

RB Interest rate paid by builders (associated with their holding inventories of unsold houses).

RM Mortgage rate.

RSE Ratio of average earnings in London and the South East to the GB average.

S Private sector housing starts.

SO Share of population aged 60 or over.

SY Share of population aged 25-35.

T Standard rate of income tax.

U Stock of uncompleted dwellings.

UD Stock of completed but unsold dwellings.

UR Unemployment rate.

W Average earnings in the construction industry.

WT Mean daily air temperature.

Y Real personal disposable income.

Z Exogenous variable.

Appendix 2

A Simple Model of the Housing Market

The simplest version of the Hendry model (as set out in Section 2) has the following equations;

$$c_t^s = \beta_0 + \beta_1 u_{t-1} - \beta_2 cc_t + \beta_3 pn_t \tag{1}$$

$$c_t^d = \gamma_0 + \gamma_1 (y_t - n_t) + \gamma_2 n_t - \gamma_3 (pn_t - ph_t) - \gamma_4 RM_t \tag{2}$$

$$h_t^d = \lambda_0 + \lambda_1 (y_t - n_t) - \lambda_2 (ph_t - pc_t) - \lambda_3 RM_t - \lambda_4 R_t + \lambda_5 m_t + \lambda_6 n_t + \lambda_7 f_t \tag{3}$$

$$H_t = (1 - \delta_t) H_{t-1} + C_t + O_t \tag{4}$$

$$U_t = U_{t+1} + S_t - C_t \tag{5}$$

$$u_t = \psi_0 + \psi_1 (pn_t - cc_t) \tag{6}$$

To show how (1) to (6) solve to give a unique static equilibrium (dropping the t subscripts) first let $c^s = c^d$ Hence one finds that:

$$\beta_0 + \beta_1 u - \beta_2 cc + \beta_3 pn = \gamma_0 + \gamma_1 (y - n) + \gamma_2 n - \gamma_3 pn + \gamma_3 ph - \gamma_4 RM$$

which on rearrangement gives;

$$(\beta_3 + \gamma_3) pn = -\beta_0 + \gamma_0 + \gamma_1 (y - n) + \gamma_2 n - \gamma_4 RM + \beta_2 cc - \beta_1 u + \gamma_3 ph \tag{7}$$

From (3) it follows that $ph = \frac{1}{\lambda_2}\left(\lambda_0 + \lambda_1 (y - n) + \lambda_2 pc - \lambda_3 RM \ldots - \lambda_7 f_t\right) - h$ (8)

From (4) it follows that $\delta H = C$ (assuming that $O_t = O$). Therefore, taking logs gives;

$$d + h = c \text{ where } d = \log \delta. \tag{9}$$

From (5) it follows that, since $U_t = U_{t-1}$ in equilibrium, then $S = C$. (10)

Next we *assume* that, in equilibrium, $C = KU$. Therefore, taking logs gives;

$$c = k + u \tag{11}$$

From (9) and (11) it follows that;

$$h = k - d + u \tag{12}$$

whilst from (12) and (8) it can be seen that;

$$ph = \frac{1}{\lambda_2}\left(\lambda_0 + \lambda_1(y-n) + \lambda_2 pc - \lambda_3 RM \ldots - \lambda_7 f_t\right) - k + d - u \qquad (13)$$

Using (13) and (7) one can solve for *pn* by substituting for *ph* in the latter giving;

$$(\beta_3 + \gamma_3)\, pn = [A] - (\gamma_3 + \beta_1)\, u \qquad (14)$$

where A contains just exogenous terms.

Hence from (14) and (6) it can be seen that u is a function of exogenous variables alone. Obviously one can then substitute back to find equilibrium values of *c*, *h*, *ph* and *pn* where each is expressed in terms of exogenous variables.

Appendix 3: Data Sources

All data are seasonally unadjusted

C Private sector housing completions (GB), thousands. *Economic Trends* Annual Supplement, Table S9.

CC Construction (materials) costs index, 1975=100. Monthly Digest of Statistics, Table 18.6.

DEARN Differential between average earnings in manufacturing and services,£ per week. Interpolated from annual data published in the New Earnings Survey, Part A, Table 4.

DTAX Differential between the highest rate of income tax and the standard rate, % points. Financial Statement and Budget Report.

F Average family size, persons. Annual data from the Family Expenditure and General Household Surveys were smoothed using a Kalman filter package. Quarterly figures were then obtained by interpolation.

H Stock of owner-occupied housing, thousands. Interpolated from annual data published in *Housing and Construction Statistics*, Table 9.3 of 1974-84 annual edition.

HIG Household sector income gearing, %. This has been calculated using proxy for stocks of household sector debt multiplied by the relevant interest rates, all measured relative to household sector disposable income. Dicks (1987) gives details.

HO Number of households, thousands. Estimated from POP and F.

HOD Number of households due to demographic factors, thousands. Estimated using actual changes in population shares but assuming headship rates remain constant (see text, page 9). Dicks (1988a) gives more details.

M Stock of outstanding loans for house purchase to the personal sector (mortgages),£ mns. Figures for the flows from 1963 onwards are published in Financial Statistics, Table 9.2, broken down into lending by banks, building societies, local authorities other public sector and other. Stock data from 1975 onwards are published in *Financial Statistics,* Tables 9.4 and 14.4 (although the two sources do not reconcile perfectly). We have used the flow data to build-up our own stock estimates, tying them into the end-1986 stock data from Table 14.4. Annual figures prior to 1963 were taken from the Bank of England *Statistical Abstract (November 1970)* and interpolated to produce quarterly estimates. The poor quality of this data is noted in the Bank of England *Quarterly Bulletin* articles 'Personal Saving and Financial Investment: 1951-65' (September 1966) and 'Sector Financing Accounts: 1952-66' (December 1967).

MR Measure of mortgage rationing, £ mns. Two proxies were used. The first, based on Wilcox (1985), is derived by comparing the within sample forecast of the year produced by his mortgage equation with the forecast produced if the actual value of the loan-to-value ratio of first-time buyers is replaced by a 'market clearing' value. For our purposes we assumed a market clearing value of 0.9. The second measure, based on Hall and Urwin (1989), is simply the difference between predicted mortgage demand and supply as gauged by their disequilibrium model.

PC Retail prices index, 1975=100. *Economic Trends* Annual Supplement, Table 114.

PH Price index of second-hand dwellings, 1980=100. Until 1968Q1 a simple average, but a weighted average thereafter. Only annual data are published, but the Department of the Environment has kindly provided us with quarterly figures. These are based on data taken from the five per cent sample survey of building society mortgages run by the D of E in conjunction with the Building Societies Association (see articles in *Economic Trends* (October 1982) and the *BSA Bulletin (*October 1982)).

PL Price of land, £ per plot. Housing and Construction Statistics, Table 2.2. This covers private sector housing land at constant average density in England and Wales, and is the weighted average price per plot. Figures on this basis have been published bi-annually since 1967 (see *Economic Trends* (February 1974). Previously only annual data are available (see *Economic Trends* (February 1971). We have interpolated these data to give quarterly estimates.

PN Price index of new dwellings, 1980=100. *Economic Trends* Annual Supplement (1988), Table 62. Unlike the PH index this series is based on building society mortgages which have been approved (rather than completed). Note, however, that before 1988 a completions -based series was published in *Economic Trends*, and this is the series actually used by Ericsson and Hendry. We are forced to use the approvals-based series because we want to include data for the most up-to-date period. It should also be noted that neither our or Ericsson and Hendry's PN series are compiled from the 5% sample survey, but are calculated from information provided by a panel of building societies (covering about 90% of total assets until 1981 and about 85% thereafter). Although the Department of Environment do calculate a mixed-adjusted index based on the 5% sample survey the BSA's '*Compendium of Building Society Statistics*' (6th Edition) claims that this survey has a sufficiently small sample that 'not too much weight could be placed on the results'. We have, therefore, chosen to use the approvals-based index, which the BSA claim has a small sampling error.

POP Population (GB), Thousands. *Annual Abstract of Statistics*, Table 2.1.

POY Proportion of total personal income from sources other than wages, salaries and forces pay. Derived from figures published in *Economic Trends*, Table 10.

RM Mortgage rate (as charged by building societies), %. *Compendium of Building Society Statistics* (6th Edition) Table C2.

RSE Ratio of average earnings in London and the South East to the GB average. From 1971 onwards annual data have been used from the New Earnings Surveys. Prior to that date figures relating to manufacturing have been taken from *Historical Abstract of Labour Statistics, 1986 - 1968* and *British Labour Statistics Yearbook* (1969). These figures were then interpolated.

S Private sector housebuilding starts (GB), thousands. *Economic Trends* Annual Supplement, Table 59.

SO Share of population aged 60 or over (GB). *Annual Abstract of Statistics*, Table 2.3.

SY Share of population aged 25-35 (GB). *Annual Abstract of Statistics*, Table 2.3.

T Standard Rate of Income Tax, %. *Annual Abstract of Statistics and Inland Revenue Statistics.*

U Stock of uncompleted dwellings, thousands. Derived from the starts and completions data and linked in with figures published in *Housing and Construction Statistics*, 1977-1987, Table 6.1.

UD Stock of unsold (but completed) dwellings, thousands. A series which covered about three-quarters of all private sector housebuilding was published in *Housing Statistics* (and later in *Housing and Construction Statistics*) for the period 1966-1979 based on the private enterprise housing enquiry. These figures have been interpolated to give quarterly estimates. The CSO has also provided us with a series for unsold dwellings running from 1974 to 1987. The correlation between the two series over the period 1974-1979 is 0.97, suggesting that we should not introduce very large errors if we link the two together. For 1965 we have assumed that the stock was flat. The adequacy of this assumption was tested by using our model of UD (based on a sample beginning in 1966) to predict values for 1965. These indicated little variation in the stock for that year.

UR Unemployment rate (UK), %. We have used the total excluding school leavers as a percentage of the working population. Department of Employment Gazette, Table 2.1.

W Index of average earnings in the construction industry, January 1980 = 100. *Department of Employment Gazette*, Table 5.3. There are several breaks in the series due to changes in the SIC.

WT Mean daily air temperature at sea-level, degrees celsius. *Monthly Digest of Statistics*, Table 20.1.

Y Real Personal Disposable Income,£ mn (1980 prices). *Economic Trends* Annual Supplement, Table 19.

Appendix 4: Test Statistics

We use the following tests;

$\eta_1(.)$ Modified lagrange-multiplier statistic for testing against residual autocorrelation (see Harvey (1981)).

$\eta_2(.)$ Wald statistic for testing against the relevant unrestricted maintained model (see Harvey (1981)).

$\eta_3(.)$ Chow's statistic for testing parameter constancy (see Chow (1960)).

$\eta_4(.)$ White's statistic for testing against residual heteroscedasticity (see White (1980)).

$\eta_4^*(.)$ Engle's ARCH statistic for testing against residual heteroscedasticity (see Engle (1982)).

$\varepsilon_1(.)$ Lagrange multiplier statistic for testing against residual autocorrelation (see Harvey (1981)).

$\varepsilon_1^*(.)$ Ljung-Box statistic for testing against residual autocorrelation (see Ljung and Box (1979)).

$\varepsilon_3(.)$ Hendry's static 'forecast' statistic for testing parameter constancy (see Davidson, Hendry, Srba, and Yeo (1978)).

$\varepsilon_3^*(.)$ Hendry's dynamic 'forecast' statistic for testing parameter constancy. This is equivalent to $\varepsilon_3(.)$ except that when calculating the forecast predicted values (rather than actuals) are used for all lagged dependent variables.

$\varepsilon_4(.)$ Breusch and Pagan's statistic for testing against residual heteroscedasticity (see Breusch and Pagan (1979)).

$\varepsilon_4^*(.)$ Engle's ARCH statistic for testing against residual heteroscedasticity (see Engle (1982)).

$\varepsilon_5(.)$ Jarque and Bera's statistic for testing against non-normality in the residuals (based on skewness and excess kurtosis) (see Jarque and Bera (1980)).

All the $\eta(.)$ tests are F-tests, whilst the $\varepsilon(.)$ tests have chi-squared distributions.

Φ_7, Φ_8 and Φ_9 are tests for normality. Φ_7 is the Shapiro-Wilk statistic (see Maddala (1979)), whilst Φ_8 and Φ_9 are tests for skewness and kurtosis (see Kiefer and Salmon (1982)). Since these tests are less commonly used than the Jarque-Bera statistic (even though they have the advantage of being additive) we report their critical values for comparison.

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