

# AN EMPIRICAL ANALYSIS OF M4 IN THE UNITED KINGDOM

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## **Abstract**

This paper presents an econometric analysis of M4 balances based on a split between the personal and corporate sectors. For the personal sector we find that simultaneous estimation of the demand for money and a consumption function yields encouraging results. The dynamic interaction of money and consumption may have an important role to play in explaining the recent behaviour of both variables. Modelling the corporate sector's money holdings is more problematic. The endogeneity of interest rates cannot be ignored and corporate behaviour is more likely to resemble the portfolio allocation than a traditional demand for money approach. Nevertheless, a relatively simple model can be estimated for corporate sector M4, which offers a starting point for future research.



## 1 Introduction

Analysis of the monetary aggregates plays an important role in UK monetary policy. There are currently two official monitoring ranges: for M0 (0 to 4% growth per annum) and M4 (3 to 9%). The usefulness of money as an intermediate indicator rests in part on the assumption that there exists a reasonably stable - or at least predictable - relationship between money growth and the growth of nominal income. We also need to understand what causes the monetary aggregates to change and their responsiveness to interest rates in particular. This paper presents an empirical analysis of the behaviour of M4 balances in the UK since 1977. The behaviour of M4 is studied in a companion paper (Breedon and Fisher, 1993). Our understanding of recent M4 behaviour has been limited and there are few useful empirical models available. The aim of this paper is to formulate some provisional relationships which might offer some useful insights and serve as a starting point for further research.

M4 was first introduced as an official monetary aggregate in 1987. Along with notes and coin it includes the sterling deposit liabilities of all UK banks and building societies to other private sector UK residents.<sup>(1)</sup> It replaced M3, the previous main broad money aggregate, which did not include deposits with building societies. Since M4 was introduced there have been few published studies of its behaviour. The most recent study conducted by the Bank of England was by Hall, Henry and Wilcox (1989), updated by Brookes, Hall, Henry and Hoggarth (1991). The Hall, Henry and Wilcox paper presented one of the first applications of the Johansen technique for estimating long-run relationships and examined M0, M1, M3 and M4. The M4 model related aggregate real M4 balances to real GDP, inflation, real personal sector total gross wealth and an equity price term. The preferred equation was notable for the relative importance of wealth rather than

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(1) See the May 1987 *Bank of England Quarterly Bulletin* pages 212 to 219 for a full definition.



income as the scale variable and for the absence of dynamic terms. A similar result was reported by Brookes *et al.* Those equations are now seen to be unsatisfactory, with the equity price term in particular causing problems.

The main purpose of the research reported in this paper is to identify what might be the most important factors driving M4. A secondary and complementary aim is to utilise a relatively new approach to econometric modelling. This is essentially data based, but retains sufficient economic structure to offer a behavioural interpretation. The final specifications should be taken as illustrative rather than definitive.

Section 2 of the paper presents a simple analysis of broad money, discussing the liability management view of bank and building society behaviour.<sup>(2)</sup> This analysis suggests that a sectoral split of M4 is likely to be the most appropriate way to proceed.<sup>(3)</sup> Section 3 presents an empirical analysis of personal sector holdings of M4 balances. The methodology chosen reveals that joint estimation of money demand and consumption expenditure may be important. The results are encouraging since they provide a stable, parsimonious explanation of personal sector M4 and a promising consumption function.

Section 4 presents an empirical analysis of corporate sector holdings of M4 balances. The results here are less satisfactory - mirroring the findings of earlier work with disaggregated Divisia indices (Fisher, Hudson and Pradhan, 1993). Nevertheless we do obtain a reasonably plausible model of corporate sector M4. Section 5 concludes the paper and summarises the results.

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(2) For a more detailed analysis see Goodhart (1984).

(3) A sectoral analysis is also preferred by Congdon and Ward (1993), who report an equation for personal sector M4.

## 2 A brief analysis of broad money and its counterparts

One starting point for an analysis of broad money is to consider its counterparts, as derived by setting out the other components of the consolidated balance sheet of banks and building societies. We can express M4 as being identically equal to bank and building society lending to the non-bank, non-building society sector ("M4 lending"), less net external transactions of banks and building societies ("Externals"), less net non-deposit liabilities ("NNDLs") plus a public sector contribution less public sector externals.<sup>(4)</sup> The public sector contribution is equal to the PSBR less debt sales to the non-bank, non-building society private sector.

The counterparts' relationship is an identity and therefore consistent with any particular behavioural model of M4. Nevertheless, the counterparts are useful to examine the liability management view of bank and building society behaviour.

The term "liability management" refers to the process whereby banks adjust their *deposit* rates in order to bring their liabilities (deposits) into line with their assets (lending). Conversely "asset management" refers to the adjustment of *lending* rates in order to bring their assets into line with their liabilities. While both activities are doubtless undertaken simultaneously, there is a long-standing view (see Goodhart 1984) that liability management dominates. Banks and building societies will generally undertake all profitable lending activities (allowing for risk and hence "credit crunch" behaviour) at market lending rate levels and then compete more or less aggressively for deposits as necessary (allowing for the fact that lending often entails the initial creation of a matching deposit). Despite the sequential description, this process *simultaneously* determines deposits, lending and interest rates.

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(4) Again, see *Bank of England Quarterly Bulletin*, May 1987, page 217 for further details.

Charts 2.1 and 2.2 illustrate the counterparts identity. Chart 2.1 shows M4 and M4 lending flows since 1983. The economic cycle is clearly reflected in both series with the lending figures showing the greater variability. For both series the fluctuations are greater than might be expected simply in response to the cycle in activity. The explanation is almost certainly connected with the process of financial liberalisation which should have shifted the supply curve of the financial services industry, leading to lower transactions costs and greater turnover. An expansion of lending activity should lead to a rise in deposit rates relative to base rates. More importantly perhaps, interest differentials between assets will reflect financial deregulation. As the financial system becomes more efficient, liquidity constraints are reduced and relative rates of return across assets should more accurately reflect the relative risk of holding those assets. The price of previously illiquid assets - such as housing - will rise, increasing measured wealth. In our empirical results we explain M4 wholly or partly by wealth and interest rates. We thus rely on changes in asset prices and interest differentials to reflect any effects of financial liberalisation. We might then expect to find stable relationships explaining M4, but the simple correlation between M4 and nominal income need not be stable.

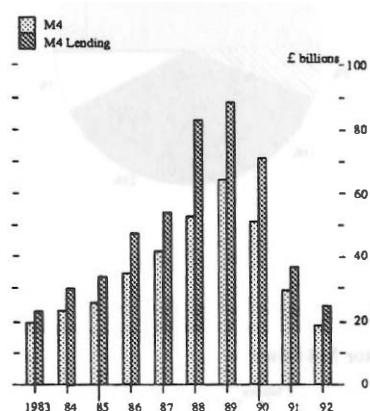
Chart 2.2 shows the contributions of the public sector (including net external finance), externals and NNDLs to the difference between M4 and M4 lending flows. The public sector contribution reflects the means by which a public sector deficit is financed. If the PSBR is offset by sales of gilts to the non-bank, non-building society private sector and the overseas sector, then the public sector contribution will be small. Since 1986 the difference between M4 and M4 lending is largely accounted for by externals (almost certainly related to the large current account deficit) and NNDLs.

If liability management dominates, then we should be able to see the consequences by disaggregating M4 deposits into wholesale and retail components. Building society retail deposits are those made by individuals or their intermediaries in the operation of savings

schemes.<sup>(5)</sup> Bank retail deposits are those arising from a customer's acceptance of an advertised rate for a particular product. Wholesale deposits will be the rest of M4 deposits.

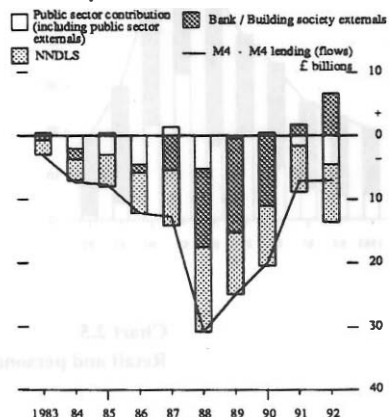
**Chart 2.1**

**M4 and credit flows**



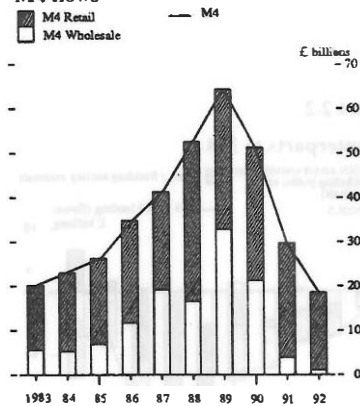
**Chart 2.2**

**Counterparts to M4**

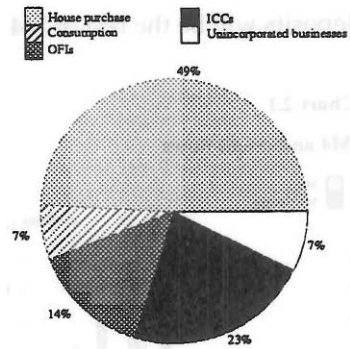


(5) And some corporate deposits under £50,000.

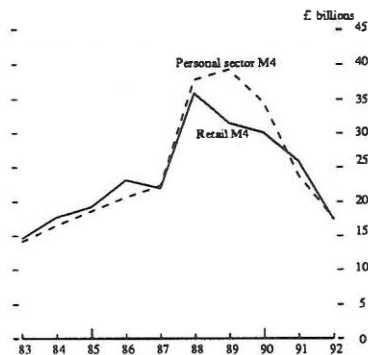
**Chart 2.3**  
**Retail and wholesale components of M4 flows**



**Chart 2.4**  
**M4 lending outstanding**



**Chart 2.5**  
**Retail and personal sector M4 flows**



If lending institutions need to raise deposits quickly it is more likely that they will do so in the wholesale market - partly because of the quantity of funds available at short notice but mostly because those funds are likely to be more price sensitive, at least in the short run. Chart 2.3 shows the decomposition of M4 flows into wholesale and retail components. The rapid expansion of M4 since 1983 is mirrored in wholesale market funding of banks and building societies which rose from a 20% contribution to the stock of M4 in 1983 to a peak of 30% in 1990.

If one accepts the liability management story, one approach to modelling M4 would be to build up the counterparts, concentrating on lending flows in particular. A decomposition of M4 lending for 1992 is shown in Chart 2.4. The largest component identified in the chart is lending to the personal sector for house purchase followed by lending to industrial and commercial companies (ICCs), other financial institutions (OFIs), unincorporated businesses and to the personal sector for consumption. At a minimum this suggests three models would be required: corporate (ICCs, OFIs and unincorporated; 44%); house purchase (49%); and consumption (7%).

Unfortunately the stocks of these variables are very difficult to model. Some of the lending represents long-term contracts (eg 25-year mortgages) which may require separate modelling of new flows and repayments. Corporate sector borrowing is especially challenging. Companies have a much wider degree of access to capital markets, requiring us to account for choices between capital and commercial paper issues and foreign currency finance, not just M4 lending.

Even if we obtained satisfactory models of M4 lending components, the determination of M4 by this route would require models of externals, NNDLs and the public sector contribution - each of which raises new problems. There does not seem to be much prospect of modelling M4 successfully by modelling its counterparts - even if we accept the

dominance of liability management. So what can we learn from the counterparts and liability management?

There are two important messages from this analysis. The first and most crucial is that a retail/wholesale split of M4 may be beneficial for modelling aggregate M4. The second is that an understanding of the process driving deposit rates may help in identifying appropriate demand equations for M4 balances. Since the exercise of liability management involves the setting of deposit rates these should contain relevant information to model M4 directly.

In practice the retail/wholesale split of M4 is not entirely convenient. The income and capital accounts, which will be used to provide the explanatory variables, are disaggregated by sector. Fortunately the retail/wholesale split of M4 corresponds quite closely and naturally to the personal/corporate (ICCs and OFIs) sector split - as shown in Chart 2.5. The correlation coefficient of the quarterly growth rate between personal and retail sectors is 0.97 (ie 97%). Hence in our empirical estimation we first model the personal sector M4 component and then the corporate sector.

A major problem with analysing any M4 component is the absence of long runs of detailed data on deposit rates. We would expect this to be most crucial for the corporate sector as the marginal source of funds and (probably) the most price-sensitive: it is the corporate sector which provided most of the volatility in M4 growth since 1983.

Disaggregation allows for slightly different modelling strategies for the personal and corporate sectors and these are discussed in each section.

### 3 Personal sector M4

#### 3.1 Introduction

The main aim of this section is to model the demand for M4 balances by the personal sector. The underlying economic theory is that of a conventional "demand for money" function in which real money balances are related to income and wealth (possibly as a proxy for permanent income) and real rates of return. Gross wealth is used with the intention of allowing for a portfolio allocation model: we know that M4 contains some savings balances as well as transaction balances. A dynamic adjustment model is specified in which agents adjust slowly to their desired holdings of real money balances.

The data set spans the period Q1 1977-Q4 1992 and consists of: real personal sector M4 deposits ( $m_t$ ), real consumption ( $c_t$ ), real disposable income ( $y_t$ ), real total (financial and tangible) gross personal sector wealth ( $w_t$ ), the 91-day Sterling Treasury bill rate as a proxy for the return on alternative assets ( $r_t$ ), an own-weighted average interest rate on personal sector M4 deposits ( $r_t^d$ ) and the inflation rate ( $\Delta p_t$ ).<sup>(6)</sup> The construction of  $r_t^d$  is explained in Fisher *et al* (1993). A full list of data sources is given in Appendix A. The implicit deflator of consumption was used to deflate all the nominal variables and in the definition of the inflation rate. All variables other than interest rates are in logarithms and are seasonally adjusted. The relatively short data set reflects the absence of reliable earlier data on wealth.

The inclusion of  $c_t$ ,  $w_t$  and  $y_t$  was intended to allow free choice of activity variable in explaining  $m_t$ . It became apparent that the data set allows for the identification of separate money demand and

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(6) The assumption of no long-run monetary illusion is behind the use of real rather than nominal variables, while the presence of the inflation rate in the data set allows for quite rich adjustment processes to the real values. Further, it avoids dealing with  $I(2)$  variables.



consumption functions and that allowing for dynamic interactions may improve both specifications.

All the variables listed have been extensively described in previous research as being  $I(1)$ <sup>(7)</sup> and this feature is carefully considered when modelling.

### 3.2 Econometric methodology

The paper mainly follows Hendry and Mizon's (1993) sequential modelling strategy for analysing non-stationary time series with cointegrating relationships. This requires the estimation of an unrestricted vector autoregression (VAR) model to act as a bench mark for subsequent structural modelling. Reducing a closed, congruent VAR model to an open structural representation requires mapping from  $I(1)$  to  $I(0)$ , weak exogeneity and encompassing, in order to validate inference, conditioning and simplification respectively.<sup>(8)</sup>

The reported results follow these steps. First we study the number of long-run relationships (cointegrating vectors) in the closed VAR defined by the data set. Then we consider a partially specified system for  $m_t$  and  $c_t$  conditional on the remaining variables, testing for the weak exogeneity assumption. The resulting open VAR is tested for parameter constancy and white noise, normally distributed errors. This simplified open VAR is then a useful baseline against which to test the ensuing structural model which is obtained by imposing chosen identification conditions and over-identification restrictions on the model.

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(7)  $I(k)$  denotes that a time series must be differenced  $k$  times before it becomes stationary.

(8) A closed system is one in which all variables are modelled as opposed to an open system in which we do not model a subset of variables ie we condition on that subset.

Finally, it should be remembered that, despite running the data through these various econometric procedures our aim is to uncover relatively simple "facts" about the data which will be helpful in future research. The precise equations reported should be regarded as illustrative.

### 3.3 Investigating the long-run relationships

In this sub-section we apply the cointegration analysis developed in Johansen (1988), fitting a closed VAR model to the seven dimensional vector  $X_t = (m_t, c_t, w_t, y_t, r_t, r_t^d, \Delta p_t)$ . A constant term and four lags of each variable - to control for residual autocorrelation - were included in the VAR. Additionally, in order to obtain residual normality and parameter constancy, four impulse dummy variables were included for Q2 1979, Q4 1980, Q3 1988 and Q1 1992.

The Johansen procedure allows for the maximum likelihood estimation of  $r$  long-run relationships between  $n$   $I(1)$  variables ( $r < n$ ). The long-run relationships correspond to those combinations of variables which have  $I(0)$  residuals. Being a statistical exercise it picks out those combinations with the most stationary residuals - but these need not correspond to meaningful economic relationships. The cointegrating vectors will, however, usually be linear combinations of the underlying economic relationships and we need to recover these using identification conditions.

Table 3.1 summarises the results of the cointegration procedure, with asterisks showing rejections of the null at the 5% confidence level. According to that, we can conclude that there are two cointegrating relationships among the seven variables and a linear trend in the data. The estimated cointegrating vectors are not reported because of the lack of structural interpretation.

**Table 3.1****Personal sector: cointegration test statistics**

<b>r</b>	<b>trace test</b>		<b>eigenvalue test</b>	
	<b>A</b>	<b>B</b>	<b>A</b>	<b>B</b>
0	178.4*	162.3*	56.5*	55.5*
1	121.9*	106.8*	40.8*	40.8*
2	81.1*	66.0	35.5*	25.5
3	45.6	40.5	25.1	24.9
4	20.5	15.6	10.6	9.7
5	9.9	5.9	8.6	5.2
6	1.3	0.7	1.3	0.7

**Notes:**

**r** = number of cointegrating vectors under the null hypothesis,

**A** = subject to the restriction that there are no linear trends in the data,

**B** = no restrictions,

**\*** = rejection of the null at the standard 5% significance level.

In order to simplify the system we partition the vector  $X_t$  into  $(Y_t, Z_t)$  where the vector  $Y_t$  contains the endogenous variables to be modelled conditional on  $Z_t$ . This requires weak exogeneity of  $Z_t$  and, to test for this, we use the two exogeneity tests of Urbain (1992). The first test is for the presence of the cointegrating vectors in the marginal model of  $Z_t$ . The second is for the presence of the residuals of the marginal model for  $Z_t$  in the conditional models for  $Y_t$ . These tests, if passed, allow us to treat  $Z_t$  as weakly exogenous when the parameters of interest are the long-run coefficients and the short-run coefficients respectively.

From preliminary tests we find that the partition of  $X_t$  into  $(Y_t, Z_t)$  where  $Y_t = (m_t, c_t)'$  and  $Z_t = (y_t, w_t, r_t, r_t^d, \Delta p_t)'$ , allows us to treat  $Z_t$  as weakly exogenous when the parameters of interest are both the long and short-run coefficients. This immediately suggests that we need to model money demand and the consumption decision simultaneously.

**Table 3.2**

**Personal sector: testing over-identifying restrictions on the long-run relationships**

cointegrating vectors						
	$\beta_1$	$\beta_2$	$\beta_1$	$\beta_2$	$\beta_1$	$\beta_2$
	restrictions			restrictions		
	$\beta_{15} = -\beta_{16}$ $\beta_{26} = 0$ $\chi^2(2) = 0.57 (0.75)$			$\beta_{13} = \beta_{14} = -0.5$ ; $\beta_{15} = -\beta_{16}$ $\beta_{23} + \beta_{14} = -1.0$ ; $\beta_{26} = 0$ $\chi^2(5) = 1.25 (0.94)$		
$m_t$	1.0	-	1.0	-	1.0	-
$c_t$	-	1.0	-	1.0	-	1.0
$w_t$	-0.39	-0.17	-0.41	-0.20	-0.50	-0.10
$y_t$	-0.79	-0.72	-0.70	-0.67	-0.50	-0.90
$r_t$	2.23	0.60	2.07	0.44	1.92	0.56
$\pi_t^d$	-1.79	-0.14	-2.07	-	-1.92	-
$\Delta p_t$	4.74	-0.39	5.40	-0.27	5.68	-0.65
loading coefficients						
	$\alpha_1$	$\alpha_2$	$\alpha_1$	$\alpha_2$	$\alpha_1$	$\alpha_2$
$\Delta m_t$	-0.096	0.227	-0.092	0.230	-0.075	0.172
$\Delta c_t$	-0.103	-0.094	-0.098	-0.123	-0.101	-0.117
residual analysis						
standard errors	$\sigma_1\%$		$\sigma_2\%$		$\sigma_{12} = 0.16$	
autocorrelation	BP <sub>1</sub> (13)		BP <sub>2</sub> (13)		= 12.9	
heteroscedasticity	ARCH <sub>1</sub> (2)		ARCH <sub>2</sub> (2)		= 0.19	
normality	JB <sub>1</sub> (2)		JB <sub>2</sub> (2)		= 3.7	

Notes:

subindexes 1, 2 correspond to residuals in  $\Delta m_t$ ,  $\Delta c_t$  equations,

$\sigma_{12}$  is the correlation coefficient between residuals,

BP is the Box-Pierce test,

ARCH is the test for autoregressive conditional heteroscedasticity,

JB is the Jarque-Bera test for normality.

All tests are asymptotically  $\chi^2$  with degrees of freedom as shown in brackets.

The next step is to take the partitioned (or open) VAR, impose some identifying conditions and then test for likely over-identifying restrictions.

Table 3.2 shows the estimates of the two cointegrating vectors ( $\beta_1, \beta_2$ ) stemming from the partial system (ie the open VAR) and tests for several structural hypotheses on the cointegrating relationships. The bottom part of Table 3.2 reports some tests on the open VAR residuals. No signs of residual autocorrelation (Box-Pierce statistics), autoregressive conditional heteroscedasticity (ARCH) or non-normality (Jarque-Bera tests) are detected.

In order to ensure exact identification of the long-run structure, we have normalised the cointegrating vectors in a way in which consumption does not enter the long-run demand for money equation and money does not enter the consumption equation. Our chosen conditions allow for short-run interaction between money and consumption but imposes more conventional long-run relationships. More precisely, let  $\beta_{ik}$  be the  $k$ th-element of the  $i$ th-cointegrating vector,  $i=1,2$  and  $k=1,\dots,7$ . Then, the normalization rule is  $\beta_{11}=\beta_{22}=1$  and  $\beta_{12}=\beta_{21}=0$ .

Other identification conditions could be imposed. If the chosen conditions reflect underlying behaviour then the estimated long-run relationships should be stable over different samples. Instability of the long-run relationships is therefore one indication that the identification conditions are not appropriate. As shown below, our estimated relationships are highly stable.

The results are shown in the first two columns of Table 3.2, with the two cointegrating vectors resembling a money demand equation and a consumption equation. In the following columns of Table 3.2, tests for various structural hypotheses are reported. The statistics given are tests for over-identifying restrictions and are distributed as  $\chi^2$  with degrees of freedom equal to the number of over-identifying

restrictions.<sup>(9)</sup> First, we test for the restrictions  $\beta_{15}=-\beta_{16}$  and  $\beta_{26}=0$ , ie that it is the interest rate differential which enters the long-run money demand equation and that the coefficient of  $r_t^d$  in the consumption equation equals zero. We cannot reject either hypothesis at conventional significance levels.

Second, we test for long-run homogeneity with respect to wealth and disposable income in both equations, ie the wealth and disposable income coefficients in each equation sum to unity. Imposing this restriction gives wealth and disposable income elasticities in the money demand equation of 0.51 and 0.49. On this basis, we impose the additional restriction that they both equal 0.5. The restrictions are easily accepted.

The restricted cointegrating vectors are shown in the third column of Table 3.2, although it is useful to express them in a slightly different way in order to make clear the sign on inflation in the long-run consumption equation. Let  $\pi_t=4\Delta p_t$ , that is the annualised inflation rate, then the cointegrating vectors can be written:

$$m_t = 0.5w_t + 0.5y_t - 1.92(r_t - r_t^d) - 1.42\pi_t \quad (1)$$

$$c_t = 0.1w_t + 0.9y_t - 0.56(r_t - \pi_t) - 0.40\pi_t \quad (2)$$

Both personal sector M4 and consumption depend negatively on the inflation rate, with the first also depending negatively on the interest differential and the second on the real interest rate. The presence of inflation in the long-run relationships could be explained simply as a statistical artefact due to the price level being I(2). However, it could also represent some sort of inflation adjustment to the level of income. We do not pursue this further here.<sup>(10)</sup>

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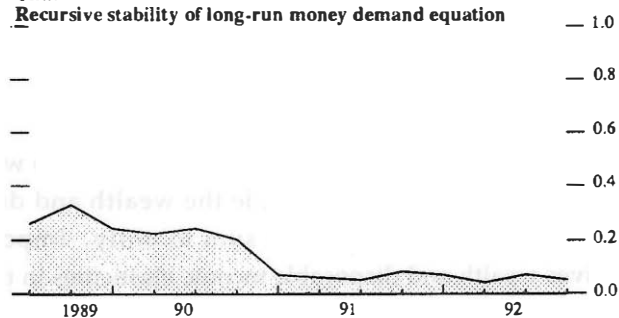
(9) See Johansen and Juselius (1992).

(10) In the case of equation (2) the last two terms could be alternatively written as  $-0.16(r_t - \pi_t) - 0.40r_t$ . This form is even harder to explain.

### *Personal sector : recursive stability tests*

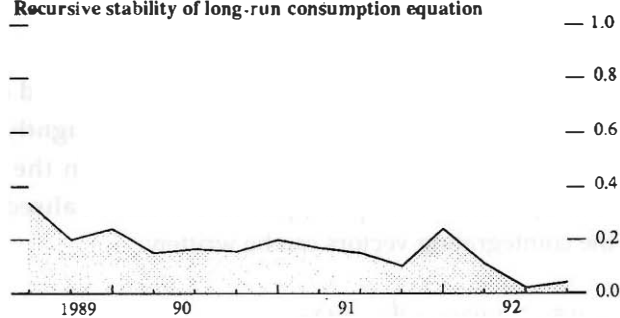
**Chart 3.1 :**

**Recursive stability of long-run money demand equation**



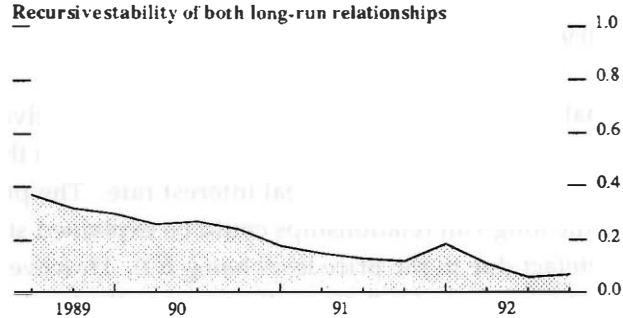
**Chart 3.2 :**

**Recursive stability of long-run consumption equation**



**Chart 3.3 :**

**Recursive stability of both long-run relationships**



Note : 5% significance level = 1.0

As a final test we need to show that our estimated relationships are stable. Charts 3.1 to 3.3 show test statistics for the stability of the estimated long-run relationships,<sup>(11)</sup> computing recursively the  $\chi^2$  tests for restrictions on  $\beta$  as the sample size increases.<sup>(12)</sup> On the basis of the evidence presented, we cannot reject the stability hypothesis. Hence our results do not suggest an inappropriate choice of identification conditions.

### 3.4 The simplified VAR

The cointegration analysis in Section 3.2 allows us to map the I(1) system into I(0) by defining two error correction terms expressing deviations of personal sector M4 and consumption from their long-run path:

$$ecm-m_t = m_t - .5w_t - .5y_t + 1.92(r_t - r_t^d) + 1.42\pi_t \quad (3)$$

$$ecm-c_t = c_t - .1w_t - .9y_t + .56(r_t - \pi_t) + .40\pi_t \quad (4)$$

The open VAR can be simplified by excluding insignificant variables. Table 3.3 shows F-tests and associated p-values for the significance of each retained regressor in the simplified partial system of  $Y_t$  conditional on  $Z_t$ . The bottom part of the table also includes measures of goodness of fit and  $\chi^2$  tests for the residuals being white noise and normally distributed. No signs of residual autocorrelation or non-normality are detected.

It is worth noting that, in order to reduce the dimensionality of the parameter space, the likelihood function has been concentrated by

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(11) See Hansen and Johansen (1992).

(12) Specifically, each figure reports the outcome (scaled by the 5% critical value so that a test statistic less than unity does not reject the null hypothesis) of testing that one cointegrating vector or both are contained in the cointegrating space when the sample is extended, starting in Q3 1988.



regressing all the variables in the VAR on a constant term and the four impulse dummies, so the latter do not appear in Table 3.3 or the remaining results.

All the retained regressors in the simplified open VAR are significant at standard confidence levels and the importance of both error correction terms is clear. Furthermore, the resulting VAR seems congruent with the data, as shown by the reported "trace correlation" ( $TC=.874$ ) and "vector alienation coefficient" ( $VAC=.045$ ) statistics. These are system statistics analogous to single equation  $(R^2)^{1/2}$  and  $(1-R^2)$ , respectively. The fit of both questions and the estimated residuals are shown in Charts 3.4 to 3.7.

Finally, Charts 3.8 to 3.11 report sequences of Chow statistics (scaled by their 5% critical value) testing for parameter constancy. The Chow statistic is calculated as:

$$Chow(n, t-k) = \frac{(RSS_{t+n} - RSS_t)/n}{RSS_t/(t-k)} F(n, t-k) \quad (5)$$

where  $RSS_{t+n}$  is the recursive residual sum of squares and  $n$  is the "forecast horizon". Specifically, in Charts 3.8 and 3.10 (1-step forecast tests) the "forecast horizon" is fixed and equal to 1, and the sequence of statistics is defined as:  $\{Chow(1, t-k), t=h, \dots, T-1\}$ . Meanwhile, in Charts 3.9 and 3.11 (break-point Chow Statistic) the "forecast horizon" is decreasing and the sequence is calculated as:  $\{Chow(n, t-n-k), n=T-h, \dots, 1\}$ . No sign of parameter instability can be detected from the recursive analysis.

On the previous basis, it is not possible to reject the hypothesis that the simplified partial model has acceptably constant parameters and approximately white noise, normally distributed errors.

**Table 3.3**  
**Personal sector: the simplified VAR**

F-tests on retained regressors (and probability values)						
	$\Delta m_{t-1}$	$\Delta c_{t-3}$	$\Delta w_{t-3}$	$\Delta y_t$	$\Delta y_{t-1}$	$\Sigma \Delta y_{t-i}$
F=	3.41	5.18	3.92	6.68	10.41	4.40
(Pr=)	(0.042)	(0.009)	(0.027)	(0.003)	(0.000)	(0.018)
	$\Delta^2 p_t$	$\Sigma \Delta^2 p_{t-i}$	$\Delta r_{t-1}$	$\Delta r^d_{t-1}$	$\Delta r^d_{t-2}$	$\Delta r^d_{t-3}$
F=	80.85	3.39	3.36	2.10	9.89	5.79
(Pr=)	(0.000)	(0.043)	(0.043)	(0.134)	(0.000)	(0.006)
	$(ecm-m)_{t-1}$	$(ecm-c)_{t-1}$				
F=	13.91	20.61				
(Pr=)	(0.000)	(0.000)				

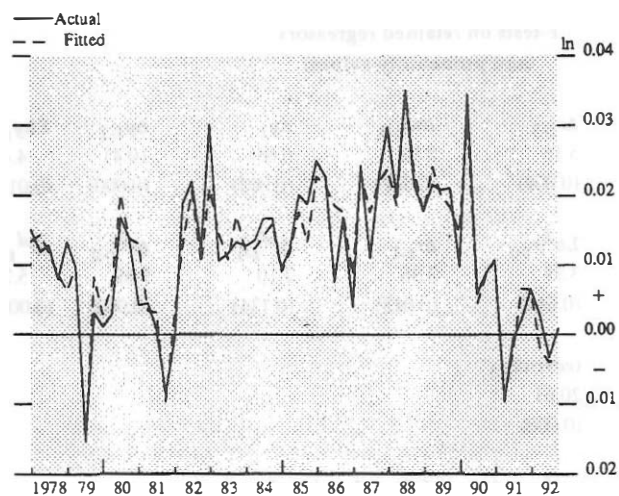
**measures of goodness of fit and residual analysis**

fit	TC	= 0.874	VAC	= 0.045	$\sigma_{12} = 0.34$
standard errors	$\sigma_1 \%$	= 0.36	$\sigma_2 \%$	= 0.54	
autocorrelation	$BP_1(6)$	= 7.4	$BP_2(6)$	= 6.9	
normality	$JB_1(2)$	= 3.9	$JB_2(2)$	= 0.5	

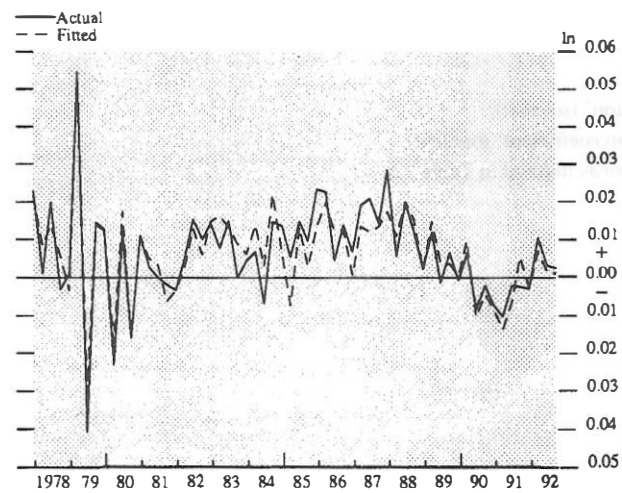
Notes:

TC is the "trace correlation" (see text),  
VAC is "vector alienation coefficient" (see text),  
and other diagnostics are as defined in Table 3.2.

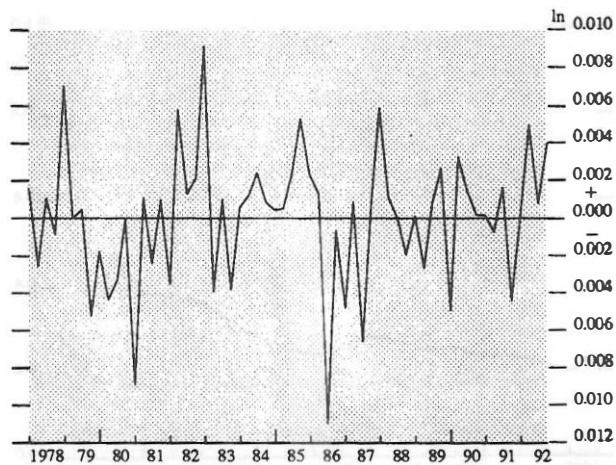
**Chart 3.4**  
**Personal sector; actual and fitted values of M4 equation**



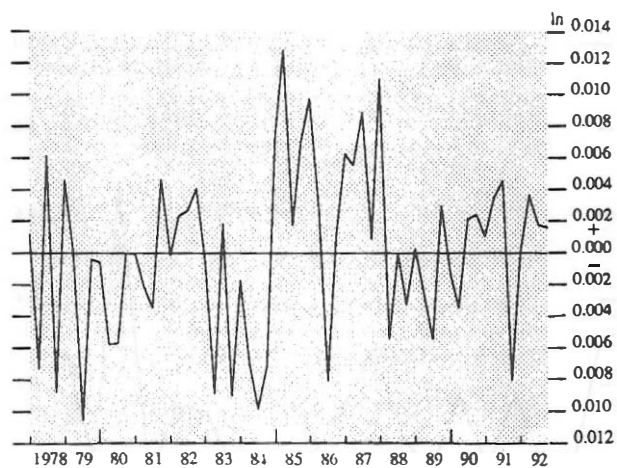
**Chart 3.5**  
**Personal sector; actual and fitted values of consumption equation**



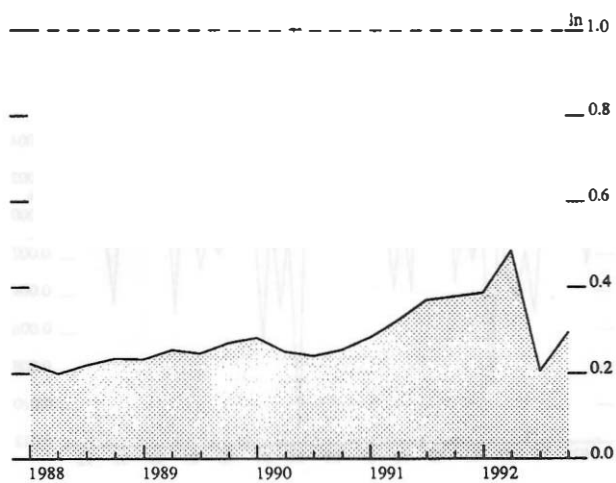
**Chart 3.6**  
**Personal sector; residuals of M4 equation**



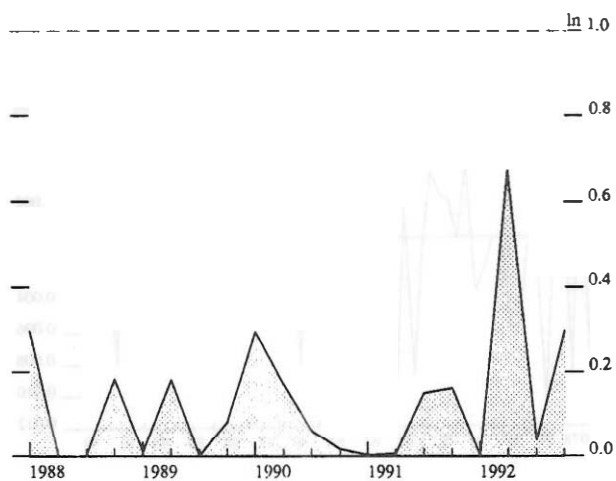
**Chart 3.7**  
**Personal sector; residuals of consumption equation**



**Charts 3.8**  
**Personal sector; M4 equation 1-step Chow tests**



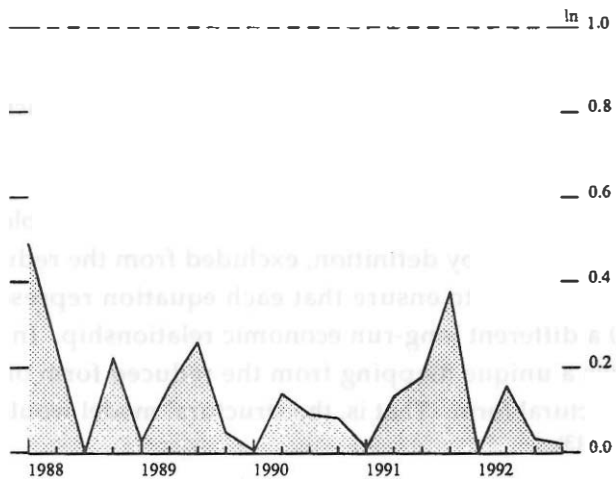
**Chart 3.9**  
**Personal sector; M4 equation break-point Chow tests**



Note: 5% significance level = 1.0.

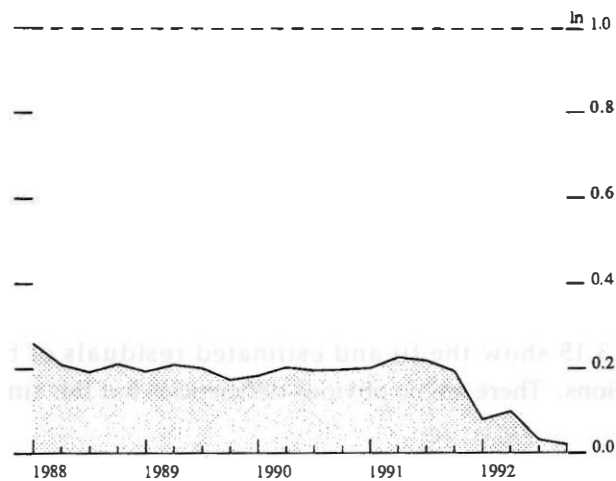
**Chart 3.10**

**Personal sector: consumption equation 1-step Chow tests**



**Chart 3.11**

**Personal sector: consumption equation break-point Chow tests**



Note: 5% significance level = 1.0.

### 3.5 The structural model

So far, we have focused on the reduced form of the model with structural information incorporated only into the long-run relationship. In the following, we will try to recover the full dynamic structural form. Following Bårdsen and Fisher (1993), we propose the structural form to be that with only one long-run relationship entering each structural equation. These equations are then allowed to have contemporaneous relationships between the endogenous variables in the dynamics (which are, by definition, excluded from the reduced form). The point here is to ensure that each equation represents (adjustment to) a different long-run economic relationship. In this context, it allows a unique mapping from the reduced form of the model to the structural form. That is, the structural model would be exactly identified.<sup>(13)</sup>

Table 3.4 shows the final Full Information Maximum Likelihood (FIML) estimates of the structural model. In comparison to the previous VAR, some further simplifications have been made, excluding from each equation those variables which were jointly significant in the open VAR but which were not in the structural equations. This provides some overidentifying restrictions that are tested for in the lower half of Table 3.4. The statistic reported is the Hendry and Mizon (1993) encompassing test against the simplified VAR, which is easily accepted. Thus we cannot reject the hypothesis that the structural representation encompasses the statistical system, providing a valid parsimonious representation.

Charts 3.12 to 3.15 show the fit and estimated residuals of both structural equations. There are no obvious deficiencies but this simply

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(13) This choice of identification condition does not prevent both endogenous variables from reacting to both ecm terms. This is ensured by the presence of both contemporaneous terms in each equation.

reflects the clean diagnostics and the testing down procedure. Table 3.5 shows the restricted reduced form of the structural model.

The structural model contains no information not available in the reduced form. However, it makes some things clearer. In the money demand equation both consumption and money react to the deviation of money from desired long-run levels. Similarly, in the consumption equation, both variables react to deviations in consumption from desired long-run levels. It is interesting to note that this yields a negative contemporaneous correlation between M4 and consumption in one equation and a positive correlation in the other. These conflicting correlations ensure stability but make it difficult to identify a particular simple correlation in the data (consider the analogous case of supply and demand, price and quantity correlation).

One possible interpretation of this system is that we are implicitly modelling the demand and supply of credit having substituted consumption for credit demand. Short-run restrictions on the supply of credit could then explain the short-run relationship between money and consumption.

One empirical danger is that consumption and savings are related to net financial balances via a wealth identity. In this respect the choice of total gross wealth is important. Revaluation effects (eg on housing) and the choice of gross rather than net wealth ensures that there is no identity linking the variables.



**Table 3.4**

**Personal sector: the structural model**

money demand equation					
$\Delta m_t =$	0.56 $\Delta m_{t-1}$ (3.19)	+	0.15 $\Delta w_{t-3}$ (2.06)	+	0.27 $\Delta y_t$ (1.78)
+	0.65 $\Delta y_{t-1}$ (2.44)	-	2.15 $\Delta^2 p_t$ (3.92)	-	0.44 $\sum_{i=1}^2 \Delta^2 p_{t-i}$ (1.77)
-	0.29 $\Delta r_{t-1}$ (2.25)	+	0.45 $\Delta r_{t-1}^d$ (2.08)	-	1.16 $\Delta r_{t-2}^d$ (2.55)
+	0.61 $\Delta r_{t-3}^d$ (2.95)	-	0.158 $(ecm-m)_{t-1}$ (3.20)	-	1.46 $\Delta c_t$ (2.39)

consumption equation					
$\Delta c_t =$	0.24 $\Delta c_{t-3}$ (3.59)	+	0.10 $\Delta w_{t-3}$ (3.02)	+	0.25 $\Delta y_t$ (4.11)
+	0.10 $\Delta y_{t-1}$ (1.68)	-	0.15 $\sum_{i=2}^3 \Delta y_{t-i}$ (3.51)	-	0.38 $\sum_{i=1}^2 \Delta^2 p_{t-i}$ (3.73)
-	0.35 $\Delta r^d_{t-2}$ (2.25)	-	0.30 $(ecm-c)_{t-1}$ (7.17)	+	0.79 $\Delta m_t$ (9.29)

residual analysis				
standard errors	$\sigma_1\%$	= 0.975	$\sigma_2\%$	= 0.524
autocorrelation	$BP_1(6)$	= 7.4	$BP_2(6)$	= 6.9
normality	$JB_1(2)$	= 3.0	$JB_2(2)$	= 0.8
encompassing	$HM(7)$	= 2.24		

Notes:

$$(ecm-m)_t = m_t - 0.5 w_t - 0.5 y_t + 1.92 (r_t - r_t^d) + 5.68 \Delta p_t$$

$$(ecm-c)_t = c_t - 0.1 w_t - 0.9 y_t + 0.56 (r_t - \pi_t) + 0.40 \pi_t$$

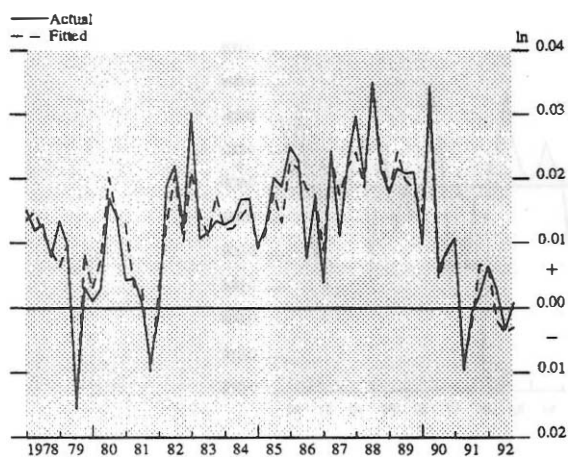
$t$ -ratios are given in parentheses,

$HM(\cdot)$  is the Hendry-Mizon Test against the simplified VAR,

other diagnostics are as defined in Table 3.2.

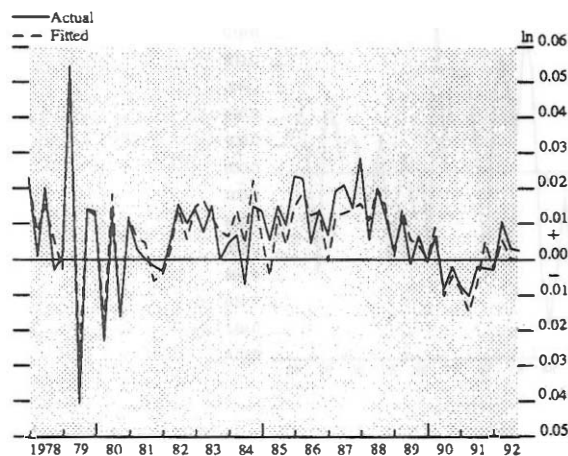
**Chart 3.12**

**Personal sector; actual and fitted values of M4 equation: structural form**



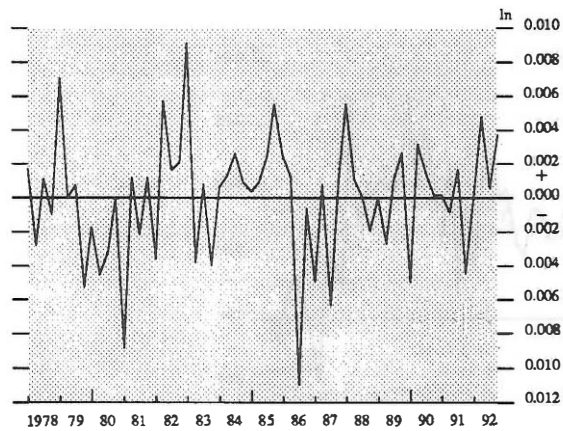
**Chart 3.13**

**Personal sector; actual and fitted values of consumption equation: structural form**



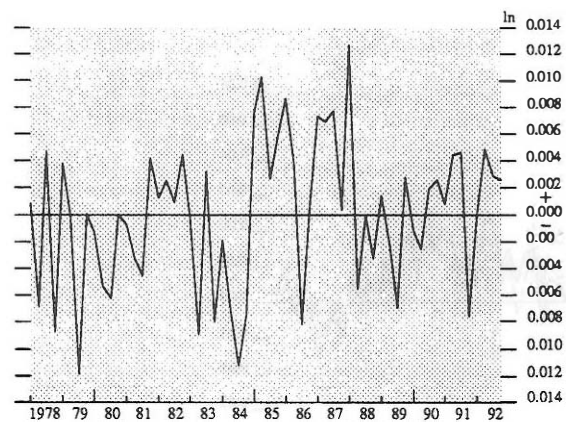
**Chart 3.14**

**Personal sector; residuals of M4 equation: structural form**



**Chart 3.15**

**Personal sector; residuals of consumption equation: structural form**



**Table 3.5**

**Personal sector: restricted reduced form of structural model**

dependent variable	explanatory variables					
	$\Delta m_{t-1}$	$\Delta c_{t-3}$	$\Delta w_{t-3}$	$\Delta y_t$	$\Delta y_{t-1}$	$\Sigma \Delta y_{t-i}$
$\Delta m_t$	0.258 (0.082)	-0.163 (0.045)	0.002 (0.024)	-0.040 (0.043)	0.232 (0.051)	0.100 (0.030)
$\Delta c_t$	0.205 (0.0607)	0.112 (0.047)	0.099 (0.033)	0.215 (0.063)	0.287 (0.067)	-0.069 (0.028)
	$\Delta^2 p_t$	$\Sigma \Delta^2 p_{t-i}$	$\Delta r_{t-1}$	$\Delta r^d_{t-1}$	$\Delta r^d_{t-2}$	$\Delta r^d_{t-3}$
$\Delta m_t$	-0.996 (0.070)	0.049 (0.087)	-0.136 (0.049)	0.206 (0.090)	-0.305 (0.088)	0.284 (0.075)
$\Delta c_t$	-0.792 (0.094)	-0.338 (0.108)	-0.108 (0.040)	0.164 (0.073)	-0.589 (0.117)	0.226 (0.063)
	$(ecm-m)_{t-1}$	$(ecm-c)_{t-1}$				
$\Delta m_t$	-0.073 (0.012)	0.201 (0.033)				
$\Delta c_t$	-0.058 (0.011)	-0.138 (0.044)				
standard errors	$\sigma_1\% = 0.359$		$\sigma_2\% = 0.545$		$\sigma_{12} = 0.333$	

### 3.6 Conclusions: personal sector

The equations reported above should not be regarded as definitive. Alternative choices of data variables could be justified - particularly for wealth or interest rates - and many marginal differences to the models could be explored. These include the functional form (eg the possible inflation-adjustment of income) and the particular identification and

over-identification conditions used. At this stage in our research we should look for more general conclusions.

Joint modelling of money demand and consumption seems to be adding substantially to our ability to explain both variables. During the recent UK economic cycle, consumption functions have tended to underpredict during the boom and overpredict during the recession. These dynamic errors appear to be removed by taking into account the effects of money balances - see Chart 3.15. This result holds despite our assumption that the long-run relationships are "separable" in the sense that the variables are excluded from each other's ecm terms. This seems intuitively plausible. Short-run restrictions on credit might easily be sufficient to generate such results and this is clearly an area where further theoretical research may be useful.

It is unlikely that our preferred specifications in Table 3.4 could have been realised by a single equation approach - at the simplest level the appropriate instruments for the simultaneous endogenous terms would not have been apparent (the excluded ecm term is the obvious choice in each case). The Hendry and Mizon (1993) sequential strategy has been very useful in this respect. But it should be noted that the choices of data set and the identification /over-identification conditions are crucial - and these remain a matter for prior economic analysis not statistical technique.

We have confirmed the importance of wealth - the main finding of Hall, Henry and Wilcox (1989) (HHW). This is not surprising given that M4 includes savings as well as transaction balances. In addition we also have strong effects from income which HHW did not. A further addition to the HHW formulation is the role for interest rates and inflation. The interest differential simply reflects the relative cost of holding M4 and its significance in our results could be due to the use of sectoral data. The role played by inflation is more problematic. This could simply be part of the dynamics or it could reflect an inflation adjustment to income.

We do not find it necessary to include any additional variables for financial de-regulation but any direct effects could be proxied by several of the included variables.

Overall the results reported in this section are highly encouraging both for M4 and for consumption. A need for further theoretical research is apparent in respect of the joint consumption/money demand decision and many aspects of the empirical specifications could also be explored further.

## **4 Corporate sector M4**

### **4.1 Introduction**

A textbook transaction demand for money approach is unlikely to be appropriate in modelling the demand for corporate sector M4 and, if applied, tends to produce poor empirical results. The corporate sector - defined here to include "Other Financial Institutions" (primarily life assurance and pension funds) as well as Industrial and Commercial Companies - holds a relatively small proportion of its financial assets in the form of money balances.<sup>(14)</sup> At the end of 1992, the corporate sector held 10% of its financial assets in M4 balances whereas the personal sector held 25% (if we exclude their life assurance and pension fund holdings, which are generally regarded as being illiquid by the personal sector, this figure rises to 51%). In general the corporate sector is more likely to switch among money, gilts, equities and overseas assets according to relative rates of return and liquidity preference. Hence a portfolio allocation model with little or no transactions component may be most appropriate.

---

(14) In preliminary testing we found no interesting differences when modelling M4 holdings by OFIs and ICCs separately. Of course, this could reflect mis-specification in respect of both sub-sectors but we leave this split for further research.

Any non-price effect of financial liberalisation is perhaps more likely to affect the corporate sector than the personal sector. The boom in asset prices may have reflected either the expectations of higher profits following supply side reforms or the increased competition for providing financial services following de-regulation. In either case, by conditioning on wealth and interest rates we seem to capture any effects from financial liberalisation.

For the current exercise we choose a partial approach in which corporate sector M4 holdings are modelled as a function of total financial assets (with a null hypothesis of a unit elasticity) and relative rates of return between M4 balances and competing assets. The main concerns are:

- (a) we do not have very good information on actual rates of return (particularly on M4 balances); and
- (b) the relative rate of return, tested and treated as weakly exogenous for the personal sector, should be endogenous for the corporate sector.

The first of these problems is addressed by taking the London three-month interbank rate ( $rs$ ) as a proxy for the rate paid on M4 deposits and the 20 year par yield ( $rl$ ) as the alternative rate of return.<sup>(15)</sup> (Gilts are a major component of OFI's financial assets.) The spread ( $rl-rs$ ) seems to work well as a measure of the cost of holding M4 balances but could also be interpreted as a measure of monetary policy tightness since monetary policy impinges more directly on short rates than long rates. In either interpretation we address the second problem by including price inflation as an additional variable. Initially this is seen as an (weakly exogenous) instrument for lending activity.

---

(15) Experiments with holding period returns for equities, gilts and overseas assets give series which are extremely volatile and yield poor econometric results. Some sort of conditional smoothing may be necessary.

However, it also allows us to interpret one of the long-run relationships as a policy reaction function.

The data set covers the period Q1 1977 - Q4 1992 and consists of real break-adjusted corporate sector M4 deposits ( $mc_t$ ), real total corporate sector financial assets (excluding trade credit) ( $wc_t$ ), the spread between the 20-year par bond yield and LIBOR ( $sl_t$ ) and the inflation rate of the GDP deflator ( $\Delta pg_t$ ). The level of the GDP deflator was used to define the real variables. Pre-testing including the level of GDP did not lead to satisfactory results. All variables are in logarithms and are seasonally adjusted as appropriate. All the variables can be treated as I(1) over this sample period. As in the personal sector, it is the quality of the wealth data which restricts the length of the sample period.

The same specification and testing strategy is employed as for the personal sector, starting with the long-run relationships and then continuing with the dynamic reduced form and structural form estimates.

## 4.2 Investigating the long-run relationships

We have a five dimensional VAR modelling the vector  $X_t = (mc_t, rs_t, wc_t, \Delta pg_t, rl_t)$ . A constant term and four lags are included. Two dummy variables were formed for stock market falls in 1987 and 1990. D87 is unity in Q4 1987 and -0.25 for the preceding four quarters; D90 is unity in Q3 1990 and -0.5 in the following two quarters. These dummies are necessary for normality of the marginal model of financial wealth and are dropped from our final specifications.

Results of the Johansen procedure are given in Table 4.1. These show that there may be two cointegrating vectors. In order to investigate these we partition the vector  $X_t$  into  $(Y_t, Z_t)$  where  $Y_t = (mc_t, rs_t)'$  and  $Z_t = (wc_t, \Delta pg_t, rl_t)'$  testing as before for the weak exogeneity of  $Z_t$  which is accepted.



Table 4.2 shows the results of imposing identification conditions and testing two structural hypotheses on the open VAR. In order to identify the two vectors we set  $\beta_{11} = \beta_{22} = 1$  and  $\beta_{14} = \beta_{23} = 0$ , excluding inflation from one vector and real wealth from the other. These cointegrating relationships are still difficult to interpret and so we impose further over-identification restrictions: the unit elasticity between money and wealth in vector one ( $\beta_{13} = -1$ ) and the exclusion of money, wealth, and the bond rate from vector two ( $\beta_{21} = \beta_{23} = \beta_{25} = 0$ ). These restrictions are easily supported at a 5% level. Ignoring intercept terms, the two restricted relationships can then be written as:

$$mc_t = wc_t - 8.82 (rl_t - rs_t) \quad (6)$$

$$rs_t = 0.56\pi_t \quad (7)$$

where  $\pi_t = 4\Delta p g_t$  is the annualised inflation rate. Equation (7) could be interpreted as a monetary policy reaction function in which short-term rates vary according to observed inflation (although with a less than unit coefficient). It could also be a highly simplified model of the credit side with high inflation indicating a high level of activity, raising the demand for credit and hence its price. For our purposes this is a "nuisance" equation and its precise form and interpretation are not the primary focus.

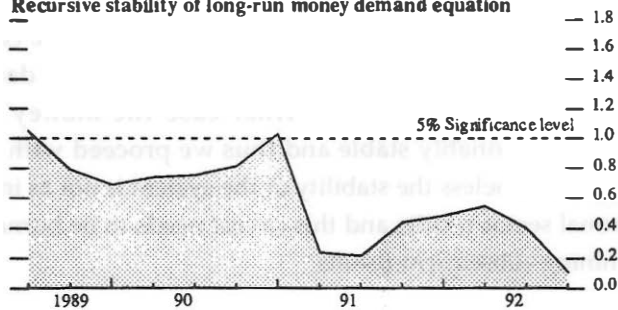
Charts 4.1 to 4.3 plot test statistics for the stability of the estimated long-run relationships. The stability of the money demand relationship (Chart 4.2) is supported except for two points where the test statistic just creeps over the 5% critical value. However, the test for stability of the interest rate equation, and the joint test, rejects stability for samples ending before 1991. There are a number of reasons why the interest rate equation may show instability. If it is a policy reaction function then, with frequent changes of intermediate policy target, we might expect instability in the inflation coefficient. The fact that instability coincides with the point of ERM entry is evidence to support this

reasoning. Alternatively, we may just be witnessing a small sample phenomenon arising from using an asymptotically valid procedure over too small a sample. In other exercises we have sometimes found that data sets which stop halfway through a business cycle can lead to peculiar estimates of long-run relationships. Using our full data sample should avoid this problem. In either case the money demand relationship is reasonably stable and thus we proceed with dynamic estimation. Nevertheless the stability of the system is not as impressive as the personal sector results and this caveat needs to be borne in mind when examining subsequent results.

### *Corporate sector : recursive stability tests*

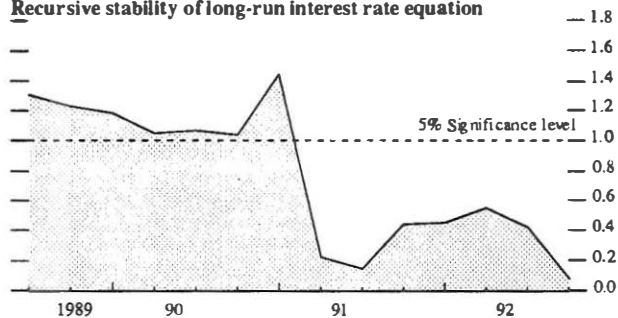
**Chart 4.1 :**

**Recursive stability of long-run money demand equation**



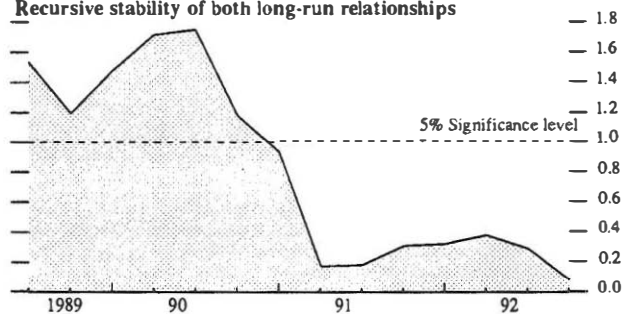
**Chart 4.2 :**

**Recursive stability of long-run interest rate equation**



**Chart 4.3 :**

**Recursive stability of both long-run relationships**



**Table 4.1****Corporate sector: cointegration test statistics**

r	trace test		eigenvalue test	
	A	B	A	B
0	102.6*	90.4*	45.6*	40.9*
1	57.0*	49.6*	24.8**	24.4**
2	32.2	25.2	20.5	17.0
3	11.7	8.2	6.9	7.4
4	4.8	0.8	4.8	0.8

Notes:

- r = number of cointegrating vectors under the null hypothesis,  
 A = subject to the restriction that there are no linear trends in the data,  
 B = no restrictions,  
 \* = rejection of the null at the standard 5% significance level,  
 \*\* = rejection of the null at 10% significance level.

Table 4.2

Corporate sector: testing over-identifying restrictions on the long-run relationships

cointegrating vectors					
	$\beta_1$	$\beta_2$	$\beta_1$	$\beta_2$	
	restrictions				
	$\beta_{11} = -\beta_{13}$ $\beta_{12} = -\beta_{15}$ $\beta_{21} = \beta_{25} = 0$ $\chi^2(4) = 0.99$				
$mc_t$	1.0	-0.05	1.0	-	
$rs_t$	-14.25	1.0	-8.82	1.0	
$wc_t$	-0.25	-	-1.0	-	
$\Delta p8_t$	-	-0.33	-	-2.31	
$rl_t$	31.44	-2.06	8.82	-	
loading coefficients					
	$\alpha_1$	$\alpha_2$	$\alpha_1$	$\alpha_2$	
$\Delta mc_t$	-0.339	-4.670	-0.098	-0.764	
$\Delta rs_t$	-0.069	-1.235	0.008	-0.099	
residual analysis					
standard errors	$\sigma_1\%$ = 1.39		$\sigma_2\%$ = 0.68		$\sigma_{12} = 0.27$
autocorrelation	$BP_1(11)$ = 12.3		$BP_2(11)$ = 9.1		
heteroscedasticity	$ARCH_1(4)$ = 2.2		$ARCH_2(4)$ = 2.1		
normality	$JB_1(2)$ = 0.4		$JB_2(2)$ = 1.3		

Notes:

subindexes 1, 2 correspond to residuals in  $\Delta mc$ ,  $\Delta rs$  equations,

$\sigma_{12}$  is the correlation coefficient between residuals,

$BP$  is the Box-Pierce test,

$ARCH$  is the test for autoregressive conditional heteroscedasticity,

$JB$  is the Jarque-Bera test for normality.

All tests are asymptotically  $\chi^2$  with degrees of freedom as shown in brackets.

**Table 4.3**  
**Corporate sector: the simplified VAR**

F-tests on retained regressors (and probability values)					
	$\Delta mc_{t-1}$	$\Delta mc_{t-2}$	$\Delta mc_{t-3}$	$\Delta rs_{t-3}$	$\Delta rl$
F=	2.13	3.43	2.42	3.44	16.85
(Pr=)	(0.130)	(0.041)	(0.100)	(0.040)	(0.000)
	$\Delta^2 pg_t$	$\Delta^2 pg_{t-1}$	$\Delta^2 pg_{t-2}$	$\Delta^2 pg_{t-3}$	$\Delta rw_{t-1}$
F=	15.99	11.37	8.85	2.55	2.42
(Pr=)	(0.000)	(0.000)	(0.001)	(0.089)	(0.100)
	$\Delta rw_{t-3}$	$(ecm-mc)_{t-1}$	$(ecm-rs)_{t-1}$		
F=	1.91	10.40	4.83		
(Pr=)	(0.160)	(0.000)	(0.013)		

**measures of goodness of fit and residual analysis**

fit	TC	= 0.83	VAC	= 0.082	$\sigma_{12} = 0.25$
standard errors	$\sigma_1 \%$	= 1.54	$\sigma_2 \%$	= 0.74	
autocorrelation	$BP_1(4)$	= 1.31	$BP_2(4)$	= 6.46	
normality	$JB_1(2)$	= 0.18	$JB_2(2)$	= 0.05	

Notes:

TC is the "trace correlation" (see text),  
VAC is the "vector alienation coefficient" (see text),  
subindexes 1,2 correspond to residuals in  $\Delta mc$ ,  $\Delta rs$  equations  
other diagnostics are defined as in Table 4.2.

### 4.3 The simplified VAR

The cointegration analysis in the preceding section allows us to create the following two error-correction terms:

$$(ecm - mc)_t = mc_t - wc_t + 8.82 (rl_t - rs_t) \quad (10)$$

$$(ecm - rs)_t = rs_t - 2.31 \Delta pg_t \quad (11)$$

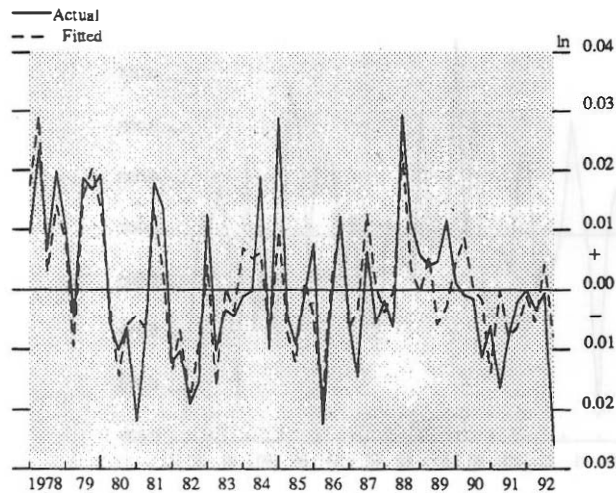
The open VAR can be considerably simplified and Table 4.3 shows  $F$ -tests and associated  $p$ -values for the retained regressors in the simplified partial system. The fit of this system is only slightly worse than that of the personal sector ( $TC = 0.830$  compared with 0.874 reported in Section 3.3 and  $VAC = 0.082$  compared with 0.045). The fit of the equations are shown in Charts 4.4 to 4.7.

Finally, one-step forecast statistics and break-point Chow statistics are shown in Figures 4.8 to 4.11. As before, there is some indication of instability in the equation for  $\Delta rs$  which breaks the 5% critical value on each type of test, but the equation for  $\Delta mc$  is reasonably stable.

Overall the corporate sector equations are not quite as reliable as the personal sector. However, most of the problems are associated with the endogeneity of interest rates and hence the specification of the interest rate equation. It is not obvious that it is possible to specify a stable interest rate equation if the behaviour it represents is in part a policy reaction function. Nevertheless the results presented here are sufficiently encouraging for the equation of interest (corporate sector M4 balances) for us to continue with a structural form specification.

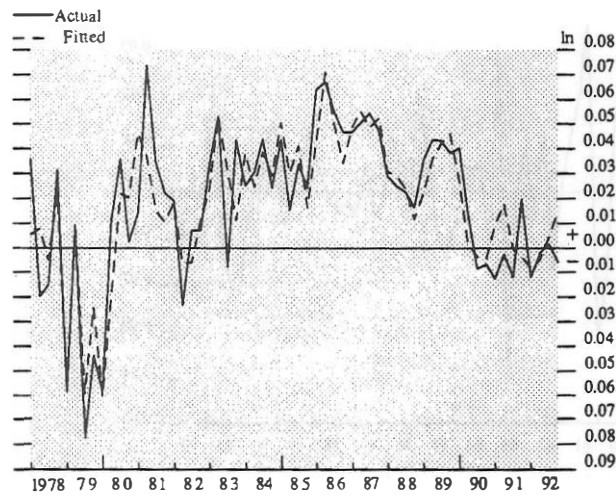
**Chart 4.4**

**Corporate sector: actual and fitted values of interest rate equation**



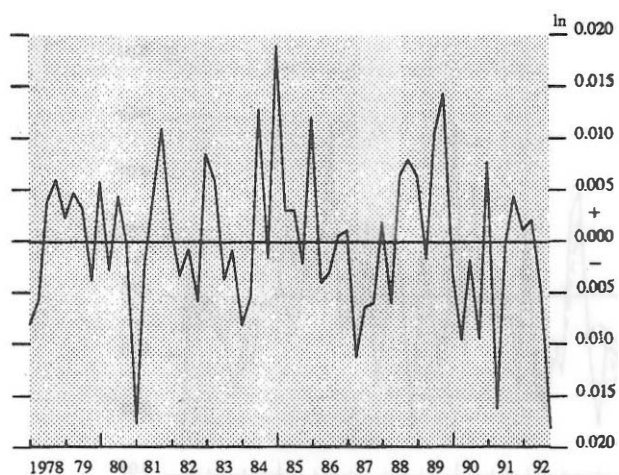
**Chart 4.5**

**Corporate sector: actual and fitted values of M4 equation**

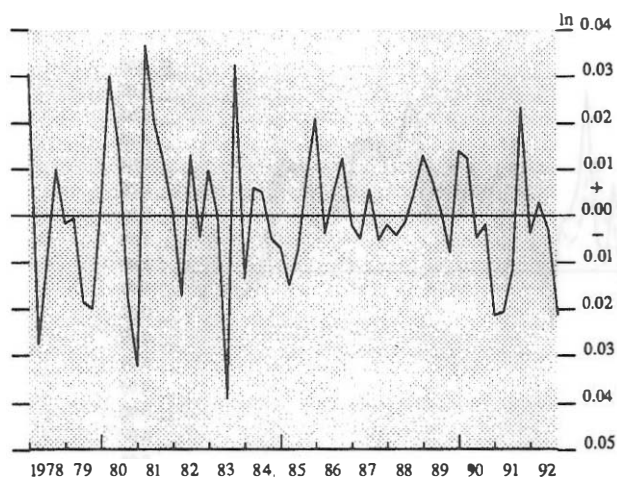




**Chart 4.6**  
**Corporate sector: residuals of interest rate equation**

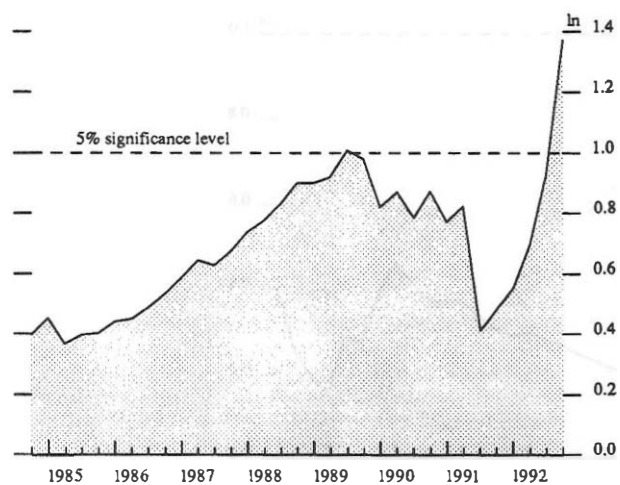


**Chart 4.7**  
**Corporate sector: residuals of M4 equation**



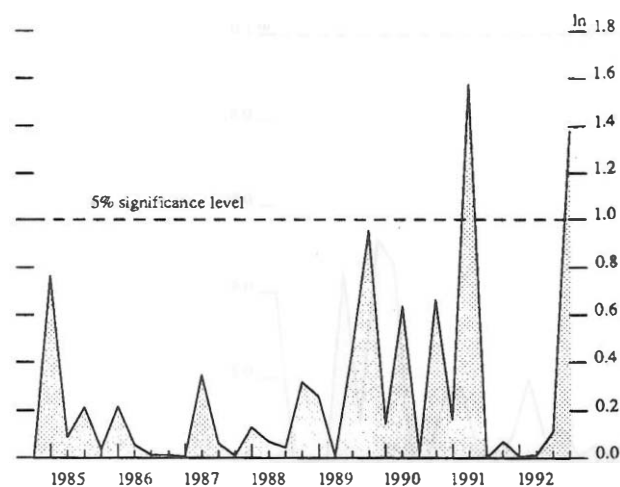
**Chart 4.8**

**Corporate sector: interest rate equation break-point Chow tests**



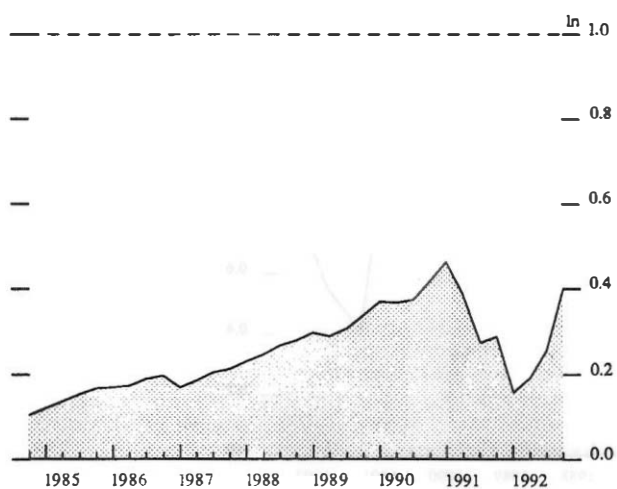
**Chart 4.9**

**Corporate sector: interest rate equation 1-step Chow tests**



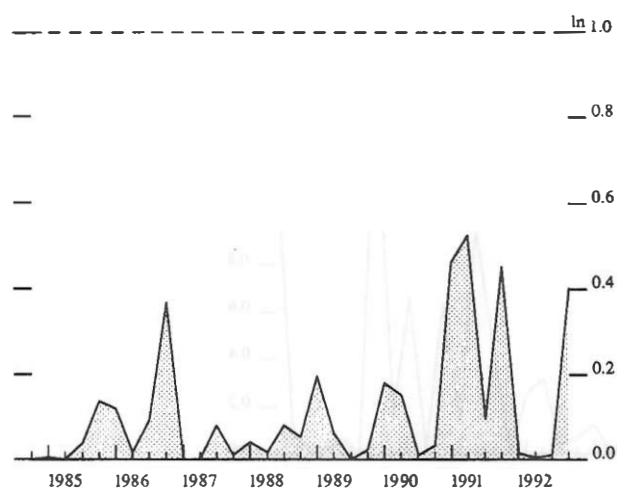
**Chart 4.10**

**Corporate sector: M4 equation break-point Chow tests**



**Chart 4.11**

**Corporate sector: M4 equation 1-step Chow tests**



Note: 5% significance level = 1.0.

#### 4.4 The structural model

We identify the equations as before, by conditioning each on one and only one long-run relationship and re-introducing contemporaneous dynamics. The structural estimates allow further simplifications until a parsimonious model is obtained. These over-identifying restrictions are tested and the result is reported in Table 4.4. The test statistic is easily accepted.

Charts 4.12 to 4.15 show the fit and residuals of the preferred specification and Table 4.5 gives the restricted reduced form of the structural model.

The main interest in the structural form is the dynamic adjustment. This shows that the feedback from money to interest rates is rather weak. The restricted residual form indicates a zero effect from the  $(ecm-mc)_{t-1}$  term on interest rates. This suggests that in the long run the system may actually be recursive with interest rates being set independently and corporate sector money holdings conditionally. This probably reflects the difference between our chosen short rate of interest and the (unknown) rate of return on corporate sector M4 balances. Our proxy is obviously less sensitive to the demand and supply of M4.

**Table 4.4**

**Corporate sector: the structural model**

**interest rate "reaction" equation**

$$\begin{aligned}
 \Delta rs_t = & \quad 0.996 \Delta rl_t \quad + \quad 0.315 \Delta^2 pg_t \quad + \quad 0.310 \Delta^2 pg_{t-1} \\
 & (5.84) \quad \quad \quad (3.47) \quad \quad \quad (2.26) \\
 & + \quad 0.208 \Delta^2 pg_{t-2} \quad + \quad 0.13 \Delta^2 pg_{t-3} \quad - \quad 0.055 \Delta wc_{t-3} \\
 & (0.13) \quad \quad \quad (1.50) \quad \quad \quad (2.28) \\
 & + \quad 0.057 \Delta mc_{t-1} \quad - \quad 0.073 \Delta mc_{t-2} \quad + \quad 0.063 \Delta mc_{t-3} \\
 & (1.82) \quad \quad \quad (1.58) \quad \quad \quad (2.24) \\
 & - \quad 0.141 (ecm-rs)_{t-1} \\
 & (3.49)
 \end{aligned}$$

**money demand equation**

$$\begin{aligned}
 \Delta mc_t = & \quad -5.04 \Delta rl_t \quad + \quad 4.34 \Delta rs_t \quad - \quad 0.53 \Delta rs_{t-3} \\
 & (2.99) \quad \quad \quad (3.31) \quad \quad \quad (2.94) \\
 & + \quad 0.24 \Delta wc_{t-3} \quad + \quad 0.56 \Delta mc_{t-2} \quad - \quad 2.27 \Delta pg_t \\
 & (1.81) \quad \quad \quad (3.41) \quad \quad \quad (4.06) \\
 & - \quad 3.32 \Delta pg_{t-1} \quad - \quad 2.52 \Delta pg_{t-2} \quad - \quad 0.95 \Delta pg_{t-3} \\
 & (4.11) \quad \quad \quad (3.52) \quad \quad \quad (2.26) \\
 & - \quad 0.095 (ecm-mc)_{t-1} \\
 & (6.06)
 \end{aligned}$$

**residual analysis**

standard errors	$\sigma_1\%$	= 0.75	$\sigma_2\%$	= 3.26
autocorrelation	$BP_1(6)$	= 2.4	$BP_2(6)$	= 11.4
normality	$JB_1(2)$	= 0.3	$JB_1(2)$	= 0.2
encompassing	$HM(6)$	= 7.5		

Notes:

$$(ecm-rs)_t = rs_t - 2.31 \Delta pg_t$$

$$(ecm-mc)_t = mc_t - wc_t - 8.82 (rs_t - rl_t)$$

*t*-ratios are given in parentheses,

$HM(\cdot)$  is the Hendry-Mizon Test against the simplified VAR,

subindexes 1,2 correspond to residuals in  $\Delta rs$ ,  $\Delta mc$  equations

other diagnostics are as defined in Table 4.2.

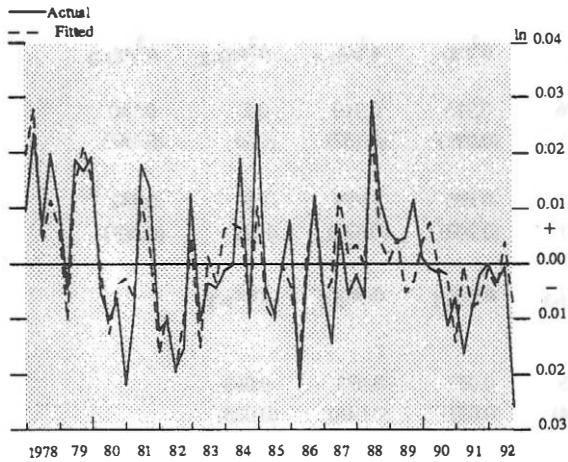
Table 4.5

Corporate sector: restricted reduced form or structural model

dependent variable	explanatory variables				
	$\Delta r l_t$	$\Delta^2 p g_t$	$\Delta^2 p g_{t-1}$	$\Delta^2 p g_{t-2}$	$\Delta^2 p g_{t-3}$
$\Delta r s_t$	0.996 (1.71)	0.315 (0.091)	0.310 (0.137)	0.2 (0.1)	0.130 (0.087)
$\Delta m c_t$	-0.711 (0.38)	-0.895 (0.203)	-1.973 (0.377)	-1.6 (0.3)	-0.382 (0.207)
	$\Delta w c_{t-3}$	$\Delta m c_{t-1}$	$\Delta m c_{t-2}$	$\Delta m c_{t-3}$	
$\Delta r s_t$	-0.055 (0.024)	0.057 (0.031)	-0.073 (0.046)	0.063 (0.028)	
$\Delta m c_t$	-0.001 (0.053)	0.248 (0.111)	0.244 (0.119)	0.275 (0.109)	
	$\Delta r s_{t-3}$	$(ecm-mc)_{t-1}$	$(ecm-rs)_{t-1}$		
$\Delta r s_t$	0	0	-0.141 (0.040)		
$\Delta m c_t$	-0.525 (0.179)	-0.095 (0.016)	-0.612 (0.144)		
standard errors	$\sigma_1 \% = 0.75$		$\sigma_2 \% = 1.62$		

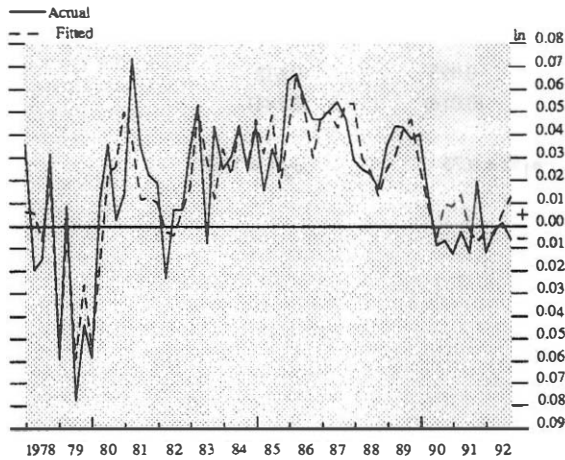
**Chart 4.12**

**Corporate sector; actual and fitted values of interest rate equation: structural form**



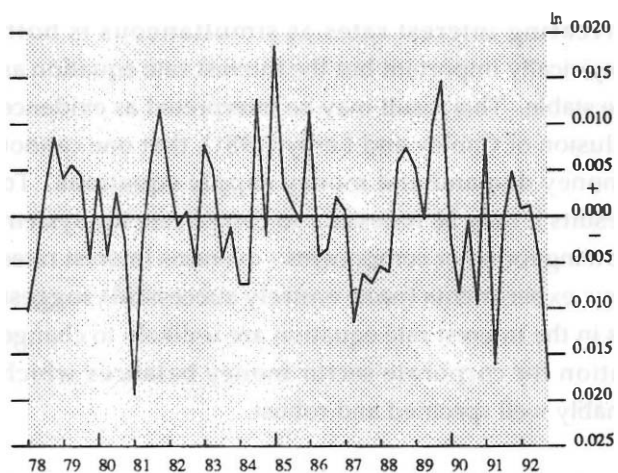
**Chart 4.13**

**Corporate sector; actual and fitted values of M4 equations: structural form**



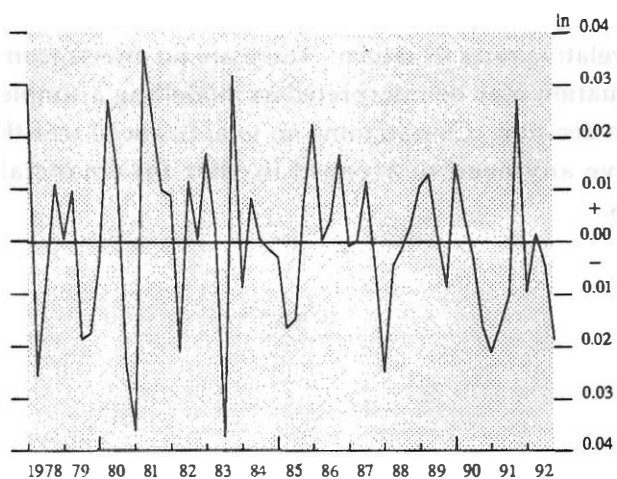
**Chart 4.14**

**Corporate sector; residuals of interest rate equation: structural form**



**Chart 4.15**

**Corporate sector; residuals of M4 equation: structural form**





#### 4.5 Conclusions: corporate sector

As expected, the corporate sector is more difficult to model than the personal sector. Treating interest rates as simultaneous is both theoretically and empirically important but the interest rate equation as specified may not be stable. This result may be interpreted as evidence to support the conclusion of Cooley and Leroy (1981), that one cannot identify separate money demand and money supply equations. To improve on these results it may be necessary to complicate the system further, perhaps allowing for other components - overseas interest rates for example. Various experiments (none entirely successful) suggest that further changes in the interest rate equation are unlikely to change the preferred equation for corporate sector money balances which appears to be reasonably well specified and robust.

In these circumstances a single equation approach, using a number of instruments for the interest rate differential, may be more robust than simultaneous estimation.

The corporate sector model explains M4 as a fraction of total financial wealth subject to relative rates of return. There are no effects from output and the equation may be interpreted as modelling a simple portfolio allocation decision. Conditioning on total financial wealth appears to remove any need to account further for financial liberalisation effects.

## 5 Overall conclusions and summary

The results presented in this paper have extended previous studies of the demand for M4 in two directions. First we have found good theoretical and empirical reasons for disaggregating money into personal and corporate sector balances [Congdon and Ward (1993) also look at a personal sector M4 equation]. Recent work on Divisia money (Fisher *et al*, 1993) came to the same conclusion and the same result: that it is corporate sector behaviour that is hardest to model. Second, our sectoral equations are estimated within a simultaneous system and have been derived using the Hendry and Mizon (1993) strategy for encompassing the VAR. The novelty in our results is the use of structural identification restrictions in both the long-run and the short-run parts of the equation.

The results themselves confirm earlier studies by Hall *et al* (1989) in concluding that wealth is an important explanatory variable for M4. In addition we find that the wealth effects are different across sectors. In the personal sector wealth and income are equally important perhaps reflecting the use of M4 for both transactions and saving purposes. In the corporate sector we find no role for income (or any other activity variable) and money appears to be just one of the many assets which are held.

Other differences relate to the inclusion of significant terms from interest rate differentials in accordance with our theoretical priors and a much richer dynamic structure. Interest rate effects are usually very difficult to establish in econometric models and the sectoral split may play an important part in giving us these results. The richer dynamic structure arises from encompassing a data-congruent VAR.

The simultaneous estimation strategy reveals a short-term link between consumption and personal sector money demand that improves both structural-form equations. In particular, UK consumption functions have tended to underpredict during the boom and overpredict during

the recession. Including money as an (endogenous) explanatory factor appears to eliminate these errors.

Given that M4 data are available earlier than consumption data, personal sector M4 may be a useful short-term indicator of consumption. However, the conflicting signs across equations suggest that the message will not be simple to extract. Our equations suggest that an increase in consumption reduces personal sector M4 whereas an increase in M4 increases consumption. Both effects occur simultaneously.

One implication of our results from both sectors is that if the wealth-income ratio were to stabilise then so would M4 velocity. If the change in the wealth-income ratio has reflected the process of financial liberalisation then we may see M4 velocity becoming more stable in future.

Overall these results are encouraging both in support of the underlying analysis of broad money and for the modelling strategy employed. In both sectors the empirical specification could be subject to many variations in terms of data set, functional form and restrictions although the results as reported are reasonably promising, especially for the personal sector. Further work on the personal sector should explore the theoretical linkages between consumption and money demand and the possible role of credit restrictions in explaining the short-run relationships.

The way forward for the corporate sector is less clear although a single equation instrumental variable analysis may be more robust. Better data on deposit rates would improve our estimates, and make interpretation less problematic. The split between industrial and commercial companies on the one hand and other financial institutions on the other is also a possible avenue to explore although no differences were found in the course of this work.

## Appendix A - Data Sources

### Personal Sector:

Break-adjusted, seasonally adjusted M4: Bank of England

Real consumption: CSO code CAAB

Real gross wealth = gross financial wealth plus housing wealth plus  
stock of consumer durables: Bank of England model database

91-day Sterling Treasury Bill rate average: Bank of England

Personal sector own-weighted interest rate on M4 - Fisher *et al* (1993)

Consumption deflator: CSO code DJBA/DJDH

### Corporate Sector:

Break-adjusted, seasonally adjusted M4: Bank of England

Total financial assets of the corporate sector: Financial Statistics Tables  
14.2, 14.3

London 3-month interbank rate - CSO code AMIJ

GDP deflator: CSO code DJBA/DJDH

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