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Estimating Investment Functions for a Small-Scale Econometric Model

by

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The views expressed in this paper are not necessarily those held by the Bank and are the personal responsibility of the author. Comments and criticisms are welcome.

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Introduction

This note summarises the results of an exercise in estimating investment functions for inclusion in a small-scale econometric model of the economy. The overall exercise in model-building is a joint project involving three staff from Economic Analysis, Research and Publications. Its aim is to produce a small-scale model of the economy with reasonably good forecasting and policy simulation properties.

One of the main difficulties with previous versions of the model and, indeed, with other models of the Irish economy is their relatively unsatisfactory modelling of investment. The estimated equations generally have a poor fit compared to other areas of the model resulting in rather large forecasting errors and undermining confidence in policy simulations.

Types of investment

The normal procedure is not to attempt to model investment as one aggregate but to divide it into at least two components - investment in machinery and equipment and investment in building and construction. This is retained in the present model with a further disaggregation of building and construction into that component accounted for by state activity and that undertaken by the private sector.

The are a number of factors which motivate the separate treatment of the two components. Machinery and equipment investment is generally undertaken by the corporate sector and is usually thought of as being driven by an expectation of output growth and some sort of cost or relative price variable. (Some of this investment is generated by the public sector but this component is quite small and it is not separately distinguished in the present analysis.)

Building and construction activity, by contrast, is undertaken by a number of different groupings - the corporate sector drives commercial and industrial building activity, the private household sector typically creates the demand for residential construction while the public sector undertakes significant infrastructural investment.

Each set of agents presumably reacts to different variables - or, indeed, to the same variables in different ways.

There are, however, other reasons for treating these categories separately. In particular, the outcome of the activity - the addition to the capital stock - may have different effects depending on the type of investment, as the impact on the productive capacity of the economy of the various forms of investment is presumably different. Because distinct supply-side effects may need to be identified in the model at a later stage, a complete aggregation of investment would seem unwise. Of course, on the other hand, exhaustive disaggregation would be both unsuitable for a small-scale model and would run into difficulties in terms of data availability.

Therefore, as a reasonable compromise, a three-way distinction is proposed -

Machinery and Equipment Investment - Non-Building Investment (INB)

Building and Construction - public sector - Public Building Investment (PUBI)

- private sector - Other Building Investment (IBO)

It would be convenient to treat Public Building Investment (PUBI) as purely exogenous variable - essentially a policy variable which can be reset in simulations but which does not respond to changes in other variables in the model. However, the question of this variable's exogeneity is examined as an integral part of this analysis.

Literature Review

There is a reasonable amount of research available on the determinants of investment in an Irish context, a brief summary of which is provided below. This research has been examined in an attempt to encompass as many theories as possible in the present exercise.

It may be useful to briefly outline the meaning of some 'labels' used in the discussion. The typical 'accelerator' or 'Keynesian' model of investment is one in which the level of investment generally depends solely on output - factor proportions are assumed fixed. The 'neo-classical' model, on the other hand, emphasises the relative price of capital and labour as a determining variable. 'Tobin's q' is a type of neo-classical model relating investment to the ratio of the market value of a firm - as determined on the stock market - to the replacement value of its assets.

Kelleher (1976) appears to be the first econometric study of any significance and was undertaken as part of a previous model-building exercise. He models total private non-residential investment as a function of its own lagged value and current and lagged values of real GNP. This is based on the optimal capital stock being directly related to the value of real GNP - a type of accelerator mechanism. Some interest rate and cost variables were examined but found to be of no significance. A similar model was used for private residential investment with disposable income replacing GNP.

Bradley (1979) reviews a wide range of investment models for private non-residential investment including the simple accelerator model and a number of more neo-classical approaches. His conclusions are that there is no clear 'winner'. The results of estimating some of the neo-classical models are considered a little disappointing by the author in that strong price effects are not typically found.

Boyle and Sloane (1981) estimate demand for capital and labour inputs for a large number of sectors of Irish manufacturing. While their main focus is on labour demand - for production and non-production workers - a neo-classical demand for capital is also estimated but not directly related to investment demand. They point to the difficulties involved in obtaining a proper cost of capital variable.

Kelly (1986) examines 'Tobin's q' theory in an Irish setting but comes to the conclusion that various models based on the theory do not fit the data well - although he does not appear to disaggregate investment in any way. (Including public investment is likely to distort the results as the theory cannot really be applied to it.)

Bradley and FitzGerald (1988) follow a different and more sophisticated approach to modelling factor input demands. They pointed to a three-stage decision making process applying to the industrial sector of an open economy which is open to inward investment. A firm - typically, a multinational - would initially decide how much to produce, then where to produce it and finally, the combination of inputs to use. Normally, output is assumed to be given in estimating factor demands - but the paper points out that a vital element is missed in this approach. All other things being equal - an increase in the price of a factor of production in Ireland will not only lead to substitution away from that factor in Ireland but also a substitution of production itself away from Ireland.

Bradley et al. (1989) describes the estimation of the ESRI's large-scale model HERMES. Again the authors point to the multi-stage process of determining factor demands, as noted in Bradley and FitzGerald (1988). A desired level of the capital stock is derived based on the desired level of output in Ireland and (expected) relative factor prices. Investment is then modelled as a function of the change in the desired capital stock and the lagged ratio of investment to the desired capital stock - a type of error correction mechanism. A variable representing the deviation of unit costs from their long-run average is also included - on the grounds that if unit costs are 'high' then this tends to depress investment.

In the same HERMES model, non-residential investment in the other non-industrial sectors is modelled in a much simpler manner. In the case of agriculture, it is a simple accelerator mechanism with a real cost of capital variable. For marketed services the change in the capital stock is simply related to output changes but including an ECM term and a time trend - this followed an attempt to model investment in the sector using a similar approach to that used for the industrial sector but which gave rise to simulation difficulties. Residential investment - per capita - is modelled as a function of disposable income per capita, government housing transfers, real interest rates and inflation although the actual estimation results indicate a lack of significance for the last two variables. Public investment is treated as being exogenous in HERMES.

Bradley, Whelan and Wright (1993) gives a description of investment as modelled in the ESRI's small-scale model HERMIN. Non-residential investment is divided between the 'tradeable' and 'non-tradeable' sectors. In each case a factor proportions equation - investment per person employed - is estimated using a very similar approach to that used in the industrial sector of the HERMES model. Private residential construction per capita, on the other hand, is simply modelled as a function of per capita personal disposable income. While a sound theoretical justification is given for the functional forms the actual results indicate some estimation problems.

The related issue of actually measuring the cost of capital to Irish industry has produced a long line of papers, including Geary, Walsh and Copeland (1975), Geary and McDonnell (1976), Flynn and Honahan (1984), Ruane and John (1984) and, most recently, Frain (1990). The difficulties involved in actually producing a meaningful series are considerable - given the complexities of the tax and grant systems.

There have also been a number of studies which concerned themselves exclusively with a component of building investment - the private residential housing market. These include Kenneally and McCarthy (1982), Thom (1983) and Irvine (1986). The first of these uses high frequency data over a relatively short time-frame of seven years 1969-1976. Variables include the cost of capital, income, real house prices, household formation, cost of raw materials, the stock of Local Authority housing and mortgage availability. The are separate relationships for housing starts and housing completions with an adjustment mechanism of the actual to the desired stock of housing. The model is a multi-equation one which contains much more detail than would be appropriate for the present exercise. Thom (1983) concentrates more on the determinants of real house prices using similar but not identical variables. Irvine (1986) deals with the effect of inflation on housing demand and concludes - based on a micro-simulation rather then aggregate data - that an increase in inflation should reduce housing demand. This slightly counter-intuitive results is based on the fact that inflation erodes the real value of the tax 'breaks' given to mortgage holders, which are typically not indexed.

Methodology

The overall approach to estimation is in line with the 'Hendry' or LSE approach - it has been described already in a number of places - see, for example, Hendry and Doornik (1994) - and a further description is not given here. The actual method of implementing this approach is two-fold. Initially, relationships between a dependent variables and supposedly exogenous variables are explored using conventional regression techniques (OLS) in order to try to identify long-run cointegrating relationships and error correction mechanisms.

However, another wider and possibly more satisfactory approach is then applied. As a first step a VAR is estimated imposing no structure on the data - allowing it to speak for itself. Formal tests of cointegration are then applied using the Johansen procedure to try to identify the long-run relationships in the system. The cointegrating vectors thus obtained are then examined and, if appropriate, incorporated into a parsimonious model of the VAR system in first differences - i.e. an I(0) system.

This strategy has been described by Hendry as ‘encompassing the VAR’ as it is an attempt to arrive at a structural econometric model which is consistent with the evidence of an unrestricted VAR, see Hendry and Mizon (1993) and Hendry and Doornik (1994). A comparison is then made between these results and the initial OLS regression results to see if the relationships implied by the former are valid restrictions on the data when viewed in this broader context.

Private Building Investment (IBO)

In estimating a relationship for the volume of private building investment (IBO) a straight-forward OLS regression - equation 1- incorporating all relevant variables suggested by theory and previous research is the initial starting point. The general equation includes lagged values of the dependent variable as well as current and lagged values of real GNP (LGNP), real interest rates (RI), real public investment (LRPUBI) and the change in the population aged 15 and over (DLPOP). All the variables are in logs except the interest rate and they are all I(1) - including the population change variable - and cover the period from 1961 to 1991. Two lags are used for each variable with the exception of the population change variable where only one lag is used. (The second lag was initially included but was found to be non-significant).

Some other potentially influential variables identified in earlier studies have been also omitted - namely the real price of investment, real housing transfers and inflation. Their influence will be tested for at a later stage using omitted variable tests. Those familiar with the Hendry approach will be surprised at this strategy, as it seems to fly in the face of the general to specific philosophy, but it seems unavoidable given the low number of observations. Putting all the variables in the initial equation would overload it - exhausting degrees of freedom and making the process of model reduction difficult.

EQ(1) Modelling LIBO by OLS
The present sample is: 1963 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	-1.7393	0.71634	-2.428	0.0282	0.2821
LIBO_1	0.52912	0.21135	2.503	0.0243	0.2947
LIBO_2	-0.13924	0.23147	-0.602	0.5565	0.0236
LGNP	0.050522	0.68828	0.073	0.9425	0.0004
LGNP_1	1.0363	1.0235	1.012	0.3274	0.0640
LGNP_2	-0.64880	0.61308	-1.058	0.3067	0.0695
RI	-0.31046	0.45372	-0.684	0.5042	0.0303
RI_1	-0.32837	0.43452	-0.756	0.4615	0.0367
RI_2	-0.67079	0.44951	-1.492	0.1564	0.1293
DLPOP	0.66886	4.7671	0.140	0.8903	0.0013
DLPOP_1	-15.495	5.5618	-2.786	0.0138	0.3410
LRPUBI	0.41980	0.13743	3.055	0.0080	0.3835
LRPUBI_1	-0.14407	0.23635	-0.610	0.5513	0.0242
LRPUBI_2	0.073411	0.20681	0.355	0.7276	0.0083

R^2 = 0.974498 F(13, 15) = 44.092 [0.0000] SEE=0.0565575
DW = 2.26
RSS = 0.04798121584 for 14 variables and 29 observations
AR 1- 2F(2, 13) = 0.50951 [0.6123]
ARCH 1 F(1, 13) = 0.28169 [0.6045]
Normality $Chi^2(2)$= 0.65049 [0.7223]
RESET F(1, 14) = 2.9802 [0.1063]

As will be shown latter, the typical ‘conundrum’ pointed out by Hendry in which the model-builder is faced with discovering omitted variables at later stage of the modelling process - which were not included in the original specification - does not arise in this case. All these ‘omitted variables’ are found to be non-significant when tested at a later stage.

The only other variable identified in previous research which might be of interest is raw material costs. However, a data series was not available on a consistent basis over a sufficiently long period so it has been omitted.

Ostensibly, equation 1 has reasonably good explanatory power and a substantial number of significant variables. However, there are also a fair number of apparently redundant variables. Its test diagnostics seem quite acceptable. (Each equation or system of equations in this analysis has a test summary attached to it - indicating the extent to which the model conforms to the classical assumptions, in particular, as they relate to the distribution of the residual. Failure to conform to these assumptions undermines - to a greater or lesser extent - the ability to make any inferences. The tests are fairly self-explanatory with the possible exception of the RESET test - which is one of functional form. The significance level is indicated in brackets with an asterisk or double asterisk indicating 5% or 1% significance. The tests are described in detail in Hendry and Doornik (1994))

The task now is to reduce this equation to a more parsimonious form by the elimination of redundant variables without leading to any significant deterioration in either its test summary or its explanatory power. This process of model reduction is monitored by a series of F-tests to show if each step in the process eliminates significant information or not. A failure of an F-test suggests that the particular model reduction in question is inappropriate and the modeller should move back a step. The Schwartz Criterion (SC) is also calculated at each stage to guide the model reduction process. This statistic takes account of the benefits of reducing the number of variables as against the costs of the reduction in explanatory power. The progress summary is outlined in table 1 on page 11.

The first variable to be eliminated is the second lag of real public investment. This does not alter the equation much and the F-test and SC both indicate a valid and useful reduction. This is followed by the elimination of the first lag of public investment, the current value of the GNP variable and the current value of the population variable. This results is equation 3. All of these reductions are accepted by the F-test and the absolute value of the SC has risen. The test summary also indicates no major problem - a heteroscedasticity test has been added as the degrees of freedom have increased.

Model reduction now becomes a little more difficult. The least significant variables are the current value and first lag of the real interest rate variable. The current value is the weaker of the two and is chosen for elimination. This reduction is also accepted by the F-test and further improves the SC statistic. This brings us to equation 4.

EQ(3) Modelling LIBO by OLS

The present sample is: 1963 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	-1.8106	0.52024	-3.480	0.0024	0.3772
LIBO_1	0.39468	0.14856	2.657	0.0151	0.2608
LGNP_1	1.3562	0.40917	3.314	0.0035	0.3545
LGNP_2	-0.91335	0.41684	-2.191	0.0405	0.1936
RI	-0.31882	0.39006	-0.817	0.4233	0.0323
RI_1	-0.40964	0.37898	-1.081	0.2926	0.0552
RI_2	-0.78182	0.37770	-2.070	0.0516	0.1764
DPLOP_1	-16.217	3.5074	-4.624	0.0002	0.5167
LRPUBI	0.34987	0.098412	3.555	0.0020	0.3872

R^2 = 0.972276 F(8, 20) = 87.673 [0.0000] SEE= 0.0510699
DW = 1.84
RSS = 0.05216266311 for 9 variables and 29 observations
AR 1- 2F(2, 18) = 0.076907 [0.9263]
ARCH 1 F(1, 18) = 0.16394 [0.6903]
Normality Chi^2(2)= 0.019657 [0.9902]
Xi^2 F(16, 3) = 0.1411 [0.9970]
RESET F(1, 19) = 3.0553 [0.0966]

At this stage, the only further reduction that will not cause either a failure of the F-test or a deterioration in the SC statistic would be the elimination of the first lag of the real interest rate variable. This is not proceeded with, however, as it represents the elimination of a possibly significant policy influence. In any case, the model has now been considerably reduced in size, has almost the same explanatory power as the original general equation and has quite acceptable test statistics.

EQ(4) Modelling LIBO by OLS

The present sample is: 1963 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	$PartR^2$
Constant	- 1.6461	0.47595	-3.459	0.0024	0.3629
LIBO_1	0.36715	0.14355	2.558	0.0183	0.2375
LGNP_1	1.4014	0.40220	3.484	0.0022	0.3663
LGNP_2	- 0.96031	0.40959	-2.345	0.0290	0.2075
RI_1	- 0.49445	0.36161	-1.367	0.1860	0.0818
RI_2	- 0.76562	0.37418	-2.046	0.0535	0.1662
DLPOP_1	-14.867	3.0697	-4.843	0.0001	0.5276
LRPUBI	0.35511	0.097423	3.645	0.0015	0.3875

R^2 = 0.971349 F(7, 21) = 101.71 [0.0000] SEE= 0.0506647
DW = 1.82
RSS = 0.05390514307 for 8 variables and 29 observations
AR 1- 2F(2, 19) = 0.15031 [0.8615]
ARCH 1 F(1, 19) = 0.16702 [0.6873]
Normality $Chi^2(2)$= 0.57156 [0.7514]
Xi^2 F(14, 6) = 0.3001 [0.9703]
RESET F(1, 20) = 2.2058 [0.1531]

A comment on the coefficients, however, might be warranted at this stage. The lagged dependent variable (LIBO_1), the first lag of the GNP variable (LGNP_1) and the real interest rate variables (RI_1, RI_2) all have the expected sign. The second lag of GNP (LGNP_2) has a negative coefficient but this is more than offset by the larger positive coefficient on the first lag implying a long-run positive relationship between GNP and building investment. The volume of real public investment (LRPUBI) has a positive coefficient. This suggest that public investment stimulates private construction investment. One might have expected some substitution effect between public and private housing investment - e.g. a greater supply of public housing investment might adversely affect the demand for private housing. However, the estimated relationship suggests that positive spillover effects from public spending outweigh this effect if, indeed, it exists.

Table 1: Progress to date for modelling LIBO:

model	T	k	df	Schwarz
4	29	8	21	-5.3589
3	29	9	20	-5.2757
2	29	12	17	-4.997
1	29	14	1	-4.7787

Tests of model reduction

```
Model    1 -->  2: F( 2,  15) =   0.10507 [0.9009]
Model    1 -->  3: F( 5,  15) =   0.26144 [0.9272]
Model    2 -->  3: F( 3,  17) =   0.40872 [0.7487]
Model    1 -->  4: F( 6,  15) =   0.30866 [0.9226]
Model    2 -->  4: F( 4,  17) =   0.45875 [0.7649]
Model    3 -->  4: F( 1,  20) =   0.66809 [0.4233]
```

However, the most problematic coefficient is the one on the lagged population change variable (DLPOP_1). This would appear - on first sight - to have the wrong sign. An increase in the rate of change of the population might be expected to generate greater investment, at least in the housing sector. However, one must remember that what one is looking at here is a partial elasticity only - it assumes all other variables are held constant. In fact, if the population growth rate increases and GNP is held constant income per head will be on a declining path which is, in fact, likely to depress investment rather than stimulate it. The size of the coefficient might also seem large but one has to remember that even small changes in the rate of population change can have significant results in terms of per capita incomes. Nevertheless, even allowing for these factors, one has to admit that this is a surprisingly large coefficient - but there is no statistical justification for removing this variable from the equation as it appears highly significant.

Test of stability were also conducted on equation 4 by two methods. The within-sample stability of each coefficient was tested using the tests of Hansen (1992) - there was no sign of parameter instability at either the 5 or 1 per cent. level although these tests are compromised somewhat by the non-stationarity of the variables. The equation was also estimated using recursive least squares starting with a minimum number of observations. Chow tests were applied but these did not indicate any significant break in the overall relationship. They are reproduced graphically in the appendix along with graphs of the actual and fitted series.

At this point omitted variable test were also conducted using two lags of each of the variables already mentioned - the real price of investment, real housing transfers and inflation. Their omission was tested individually and jointly but the results indicated a lack of significance.

The implied long-run relationship between the variables as indicated by the reduced model - equation 4 - is given below with standard errors in brackets. This is a candidate for a cointegrating relationship. Its residual - the error correction or cointegrating variable - is stationary as can be seen from the unit root test.

Solved Static Long Run equation

```
LIBO =   - 2.601 + 0.697 LGNP - 1.991 RI + 0.5611 LRPUBI
(SE)     (0.7444) (0.09638)    (0.918)    (0.1116)

         - 23.49 DLPOP
          (6.577)
```

Unit root tests 1965 to 1991

Critical values: 5%=-1.954 1%=-2.652

	t-adf	lag
ECM	-2.8489**	2
ECM	-3.4124**	1
ECM	-3.5409**	0

One way of examining the reliability of this relationship - in advance of formal cointegration tests - is to convert the equation to one in first differences. The result is shown in equation 5 below. The inferences from the t-statistics are now quite reliable as the variables are I(0) and the test diagnostics are satisfactory. The significance of the variables generally drops as one might expect but they all have the expected sign. The explanatory power of the equation is much lower but it is quite respectable for a relationship in first differences of an investment equation.

EQ(5) Modelling DLIBO by OLS

The present sample is: 1964 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	- 0.0042151	0.027247	-0.155	0.8786	0.0012
DLIBO_1	0.030246	0.19865	0.152	0.8805	0.0012
DLGNP_1	1.3194	0.58809	2.243	0.0363	0.2011
DLGNP_2	- 0.38532	0.61368	-0.628	0.5372	0.0193
DRI_1	- 0.23214	0.39546	-0.587	0.5638	0.0169
DRI_2	- 0.60729	0.38336	-1.584	0.1289	0.1115
DLRPUBI	0.32846	0.13091	2.509	0.0208	0.2394
DDLPOP_1	-10.656	4.3922	-2.426	0.0248	0.2274

R^2 = 0.558954 F(7, 20) = 3.621 [0.0111] SEE= 0.0635752
DW = 2.30
RSS = 0.08083604339 for 8 variables and 28 observations
AR 1- 2F(2, 18) = 1.3441 [0.2857]
ARCH 1 F(1, 18) = 1.2934 [0.2703]
Normality $Chi^2(2)$= 0.34288 [0.8425]
Xi^2 F(14, 5) = 1.1339 [0.4817]
RESET F(1, 19) = 0.39691 [0.5362]

A final test before moving to a wider framework is to simply insert the residual from the long-run relationship as an explanatory variable in the differenced equation to see if it is significant and of the right sign. As can be seen from equation 6, the ECM variable is highly significant with the expected negative coefficient. The resulting equation also has significantly higher explanatory power and its diagnostics are quite acceptable. However, the ECM variable dominates the equation somewhat leading to a number of previously significant variables becoming insignificant.

EQ(6) Modelling DLIBO by OLS

The present sample is: 1964 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	0.013529	0.022409	0.604	0.5532	0.0188
DLIBO_1	0.059181	0.15933	0.371	0.7144	0.0072
DLGNP_1	0.60028	0.51416	1.168	0.2574	0.0669
DLGNP_2	-0.14903	0.49619	-0.300	0.7672	0.0047
DRI_1	0.87160	0.44765	1.947	0.0665	0.1663
DRI_2	0.19424	0.38348	0.507	0.6183	0.0133
DLRPUBI	0.45784	0.11122	4.117	0.0006	0.4714
DDLPOP_1	3.2586	5.3180	0.613	0.5473	0.0194
ECM_1	-0.70379	0.20170	-3.489	0.0025	0.3905

R^2 = 0.731194 F(8, 19) = 6.4604 [0.0004] SEE= 0.0509217
DW = 1.87
RSS = 0.04926739369 for 9 variables and 28 observations
AR 1- 2F(2, 17) = 0.089574 [0.9147]
ARCH 1 F(1, 17) = 0.012974 [0.9106]
Normality $Chi^2(2)$= 0.76209 [0.6831]
Xi^2 F(16, 2) = 0.16855 [0.9882]
RESET F(1, 18) = 0.21136 [0.6512]

Having identified a contender for a possible cointegrating relationship from OLS, one can now try to establish the validity of this relationship by a more general approach which avoids some of the weakness of the initial OLS strategy. The first step is to estimate an unrestricted system - a vector autoregression - with the five variables in question.

The results using two lags of each variable are shown as system 1. A test summary is also shown. As can be seen, these diagnostics are more or less satisfactory or - in Hendry’s terminology - the system is ‘data-congruent’. A small glitch on the test summary is some sign of autocorrelation in the population change variable equation at the five per cent. level. This problem could be eliminated by increasing the number of lags to three but it is not thought to be serious enough to justify doing so. Stability tests similar to those carried on the single OLS relationship were applied but did not reveal any problems.

SYS(1) Estimating the unrestricted reduced form by OLS

The present sample is: 1964 to 1991

URF Equation 1 for LIBO

Variable	Coefficient	Std.Error	t-value	t-prob
LIBO_1	0.78259	0.26968	2.902	0.0099
LIBO_2	- 0.045829	0.26641	-0.172	0.8655
LGNP_1	1.0257	0.71545	1.434	0.1698
LGNP_2	- 0.71539	0.75552	-0.947	0.3570
RI_1	- 0.33140	0.52187	-0.635	0.5339
RI_2	- 0.77553	0.50874	-1.524	0.1458
DLPOP_1	-13.190	5.1391	-2.567	0.0200
DLPOP_2	7.8559	6.0136	1.306	0.2088
LRPUBI_1	0.11536	0.19460	0.593	0.5611
LRPUBI_2	- 0.16586	0.17185	-0.965	0.3480
Constant	- 0.65380	0.78205	-0.836	0.4147

SEE = 0.0662458 RSS = 0.07460457031

URF Equation 2 for LGNP

Variable	Coefficient	Std.Error	t-value	t-prob
LIBO_1	-0.011996	0.097683	-0.123	0.9037
LIBO_2	0.00084937	0.096502	0.009	0.9931
LGNP_1	1.2451	0.25915	4.804	0.0002
LGNP_2	-0.20112	0.27367	-0.735	0.4724
RI_1	-0.097313	0.18903	-0.515	0.6133
RI_2	-0.17866	0.18428	-0.970	0.3459
DLPOP_1	-1.2565	1.8615	-0.675	0.5088
DLPOP_2	-0.20001	2.1783	-0.092	0.9279
LRPUBI_1	-0.10191	0.070490	-1.446	0.1664
LRPUBI_2	0.055750	0.062249	0.896	0.3830
Constant	-0.0039783	0.28328	-0.014	0.9890

SEE = 0.0239958 RSS = 0.009788534553

URF Equation 3 for RI

Variable	Coefficient	Std.Error	t-value	t-prob
LIBO_1	0.10437	0.12338	0.846	0.4093
LIBO_2	-0.071069	0.12188	-0.583	0.5675
LGNP_1	0.042463	0.32732	0.130	0.8983
LGNP_2	-0.028659	0.34565	-0.083	0.9349
RI_1	0.25686	0.23875	1.076	0.2970
RI_2	-0.070530	0.23275	-0.303	0.7655
DLPOP_1	-5.7517	2.3511	-2.446	0.0256
DLPOP_2	0.11751	2.7512	0.043	0.9664
LRPUBI_1	0.017572	0.089031	0.197	0.8459
LRPUBI_2	0.043667	0.078622	0.555	0.5859
Constant	-0.68746	0.35778	-1.921	0.0716

SEE = 0.0303072 RSS = 0.01561496616

URF Equation 4 for DLPOP

Variable	Coefficient	Std.Error	t-value	t-prob
LIBO_1	-0.013774	0.013560	-1.016	0.3240
LIBO_2	0.018950	0.013396	1.415	0.1752
LGNP_1	0.019782	0.035975	0.550	0.5895
LGNP_2	-0.010890	0.037989	-0.287	0.7778
RI_1	-0.033453	0.026241	-1.275	0.2195
RI_2	-0.044922	0.025581	-1.756	0.0971
DLPOP_1	0.64088	0.25841	2.480	0.0239
DLPOP_2	-0.23374	0.30238	-0.773	0.4501
LRPUBI_1	0.015739	0.0097852	1.608	0.1261
LRPUBI_2	-0.021421	0.0086412	-2.479	0.0240
Constant	-0.079811	0.039323	-2.030	0.0583

SEE = 0.003331 RSS = 0.0001886249297

URF Equation 5 for LRPUBI

Variable	Coefficient	Std.Error	t-value	t-prob
LIBO_1	0.81102	0.32281	2.512	0.0224
LIBO_2	0.15906	0.31891	0.499	0.6243
LGNP_1	0.0074234	0.85643	0.009	0.9932
LGNP_2	-0.40471	0.90439	-0.447	0.6602
RI_1	0.36334	0.62470	0.582	0.5685
RI_2	-0.15961	0.60899	-0.262	0.7964
DLPOP_1	-1.6179	6.1518	-0.263	0.7957
DLPOP_2	23.989	7.1985	3.332	0.0039
LRPUBI_1	0.56013	0.23295	2.405	0.0279
LRPUBI_2	-0.51810	0.20572	-2.518	0.0221
Constant	2.4573	0.93615	2.625	0.0177

SEE = 0.0792993 RSS = 0.106902342

correlation of URF residuals

	LIBO	LGNP	RI	DLPOP	LRPUBI
LIBO	1.000				
LGNP	0.1408	1.000			
RI	-0.1955	0.08062	1.000		
DPOP	0.1922	0.5441	-0.1648	1.000	
LRPUBI	0.5970	0.2390	-0.1249	0.2600	1.000

standard deviations of URF residuals

LIBO2	LGNP	RI	DLPOP	LRPUBI
0.06625	0.02400	0.03031	0.003331	0.07930

R^2(LR) = 0.999982 R^2(LM) = 0.679738

correlation of actual and fitted

LIBO	LGNP	RI	DLPOP	LRPUBI
0.9752	0.9974	0.8672	0.9105	0.9699

```
LIBO    : Portmanteau  4 lags=   0.8806
LGNP    : Portmanteau  4 lags=   4.1122
RI      : Portmanteau  4 lags=   11.193
DLPOP   : Portmanteau  4 lags=    6.471
LRPUBI  : Portmanteau  4 lags=   5.4714
LIBO    : AR 1- 2F( 2, 15) =     0.3672 [0.6987]
LGNP    : AR 1- 2F( 2, 15) =     2.6832 [0.1009]
RI      : AR 1- 2F( 2, 15) =     0.6491 [0.5366]
DLPOP   : AR 1- 2F( 2, 15) =     4.4263 [0.0308] *
LRPUBI  : AR 1- 2F( 2, 15) =     2.2521 [0.1395]
LIBO    : Normality Chi²(2)=    0.79938 [0.6705]
LGNP    : Normality Chi²(2)=    0.49398 [0.7811]
RI      : Normality Chi²(2)=     4.2081 [0.1220]
DLPOP   : Normality Chi²(2)=     2.2286 [0.3281]
LRPUBI  : Normality Chi²(2)=    0.94889 [0.6222]
LIBO    : ARCH 1 F( 1, 15) =   0.055754 [0.8165]
LGNP    : ARCH 1 F( 1, 15) = 0.00058043 [0.9811]
RI      : ARCH 1 F( 1, 15) =   0.055309 [0.8173]
DLPOP   : ARCH 1 F( 1, 15) =   0.067807 [0.7981]
LRPUBI  : ARCH 1 F( 1, 15) =    0.62189 [0.4426]
Vector portmanteau  4 lags=   102.17
Vector AR 1-2 F(50, 17) =     2.3967 [0.0254] *
Vector normality Chi²(10)=    14.058 [0.1704]
```

There are, of course, no conventional measures of explanatory power in the VAR framework - i.e. each equation does not have an R-square, as such, for the simple reason that there are no exogenous 'explanatory' variables in the system. The overall fit can be judged from either of two 'manufactured' R-squares based on the likelihood ratio or Lagrange Multiplier principles but the most intuitive measure is simply the degree of correlation of actual and fitted values of the variables which is quite high.

The next step is to move to an application of the Johansen procedure to test for cointegration between the five variables. This procedure is described in Johansen (1988) but a brief outline might be useful. At the moment, we are considering a VAR system in which there are no exogenous variables

$$Y_t = \sum_{i-1}^{m} \pi_i Y_{t-i} + V_t, \quad V_t \sim IN(0, \Omega)$$

As the data are I(1), one can usefully to transform the system to error correction form:

$$\Delta Y_t = \sum_{i=1}^{m-1} \delta_i \Delta Y_{t-i} + P_0 Y_{t-1} + V_t$$

Clearly, this system is balanced only if both ΔY_t and $P_0 Y_{t-1}$ are I(0). For this to be the case, the rank of P_0 must be less than the number of variables n - i.e. $r(P_0) = p<n$. P_0 can be broken down into two matrices $P_0 = ab'$ where a and b are n x p matrices of rank p and $b'Y_t$ comprises p cointegrating I(0) relationships.

$$\Delta Y_t = \sum_{i=1}^{m-1} \delta_i \Delta Y_{t-i} + a(b'Yt) + V_t$$

The Johansen procedure involves the use of maximum likelihood methods to arrive at the rank of P_0 and values for both the a and b matrices. While the b matrix - as already noted - is simply the matrix of cointegrating vectors which give rise to error correction or disequilibrium values, the a matrix represents the loadings or weights for each of these variables in the equation for the change in each of variables. The procedure also allows tests of restrictions on the rank of P_0 and on the elements of both the a and b matrices. The results of the cointegration analysis are present in table 2.

There are two tests for determining the rank of the ‘b’ matrix - the ‘trace’ test and ‘maximum eigenvalue’test. The ‘trace test’ is a likelihood ratio of the hypotheses $r(P_0) = P$ against $r(P_0) > P$ while the maximum eginvalue test is one of $r(P_0) = P$ against $r(P_0) =P + 1$. The exact number of cointegrating vectors is rather indeterminate as is frequently the case but a reasonable interpretation of the trace test would seem to be that there is at least one cointegrating relationship. If the significance level is taken at 10% this result is supported by the maximum eigenvalue test.

Table 2: Cointegration analysis 1964 to 1991

eigenvalue μi	loglik for	rank
	520.784	0
0.69357	537.342	1
0.506588	547.232	2
0.411915	554.664	3
0.17165	557.301	4
0.0310423	557.742	5

Ho:rank=p	**-Tlog(1-μ)**	**T-nm**	**95%**	**-Tlg(1-μ)**	**T-nm**	**95%**
p == 0	33.12	21.29	33.5	73.92*	47.52	68.5
p <= 1	19.78	12.72	27.1	40.8	26.23	47.2
p <= 2	14.86	9.556	21.0	21.02	13.51	29.7
p <= 3	5.273	3.39	14.1	6.156	3.957	15.4
p <= 4	0.883	0.5676	3.8	0.883	0.5676	3.8

standardised ß' eigenvectors

LIBO2	LGNP	RI	DLPOP	LRPUBI
1.000	-0.7136	2.650	36.57	-0.8439
-4.693	1.000	11.57	9.924	3.315
1.066	-0.7991	1.000	1.811	0.1209
0.03175	0.01138	0.3290	1.000	-0.07367
2.144	-3.315	-3.774	-67.92	1.000

standardised a coefficients

LIBO2	-0.1403	-0.04063	-0.2659	-0.1355	-0.01205
LGNP	-0.02734	-0.01548	-0.07025	0.2035	0.005584
RI	-0.1249	-0.02780	0.03259	-0.5355	0.004635
DLni561	-0.01637	-0.004533	-0.001653	0.05896	7.521e-005
LRPUBI	0.6378	-0.1163	-0.1878	0.06148	-0.007043

long-run matrix Po= aß', rank 5

	LGNP	RI	DLPOP	LRPUBI	LIBO2
LIBO2	-0.2632	0.3103	-1.107	-5.334	-0.05050
LGNP	-0.01115	0.04396	-0.2760	-1.457	-0.04616
RI	0.03330	0.01380	-0.8137	-5.634	0.06124
DlPOP	0.005176	0.008892	-0.07837	-0.5929	-0.005682
LRPUBI	0.9701	-0.3973	0.2037	22.37	-0.9580

The vector corresponding to the largest eigenvalue is familiar - matching very closely the long-run relationship which was arrived at using OLS. The signs on the coefficients are all the same and the size of the coefficients are also broadly similar. In fact, the closeness of the two relationships can be easily seen in the attached graphs - the first panel shows the residuals from the OLS long-run relationship - the ECM variable - and the second panel shows the variable generated by the first cointegrating vector derived from the Johansen procedure CIvec1 (hereafter CIa).

They are essentially the same - as can be seen clearly when they are mean-corrected and placed together.

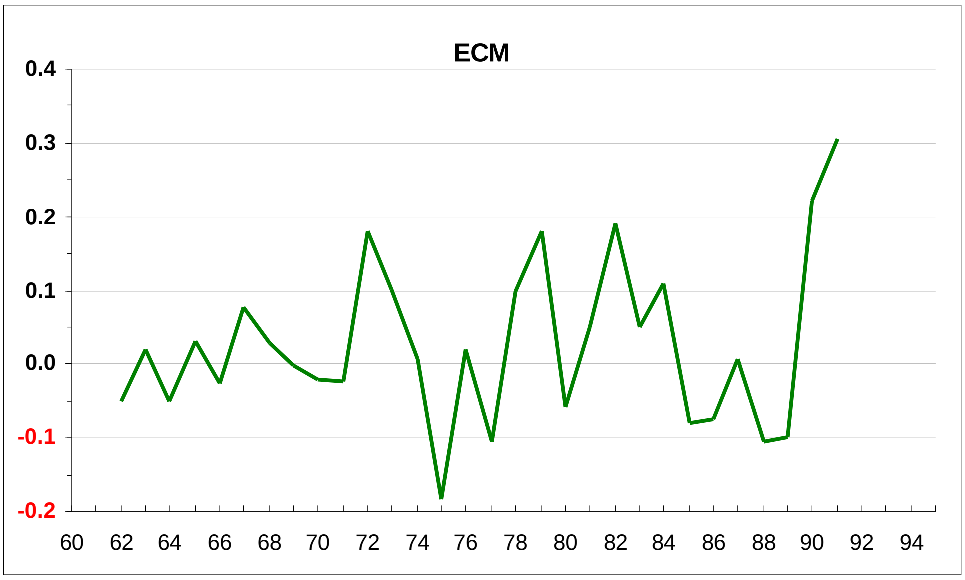
In fact, one can formally test the proposition that there is one cointegrating relationship and that it is the one identified by the earlier OLS regression. This involves imposing the restriction that the rank of the cointegrating matrix b is one and that the relationship identified by the OLS regression is the single cointegrating vector. This can be tested within the Johansen procedure. Unsurprisingly, this joint restriction cannot be rejected at either the one or five per cent. levels.

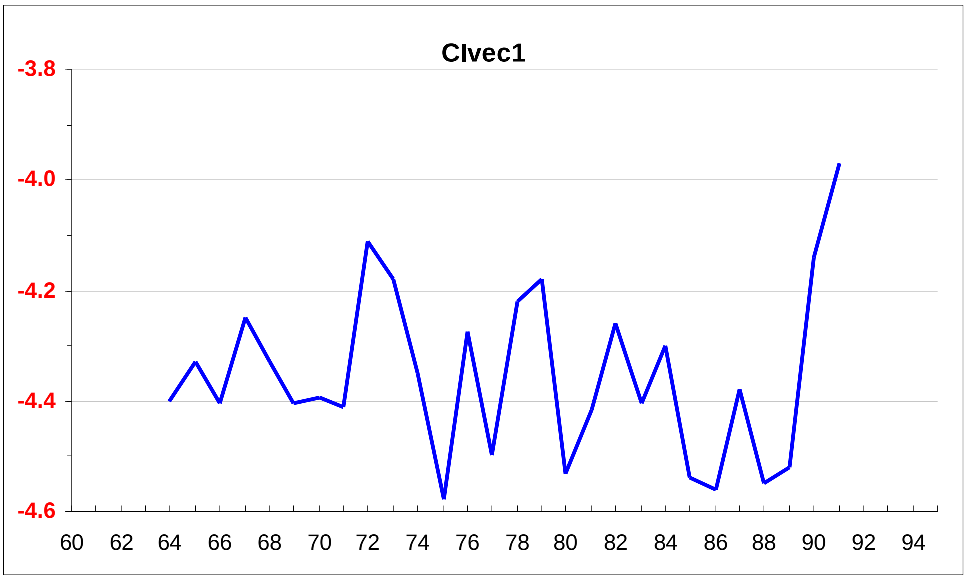
LR-test, rank (P_0) = 1 : Chi^2 (≈ 4) = 7.3333 (0.1193)

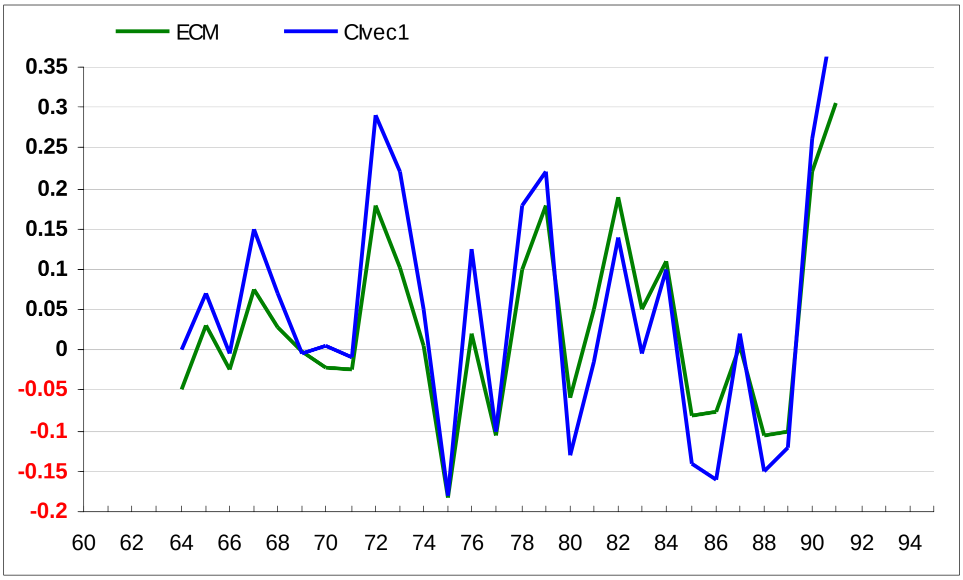
However, in order to accept the validity of the OLS relationship further steps need to be taken. One also has to impose the restriction that the cointegrating variable influences - and only influences - the evolution of the first variable in the system - i.e. the building investment. This a test of the weak exogeneity of the conditioning variables in the OLS relationship, in the sense of Engle, Hendry and Richard (1983). Put at simplest, it is a test to establish that a disequilibrium in the system is eliminated by changes in the supposedly endogenous variable. If this is not the case the picture is more complicated and the OLS relationship may be rather misleading.

There are two ways in which this test can be carried out. The restriction that the a matrix - the matrix determining the weights or loadings of the cointegrating vectors in the relationships for each variable - is of the form {a 0 0 0} a ≠ 0 could be tested within the Johansen procedure. However, an alternative and possibly clearer way of looking at this problem is to return to the VAR framework and move to modelling the system in first differences i.e. to actually modelling

$$\Delta Y_t = \sum_{i=1}^{m-1} \delta_i \, \Delta Y_{t-1} + a(b' \, Y_{t-1}) + V_t.$$


ECM
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94


CIvec1
-3.8
-4.0
-4.2
-4.4
-4.6
60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94


ECM
CIvec1
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94

In this case, we place the single cointegrating variable CIa, estimated from the Johansen procedure with rank (P_0) = 1, into the system since we believe that it helps to determine system dynamics. One lag is used in this differenced system corresponding to two lags in the levels system. The system test statistics are satisfactory - the Vector AR test is only marginally significant at the five per cent. level. The system fit is much poorer, of course, but one would expect this to be the case given that it is now in first differences. The CIa variable is reasonably significant in the first equation. However, it is worth noting that it has some level of significance in the other equations particularly that for the policy variable.

SYS(2) Estimating the unrestricted reduced form by OLS
The present sample is: 1964 to 1991

URF Equation 1 for DLIBO

Variable	Coefficient	Std.Error	t-value	t-prob
DLIBO_1	0.25384	0.22554	1.125	0.2731
DLGNP_1	1.4749	0.60378	2.443	0.0235
DRI_1	0.49626	0.46132	1.076	0.2942
DDLPOP_1	-6.6492	5.9377	-1.120	0.2754
DLRPUBI_1	0.048218	0.14130	0.341	0.7363
CIa_1	-0.41820	0.21553	-1.940	0.0659
Constant	-1.2232	0.61543	-1.988	0.0601

SEE = 0.0685944 RSS = 0.09880908166

URF Equation 2 for DLGNP

Variable	Coefficient	Std.Error	t-value	t-prob
DLIBO_1	0.085161	0.080958	1.052	0.3048
DLGNP_1	0.44775	0.21673	2.066	0.0514
DRI_1	0.080892	0.16559	0.489	0.6303
DDLPOP_1	-0.024823	2.1313	-0.012	0.9908
DLRPUBI_1	-0.098081	0.050719	-1.934	0.0667
CIa_1	-0.078852	0.077363	-1.019	0.3197
Constant	-0.20757	0.22091	-0.940	0.3581

SEE = 0.0246221 RSS = 0.01273122211

URF Equation 3 for DRI

Variable	Coefficient	Std.Error	t-value	t-prob
DLIBO_1	0.17057	0.10596	1.610	0.1224
DLGNP_1	-0.29011	0.28365	-1.023	0.3181
DRI_1	-0.15200	0.21672	-0.701	0.4908
DDLPOP_1	-1.1601	2.7895	-0.416	0.6817
DLRPUBI_1	-0.022254	0.066381	-0.335	0.7408
CIa_1	-0.11893	0.10125	-1.175	0.2533
Constant	-0.33261	0.28913	-1.150	0.2629

SEE = 0.0322254 RSS = 0.02180799862

URF Equation 4 for DDLPOP

Variable	Coefficient	Std.Error	t-value	t-prob
DLIBO_1	0.0038700	0.012496	0.310	0.7598
DLGNP_1	0.038189	0.033453	1.142	0.2665
DRI_1	0.024721	0.025559	0.967	0.3445
DDLPOP_1	0.032874	0.32898	0.100	0.9214
DLRPUBI_1	0.0099852	0.0078287	1.275	0.2161
CIa_1	-0.015425	0.011941	-1.292	0.2105
Constant	-0.045525	0.034098	-1.335	0.1961

SEE = 0.00380052 RSS = 0.0003033223873

URF Equation 5 for DLRPUBI

Variable	Coefficient	Std.Error	t-value	t-prob
DLIBO_1	0.29111	0.32674	0.891	0.3830
DLGNP_1	1.6345	0.87470	1.869	0.0757
DRI_1	-0.56998	0.66831	-0.853	0.4034
DDLPOP_1	-21.095	8.6020	-2.452	0.0230
DLRPUBI_1	0.31995	0.20470	1.563	0.1330
CIa_1	0.57623	0.31223	1.846	0.0791
Constant	1.5946	0.89157	1.789	0.0881

See = 0.0993733 RSS = 0.2073761838

correlation of URF residuals

	DLIBO	DLGNP	DRI	DDLPOP	DLRPUBI
DLIBO	1.000				
DLGNP	0.3179	1.000			
DRI	-0.1838	0.03465	1.000		
DDLPOP	0.2285	0.5388	0.04575	1.000	
DLRPUBI	0.7062	0.4142	-0.06315	0.2763	1.000

standard deviations of URF residuals

DLIBO	DLGNP	DRI	DDLPOP	DLRPUBI
0.06859	0.02462	0.03223	0.003801	0.09937

R^2(LR) = 0.921614 R^2(LM) = 0.355451

correlation of actual and fitted

DLIBO	DLGNP	DRI	DDLPOP	DLRPUBI
0.6789	0.5610	0.5501	0.5093	0.6563

```
DLIBO      : Portmanteau  4 lags  =    1.7782
DLGNP      : Portmanteau  4 lags  =    5.6283
DRI        : Portmanteau  4 lags  =   10.999
DDLPOP     : Portmanteau  4 lags  =    3.1906
DLRPUBI    : Portmanteau  4 lags  =    3.2319
DLIBO      : AR 1- 2F( 2, 19)     =    1.1937 [0.3248]
DLGNP      : AR 1- 2F( 2, 19)     =    1.4112 [0.2683]
DRI        : AR 1- 2F( 2, 19)     =    0.36788 [0.6970]
DDLPOP     : AR 1- 2F( 2, 19)     =    0.54657 [0.5878]
DLRPUBI    : AR 1- 2F( 2, 19)     =    0.96069 [0.4005]
DLIBO      : Normality Chi²(2)    =    0.64549 [0.7242]
DLGNP      : Normality Chi²(2)    =    0.61606 [0.7349]
DRI        : Normality Chi²(2)    =    4.8311 [0.0893]
DDLPOP     : Normality Chi²(2)    =    1.3246 [0.5157]
DLRPUBI    : Normality Chi²(2)    =    2.4437 [0.2947]
DLIBO      : ARCH 1 F( 1, 19)     =    0.17659 [0.6790]
DLGNP      : ARCH 1 F( 1, 19)     =    0.41692 [0.5262]
DRI        : ARCH 1 F( 1, 19)     =    0.026271 [0.8730]
DDLPOP     : ARCH 1 F( 1, 19)     =    0.23803 [0.6312]
DLRPUBI    : ARCH 1 F( 1, 19)     =    1.2044 [0.2862]
DLIBO      : Xi²  F(12,  8)       =    0.2194 [0.9905]
DLGNP      : Xi²  F(12,  8)       =    0.44722 [0.8990]
DRI        : Xi²  F(12,  8)       =    0.27394 [0.9782]
DDLPOP     : Xi²  F(12,  8)       =    0.25202 [0.9839]
DLRPUBI    : Xi²  F(12,  8)       =    1.3871 [0.3284]
Vector portmanteau  4 lags        =   93.808
Vector AR 1-2 F(50, 35)           =    1.7554 [0.0412] *
Vector normality Chi²(10)         =   15.232 [0.1238]
Vector Xi²    Chi²(180)           =  168.53 [0.7199]
```

In particular, the results suggest that the policy variable - i.e. the volume of public investment is not weakly exogenous as far as private building investment is concerned. The term ‘weakly exogenous’ means that it should make no difference whether the variable is modelled or not. Clearly, the VAR results suggest that this is not the case since the error correction variable in the private building equation appears fairly significant in the equation for the policy variable itself . In other words, there may be a degree of feedback in the system, in particular, between the disequilibrium in the private building market and the policy variable. The results indicate that suppression of this feedback would appear to be an unacceptable restriction on the data.

In order to confirm this, one can carry out in the VAR framework the test of the restrictions on the ‘a’ matrix in the Johansen procedure. This is done by simply deleting the variable CIa from all equations but the first and reestimating the system using full information maximum likelihood. The deletions can then be tested using an Chi^2 test for a valid restriction. Unsurprisingly, this points to a rejection, at least at the 5 per cent. level although not at the 1 per cent. level.

Chi^2 (4) = 10.133 (0.0382)*

The only way one can move to accepting the validity of the original OLS results is by simply overriding the statistical results relating to policy formation. There are, in fact, two apparently significant results in the VAR which would have to be suppressed. The first is the one already mentioned - the fact that the cointegrating variable - the ECM in the OLS regression - probably affects one of the supposedly exogenous variables. However, a second problem is the fact that the policy variable is also apparently affected by the population change variable with a lag. Given that both variables appear as separate exogenous variables in the OLS relationship, this linkage is ignored which could make the result of simulations rather misleading.

If one simply imposes exogeneity on the policy variable - by not modelling it in the system - one can see from system 3 that the first equation simply collapses towards the earlier OLS result or very close to it. In this system the population change variable has also been exogenised - but this is not as contentious, as its change appears to be genuinely exogenous, in that no variables in its equation in system 2 seem particularly significant. Indeed, the evidence from the VAR is that one might even consider exogenising the real interest rate variable before one would exogenise the volume of public investment.

SYS(3) Estimating the model by FIML
The present sample is: 1964 to 1991

Equation 1 for DLIBO

Variable	**Coefficient**	**Std.Error**	**t-value**	**t-prob**	**HCSE**
DLIBO_1	0.11466	0.16650	0.689	0.4989	0.16229
DLGNP_1	0.65099	0.47630	1.367	0.1869	0.41173
DRI_1	0.78137	0.34972	2.234	0.0370	0.43242
DDLni561_1	3.9322	4.8894	0.804	0.4307	4.7069
DLRPUBI_1	-0.11449	0.10992	-1.042	0.3101	0.10177
CIa_1	-0.70922	0.17633	-4.022	0.0007	0.17955
DLRPUBI	0.48721	0.11317	4.305	0.0003	0.12206
DDLPOP	0.51129	2.9629	0.173	0.8647	2.8646
Constant	-2.0287	0.50264	-4.036	0.0006	---

SEE = 0.0497244

Equation 2 for DLGNP

Variable	Coefficient	Std.Error	t-value	t-prob	HCSE
DLIBO_1	0.042954	0.068247	0.629	0.5362	0.058391
DLGNP_1	0.25900	0.19299	1.342	0.1946	0.17957
DRI_1	-0.035739	0.11899	-0.300	0.7670	0.10660
DDLni561_1	-0.043683	1.4584	-0.030	0.9764	1.2293
DLRPUBI_1	-0.14317	0.044931	-3.186	0.0046	0.037847
DLRPUBI	0.050957	0.042396	1.202	0.2434	0.043474
DDLPOP	3.4092	1.1502	2.964	0.0077	0.95322
Constant	0.025101	0.0075265	3.335	0.0033	---

SEE = 0.0205926

Equation 3 for DRI

Variable	Coefficient	Std.Error	t-value	t-prob	HCSE
DLIBO_1	0.16332	0.11069	1.475	0.1557	0.10822
DLGNP_1	-0.21596	0.31301	-0.690	0.4982	0.42716
DRI_1	-0.28853	0.19299	-1.495	0.1505	0.18040
DDLni561_1	-3.5613	2.3653	-1.506	0.1478	3.2706
DLRPUBI_1	-0.010048	0.072873	-0.138	0.8917	0.079825
DLRPUBI	-0.052497	0.068762	-0.763	0.4541	0.057715
DDLPOP	1.1339	1.8656	0.608	0.5502	1.4893
Constant	0.0058619	0.012207	0.480	0.6363	---

SEE = 0.0333986

LR test of over-identifying restrictions: $Chi^2(2)$ = 2.15818 [0.3399]

correlation of residuals

	DLIBO	DLGNP	DRI
DLIBO	1.000		
DLGNP	0.01070	1.000	
DRI	-0.2030	0.07726	1.000

```
DLIBO   : Portmanteau  4 lags=  0.13431
DLGNP   : Portmanteau  4 lags=   3.2478
DRI     : Portmanteau  4 lags=   11.164
DLIBO   : AR 1- 2F( 2, 17) =   0.012771 [0.9873]
DLGNP   : AR 1- 2F( 2, 17) =     1.1492 [0.3403]
DRI     : AR 1- 2F( 2, 17) =    0.39338 [0.6808]
DLIBO   : Normality Chi²(2)=     1.0666 [0.5867]
DLGNP   : Normality Chi²(2)=     5.2333 [0.0730]
DRI     : Normality Chi²(2)=      5.007 [0.0818]
DLIBO   : ARCH 1 F( 1, 17) =   0.047442 [0.8302]
DLGNP   : ARCH 1 F( 1, 17) =    0.38624 [0.5425]
DRI     : ARCH 1 F( 1, 17) =   0.010052 [0.9213]
DLIBO   : Xi²    F(16,  2) =    0.10836 [0.9978]
DLGNP   : Xi²    F(16,  2) =    0.14937 [0.9923]
DRI     : Xi²    F(16,  2) =   0.087074 [0.9992]
Vector portmanteau  4 lags=     32.94
Vector AR 1-2 F(18, 34) =      1.5822 [0.1218]
Vector normality Chi²( 6)=    12.627 [0.0494] *
Vector Xi²    Chi²( 96) =     89.664 [0.6625]
```

Once the variables have been exogenised and system conditioned on them, the error correction variable can safely be deleted from all equations but the first. This is a quite acceptable restriction in the context of the reduced system. The importance of the exogeneity of the policy variable rests on the fact that it will remain as a contemporaneous conditioning variable in the wider model. In fact, it would be desirable, therefore, for it to have the properties of both weak and strong exogeneity in the sense of Engle, Hendry and Richard (1983). As already notes, the term 'weak exogeneity' means that the policy variable does not respond to the disequilibrium in the system. A lack of weak exogeneity means that the policy variable must be modelled in order for the relationship between the variables to be valid.

'Strong exogeneity' means that, in addition to this weak for of exogeneity, the policy variable must not be influenced by the previous history of modelled variables - it must not be Granger-caused by these variables. A lack of 'strong' exogeneity does not require the modelling of the policy variable in order for the estimated relationship to be valid but it does undermine the validity of conditional dynamic forecasts or simulations. This is because it cuts across the idea that the variable can simply be reset in simulations or forecasts - that the variable is, in some sense, determined completely outside of the model and will be uninfluenced by develop ments within the model.

Unfortunately, the results of the VAR approach are not particularly reassuring on either of these points. The two disturbing pieces of evidence are the semi-significance of the cointegrating variable from the policy variable equation in system 3 and the appearance of significant variables in the policy variable equation in system 1. In the latter case, most of these variables will assume the status of modelled variables in the wider model. This undermines the treatment of the policy variable as a non-modelled exogenous one.

Of course, one could simply decide to ignore all this evidence on the grounds that it is implausible. For instance, the apparent link between a disequilibrium in the long-run relationship and public investment, for instance, has no obvious rationale, particularly as the link is a positive one, i.e. a positive disequilibrium pushes up public investment. Equally, one could argue that the apparent influence of other variables on the policy variable makes little sense. However, in adopting such an approach, one is, strictly speaking, 'over-riding' rather than 'encompassing' the evidence of the VAR and one would have to be aware that a strategy of using the basis OLS relationship in the wider model without modelling of the policy variable has the potential weakness.

Non-Building Investment

The approach to modelling non-building investment is essentially similar. The initial starting point is the estimation of another general equation - equation 1 below. The explanatory variables include the lag of GNP (LGNP), the real interest rate (RI) and the real value of government grants to industry LRGRANT). Other variables were tested using omitted variable test at a latter stage - including a competitiveness measure and a measure of relative factor prices.

Unfortunately, these did not seem to be significant although it must be noted that obtaining an adequate measure of both these variables is not that straight-forward and it is possible that there exists some formulation of each of these variables which would be significant if tested. The exclusion of relative factor prices is disappointing as it means that the model is of the accelerator type which is in some ways rather unsatisfactory. However, this is not to say that some of the mechanisms identified in Bradley et al. (1989) will not be contained within the wider model. Clearly, competitiveness must enter the determination of exports and, thereby, output and investment. However, a direct role for relative factor prices within Ireland is not included. Further work in this area might be useful. and will be carried out as part of the overall modelling exercise.

EQ(1) Modelling LINB by OLS

The present sample is: 1963 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	-9.4367	4.7519	-1.986	0.0634	0.1883
LINB_1	0.16578	0.32444	0.511	0.6159	0.0151
LINB_2	-0.26287	0.33348	-0.788	0.4414	0.0353
LGNP	1.5692	0.83264	1.885	0.0767	0.1728
LGNP_1	-0.24412	1.3383	-0.182	0.8574	0.0020
LGNP_2	0.28699	1.0810	0.265	0.7938	0.0041
RI	-0.072423	0.69377	-0.104	0.9181	0.0006
RI_1	-0.60756	0.71234	-0.853	0.4056	0.0410
RI_2	-0.38845	0.69949	-0.555	0.5859	0.0178
LRGRANT	0.19430	0.17579	1.105	0.2844	0.0670
LRGRANT_1	-0.13732	0.21869	-0.628	0.5384	0.0227
LRGRANT_2	0.32793	0.17562	1.867	0.0792	0.1702

R^2 = 0.976856 F(11, 17) = 65.231 [0.0000] SEE =0.0922806
DW = 1.82
RSS = 0.1447669535 for 12 variables and 29 observations
AR 1 -2F (2, 15) = 0.30441 [0.7420]
ARCH 1 F (1, 15) = 0.99224 [0.3350]
Normality Chi^2 (2) = 0.93025 [0.6281]
RESET F (1, 16) = 0.09011 [0.7679]

However, allowing for these defects the explanatory power of the general model with two lags of each variable is quite good and no defects are obvious from the test summary. The process of model reduction now takes place with the careful elimination of redundant variables. This is done on a step by step basis, as before, eventually arriving at equation 7 below. The insignificance of these reductions is again illustrated by the F-test results and Schwartz Criteria in Table 3 on page 29. The test summary is also satisfactory for this reduced equation.

EQ(7) Modelling LINB by OLS

The present sample is: 1963 to 1991

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	-8.2750	0.65960	-12.545	0.0000	0.8677
LGNP	1.4258	0.089700	15.896	0.0000	0.9133
RI_1	-0.78239	0.50261	-1.557	0.1326	0.0917
LRGRANT	0.13317	0.082161	1.621	0.1181	0.0987
LRGRANT_2	0.23601	0.069748	3.384	0.0025	0.3230

```
R² = 0.973517  F(4, 24) = 220.56 [0.0000] SEE = 0.0830799
DW = 1.62
RSS =  0.1656544987 for 5 variables and 29 observations
AR 1- 2F( 2, 22) =   1.0902 [0.3536]
ARCH 1 F( 1, 22) =   0.42473 [0.5213]
Normality Chi²(2)=   3.2758 [0.1944]
Xi²     F( 8, 15) =  1.0807 [0.4260]
Xi*Xj  F(14,  9) =   1.1315 [0.4385]
RESET  F( 1, 23) =   0.18091 [0.6745]
```

This formulation does not contain a lagged dependent variable but does contain current real GNP and is, therefore, quite different from the model for building investment. The further elimination of the lagged real interest rate variable would be accepted on statistical grounds but it is not proceeded with - again because of the wish to include some sort of effect from interest-rate changes. For the same reason, the current value of the real level of grants is maintained in the relationship although its significance is in some doubt. The solved static long-run equation corresponding to this model is given below. The coefficients seem to be correctly-signed with the main features being the rather weak interest rate effects contrasting with the much greater significance of the grant variables. This result is probably not all that surprising given the nature of industrial policy.

Solved Static Long Run equation

```
LINB =    -8.275       +1.426 LGNP -0.7824 RI
(SE)    (0.5026)      (0.6596)    (0.0897)

                    +0.3692 LRGRANT
                 (  0.07196)
```

Table 3: Progress to date for modelling LINB:

model	T	k	df	Schwarz
7	29	5	24	-4.5846
6	29	6	23	-4.4963
5	29	7	22	-4.3826
4	29	8	21	-4.2672
3	29	9	20	-4.1816
2	29	10	19	-4.0959
1	29	12	17	-3.9066

Tests of model reduction

```
Model   1 -->  2: F( 2,  17) =   0.37231 [0.6946]
Model   1 -->  3: F( 3,  17) =   0.43091 [0.7335]
Model   2 -->  3: F( 1,  19) =   0.58689 [0.4530]

Model   1 -->  4: F( 4,  17) =    0.4651 [0.7605]
Model   2 -->  4: F( 2,  19) =   0.59736 [0.5603]
Model   3 -->  4: F( 1,  20) =   0.62065 [0.4400]

Model   1 -->  5: F( 5,  17) =   0.37466 [0.8591]
Model   2 -->  5: F( 3,  19) =   0.40284 [0.7526]
Model   3 -->  5: F( 2,  20) =   0.31737 [0.7317]
Model   4 -->  5: F( 1,  21) =  0.014345 [0.9058]

Model   1 -->  6: F( 6,  17) =   0.31965 [0.9177]
Model   2 -->  6: F( 4,  19) =   0.31407 [0.8650]
Model   3 -->  6: F( 3,  20) =   0.22784 [0.8759]
Model   4 -->  6: F( 2,  21) =  0.032006 [0.9685]
Model   5 -->  6: F( 1,  22) =  0.051996 [0.8217]

Model   1 -->  7: F( 7,  17) =    0.3504 [0.9185]
Model   2 -->  7: F( 5,  19) =   0.36581 [0.8656]
Model   3 -->  7: F( 4,  20) =   0.31709 [0.8632]
Model   4 -->  7: F( 3,  21) =   0.21988 [0.8815]
Model   5 -->  7: F( 2,  22) =   0.33778 [0.7170]

Model   6 -->  7: F( 1,  23) =   0.65037 [0.4282]
```

The equation has also been tested for parameter stability. The within sample stability of the coefficients is acceptable at the usual confidence levels using the Hansen tests. However, using a minimum number of observations and estimating the equation recursively 1-step at a time reveals something of a break towards the very end of the sample - using conventional Chow tests, reproduced in the appendix. This indicates that the relationship is less stable than that for building investment - but since no other relationship can be found among the present set of variables then on has no choice but to live with this.

EQ(8) Modelling DLINB by OLS

The present sample is: 1964 to 1992

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	-0.024980	0.033018	-0.757	0.4567	0.0233
DLGNP	1.8842	0.79746	2.363	0.0266	0.1887
DRI_1	-0.42756	0.63098	-0.678	0.5045	0.0188
DLRGRANT	-0.0013587	0.14038	-0.010	0.9924	0.0000
DLRGRANT_2	0.12057	0.12940	0.932	0.3608	0.0349

```
R² = 0.252831  F(4, 24) = 2.0303 [0.1221] SEE = 0.104682
DW = 2.03
RSS =  0.2630000837 for 5 variables and 29 observations
AR 1- 2F( 2, 22) =     0.37956 [0.6886]
ARCH 1 F( 1, 22) =  0.0093649 [0.9238]
Normality Chi²(2)=       2.097 [0.3505]
Xi²     F( 8, 15) =    0.23659 [0.9772]
Xi*Xj  F(14,  9) =    0.14844 [0.9991]
RESET  F( 1, 23) =     1.3735 [0.2532]
```

Moving to first differences produces equation 8 which also has a favourable test summary. The variables have the expected signs but the explanatory power of the equation is low. Adding an ECM variable from the long-run relationship - equation 9 - does not improve the situation much although it has an appropriately signed though not very significant coefficient. As with the previous equation, the significance of variables other than the change in GNP has dropped away rather disappointingly.

EQ(9) Modelling DLINB by OLS

The present sample is: 1964 to 1992

Variable	Coefficient	Std.Error	t-value	t-prob	PartR²
Constant	-0.023762	0.032026	-0.742	0.4656	0.0234
DLGNP	1.7897	0.77556	2.308	0.0304	0.1880
DRI_1	-0.061538	0.65377	-0.094	0.9258	0.0004
DLRGRANT	0.040005	0.13859	0.289	0.7754	0.0036
DLRGRANT_2	-0.016064	0.15211	-0.106	0.9168	0.0005
ECM_1	-0.38688	0.24348	-1.589	0.1257	0.0989

```
R² = 0.326738  F(5, 23) = 2.2324 [0.0855] SEE = 0.101507
DW = 1.61
RSS =  0.2369851741 for 6 variables and 29 observations
AR 1- 2F( 2, 21) =    0.75537 [0.4822]
ARCH 1 F( 1, 21) =     1.2599 [0.2743]
Normality Chi²(2)=       5.18 [0.0750]
Xi²     F(10, 12) =    0.56155 [0.8157]
Xi*Xj  F(20,  2) =   0.081204 [0.9997]
RESET  F( 1, 22) =    0.39484 [0.5362]
```

Having obtained these slightly unsatisfactory results, the wider VAR approach is used. In this case, the system is estimated using three lags of each variable - system 1 below. The lag length of three is chosen as using only two lags leaves quite significant autocorrelation in the residuals of some of the equations. With three lags, however, the system test summary does not show significant problems and the systems fit seems reasonably satisfactory although stability show some signs of instability towards the end of the sample.

SYS (1) Estimating the unrestricted reduced form by OLS

The present sample is: 1964 to 1991

URF Equation 1 for LINB

Variable	Coefficient	Std.Error	t-value	t-prob
LINB_1	0.34004	0.40558	0.838	0.4150
LINB_2	-0.52609	0.38872	-1.353	0.1960
LINB_3	0.11445	0.40464	0.283	0.7812
LGNP_1	2.0803	1.1043	1.884	0.0791
LGNP_2	-0.52022	1.8787	-0.277	0.7856
LGNP_3	-0.0048753	1.4223	-0.003	0.9973
RI_1	-1.0062	0.82512	-1.219	0.2415
RI_2	-0.11655	0.86741	-0.134	0.8949
RI_3	0.0094882	0.87220	0.011	0.9915
LRGRANT_1	0.16047	0.21634	0.742	0.4697
LRGRANT_2	0.049608	0.28585	0.174	0.8645
LRGRANT_3	0.13673	0.23339	0.586	0.5667
Constant	-8.8576	7.1967	-1.231	0.2374

SEE = 0.109583 RSS = 0.1801270515

URF Equation 2 for LGNP

Variable	Coefficient	Std.Error`	t-value	t-prob
LINB_1	0.021173	0.099329	0.213	0.8341
LINB_2	-0.18404	0.095200	-1.933	0.0723
LINB_3	-0.063434	0.099098	-0.640	0.5318
LGNP_1	1.2349	0.27045	4.566	0.0004
LGNP_2	-0.31082	0.46009	-0.676	0.5096
LGNP_3	0.45755	0.34833	1.314	0.2087
RI_1	-0.16285	0.20208	-0.806	0.4329
RI_2	0.061677	0.21243	0.290	0.7755
RI_3	-0.10131	0.21360	-0.474	0.6421
LRGRANT_1	0.068162	0.052982	1.287	0.2178
LRGRANT_2	-0.069784	0.070006	-0.997	0.3347
LRGRANT_3	0.046812	0.057158	0.819	0.4256
Constant	-2.2000	1.7625	-1.248	0.2311

SEE = 0.0268373 RSS = 0.01080359824

URF Equation 3 for RI

Variable	Coefficient	Std.Error	t-value	t-prob
LINB_1	-0.10129	0.10773	-0.940	0.3620
LINB_2	-0.19948	0.10325	-1.932	0.0725
LINB_3	0.015553	0.10748	0.145	0.8869
LGNP_1	-0.088310	0.29332	-0.301	0.7675
LGNP_2	0.42616	0.49899	0.854	0.4065
LGNP_3	0.20594	0.37779	0.545	0.5937
RI_1	0.43719	0.21916	1.995	0.0646
RI_2	0.28378	0.23040	1.232	0.2370
RI_3	-0.44240	0.23167	-1.910	0.0755
LRGRANT_1	-0.0012413	0.057462	-0.022	0.9831
LRGRANT_2	0.085539	0.075926	1.127	0.2776
LRGRANT_3	-0.050459	0.061991	-0.814	0.4284
Constant	-3.2717	1.9115	-1.712	0.1076

SEE = 0.0291066 RSS = 0.01270792074

URF Equation 4 for LRGRANT

Variable	Coefficient	Std.Error	t-value	t-prob
LINB_1	0.77896	0.49152	1.585	0.1339
LINB_2	0.22717	0.47109	0.482	0.6366
LINB_3	0.11863	0.49038	0.242	0.8121
LGNP_1	0.49074	1.3383	0.367	0.7190
LGNP_2	-1.7996	2.2767	-0.790	0.4416
LGNP_3	-0.43609	1.7237	-0.253	0.8037
RI_1	-1.1598	0.99995	-1.160	0.2642
RI_2	1.5538	1.0512	1.478	0.1601
RI_3	-0.54216	1.0570	-0.513	0.6155
LRGRANT_1	0.99236	0.26217	3.785	0.0018
LRGRANT_2	-0.58834	0.34642	-1.698	0.1101
LRGRANT_3	0.048430	0.28284	0.171	0.8663
Constant	11.278	8.7215	1.293	0.2155

SEE = 0.132802 RSS = 0.2645455771

correlation of URF residuals

	LINB	LGNP	RI	LRGRANT
LINB	1.000			
LGNP	0.4395	1.000		
RI	0.02817	-0.05260	1.000	
LRGRANT	0.2720	0.08219	0.006807	1.000

standard deviations of URF residuals

LINB	LGNP	RI	LRGRANT
0.1096	0.02684	0.02911	0.1328

R^2(LR) = 0.999866 R^2(LM) = 0.706997

correlation of actual and fitted

LINB	LGNP	RI	LRGRANT
0.9829	0.9971	0.8934	0.9479

LINB	: Portmanteau 4 lags=	4.9883	
LGNP	: Portmanteau 4 lags=	1.1452	
RI	: Portmanteau 4 lags=	3.8036	
LRGRANT	: Portmanteau 4 lags=	3.1023	
LINB	: AR 1- 2F(2, 13) =	0.12426	[0.8842]
LGNP	: AR 1- 2F(2, 13) =	0.66013	[0.5333]
RI	: AR 1- 2F(2, 13) =	1.3101	[0.3032]
LRGRANT	: AR 1- 2F(2, 13) =	1.0408	[0.3808]
LINB	: Normality Chi²(2)=	1.3591	[0.5068]
LGNP	: Normality Chi²(2)=	2.0913	[0.3515]
RI	: Normality Chi²(2)=	0.051248	[0.9747]
LRGRANT	: Normality Chi²(2)=	5.0502	[0.0801]
LINB	: ARCH 1 F(1, 13) =	0.076885	[0.7859]
LGNP	: ARCH 1 F(1, 13) =	1.0844	[0.3167]
RI	: ARCH 1 F(1, 13) =	0.41796	[0.5292]
LRGRANT	: ARCH 1 F(1, 13) =	0.40877	[0.5337]
Vector portmanteau	4 lags =	44.01	
Vector AR 1-2 F(32, 16)	=	1.413	[0.2342]
Vector normality Chi²(8)	=	8.324	[0.4025]

Table 4: Cointegration analysis 1964 to 1991

eigenvalue μi	loglik for rank	
	339.999	0
0.387056	346.852	1
0.35232	352.933	2
0.221368	356.436	3
0.100411	357.917	4

Ho:rank=p	-Tlog(1-μ)	T-nm	95%	-T_lg(1-μ)	T-nm	95%
p ==0	13.71	7.832	27.1	35.84	20.48	47.2
p <=1	12.16	6.95	21.0	22.13	12.65	29.7
p <=2	7.006	4.003	14.1	9.969	5.697	15.4
p <=3	2.963	1.693	3.8	2.963	1.693	3.8

standardised ß' eigenvectors

LINB	LGNP	RI	LRGRANT
1.000	-1.691	1.396	-0.2623
-1.297	1.000	2.858	1.171
-0.1793	0.3885	1.000	0.1830
-4.497	7.142	1.963	1.000

standardised α coefficients

LINB	-0.8181	0.1680	-0.5063	0.02811
LGNP	-0.1431	-0.009086	-0.01970	0.02191
RI	-0.3933	-0.04903	-0.01381	-0.009349
LRGRANT	0.7802	-0.1849	-0.7197	0.005415

long-run matrix Po= αß', rank 4

	LINB	LGNP	RI	LRGRANT
LINB	-1.072	1.555	-1.113	0.3468
LGNP	-0.2263	0.3817	-0.2025	0.04519
RI	-0.2852	0.5438	-0.7214	0.03384
LRGRANT	1.125	-1.745	-0.1481	-0.5476

The Johansen procedure was then applied as before. The results are a little more disappointing, in fact, as one can see from table 4, one cannot reject the hypothesis that there is no cointegrating relationship between the variables. While this is a significant finding in itself, it may still be useful to look at the results in more detail.

Table 5: General cointegration test 1964 to 1991

ß'

LINB	LGNP	RI	LRGRANT
-0.8486	1.138	-0.6024	0.3697

LINB	1.000
LGNP	0.0000
RI	0.0000
LRGRANT	0.0000

standardised ß' eigenvectors

LINB	LGNP	RI	LRGRANT
1.000	-1.341	0.7098	-0.4356

standardised α coefficients

LINB	-0.8486
LGNP	0.0000
RI	0.0000
LRGRANT	0.0000

Restricted long-run matrix Po= αß', rank 1

	LINB	LGNP	RI	LRGRANT
LINB	-0.8486	1.138	-0.6024	0.3697
LGNP	0.0000	0.0000	0.0000	0.0000
RI	0.0000	0.0000	0.0000	0.0000
LRGRANT	0.0000	0.0000	0.0000	0.0000

Reduced form ß'

	LGNP	RI	LRGRANT
LINB	1.341	-0.7098	0.4356

loglik = 345.332 unrloglik = 346.852
LR-test, rank=1: Chi^2(_3) = 3.0396 [0.3856]

The first cointegrating vector is the only one which appears to have any economic meaning - in the other vectors the variables appear to have perverse coefficients. However, it is not as close to the OLS long-run relationship as appeared to be the case in the case of building investment. If, however, we impose the restriction that the rank of b is one and that the a matrix is of the form { 1 0 0 0] - i.e. the single cointegrating variable has full weight in the first equation and none in the others - and let the Johensen procedure estimate the one cointegrating vector itself, it produces a result similar to the OLS one in Table 5. The interesting feature in this test is not so much the actual results as the fact that restrictions are not rejected.

Moving back to a VAR system in first differences - system 2 - one can see what the full system would look like utilising this CRvec variable from this constrained Johansen procedure which is, of course, only significant in the first equation. However, the overall fit of the system is poor - as was the fit of the OLS regression. This, together with the earlier finding that the variables may not cointegrate, suggests that the group of variables examined may not be the most appropriate and some further work is probably required in order to try to find a different - though possibly overlapping - set of more strongly cointegrating variables and, perhaps, using a different functional form .

SYS (2) Estimating the unrestricted reduced form by OLS

The present sample is: 1965 to 1991

URF Equation 1 for DLINB

Variable	**Coefficient**	**Std.Error**	**t-value**	**t-prob**
DLINB_1	0.27329	0.34678	0.788	0.4415
DLINB_2	-0.21921	0.28851	-0.760	0.4578
DLGNP_1	1.1014	1.0147	1.085	0.2929
DLGNP_2	0.059883	1.3411	0.045	0.9649
DRI_1	-0.27731	0.73572	-0.377	0.7109
DRI_2	-0.20736	0.75361	-0.275	0.7865
DLRGRANT_1	-0.16930	0.18004	-0.940	0.3602
DLRGRANT_2	-0.14557	0.21730	-0.670	0.5119
CRvec1_1	-0.83119	0.35476	-2.343	0.0316
Constant	-6.4800	2.7721	-2.338	0.0319

SEE = 0.105476 RSS = 0.1891275577

URF Equation 2 for DLGNP

Variable	Coefficient	Std.Error	t-value	t-prob
DLINB_1	0.11335	0.089327	1.269	0.2216
DLINB_2	-0.023123	0.074318	-0.311	0.7595
DLGNP_1	0.26864	0.26137	1.028	0.3184
DLGNP_2	-0.39404	0.34547	-1.141	0.2699
DRI_1	-0.080400	0.18951	-0.424	0.6767
DRI_2	0.010633	0.19412	0.055	0.9570
DLRGRANT_1	0.052014	0.046376	1.122	0.2776
DLRGRANT_2	-0.034895	0.055974	-0.623	0.5413
CRvec1_1	-0.018288	0.091384	-0.200	0.8438
Constant	-0.10992	0.71406	-0.154	0.8795
SEE = 0.0271696 RSS = 0.01254920136				

URF Equation 3 for DRI

Variable	Coefficient	Std.Error	t-value	t-prob
DLINB_1	-0.00061233	0.10930	-0.006	0.9956
DLINB_2	-0.12573	0.090936	-1.383	0.1847
DLGNP_1	-0.11075	0.31982	-0.346	0.7334
DLGNP_2	-0.10467	0.42271	-0.248	0.8074
DRI_1	-0.29964	0.23189	-1.292	0.2136
DRI_2	0.13022	0.23753	0.548	0.5907
DLRGRANT_1	-0.014368	0.056746	-0.253	0.8032
DLRGRANT_2	0.074268	0.068490	1.084	0.2933
CRvec1_1	0.010032	0.11182	0.090	0.9296
Constant	0.095850	0.87373	0.110	0.9139
SEE = 0.0332449 RSS = 0.01878879443				

URF Equation 4 for DLRGRANT

Variable	Coefficient	Std.Error	t-value	t-prob
DLINB_1	0.31682	0.47408	0.668	0.5129
DLINB_2	0.26376	0.39443	0.669	0.5127
DLGNP_1	1.0141	1.3872	0.731	0.4747
DLGNP_2	-0.24506	1.8335	-0.134	0.8952
DRI_1	-1.5374	1.0058	-1.529	0.1448
DRI_2	0.46183	1.0303	0.448	0.6596
DLRGRANT_1	0.40845	0.24613	1.659	0.1154
DLRGRANT_2	-0.19217	0.29707	-0.647	0.5263
CRvec1_1	0.31149	0.48500	0.642	0.5293
Constant	2.3900	3.7897	0.631	0.5366
SEE = 0.144197 RSS = 0.3534761403				

correlation of URF residuals

	DLINB	DLGNP	DRI	DLRGRANT
DLINB	1.000			
DLGNP	0.4697	1.000		
DRI	0.09930	0.05956	1.000	
DLRGRANT	0.2956	0.06844	-0.01175	1.000

standard deviations of URF residuals

DLINB	DLGNP	DRI	DLRGRANT
0.1055	0.02717	0.03324	0.1442

R^2(LR) = 0.873957 R^2(LM) = 0.383981

```
DLINB   : Portmanteau  4 lags=   4.7546
DLGNP    : Portmanteau  4 lags=   0.3648
DRI      : Portmanteau  4 lags=   4.4458
DLRGRANT: Portmanteau  4 lags=  0.87982
DLINB    : AR 1- 2F( 2, 15) =    0.14102 [0.8696]
DLGNP    : AR 1- 2F( 2, 15) =  0.0032082 [0.9968]
DRI      : AR 1- 2F( 2, 15) =     1.2069 [0.3266]
DLRGRANT: AR 1- 2F( 2, 15) =     0.37477 [0.6937]
DLINB    : Normality Chi²(2)=    0.90948 [0.6346]
DLGNP    : Normality Chi²(2)=   0.099445 [0.9515]
DRI      : Normality Chi²(2)=     5.7842 [0.0555]
DLRGRANT: Normality Chi²(2)=      4.6912 [0.0958]
DLINB    : ARCH 1 F( 1, 15) =    0.40506 [0.5341]
DLGNP    : ARCH 1 F( 1, 15) =    0.43759 [0.5183]
DRI      : ARCH 1 F( 1, 15) =    0.40017 [0.5365]
DLRGRANT: ARCH 1 F( 1, 15) =     0.17117 [0.6849]
Vector portmanteau  4 lags=   38.047
Vector AR 1-2 F(32, 23) =    0.54594 [0.9437]
Vector normality Chi²( 8)=    12.214 [0.1419]
```

Undoubtedly, one of the reasons for this slightly disappointing result is the difficult in measuring certain variables. In particular, while the real interest is a suitable variable for a parsimonious model the linkage between this variable and the actual cost of capital variable is highly complex, see Frain (1990). Even Frain's own calculations yield a variety of series which are not weighted together to form a variable that would be useful. Measurement problems may also explain the failure to find significant relationships between both relative factor prices and competitiveness and investment. Another problem relates to changes in the quality of investment over time. In particular, the improved performance of the economy in more recent years seems to have been achieved with relatively little investment. This may be because the quality of investment in latter years has been of a consistently higher quality. Unfortunately, this is not the kind of development which can easily be incorporated within a modelling framework.

Conclusions

As far as building investment is concerned certain relationships have been identified using OLS which seem to fit the data well. However, the results are undermined to some extent by a wider VAR analysis which suggests that current policy variable cannot, strictly speaking, be viewed as being exogenous. Nevertheless, apart from this caveat, the relationship seems reasonably satisfactory when analysed in a wider cointegration/VAR framework.

The results for non-building investment are somewhat more disappointing. While the relationships estimated by OLS are not at variance with the results of a wider VAR/cointegration analysis, they are not all that inspiring in terms of fit and would produce rather large forecasting errors if used in a small-scale model. A wider search for relationships amongst a slightly different set of variables might produce better results, but in the interim, the existing relationship will be used.

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Note

Copies of graphs associated with this paper are available in hardcopy from Research Department, Central Bank on request.