A Forward-Looking Model of Housing Construction in the UK

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Abstract

This paper identifies and juxtaposes different approaches to modelling housing construction. The first two are based on dynamic marginal pricing considerations and emphasise adjustment costs and the necessary time to build, respectively. Importantly, both these models introduce some degree of forward-looking behaviour into the housebuilding decision. Both approaches are able to explain aspects of UK housing starts, 1970-90. Non-nested testing showed that the time-to-build story is more powerful in explaining the data set at hand. However, we have not been able to find any evidence in support of a third hypothesis, namely that quantity signals, proxied by turnover in the housing market, influence starts. The start to completion lag, in turn, is found to be affected by the interest rate representing the opportunity cost of delayed completions.

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1 Introduction and Summary

Being a sizeable and highly volatile part of GDP, housing construction always presents a challenging field for research. The present paper is an attempt to identify and test empirically three approaches for modelling it. All presume that the price of housing is determined by the *stock* demand and supply for it. Following Topel and Rosen's (1988) line of reasoning however, the *flow* demand, is not well defined, assuming that prices clear the market. Another view, see e.g. Ericsson and Hendry (1986), holds that the flow demand does exist.

A unifying element in the first two approaches to be examined is that they model construction depending on dynamic marginal price and cost considerations at the time when they were undertaken. Costs consist of wages, material costs and of the (lagged) price paid for land. It is argued in the empirical part that all are exogenous to the building activity.

Turning to their differences, the first approach (see Topel and Rosen 1988) centres on the fact that the cost function of a housebuilding firm exhibits adjustment costs: it is (nondecreasingly) costly to increase the level of output. This fact augments the standard rising supply function relating output to prices, introducing forward as well as backward looking dynamics.

The second approach focuses on the fact that construction is not instantaneous but takes several months to complete, we refer to this as the "time-to-build" approach, following Kydland and Prescott (1982). Accordingly, the relevant price is not the current one but rather a mix of current and expected future ones, the mix depending on the distribution of the start-to-completion lag. A similar argument applies to costs.

A third approach maintains that, apart from price considerations, quantity signals are also important in the determination of housebuilding starts.

In our work, we explore two indicators of *flow supply*, namely housing *starts* (S_t) and *completions* (C_t). We believe that starts and completions are determined only by housebuilders' considerations and we model them accordingly. Our theoretically based prior that demand factors and quantity signals should be irrelevant for these two variables is put to test and verified. Another indicator, housing *investment*, which is expenditure recorded only after sale, is beyond the scope of present analysis. In estimation we allow for the possibility that the price of *new* housing is to an extent endogenous.

Section 2 surveys the main ideas along which housing markets have so far been modelled and describes the above approaches in detail. Section 3 discusses the relevant econometric issues while 4 presents the estimation of the two main structural models (emphasising adjustment costs and the time to build) based on 1970-90 UK quarterly data (with minor variations according to the availability of variables). The dependent variable is *starts*. Hausman (1978) specification tests and Godfrey (1983) non-nested tests are also presented in this section. The latter indicates that the second model is more relevant in explaining the particular data set. That model yields an equilibrium elasticity of starts with respect to a permanent price shock of unity. We were not able to find any evidence that borrowing restrictions affecting housebuilders influence starts.

Section 5 integrates the preferred time-to-build equation into a generalised error correction model suggested in Callen, Hall and Henry (1990). In this context, the relevance of quantity signals is investigated but no evidence was found to support this hypothesis. This section marks a change in methodology from the previous one, namely a switch to more time series-oriented methods, for reasons to be explained.

The ratio of *completions* relative to *starts* (with a unit elasticity imposed) is subsequently analysed and found to be stationary. In this context, there is some evidence of the interest rate, as the opportunity cost of delayed completion, influencing the completion rate. There is again no role for quantity signals. In this respect, the message is quite clearcut and intuitively sound. The determination of housing starts and completions, as housebuilders' decisions, hinge only on price and cost considerations without reference to quantity signals.

2 Modelling the flow supply of housing

In classifying models of the housing market, one should start by making the distinction between models of *stock* and *flow* demand and supply. Most models belonging to what we could call an American tradition take the former line (see Arnott (1987), Olsen (1987), Smith *et al.* (1988) and Fallis (1985) for surveys of predominantly this approach). They analyse the market for a homogeneous good, called housing *service*, whose supply combines land and non-land inputs (housing stock of varying quality, energy, etc.) in a production function. In a schematic way, the interaction of stock demand and

supply determines the price of housing services; this, in turn, is a major factor determining the level of new construction.

British contributions to the literature, while analysing the stock demand , give more emphasis to flows (see, e.g., Ericsson and Hendry (1985), Hendry (1986), Milne (1990)).

There are relatively few separate models of the supply side of the housing market. A simple static model of new construction would relate quantity to price in the standard way:

$$I_t = \beta_0 + \beta_1 P_t + \beta_2 y_t + u_t \quad , \quad \beta_1 > 0 \qquad (1)$$

deriving from equalisation of price with marginal cost; y_t is a vector of exogenous "cost shifters" (basically land prices, labour and materials costs). Care must be exercised with respect to the underlying production technology. If that exhibits constant returns to scale, and if the time horizon is the long run (where the firm adjusts its inputs at will subject to their supply curves), then the marginal cost is independent of the quantity supplied. On the other hand, specifying the variables in (1) in logs amounts to using a generalised Cobb-Douglas production function:

$$I = Ax_1^a x_2^b$$

If we assume constant returns to scale (a+b=1), the long-run supply function will be horizontal at that price level where costs are just covered and quantity will be demand-determined. Strictly speaking therefore, in order to derive (1), we ought to exclude the possibility that a+b=1 in the underlying production function.

Poterba (1984) uses an equation like (1), augmented by the price of alternative projects and a measure of credit availability for builders, as the basis of empirical estimation of the value of one-family housing construction with US data (quarterly, 1974-82). Pursuing the idea that construction takes time to build, on which we elaborate below, he replaces current prices with the expected one-quarter ahead ones. Such a specification is reportedly supported by the data, but with widely ranging estimates of supply elasticity with respect to a price change. The price, price of alternative projects and credit variables perform in general well, in contrast with the cost index (construction wage) which is, on the whole, insignificant.

Ericsson and Hendry's (1985) work on house prices incorporates an equation like (1). The dependent variable is now completions which are also affected by work already started during past quarters. In Hendry (1986), this equation is given an explicit microeconomic justification and is extended to account for costs of unsold completions. This introduces demand-side considerations into this equation which is now the reduced form of a system. Empirical estimation with the ratio of completions over work in progress (lagged) indicates that the dynamics of the lagged dependent variable as well as price, cost, interest rate and income terms are important. Extending Hendry's work in several directions, Dicks (1990) reaches a similar estimated regresion as the one reported immediately above. Since this is effectively the reduced form of a demand and supply system, though, it is not easy to disentangle the influence of various price and cost elements on the building decision *per se* from that which occurs via demand. Finally, Giussani and Hadjimatheou (1990) once again incorporate the rising supply function (1) into a model of the UK house prices. Extentions account for the costs and availability of housebuilding, land, credit and the capital gains on structures. (The rationale for the latter term, however, is not so clear.) It is also suggested that the relation between completions and starts should be modelled. Milne (1991) models the supply of new structures relative to the total stock on a profitability term which is the difference between the house price and a minimum price depending on costs.

To our knowledge, the model of Topel and Rosen (1988) is the only one to have moved away from the rising supply function (1) in a fundamental way. They formalise the housebuilders' decision of how many new units to start so as to maximise their profits in the presence of adjustment costs. Their model is a completely supply side one, with all relevant demand side information being summarised in the price level of houses. That is assumed to clear the market, so there is no demand for housing investment. Further, since investment is a small fraction of existing stock, the general price level of housing is exogenous. This reasoning gives rise to a supply function for new homes relating quantity to a general house price index.

Topel and Rosen's firm maximises its current and discounted future stream of profits:

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

where C(.) is the cost function which depends positively on the level of construction, I(t), its change in time, $\dot{I}(t)$ due to adjustment costs and exogenous cost shifters, y(t).

This is a problem that can be solved by the calculus of variations. The resulting Euler equation is:

$$P(t) - \frac{\partial C}{\partial I} = r\frac{\partial C}{\partial \dot{I}} - \frac{d(\partial C/\partial \dot{I})}{\partial t}$$

whose discrete time counterpart is an augmented version of (1):

$$I_t = \beta_0 + \beta_1 I_{t-1} + \alpha\beta_1 E_t I_{t+1} + \beta_2 P_t + \beta_3 y_t + u_t \qquad (2)$$

where E_t is the expectation formed at time -t-, α is a discount factor and the rest of the notation is obvious. β_1 reflects adjustment costs whose absence (β_1=0) reduces the model down to the simple supply schedule relating quantity to price. It is worth noting that (2) would hold even in the presence of constant returns to scale, if adjustment costs increased with the level of production.

Using quarterly US data (number of housing starts, 1963-1984), Topel and Rosen (1988) estimate (2). They find that adjustment costs are a crucial consideration behind the housebuilding decision: A static model like (1) is rejected in favour of (2). Consequently, there are differences between short- and the long-run supply responses to price changes (with the difference increasing with adjustment costs) as well as differences in responses to transitory and permanent price changes. Their preferred estimate of the long-run average elasticity of investment to a permanent price increase is around 2.8.

A somewhat different approach to the building decision would focus on a different aspect of this activity, namely the fact that construction takes time. Thus, when the decision is made, the relevant price is that expected to hold in one or more future time periods. In order to capture this story, we build a simple variant of the time-to-build framework due in its present form to Taylor (1982) and also found in Kydland and Prescott (1982). The problem now should appropriately be formulated in discrete time. The firm seeks at time t=0 to maximise discounted future profits:

$$\max \sum_{t=0}^{\infty} \alpha^t \left(P_t F_t - C_t(I_t, y_t)\right)$$

F_t are the completed projects. The solution of this expression is:

$$\sum_s \alpha^s f_s P_{t+s} - \frac{\partial C_t(I_t, y_t)}{\partial I_t} = 0$$

where f_s is the proportion of projects that is completed -s- periods after start (assuming that this is invariant with respect to time). This expression suggests a different augmented version of (1):

$$I_t = \beta_0 + \beta_1 \Sigma\alpha^s f_s E_t P_{t+s} + \beta_2 y_t + u_t \qquad (3)$$

It is perhaps worth noting that the coefficients of $E_t P_{t+s}$ do not sum to unity.

A salient feature of the above approaches are their common implicit assumption that the market for existing houses always clears. Consequently, the housebuilders' decision of how much to construct relies only on price signals, current or future. This contrasts sharply with the view that quantity signals are at least as important. Quoting Okun (1981, p. 169): "The analysis of this chapter stresses that the vast majority of sellers are price makers. [...] In principle, they could execute that task [putting price tags on their products] by mimicking the auctioneer in an effort to "clear markets". [...] But, in practice, observed pricing behaviour is a vast distance from such do-it-yourself auctioneering..." If this the case with product markets in general, one would expect that it applies *a fortiori* to the housing market. There, individual units are far from identical, with size, quality, environmental quality and spatial fixity being only the most obvious factors that mark deviations from the competitive market paradigm (see Arnott (1987) for an exhaustive discussion). Since price *making* is to some extent important, and since it cannot be expected to clear the market entirely at least, then this line of reasoning makes us expect that quantity signals also play a role in the construction decision or, at least, that the flow supply should be *jointly* modelled with the flow demand. This view is compatible with the observation that vacancy rates in the market are counter-cyclical (Arnott (1987, p. 982)) and that construction of new units reacts slowly to both market prices and vacancy (Wheaton (1990)).

In our estimation, we shall focus on supply only, while using an alternative proxy for quantity signals which will capture demand-side considerations. This strategy reflects our prior that, for starts and completions, it is housebuilders' considerations (whether adjustment costs or profitability, etc.) that are the crucial factors. Production is for the most part not tailored to any specific client (see Barlow and King (1991) from a full discussion from an institutional viewpoint). The fact that unsold completions are unwanted can be tested by the relevance of quantity signals as proxied by turnover in the housing market.

Given this potential endogeneity in our empirical analysis of starts, we instrument the price of new housing. In this way, we are not inconsistent with the existence of quantity signals and the possibility that price is influenced by developments in the market for *new* housing.

3 Econometric issues

In this and the next section, we embark on econometric analysis of the UK housing starts, S_t (in thousands), based on equations (2) and (3) of the previous section. Quarterly UK data (70Q1-90Q2) were used. The definitions and sources of data are reported at the end. Charts of the most important variables are also presented. All variables, except the interest rate, are real (deflated by the CPI) and appear in logs. Seasonal dummies were included in all the models. Finally, the Halifax Building Society price index of *new* houses, P_t, was used. This index presents the advantage that it is hedonically adjusted, from 1983Q1 onwards, to take account of changes in the quality of new houses.

The expectations terms in (2) and (3) were replaced by their realised values and were instrumented. As Topel and Rosen (1988) correctly note, this implies that the relevant error term is now

$$\eta_t = u_t - k\varepsilon_{t+1} \quad , \quad \varepsilon_t \equiv S_{t+1} - E_t S_{t+1}$$

where ε_t is orthogonal to period -t- information and k depends on the particular equation. The structure of this composite error term entails autocorrelation of at least first order since the covariance at lag 1 is

$$E(\eta_t \eta_{t-1}) = E(u_t u_{t-1}) - kE(u_t \varepsilon_t)$$

which is nonzero even if the original disturbances are white noise because inovations u_t are part of the contemporaneous forecast error ε_t. Genuine autocorrelation in u_t can also be present resulting in higher order correlation patterns for η_t. It can be shown (see Pesaran 1987) that, in our case and if u_t is white noise, the appropriate parameterisation of η_t is as an MA(1) process. The significance of these correlations will be tested empirically.

The above reasoning calls *a priori* for explicit autocorrelation correction, rather than simply enriching the dynamics of the equation. It suffices to note here that if autocorrelation correction is undertaken via a quasi-differencing iterative process, then ε_t would appear in the regression. This implies that even current exogenous variables have to be instrumented because, being in the information set Ω_t, they affect ε_t through their innovations. Accordingly, at some expense of efficiency, only lagged variables have been used as instruments in the adjustment costs model. For reasons of comparability, the same set of instruments has been used in the time-to-build model.

Another, somewhat related, issue is the exogeneity of the relevant regressors in (2) and (3). According to the view embodied in those theories, the price of housing is determined by the *stock* demand and supply and is therefore exogenous to construction which supplies within every time period only a small fraction of the housing stock. Things are less clear with respect to the price of *new* housing (P_t), however, as the above argument does not hold. Thus, it seems safer to instrument P_t. The same question arises over the cost index in the housing construction. We leave that to be resolved empirically by use of the Hausman (1978) test. Finally, the lagged endogenous variable S_{t-1} may also be correlated with the error term u_t if the latter is autoregressive. This possibility will also be tested. If it appears to be true, it will further strengthen the case for explicitly correcting for autocorrelation. Moreover, if an iterative method for correction of autocorrelation is used, the above correlation is not a problem for estimation since only a white noise element appears on the right hand side after quasi-differentiation.

4 Empirical results: structural models of starts

We begin our reports of empirical findings with Hausman (1978) tests of the exogeneity of some of the regressors. The variables to be tested were the cost of construction and the lagged endogenous variable, the rationales having been explained above. The test is a variable addition one, requiring running the regression (the dependent variable being starts):

$$y = x_1\beta_1 + x_2\beta_2 + \hat{x}_1\alpha + u$$

where x_1 are the variables suspected for endogeneity, x_2 are variables known to be exogenous and $\hat{x}_1$ are fitted values of x_1 from a set of instruments which includes x_2. In this case, a test of H_0: $\alpha=0$ is a test of errors in variables. The instrumenting equations, using exogenous demand shifters, generate high R^2 (.98 for the cost variable and .84 for the lagged starts) so that the possibily of accepting exogeneity while it is wrong (error Type II), is virtually eliminated (see Nakamura and Nakamura 1980). We first test for the joint exogeneity of $Cost_t$ and lagged starts and then for $Cost_t$ alone. We

present below the statistics summarising the validity of the null of $\alpha=0$:

Statistics	$Cost_t$, S_{t-1}		Cost	
LM	11.74	χ^2_2	.030	χ^2_1
LR	12.70	χ^2_2	.030	χ^2_1
F	5.85	F(2,68)	.027	F(1,72)

One notices that the statistics of the first column invariably exceed even the 1% critical values whereas those of the second one are insignificant at 5%. We conclude, then, that the hypothesis that $Cost_t$ is exogenous cannot be rejected, but that the joint one with lagged starts is not supported by the data. In other words, $Cost_t$ is a valid regressor but care has to be exercised with lagged starts when there is evidence of autocorrelation.

A final note concerns the $Pland_t$ variable. It is a common observation (Evans (1988), Holmans (1990), Barlow and King (1991)) that builders hold "land banks" for some time before they actually engage in property development. Thus, the current land price may not be indicative of the land costs that a builder incurs. Besides, the data shows a high correlation of land and new house prices (see the above references). This is probably the reason why $Pland_t$ had a positive coefficient wherever it was tried as a regressor. Therefore, it seemed safer to include the first lag of $Pland_t$ as an exogenous variable in the regressions so that the need for Hausman-testing does not arise.

Table 1 reports the results of estimating the adjustment-cost model (2). Instrumental Variables (IV) estimation of the model augmented with the second and fourth order lag of the dependent variable (not shown here) produced estimates for the LM test for autocorrelation (first and fourth order) exceeding by far their critical values. It seems consequently that autocorrelation correction of fourth order is necessary. This is *prima facie* evidence against the original adjustment-costs specification, since the implication is, as discussed above, that even the original error term u_t is serially correlated.

For this reason as well as due to the fact that IV estimation coupled with MA(4) error correction typically fails to converge, we used the IV method combined with the Gauss-Newton iterative procedure (method due to Sargan 1959)

Table 1

IV/AR(4) estimates of the adjustment-costs model. Dependent variable: housing starts.

Variable	Model 1	2	2*	3	3*
Intercept	-.461	.084	.187	-.053	.083
	(-.424)	(.148)	(3.206)	(-.119)	(1.240)
P_t	.177	.186	.072	.104	.085
	(.556)	(.688)	(2.080)	(.614)	(2.179)
S_{t-1}	.547				
	(5.399)				
ES_{t+1}	.625				
	(5.033)				
$S_{t-1}+aES_{t+1}$		.555	.521	.547	.532
		(19.485)	(463.905)	(19.123)	(210.670)
$Cost_t$	.156			.048	.003
	(.333)			(.241)	(.082)
$Pland_{t-1}$	-.075			-.042	-.038
	(-.604)			(-.780)	(-3.306)
$(2Cost_t+Pland_{t-1})/3$		-.149	-.076		
		(-.628)	(-2.658)		
r_t	.002				
	(.225)				
π_t	.271				
	(.712)				
rr_t		-.002	.000	-.001	-.000
		(-.620)	(1.239)	(-.540)	(-.174)
CR_t	-.000				
	(-.000)				
ρ_1	-.292	-.257	-1.000	-.403	-1.000
	(-1.326)	(-1.364)	(-30.522)	(-2.603)	(-30.709)
ρ_4	.502	.532			
	(1.284)	(1.550)			
$\bar{R}^2$	.83	.84	.90	.87	.92
Sargan's	χ^2_{13} 2.64	χ^2_{17} 4.00	NA	χ^2_{17} 6.90	NA

Note: t-statistics appear in parentheses. * indicates IV/MA(1) estimation. Seasonal dummies were included everywhere. Instruments include S_{t-1}, lags of prices, cost, income, r_t, π_t and of other exogenous variables and a time trend. The lagged endogenous variable was included at perhaps a minor cost on consistency in order to improve efficiency. Sample: 70Q3-90Q1.

to account for first and fourth order autoregressive errors, as a feasible approximation to the unknown composite error process. We also report some results of IV/MA(1) estimation (essentially the method of Hayashi and Sims

1983) which are rather similar with those of IV/AR(4) estimation with enhanced t-statistics. Only one lag of S_t was used on grounds of theory and parsimony.

π_t is inflation rate in the past four quarters, CR_t is the ratio of credit supplied to (total) construction over total construction and the rest of the notation is obvious. The rationale for inclusion of the credit variable is an argument, articulated by Poterba (1984) and Jaffee and K. Rosen (1979), holding that credit rationing may have affected not only buyers but also the suppliers of new houses. The nominal interest rate r_t also gives an estimate of the cost of credit.

Column 1 shows the estimates of the unrestricted model. Only the lag and lead of S_t of appear significant (and positive) in the IV/AR(4) models. We note the wrong sign and lack of significance of the coefficient of $Cost_t$ in all the equations. We therefore did a Wald test on the (joint) validity of a number of restrictions. These were (a $\wedge$ denotes a coefficient):

$$\hat{CR} = 0, \quad \hat{r} = -\hat{\pi}/100, \quad \hat{Cost} = 2\,\hat{Pland}, \quad \hat{ES}_{t+1} = \alpha\hat{S}_{t-1}$$

The meaning of the first two restrictions is apparent whereas the last one was referred to in the preceding section. The third one presumes, for convenience and in contrast to the caveat discussed in section 2, that the underlying technology is the constant- returns- to-scale Cobb-Douglas. In this case, the coefficients of the factor prices are their shares in total production, modified by the (common) coefficient that the adjustment-cost model superimposes on them. Thus, if we assume (see Evans (1988)) that land costs account for one third of the final product and non-land ones (including normal profits) for the rest, the third restriction above results. The estimated Wald statistic is .657, way lower than its critical value of $\chi^2_4 = 9.49$. Thus, the restrictions cannot be rejected and are indeed embodied in the regression appearing in column 2.

That equation appears to fit the data marginally better. All the coefficients enter with their expected signs. Again, the joint coefficient of the dynamic elements of S_t is by far the most significant, whereas the others fail to exceed their critical values. However, one should be careful not to dismiss them immediately because exclusion of relevant variables from an equation may lead to inconsistent estimates of the coefficients. Finally, model 3 (IV/AR(1)) is presented in such a form that it is amenable to non-nested testing which is to be carried out later. An important observation with respect to all the estimated equations of Table 1 is that the dynamics, as delivered by the coefficients of S_{t-1} and ES_{t+1}, imply one unstable root to the equation, thus giving the required saddlepath stability condition (see Sargent (1979)).

Table 2 reports the IV estimates based on the "time-to-build" model, (3). The current and three leads of the expected price of new housing enter as regressors (all instrumented) alongside all the exogenous variables of Model (2). S_{t-1} is intended to enhance the dynamic structure of the model. No autocorrelation correction was needed this time as there was no evidence of autocorrelation either of first or fourth order. This feature seems to be an advantage over the results of Table 1. Columns 1 to 3 present the models from the most general to the most restricted.

Searching for simplification, two Wald tests were performed on the validity of two sets of restrictions. First, the significance of the CR_t variable and whether the *real* interest rate could usefully replace the nominal interest rate and the inflation rate were jointly tested. The relevant estimated statistic was 7.81, higher than the 5% critical value of $\chi^2_2 = 5.99$, signifying a high cost for imposing the restrictions.

Second, we tried to impose some structure on the coefficients

of the expected leads of P_t. Provided we can form realistic assumptions about -α- and f_s, equation (3) can be of guidance. Given that the average building firm is small to medium, it is reasonable to assume a quite high coefficient of time preference of 0.1, implying a discount factor of 0.91. Further, the CSO *Housing and Construction Statistics* 1976-86 gives an estimated lag from start to completion of around 16-18 months, which is probably a bit more than the average (see also Hendry (1984); Hillebrandt (1984, Table 3.4) maintains that the construction phase of private housing construction is about .5 - 1.5 years).

Therefore, we hypothesise that the distribution of completions is 5%, 10%, 15%, 20% and 25% within the current, 1st, 2nd, 3rd, and 4th future quarters from the time of start. In doing so, we are also assuming for simplicity that this distribution is constant over time. Hendry (1986, pp.214-15) contains a discussion of empirical work on the determinants of the distribution.

Table 2

IV estimates of the time-to-build model.

Dependent variable: housing starts.

Variable		Model 1	2	3	4
Intercept		1.921	1.819	2.982	3.072
		(1.295)	(1.419)	(4.181)	(4.048)
S_{t-1}		.490	.475	.470	.473
		(4.455)	(4.705)	(4.828)	(4.974)
P_t		.318			
		(.127)			
EP_{t+1}		-.445			
		(-.055)			
EP_{t+2}		1.016			
		(.252)			
EP_{t+3}		-2.145			
		(-.401)			
EP_{t+4}		1.481			
		(.548)			
$\sum_{s=0}^{4} \alpha^s f_s EP_{t+s}$			.533	.884	.944
			(1.099)	(2.103)	(2.117)
$Cost_t$		.032	.113	-.330	
		(.056)	(.223)	(-1.046)	
$\sum_{s=0}^{4} c_s \alpha^s Cost_{t+s}$					-.453
					(-1.096)
$Pland_{t-1}$		.066	.085	-.029	-.034
		(.450)	(.715)	(-.383)	(-.455)
r_t		-.038	-.039	-.039	-.038
		(-3.020)	(-4.246)	(-4.687)	(-4.515)
π_t		.084	-.059		
		(.154)	(-.124)		
CR_t		-.156	-.164		
		(-1.034)	(-1.182)		
$\bar{R}^2$		.79	.78	.78	.78
Sargan's		χ^2_{11} 12.65	χ^2_{14} 13.81	χ^2_{17} 15.94	15.78
LM test for serial	χ^2_1	.00	.02	.16	.15
correlation of the residuals	χ^2_4	7.99	6.60	7.62	7.45
RESET test	χ^2_1	1.01	2.58	2.46	2.58
Normality	χ^2_2	5.87	5.19	8.13	8.64
Heteroskedasticity	χ^2_1	1.24	2.86	3.00	2.88

Note: t-statistics appear in parentheses. Seasonal dummies were included everywhere. The instrument set is the same as the one reported in Table 1. Sample: 70Q3-89Q2.

We think that it is unrealistic that any sensible forecasts are formed for more remote future quarters, particularly by small firms, and we arbitrarily truncate the distribution there. The product $\alpha^s f_s$ of eq. (3) then is 0.05, 0.091, 0.12, 0.15, 0.17 for the same quarters. The Wald statistic that the coefficients of current and expected new houses prices are bound by restrictions implied by these numbers is .58, much lower than χ^2_4=11.67.

In other words, the data sustains the latter set of restrictions which are embodied in the estimates of column 2. Minor changes occur in the signs or the t-ratios of the coefficients which are still, for the most part, insignificant. All the diagnostics also appear acceptable, but some signs, notably those of $Cost_t$ and $Pland_{t-1}$, are still not the expected ones. This led to the search for further simplification. The estimate for the Wald statistic for the joint restrictions that π_t and CR_t are insignificant is 2.18, lower than the critical χ^2_2=5.99.

Column 3 of Table 2 presents the estimates of the most restricted model. The signs of the coefficients and the diagnostics are all acceptable, with the exception perhaps of the indicator for normality of the residuals which is slightly above its 5% critical value. The composite price variable is significant, as is the *nominal* interest rate which summarises the cost of borrowing for builders, since the revenue from construction is now explicitly assumed to be partially reaped in the future. The cost variables are not significant but it is probably best not to discard them for fear of misspecification, as was also discussed above.

A model with a forward convolution of costs is presented in column 4. The details on how the weights of forward costs were calculated appear in Appendix A. The model gives virtually identical estimates with those of column 3 with a marginal improvement on some of the diagnostics. The diagnostic of normality showed a worsening, though, and this was the reason for selecting the model of column 3 for the non-nested test performed between the adjustment-costs model (column 3) and the time-to-build one.

We follow Godfrey (1983) in performing a non-nested test. This requires white noise residuals, so autocorrelation correction was done wherever necessary, and the model was rewritten in quasi-differenced form. The test, essentially a variable addition test, requires estimating the two alternative models:

$$M_i: \quad y = X_i\beta_i + \varepsilon_i, \quad , \; \varepsilon_i \sim N(0,\sigma_i^2 I), \quad i=1,2$$

When the IV technique has to be used, a common set of instruments must be employed. Denoting the estimates as b_i and the theoretical values of X_i regressed on the set of instruments as $\hat{X}_i$, one then has to run the augmented regression:

$$y = X_i\beta_i + (\tilde{X}_{ij}b_i)\vartheta_i + u_i, \quad i,j=1,2, \quad i\neq j$$

where $\tilde{X}_{ij}$ is the residuals of $\hat{X}_i$ regressed on $\hat{X}_j$. The statistical validity of the estimate of ϑ_i indicates that the M_j hypothesis has much to contribute to this regression (M_i) and therefore should lead to the rejection of M_i. Cross-implementation of this procedure reveals which hypothesis is more of interest. However, this stops short of implying that one is statistically superior to the other (see Godfrey (1983, p. 356)).

Running the augmented regression described above with reference to equations 3 of Table 1 and 3 of Table 2 (adjustment-costs and time-to-build models) produced estimated t-statistics of ϑ_i of 7.098 and -2.304, respectively. On these grounds and noting the potential misspecification implied by serial correlation in the adjustment-costs model, we conclude that the time-to-build story has a greater empirical relevance but it is also worth noting the complementary nature of the two stories.

Table 3 makes an attempt at bringing together the adjustment-costs and time-to-build models by basically introducing the convolution of current and future prices into the structure of Table 1, in order to highlight the complementarity of the two approaches. We proceed from column 1 to 3 in a general-to-specific manner. The restrictions are all accepted by the relevant Wald tests. Seasonal dummies were included in all equations. The instrument set was the same as previously. We mostly obtain the correct signs for the coefficients but several of them are insignificant.

Table 3

IV/AR(4) estimates of a hybrid model.

Dependent variable: housing starts.

Variable	Model 1	2	3	3^*
Intercept	-.022	-.099	-.000	.136
	(-.038)	(-.202)	(-.000)	(3.074)
S_{t-1}	.485			
	(4.333)			
ES_{t+1}	.562			
	(6.857)			
$S_{t-1}+aES_{t+1}$		.535	.525	.515
		(15.827)	(24.264)	(566.358)
$\sum_{s=0}^{4} \alpha^s f_s EP_{t+s}$	.099	.059		
	(.330)	(.230)		
$\sum_{s=0}^{4} \alpha^s f_s EP_{t+s} - (2Cost_t + Pland_{t-1})/3$			.003	.032
			(.033)	(1.696)
$Cost_t$	.039	.075		
	(.162)	(.372)		
$Pland_{t-1}$	-.018	-.019		
	(-.370)	(-.423)		
rr_t	-.001	-.001	-.0004	.000
	(-.369)	(-.450)	(-.204)	(1.187)
ρ_1	-.267	-.331	-.307	-1.000
	(-1.140)	(-2.123)	(-2.089)	(-29.005)
$\bar{R}^2$	.85	.87	.87	.88
Sargan's	χ^2_{16} 6.31	χ^2_{17} 7.29	χ^2_{17} 7.66	NA

Note: t-statistics appear in parentheses. * indicates IV/MA(1) estimation. Seasonal dummies were included everywhere. The instrument set was the same as the one reported in Table 1. Sample: 70Q3-89Q2.

We finally highlight the estimates of the time-to-build model (in particular that of equation 3, Table 2) by presenting the implied elasticities of starts with respect to a house price shock, *ceteris paribus*. We first present the equilibrium ones (i.e. total response after all adjustment has seized) with respect to a price shock which is expected to last -τ- quarters. They are given by:

$$\frac{\partial \bar{S}}{\partial P} = k \, \Sigma \alpha^s f_s \quad , \quad k \equiv 1.668$$

since the variables are in logs. This expression yields .08, .24, .44, .69, .97 for a shock lasting only during the current or 1, 2, 3, i, i ≥ 4, quarters additionally. It is worth emphasising here the long-run elasticity of approximately unity with respect to a permanent shock. This contrasts sharply with Topel and Rosen's (1988) estimates from US data of a very high long-run elasticity whose order is between 2 and 24.

We also illustrate the adjustment process by considering the characteristic equation implicit in the dynamics of that model. We fix the free constant arbitrarily at -1. For the case of a permanent price shock, the elasticities by quarter are .5, .75, .87, .92, .95, .97 for quarters 1, 2, 3, 4, 5, ∞. We note that half of the adjustment is done within the first quarter and virtually 90% of the total response has been realised in the first three quarters.

5 Error correction models: the role of quantity signals

The issue of quantity signals is related to the importance of a demand schedule for housing construction. A relevant formulation is that of Hendry (1986) who postulates that the builder's utility function, among other things, penalises *any* deviations of actual completions from demanded ones. We do not, however, adhere to such a specification because it represents the relevant costs as symmetric. While it is probably expensive to store unsold completed units, there is no *a priori* cost for builders making less completions than required. Accordingly, a more appropriate formulation, seems to be the maximisation of the representative agent's profits subject to the constraints that in any period in time, actual completions not be higher than required ones.

Such a formulation points to future required completions as determinants, among other things, of current starts. We use (the log of) turnover in the housing market (more specifically "Particulars Delivered for Stamp Duty collection" to the Inland Revenue for 77Q2-90Q2) as an indicator of how buoyant the market is. This series seems to us to be the best directly observable proxy for quantity signals. Thus, we eschew specifying (perhaps more ambiguous) demand functions for new construction.

This section marks a change in our methodology: The empirical work will be cast in a time series-oriented framework. This is necessitated by the fact that turnover in the housing market (T_t), our proxy for quantity signals, cannot possibly be entered into the structural models because it is expected to be collinear with (average) house prices. This is also the case with *new* house prices, too: the estimated correlation coefficient between the two is roughly .40. The suspected problem of multicollinearity manifests itself in producing a negative sign for the price estimates in a time-to-build model. Partly on *a priori* grounds, we therefore discarded turnover as a regressor in that context.

Thus, it seems a safer strategy to investigate the relevance of T_t in cointegration analysis and Error Correction Models. On the other hand, structural models cannot appropriately be investigated in such a framework because of the lag structures involved there. So, despite the fact that inference based on nonstationary variables is somewhat problematic (see Stock and Watson 1988), we have not employed time-series models so far. Below, we round out our previous discussion by presenting the time-series formulations corresponding to the models of the previous section.

As a first step, we examine the order of integration of a number of series. Below, we list their DF and ADF statistics.

Given a critical value of -2.88 (Fuller 1976, p.373), at first sight, there is no clear cut answer as far as starts are concerned. An F-test reveals that the more general dynamics on which the ADF(6) estimates are based are preferable to those underlying the ADF(4) estimates. Consequently, we accept that this variable is non-stationary.

Error Correction Models (ECM) have been proposed (see, e.g., Nickell

(1985)) as convenient formulations combining short-run

Table 4

On the order of integration of variables

	DF	ADF(1)	ADF(2)	ADF(3)	ADF(4)	ADF(6)
S_t	-3.91	-3.69	-2.56	-1.97	-3.43	-2.22
C_t	-3.19	-2.16	-2.08	-1.46	-2.09	-2.08
I_t	-3.61	-3.06	-1.97	-1.89	-2.34	
P_t	-0.47	-1.81	-2.27	-2.03	-1.81	
$Cost_t$	-1.98	-1.88	-2.11	-2.29	-2.50	
$Pland_t$	1.22	-0.92	-0.81	-1.29	-1.42	
T_t	-2.25	-2.05	-1.37	-1.29	-1.66	

Sample: 70Q2-90Q2 (for the first two rows) and 69Q2-90Q2 (for the rest).

dynamics with longer-run relationships delivered by theory. The latter can be ascertained by cointegration analysis, which is proved formally to be equivalent to ECM (see Engle and Granger (1987)). An additional appeal of the ECM is that it can be derived from a minimisation of a loss function featuring adjustment costs as in Nickell (1985). In this vein, we begin by identifying a long-run, equilibrium relationship between S_t (starts), P_t and costs. We list the cointegrating equation below, along with the relevant diagnostics:

$$S_t = 4.745 + .590P_t - .665Cost_t + .102Pland_t - .069r_t \qquad (4)$$

$\bar{R}^2$: .54, DF: -6.087, ADF(1): -5.848, ADF(4): -5.243

Comparison with the critical value of (approximately) -4.59 (Engle and Yoo (1987)) reveals that the series are cointegrated.

In order to generate an ECM, we employ the following adjustment cost function, to be minimised with respect to S_t:

$$Q = \sum_{t=1}^{\infty} [\alpha(S_t^{*} - S_t)^2 + \beta(S_t - S_{t-1})^2] \qquad (5)$$

The term is employed here in a wider sense than the one by which we have used it so far. It implies costs deriving from being away from a (starred) target level of production as well from changing the level itself. Notice that latter future expectations. The important result here is the poor performance of the turnover variable, T_t. Not only is it insignificant, it appears also with a sign opposite to what is expected. Roughly the same results were achieved with a weighting scheme which is in accordance with the distribution of completions in future quarters as has been discussed above; effectively, such a scheme weights more the more remote expectations. Since the initial results were not encouraging, we did not embark on a more complete general-to-specific search.

Possibly, turnover in the market is not the only proxy of quantity signals for housebuilders. However, it seems to us that it is the most important and directly observable by both the builder and the econometrician, given the general absence of specific demand contracts (Barlow and King 1991). On these grounds, we must discard the role of quantity signals in affecting starts.

6 Error Correction Models of completions

Our work so far has been concerned with modelling housing starts. It is also interesting to analyse the rate at which starts become a finished product, i.e. completions (quarterly UK data, in thousands; 70Q1-90Q2). Given the constraint that, allowing for dropouts, the flow of completions should in the long run be equal to the flow of starts, this immediately suggests that we use cointegration analysis. A useful concept in this context is multicointegration (Granger and Lee 1989) whereby the cumulative difference of two flows (starts and completions in our context) is cointegrated with these two series, all in levels. The implication is in this case that unfinished stock is in the long run kept constant as a ratio over either of the flows.

The method requires first that the relevant flows are nonstationary. Table 4 shows that this is indeed the case for S_t and C_t in logs; the results for the series in levels (not shown here) are similar. The accumulated unfinished stock series defined as: $Q=Q_{-1}+(S-C)$, in levels, is also I(1): DF=-0.43, ADF(1)=-0.79, ADF(4)=-2.18. It is worth mentioning here that if Q were slightly modified to: $Q'=Q'_{-1}+(S-C)-1.6732$, where 1.6732 is the sample mean of S-C (expressed in thousands), it would yield DF=-1.39, ADF(1)=-1.91, ADF(4)=-3.05. Given that $\Delta Q'$ is not white noise, ADF(4) probably carries more accurate information so that the series must be considered as stationary (critical value: -2.89, taken from Fuller 1976). The message is that the

unfinished stock is stationary if we allow for a number of units that are started but never finished.

Multicointegration is obtained by regressing S_t on intercept and Q_t (defined above); the residuals yield: DF=-3.63, ADF(1)=-3.46, ADF(4)=-3.40. Compared with the critical=-3.41 of Engle and Yoo (1988), this denotes that starts are largely determined so as to be a constant ratio over the resulting stock in progress. Despite being I(0), Q'_t also appears to have "explanatory" power over S_t and C_t. The resulting statistics from regressing S_t on intercept and Q'_t are: DF=-3.86, ADF(1)=-3.51, ADF(4)=-3.85 and from regressing C_t on intercept and Q'_t are DF=-4.37, ADF(1)=-2.98, ADF(4)=-2.71, ADF(5)=-3.62. This establishes multicointegration more fully and points out the importance of unfinished stock.

It is also useful to look at the ratio C_t-S_t (in logs), where we are imposing a long-run elasticity of one. The ADF test gave the following statistics: DF=-6.48, ADF(1)=-7.40, ADF(2)=3.51, ADF(3)=-2.52, ADF(4)=-4.01 (critical: -2.89), giving quite strong evidence of stationarity. This implies that completions over starts is constant in the long run (so that, again, the rate at which units are started but not finished is constant) and the elasticity of completions with respect to starts is unity.

Seeking to explore the short-run dynamics of the ratio (in logs), we present an appropriate parsimonious representation of it:

$$(C-S)_t = \underset{(-6.395)}{-.327} + \underset{(3.791)}{.135}\,D1 + \underset{(4.154)}{.165}\,D3 + \underset{(10.317)}{.388}\,D4 + \underset{(3.015)}{.013}\,r_t + \underset{(5.834)}{.528}\,(C-S)_{t-1}$$

$\bar{R}^2$ = .66, A/C (χ^2_4): 1.05, Norm. (χ^2_2): 1.42

The diagnostics are all within the acceptance regions. The above equation serves to highlight the low serial correlation of $(C-S)_t$ as well as the positive influence of the interest rate (as the cost of keeping stock) on the speed of completion. Introducing new house price inflation and the difference in turnover, ΔT_t (individually) in the equation yields negative, entirely insignificant coefficients for both and little other change. So, it appears that there is no role for quantity signals in this formulation.

7 Conclusions

In this paper, we have dealt with the determinants of UK housing construction, 1970-90. Two indicators are analysed, housing starts and completions. Throughout, we focus only on the supply schedule, thus avoiding the controversy of whether a demand schedule for housing construction is meaningful. Our estimation, however, can readily accomodate the possibility of demand being relevant, which has moreover been tested.

With respect to housing starts, we have identified and tested three approaches. The first, introduced in the context of housing markets by Topel and Rosen (1988), emphasises adjustment costs of changing the level of output. The second, usually associated with Kydland and Prescott (1982), highlights the fact that construction takes time so that a sequence of future as well as current prices are important for housebuilders. Both the above approaches involve an element of forward-looking behaviour, although that manifests itself empirically in different ways in the two models.

It appears that both models can explain aspects of the data. In general, the costs elements of housebuilders' decisions do not show up very strongly. House prices (current and future) and nominal interest rates are highlighted in the time-to-build model, the latter influencing negatively the undertaking of construction work. There is no evidence that the availability of credit has an effect on the decision of housebuilders.

Importantly, the original adjustment-costs model shows autocorrelation of fourth order which reveals potential misspecification. On the basis of this and the results of a Godfrey (1983) test, we argue that the time-to-build story is empirically more relevant for the data set at hand. The implied elasticity of starts with respect to a permanent house price shock resulting from this model is close to unity.

Demand-side considerations surface when we investigate a third story, the relevance of quantity signals. Institutional analysis (Barlow and King 1991) suggests that housebuilders do not generally tailor-make construction to specific demand. This points to general activity in the housing market (measured by turnover) as the most relevant quantity-signal proxy. The hypothesis that quantity signals do not play any role is verified in the context of time-series methods by the failure of turnover to enter a cointegrating equation or a forward-looking error correction model.

Finally, completions have been connected to starts via the concept of multicointegration (Granger and Lee 1989). This reveals that, apart from a constant rate by which started units are never completed, the unfinished stock is in long-run proportion to both starts and completions. The long-run elasticity of completions with respect to starts is unity, with the short-run response influenced positively by the interest rate, as the opportunity cost of keeping stock, but not by quantity signals.

Appendix A

The weighting of the forward convolution of costs of equation 4, Table 2 is obtained as follows. We first assume that the (constant over time) distribution of completions out of units started in a given quartet are 5%, 10%, 15%, 20%, 25%, 15%, and 10% within the current and the 6 subsequent quarters. Then, the proportion of work started in a given quarter and carried out specifically after -s- quarters, which we call c_s, is 30%, 25%, 20%, 15%, 10% in the current and the 4 first quarters. This is obtained by dividing every percentage of projects taking -s- quarters to complete by -s- and adding up for all -s-. Again, we are only concerned in weighting only the expectations of costs in the 4 quarters ahead.

We further write total costs of starts as:

$$C(S_t)=\Sigma\alpha^s C(A_{t+s}, y_t) \tag{A1}$$

where y_t are the "cost shifters", A^t_{t+s} is the volume of work in progress out of starts at a given -t- and C(.) is assumed invariant over time. Minimising $C(S_t)$ and using (A1) yields:

$$\frac{\partial C(S_t)}{\partial S_t} = \Sigma\alpha^s \frac{\partial C(A^t_{t+s}, y_t)}{\partial S_t} = \Sigma\alpha^s c_s \frac{\partial C(S_t, y_{t+s})}{\partial S_t}$$

where A^t_{t+s}, can, by the above reasoning be written as $c_s S_t$. The caveat of the text notwithstanding, we have for convenience assumed a cost function linearly homogeneous in output.

This suggests introducing $\alpha^s c_s$ in weighting y_{t+s}. In practice, the weights were calculated as .3, .2275, .1656, .113, .0686 for s=0, 1, .. , 4. The interest rate was not entered in a convolution because it is not clear in what way this should be done.

Appendix B

From minimisation of (5) in the text, one obtains:

$$\alpha S^{*}_{t} + B(L)L^{-1}S_{t} = 0$$

where

$$B(L) \equiv -\beta + (\alpha + 2\beta)L - \beta L^{2}$$

Reparameterising (B1) along the lines suggested by Callen, Hall and Henry (1990), we obtain:

$$L_{2}\Delta S_{t} = -(1 - L_{2})(S^{*}_{t-1} - S_{t-1}) - (1 - L_{2})\Delta S^{*}_{t} + \sum_{k=1}^{\infty} d_{k}\Delta S^{*}_{t+k}$$

$$L_{1,2} = \frac{-\alpha - \beta \pm \sqrt{\alpha^{2} + 4\alpha\beta}}{-2\beta}$$

$$d_{k} \equiv \{\sum_{i=k-1}^{\infty} (-1)^{i}\alpha^{i}L_{1}^{i}\} + (-1)^{k+1}(\alpha - 1 + l_{2})$$

In empirical work, we have estimated the equation:

$$\Delta S_{t} = z_{0} + z_{1}\{(S^{*}_{t-1} - S_{t-1}) + \Delta S^{*}_{t}\} + (1 - z_{1})\sum_{i=1}^{4} d_{i}\Delta S^{*}_{t+i}$$

$$+ z_{2}\Delta S_{t-1} + z_{3}\Delta S_{t-4} \qquad \text{(B1)}$$

$$d_{1} \equiv \alpha - 1 - L_{2}$$

$$d_{2} \equiv \alpha L_{1} - (\alpha - 1 + L_{2})$$

$$d_{3} \equiv -\alpha L_{1} + \alpha^{2}L_{1}^{2} + (\alpha - 1 + L_{2}) = -d_{2} + (d_{2} + d_{1})^{2}$$

$$d_{4} \equiv \alpha L_{1} - \alpha^{2}L_{1}^{2} + \alpha^{3}L_{1}^{3} - (\alpha - 1 + L_{2}) =$$

$$= d_{2} - (d_{2} + d_{1})^{2} + (d_{2} + d_{1})^{3}$$

In equation (6) presented in the main text, we have estimated the z's and d's as appear in (B1) imposing the restrictions among the d's that are shown above. The rest of the theoretically implied restrictions were not imposed for computational ease.

Data definitions and sources

Please note: All the variables used in empirical work reported above except the interest rate are in logs. The original variables and sources are:

C_{t}: Private housebuilding completions, GB (000's). Seasonally unadjusted. Source: Datastream.

$Cost_{t}$: Index of building costs. It includes the cost of labour, materials and to an extent energy. Seasonally unadjusted. Source: *Housing Finance* and *Building*. The variable actually used is real (deflated by the CPI)

CPI: Consumer price index.

CR_{t}: Credit supplied to total construction as a ratio over the value of total construction. Source: Datastream.

I_{t}: Housing construction (not an empirical variable).

P_{t}: Halifax Building Society new house price index; UK. This series is "hedonically adjusted" after 1983Q1 for changes in the quality of the housing stock. Seasonally unadjusted. The variable actually used is real (deflated by the CPI).

π_{t}: Inflation rate, $\pi_{t} \equiv (\log(CPI_{t}) - \log(CPI_{t-4}))$

$Pland_{t}$: Average private sector housing land price per plot. Bi-annual; the quarterly series has been constructed by interpolation. It covers

England and Wales. Seasonally unadjusted. Source: *Housing and Construction Statistics.*

r_t: Retail Banks Base Rate X 100

rr_t: Real interest rate X 100, $rr_t \equiv r_t - \pi_t$ X 100

S_t: Private housebuilding starts; GB (000's). Seasonally unadjusted. Source: Datastream.

T_t: Particulars delivered for stamp duty collection; UK. Source: Inland Revenue.

UCH_t: User cost of housing capital (see, e.g., Ermisch (1990). It is constructed from data on the mortgage interest rate (source: Datastream), mortgage tax relief (source: *Inland Revenue Statistics*), Local Authority Rates (source: CSO) and *expected* house price inflation and the real price of housing, based on the Department of the Environment mix-adjusted series.

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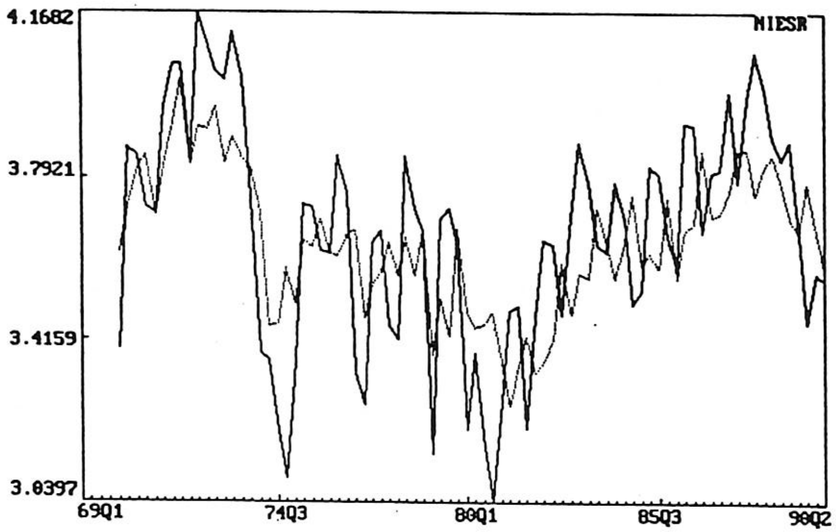
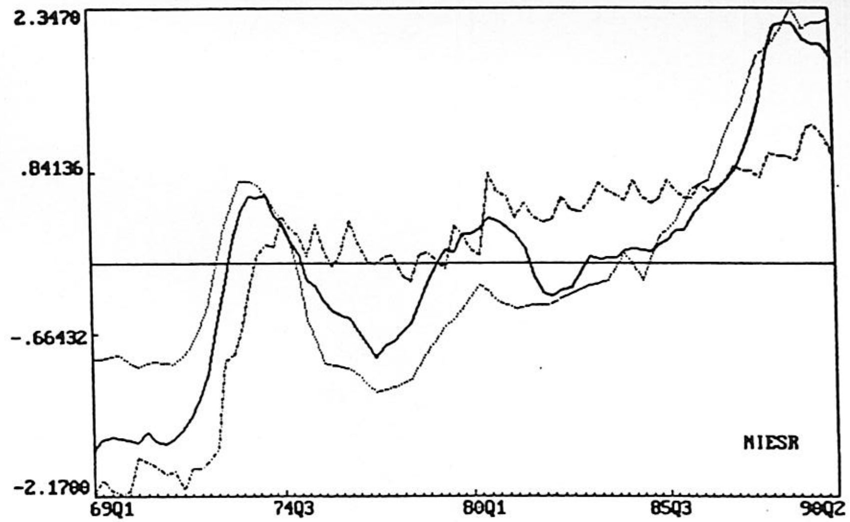
Chart 1



Starts——— Completions········· (in logs)

Chart 2



(log real) P ——(log-real) Pland ·········(log real) Cost ········ (all norm.)