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Modelling short term asset holdings of UK banks

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ABSTRACT

A dynamic AIDS model is used to explain short-term asset holdings of 'banks'. Two-stage budgeting is invoked and symmetry and homogeneity are imposed. The model is used to assess the impact of changes in the bill rate on banks' holdings of bills and parallel money-market assets. These assets are found to be very close substitutes implying that changes in bill rates due to open market operations will quickly spread to rates on parallel money-market assets such as certificates of deposit. The model therefore illustrates the operation of liability management by the banks which made successful control of broad monetary aggregates so difficult in the 1970s and 1980s.

I INTRODUCTION

Government policy in the United Kingdom, as in other industrialised countries, has in the past embraced targets for broad monetary aggregates. Financial innovation in the United Kingdom has proceeded rapidly in the 1980s and the building societies are likely to function more like the commercial banks (Building Societies Act 1986) in the future. The experience with broad monetary targets in the United Kingdom was not without its difficulties not least because of the widespread adoption of liability management by the banks in the 1970s and 1980s (and its recent adoption, as yet on a relatively modest scale, by the larger building societies). Liability management implies that the growth in monetary aggregates is strongly influenced by relative interest rates between bank liabilities such as the rate on certificates of deposit and the rate on government debt (either long or short). The cross elasticity of the supply of certificates of deposits by the banks with respect to the rate on government debt (particularly bills) is a measure of the banks' ability to 'bid away' funds from the public sector. A corollary is that the government's open market operations in the bill market will lead to near equal changes in the rate on certificates of deposit if the banks consider these two assets as close substitutes.

The regulation of financial intermediaries and the use of guidelines for prudential reserve requirements requires a model in which these institutions behave in a systematic way regarding their asset/liability decisions. In this paper we provide evidence on the above policy issues by examining a subset of the asset decisions of UK banks (including the Discount Houses). Using a new consistent data set for the monetary sector we utilise the Almost Ideal Demand System (AIDS) with an interdependent error correction model to examine some key asset demand functions for the banks. In particular we are interested in the substitutability between bills and certificates of deposit since this is an important element in the monetary transmission mechanism, when the Bank of England pursues open market operations in the bill market.

The rest of this paper is organised as follows. In the next section we outline our theoretical model, and in section III we discuss the modelling of short run dynamics in a systems framework and associated econometric issues. In section IV we discuss data problems and in section V we present our empirical results. We conclude with a brief summary.

II THEORETICAL ISSUES

Theories of the financial firm (eg Baltensberger 1980, Santomero 1984, O'Hara 1983) are very diverse and there cannot be said to be a general theory which embraces the various functions of banks. In part because it is tractable, empirical work on asset demands has often utilised the mean-variance model (Tobin 1958, Markowitz 1959, Linter 1965) but results have been rather mixed (eg Parkin 1970, Parkin et al 1970, Courakis 1975, Berndt et al 1980). In this paper we model the 'short-term' assets holdings of banks using a consumer demand model based on the Almost Ideal Demand System - AIDS - (Deaton and Muellbauer 1980). The AIDS model implies symmetry and homogeneity of 'price' responses which considerably simplifies estimation and interpretation. We wish to ascertain whether our theory model can broadly characterise the data and therefore provide a useful framework for analysing the asset holdings of banks. We delineate the decision problem of the banks by assuming weak separability and two stage budgeting. In broad terms our model of the banking system is one in which the banks set interest rates on their lending and on their 'non-wholesale' deposit liabilities and accommodates whatever demand arises at these rates. Thus the difference between the demand for bank loans, the demand for non-wholesale deposits is predetermined and we refer to this as (net) wealth, W. In this paper we are therefore only concerned with how, W, is invested or financed and not with the factors that determine its size. Thus if the demand for advances outstrips the supply of (non-wholesale) deposits, this will be reflected in a reduction in W and vice versa. The view that banks set the 'price' on some asset/liabilities, while choosing to simultaneously actively manage quantities of other assets (with interest rates on these assets being market determined) is widely accepted (Fama 1985, Goodhart 1989).

In our model the 'upper level decision' in the banks' two-stage decision process is to allocate its wealth, W, between total capital certain, CC, and total capital uncertain assets, CU. The 'lower level' decision then consists of the choice of assets within these two groups. Capital certain assets consist of notes and coin and balances at the Bank of England, NC, commercial, local authority and Treasury bills, BL, and 'parallel money', PM, (ie net holdings of certificates of deposits, and local authority deposits). Capital uncertain assets comprise public sector long-term debt, PSL, UK company securities, CS, and net foreign currency lending, FC. Our model therefore focuses on 'money-market' related behaviour and this is the main area of the operational procedures of the Bank of England when influencing monetary policy.

In formal terms we assume weak separability between CC, CU and other asset/liabilities held by the banks. We realise this is a strong assumption but it has been widely employed (often implicitly) in single equation studies and makes the model tractable.

A word of caution is in order here concerning the two-stage budgeting procedure proposed. Weak separability is necessary and sufficient for the second stage (ie 'lower level' decisions) of two-stage budgeting. However weak separability has some drawbacks. First, it places quite severe restrictions on the degree of substitutability between goods in different groups (Pudney 1981). For example whole groups will be substitutes or complements with each other. The second problem is, potentially, more serious however. In modelling the 'upper-level' decisions it would be extremely useful to be able to establish the maximisation problem in terms of group price and quantity indices (rather than having to utilize all prices that the agent faces), since this would considerably reduce the number of parameters to be estimated for the 'upper-level' equations. Strictly speaking this is only possible under somewhat restrictive assumptions. If preferences are homothetic which implies all 'expenditure elasticities' are unity or equivalently that the budget shares within each group are independent of total group expenditure, then 'group price indices' can be legitimately used in determining the upper level allocations. If preferences are not homothetic then group price indices can be used providing the utility function is strongly separable and has the Generalised Gorman polar form. However the former implies 'additivity' between groups:

$$u = u_a (q_a) + u_b (q_b) + \ldots$$

Additivity is restrictive in that (a) inferior goods are ruled out; (b) goods can only be substitutes given that inferior goods are not allowed; (c) expenditure elasticities are proportional to price elasticities. Neither of the above restrictive assumptions seems attractive in modelling asset demands. The problem then is that the group price indices P_a say are given by $P_a = P_a(u_a, p^a)$ and are dependent on u_a, which in turn depends on all other prices outside the group. One possibility is not to invoke homotheticity and assume that P_a does not vary very much with u_a and hence most of the 'explanation' of P_a is the sub-set of prices, p^a. Given the other approximations involved in empirical studies this may be a reasonable expedient to adopt if homotheticity is not found to hold in the data (which is the case for our model).

We also implicitly assume weak intertemporal separability. (Formal non-parametric tests of separability (Varian 1983, Swofford and Whitney 1986) are beyond the scope of the present paper.)

The functional form for banks' asset demand equations is an open question. Much previous work has been conducted in a single equation framework (eg Wessels 1982, Richter and Teigen 1982, Patterson et al 1987) while the various systems approaches have often been based on the Brainard-Tobin (1968) and the mean-variance model [eg Green 1984, Keating 1985]. We would argue that a systems approach is the appropriate framework in which to examine the portfolio decisions of banks and here we use the AIDS model (Deaton and Muellbauer 1980). Other demand systems (eg indirect translog Christensen et al 1975) are less amenable to the flexible dynamics we incorporate below. The budget constraint and static equilibrium AIDS asset share equations (Barr and Cuthbertson 1989, Weale 1986) are:

$$\sum_i p^{\tau}_{it} \, a^{\tau}_{it+1} = W^{\tau}_t \qquad (1)$$

$$s_i = \alpha_i + \sum_j \gamma_{ij} \ln p^{\tau}_{jt} + \beta_i \ln (W^{\tau}/P^{*\tau})_t \qquad (2)$$

s_i = a_{it}/W_t

p^{τ}_{it} = $[(1 + r_{it})(1 - g_z)]^{-1}$

r_{it} = expected (proportionate) nominal return on asset i, between t and t+1 (including any capital gains).

g_z = expected (proportionate) rate of goods price inflation between t and t+1.

a^{τ}_{it+1} = real asset holdings (= a_{it+1}/Z_{t+1})

a_{it} = nominal asset holdings of the i^{th} asset

Z_t = goods price index

W^{τ}_t = real wealth (= W_t/Z_t)

$\ln P^{*\tau}_t$ = $\Sigma\, s_i \ln p^{\tau}_{it}$

The variable p^{τ}_{it} is a real discount factor for asset i (ie approximately equal to the inverse of one plus the expected real interest rate). We designate this term the 'real (AIDS) price' because of the analogy with the AIDS model applied to consumer goods. Note that $\ln P^{*\tau}_t$ may be interpreted as a composite real discount rate.

The theoretical restrictions of the AIDS model based on consumer theory are as follows. The adding up constraints:

$$\sum_i \alpha_i = 1, \quad \sum_i \gamma_{ij} = 0, \quad \sum_i \beta_i = 0 \qquad (3a)$$

Homogeneity:

$$\sum_j \gamma_{ij} = 0 \qquad (3b)$$

Symmetry and negativity (of the Hicksian demand functions) are direct consequences of the axioms of rational choice. The former implies:[(1)]

$$\gamma_{ij} = \gamma_{ji} \qquad (3c)$$

Negativity arises from the concavity of the cost function and implies that the matrix of coefficients k_{ij}:

$$k_{ij} = \gamma_{ij} + \beta_i\beta_j \ln(W^{\tau}/P^*) - s_i\delta_{ij} + s_i s_j \qquad (3d)$$

is negative semi-definate (δ_{ij} is the Kronecker delta).

Thus our systems approach implicitly imposes data admissability in the form of adding up constraints and the additional theoretical constraints of symmetry homogeneity and negativity. If symmetry and homogeneity hold then this reduces the number of parameters to be estimated and increases efficiency. In addition one might wish to judge the model on more intuitive notions, (eg that own price effects are negative, wealth elasticities are 'reasonable' etc).

The wealth and compensated own price and cross price elasticities are:

$$E_w = (\beta_i/s_i)+1 \qquad (4a)$$

$$E_{ij}(p) = (s_i)^{-1} k_{ij} \qquad (4b)$$

Semi-elasticities with respect to the nominal return expressed at an annual percentage rate (ie R = 400r) are given by:

$$E_{ij}(R) = E_{ij}(p)/4 \qquad (4c)$$

III DYNAMIC ADJUSTMENT AND ECONOMETRIC ISSUES

Our long-run AIDS share equations (2) may be represented in vector notation:

$$s_t^* = \Pi X_t \qquad (5)$$

where s_t^* = kx1 vector of desired long-run asset shares

X_t = qx1 vector of independent variables

Π = kxq matrix of long run parameters

In a system of asset demand equations if we include only own-lags, then we must implicitly accept that all assets adjust at the same rate (Smith 1975). To avoid this problem cross-lagged terms must also be included (Brainard and Tobin 1968). The latter can be rationalised by generalising the quadratic cost of adjustment function of Christofides (1976):

$$L^* = (s - s^*)_t' C_1 (s - s^*)_t + \Delta s_t' (C_2) \Delta s_t - (\Delta s_t) C_3 (\Delta s_t^*) \quad (6)$$

where C_i (i = 1, 2, 3) are conformable adjustment matrices. Minimising L^* with respect to s_t subject to the budget constraint we obtain generalised error feedback equations:

$$\Delta s_t = \Pi^* \Delta X_t + L (s - s^*)_{t-1} \quad (7)$$

where the disequilibria in (k-1) asset shares at time t-1 influence the current period adjustment of any particular asset share. Since

$\sum_1^k (s_i - s_i^*)_{t-1} = 0$, only the (k-1) independent disequilbrium shares are

required in (7) (ie L is (k x (k-1)) (Anderson and Blundell 1983). The adding up restrictions imply that the columns of Π^* and L sum to zero. In addition on intuitive grounds we might expect the diagonal elements of L to be negative. However the latter is not required for dynamic stability. As long as the eigen values of the appropriate adjustment matrix have modulus less than unity, then the system is dynamically stable.(2)

One can also interpret (7) merely as a reasonably parsimonious method of incorporating dynamics while maintaining the adding up restrictions but without alluding to the cost function (6). We feel that quadratic costs are very unlikely to apply to adjustments in financial assets (eg costs are unlikely to rise smoothly with the size of the transaction undertaken) and we therefore interpret equation (7) merely as a convenient method of characterising sluggish adjustment. In principle it is possible to generalise (6) to yield a multiperiod interdependent costs of adjustment function but this rapidly becomes intractable (Currie and Kennally 1985), and still retains the unrealistic quadratic form.

Prior to the use of co-integration techniques estimation of (7) would have proceeded by running the unrestricted set of equations

$$s_t = \hat{R}_1 s_{t-1} + \hat{R}_2 x_t + \hat{R}_3 x_{t-1} \tag{8}$$

The main disadvantages of this approach are threefold. First, one cannot (easily) impose long-run theory restrictions (eg symmetry and homogeneity) as these depend on the non-linear functions $(I - \hat{R}_1)^{-1} (\hat{R}_2 + \hat{R}_3)$ (but see Bewley 1979). Second, in testing down to a parsimonious dynamic representation (via restrictions on the R_i matrix elements) one implicitly alters the long-run solution and the final equation (possibly after considerable 'search-time' has been invested) may be unacceptable on *a priori* grounds. Third, we cannot be sure that the ensuing long-run solution yields a co-integrating vector. For example for the UK personal sector, Weale (1986) is able to impose short-run symmetry and homogeneity (on the R_2 matrix) but these properties do not hold in the long-run. Yet, one could argue that such properties are more applicable to the long-run rather than the short-run parameters. For the above reasons we consider a systems approach using co-integration techniques.

Co-integration establishes a parameter vector which yields stationary errors (Granger 1986, Engle and Granger 1987). Assuming all variables in the long-run share equations (5) are I(1), and are co-integrated then in the 'first stage' regression, OLS on (5) yields superconsistent estimates, of Π.[3] The residuals from (k-1) of the share equations are then substituted in the dynamic system error-feedback equations (Hall 1986). The 'general to specific' methodology is then applied in this 'second stage' to obtain parsimonious dynamic equations while holding the long-run parameters fixed (Hendry et al 1984). Although attractive, there are some practical problems with the two-step procedure. The co-integration regression estimates may suffer from small sample bias (Hendry 1986) and the co-integrating vector may not be unique. However, given the relatively strong theoretical restrictions to be placed on the long-run share equations (eg homogeneity and symmetry, negative own 'price' effects) we are mainly interested in finding a set of plausible parameter estimates that conform to theory and form a co-integrating vector. We are therefore willing to risk some small sample bias at 'stage one' (and possibly an inferior 'fit' of the final equation) in order to obtain a theoretically consistent approach. We therefore adopt an informal approach, trading-off 'fit' in the second stage regressions against the system restrictions implied by our theoretical model. The theoretical structure imposed by adopting the system approach therefore limits the extent to which one can indulge in 'overfitting' and data-mining. The final parsimonious system of equations is subject to the usual test procedures (although understandably these are not as numerous as found in single equation studies).

In order to impose cross equation restrictions on the long-run parameters we use maximum-likelihood with a diagonal covariance matrix (the latter is obtained from running OLS on each equation separately). When estimating the dynamic short-run equations we report results using 3SLS (Zellner and Theil 1962). Corrections for serial correlation in systems of equations are not possible with our current software (Berndt and Savin 1975) but because of our flexible lag response this was not found to be an acute practical problem.

IV DATA USED

The asset categories modelled are 'short-term' assets of the monetary sector and, we assume weak separability between capital certain, CC, and capital uncertain, CU, assets:

Capital Certain Assets, CC

1 NC = Notes and coin and balances at the Bank of England

2 BL = Commercial, LA and Treasury bills

3 PM = Parallel money (net CDs of the monetary sector, building society CD's and local authority deposits)

Capital Uncertain, CU

1 PSL = Public sector long-term debt

2 CS = Company securities

3 FC = Net foreign currency lending

Note that 'money at call' nets out of our model since the Discount Houses are part of the Monetary Sector.

The flow data is taken from the 'Flow of Funds' matrix in Financial Statistics. Revaluation indices are chosen to be consistent across sectors of the complete matrix. Benchmark stocks are then chosen such that all elements in the matrix satisfy the accounting identities (ie zero row-sums and column sums equal to the NAFA). The data on the monetary sector assets used here therefore comes from a fully consistent complete stock-flow matrix.

The rate of return on NC is the negative of the inflation rate (of the price of total final expenditure, TFE). For bills, BL, we use the rate on 3-month commercial bills and for 'parallel money', PM, we use the rate on bank certificates of deposit. Various rates of return for PSL, CS and FC were tried all of which included the running yield and capital gains. The running yield plus a 3-year backward looking capital gain is used for these rates of return. The FT actuaries price index for all government stock and the running yield are used for PSL. The return on FCD is the yield on 3-month dollar deposits in London plus capital gains due to changes in the dollar-sterling exchange rate whle the return on CS is the FT Actuaries all share index plus the dividend yield. (A one quarter ahead and 1 year ahead capital gains variables were also tried but gave very unsatisfactory results.)

All data used are seasonally unadjusted but seasonal dummy coefficients are not reported. The regressions are run over the period 1976(4)-1986(4). Critical values of test statistics are given at a 5 percent significance level (unless stated otherwise).

V EMPIRICAL RESULTS

The estimated long-run AIDS share equations are:

$$s_t = \Gamma \ln p_t^{\tau} + B\, RW_t + \alpha \qquad (10)$$

s_t = k x 1 vector of asset shares

np_t^{τ} = k x 1 vector of real asset prices

RW = log of real wealth (= $\ln (W^{\tau}/P^{*\tau})_t$)

Γ = (k x k) matrix of 'price' coefficients

B = (k x 1) vector of real wealth coefficients

α = k x 1 vector of constants

Homogeniety implies that the row sums of the matrix Γ are zero and symmetry implies $\gamma_{ij} = \gamma_{ji}$. To satisfy the adding up constraint, the column sums of Γ, B, and J are zero and $\Sigma\alpha_i = 1$. The residuals from the long-run equations $(s-s^*)_t$ are then used in the dynamic error feedback equations:

$$\Delta s_t = C \, \Delta \ln p^{\tau}_t + K_t \, \Delta RW_t + L \, (s-s^*)_{t-1}$$

In all the equations reported we found it necessary to introduce some additional variables reflecting institutional and policy changes into the AIDS share equations in order to yield price coefficients with a priori acceptable signs. We use a dummy variable x_{1t} for the introduction of Competition and Credit Control, CCC [1971(3)-1981(3)] since this altered reserve asset requirements. Under CCC minimum holdings of reserve assets (ie broadly speaking our 'capital certain' assets plus British Government Securities with less than one year to maturity in our CU category) were 12 1/2 percent of 'eligible liabilities'. In August 1981 the above rules were replaced by the Monetary Control Provisions whereby banks only had to keep 1/2 percent of their eligible liabilities as deposits at the Bank of England (and at least 4 percent with the discount houses and/or money brokers and gilt-edged jobbers). Hence post 1981(3) we introduce a time trend x_{2t} to act as a proxy variable as agents adjust to this new regime.

The Dickey Fuller (DF) and Augmented Dickey-Fuller (ADF) statistics (table 1) indicate that none of the series appear to be I(0) (Dickey and Fuller (1979). In testing for I(1) series the %DF and ADF statistics all exceed their critical values and we take these results to indicate I(1) variables.

We first report our results from the 'lower level' equations and then results from the choice between the total of capital certain and capital uncertain assets for the 'upper level' decision.

Capital Certain Assets (Lower Level)

Table 2A(i) shows the long-run results for the 'lower level' capital certain assets with an unrestricted Γ 'price matrix'. In table 2A(ii) we impose symmetry. In 2A(iii) the equality of the own rates on bills, BL, and parallel money-market assets, PM, are imposed and the price variables in the NC equation are constrained to zero (since they are relatively small, see table 2A(ii)). Test statistics on non-stationary variables in a systems framework are not yet available (but see West (1988) and Johansen (1988) for tests on single equations) but imposing the above restrictions does not radically alter the coefficient values and hence table 2A(iii) reflects our preferred long-run results. The residuals from these three long-run equations yield DF and ADF statistics in excess of 4.0 (in absolute value) indicating stationary residuals and a co-integrating vector.

From the results in table 2A(iii) we see that there is strong substitutability between bills and parallel money-market assets. The CCC dummy x_{1t} indicates an increase in holdings of NC and BL relative to PM in the CCC period while in the post-1981 period the coefficients on $x2_t$ imply a shift primarily into bills (which reflects the changing open market operations of the Bank of England as they moved to dealing mainly in commercial bills).

The parameters in the <u>short-run</u> error feedback equations (table 2B) are not well determined and proceeding as above and imposing symmetry of the short-run price matrix, $\chi^2(3)=0.9$ ($\chi^2_c=7.8$) and equality of the coefficients on the rate on PM and bills $\chi^2(2)=2.0$, ($\chi^2_c=6.0$) we obtain the results in table 2B. (The latter restriction also implies zero short-run price effects on NC.) The own rate on BL and PM is of the correct sign, table 2B [and smaller than its long-run counterpart, table 2A(iii)]. The other short-run parameters are also smaller than their long-run counterparts. The lagged disequilibrium coefficients (l_{ij}) have eigenvalues with moduli less than unity but parameter values in excess of unity which indicate overshooting. Empirically this arises because the lagged disequilibrium shares $(s_i-s_i^*)_{t-1}$ (i=2,3) for bills and PM are very highly (negatively) correlated. Dropping one of these lagged shares for example $(s_3-s_3)_{t-1}$ and assuming equal adjustment speeds (Smith 1975) for all assets yields a coefficient on $(s_2-s^*_2)_{t-1}$ of -0.73. The latter also indicates dynamic stability but imposes the restriction that the banks adjust their holdings of bills and PM at the same rate (Smith 1975): probably, a not unreasonable assumption for these assets.

Capital Uncertain Assets (Lower Level)

We follow a similar procedure in reporting results for capital uncertain assets. Results with Γ unrestricted and with symmetry imposed are shown in tables 3A(i) and (ii), respectively. All own rates are negative in table 3A(ii). But because the own rate on holdings of CS is smaller than the effect due to the overseas rate and some elements of Γ are smaller than their short-run counterparts (see table 3B) we imposed values for γ_{22} and γ_{23} [table 3a(iii)]. We also include an additional variable in the share equations for capital uncertain assets, namely the rate of inflation, to reflect changing riskiness of the return on capital uncertain assets: this improved the co-integration properties of the equation. The DF statistics for the three equations of table 3a(iii) are (-3.1, -3.3, -3.0) and the ADF statistics are (-2.0, -3.7, -2.3) on the three capital uncertain long-run equations [table 3A(iii)] and are indicative of stationary residuals.

Symmetry of the short-run price matrix [table 3B] is accepted $\chi^2(3)=4.4$ ($\chi^2_c=7.8$) as are the restrictions $C_{22}=-0.38$, $C_{23}=0.28$ to prevent overshooting in response to a 'price' change ($\chi^2(2)=1.3$, $\chi^2_c=6.0$). The preferred short-run parameters are shown in table 3B. The three assets PSL, CS and FC are short-run substitutes with FC having a short-run and (long-run) wealth elasticity greater than unity. The short-run impact of the additional variables Δx_{1t}, Δx_{2t} and Δg_t are individually not well determined. The parameters of the adjustment matrix L indicate dynamic stability. Overall the results for capital uncertain assets are broadly satisfactory, the fit of the equations (table 3B) is reasonable given that these are share equations.

Upper Level Decision

In the 'upper level' model we only estimate the equation for total holdings of capital certain, CC, assets: the holdings of capital uncertain, CU, assets is given by the residual of the budget constraint. The rates of return on CC and CU assets are a weighted average of the rates on their constituent elements (the weights are the mean shares of each asset).

The long-run and short-run parameters for our preferred 'higher level' equation for capital certain assets are shown in table 4. The long-run price coefficients are slightly larger than their short-run counterparts (although statistically we can accept equality of these coefficients). The DF and ADF tests on the residuals of the long-run co-integrating equations are -2.7 and -2.5 and the residuals appear to be stationary given that the DF and ADF statistics have low power against highly dynamic stationary alternatives (Engle and Granger 1987, Engle and Yoo 1987). The statistical performance of the 'upper level' equation for capital certain assets is not particularly good but the relative yield variable has the correct sign.

Economic Implications

We have estimated a relatively complex model for the monetary sector involving two-stage budgeting. A key question in the conduct of monetary policy is the response of bank assets to a change in bill rates bought about by open market operations. To analyse this consider the basic long-run AIDS share equation (with symmetry imposed) for the upper level capital certain asset '1':

$$s_1^u = \sum_{j=1}^{2} \gamma_{1j}^u \ln\left[p_1^u/p_2^u\right] + \beta_1^u \left[\ln(W/Z) - \ln P^{*u} - g_z\right]$$

where

$$\ln P^{*u} = \sum_{i=1}^{2} \bar{s}_i \ln p_i^u$$

At the upper level, a change in the rate (price) on bills will have a direct long-run impact via γ_{ij} (= -0.55 table 4a) as the return on bills constitutes part of the upper level price index $\ln p_1^u$. In addition there is a 'wealth effect' via the upper level composite AIDS price index $\ln P^{*u}$ and the coefficient β_1^u (= -0.01 table 4a). The net effect of a 1 percent per annum increase in the rate on bills from these two channels is to increase banks' holdings of capital certain assets by £92 mn (and reduce their holdings of capital uncertain assets by the same amount).

At the lower level as bills constitute 65 percent of total capital certain assets a 1 per cent rise in the rate on bills causes a 0.65 percent change in the composite price index for the lower-level (ie $\ln P_t^*$ variable) which operates via the β_2 [= -0.25 table 2A(ii)] coefficient and has a direct effect via the γ_{ij} term of -51.2 [table 2A(iii)]. The net effect of these changes within the capital certain assets group (ie NC, BL, PM) in £mn is [0.11, 51.36, -51.47]. In addition we have the £92 mn increase in wealth held in capital certain assets from the upper level decision which yields an impact via the wealth coefficients β_i [table 2a(iii)] on NC, BL, PM of [-0.17, -0.25, 0.42]. The latter for bills and PM, in comparison with the direct effect from effects within the capital certain group is relatively small. The total effect on holdings of capital certain assets is the sum of the above two effects, which when transferred to changes in asset holdings (rather than shares) yields (ΔNC, ΔBL, ΔPM)=(-5: 4,636: 4,631). The switch between bills and parallel money-market assets (eg certificates of deposit) is substantial: they are very close substitutes in bank portfolios. It follows that the rate on bills and certificates of deposit are likely to move closely together as banks engage in liability management. It has been widely noted that this exacerbates problems of monetary control (Goodhart 1989).

Summary

We have used an AIDS model to analyse the holdings of capital certain and capital uncertain assets of banks, within a framework of multi-stage budgeting. With symmetry and homogeneity restrictions, the equations yield reasonably satisfactory results, and indicate that substitutability between bills and parallel money-market assets such as certificates of deposit is high. Hence control of monetary aggregates via open market purchases of bills must rely on (perhaps the tenuous empirical) links between the rate on certificates of deposit, the rate on bank lending and the 'own' interest elasticity of the demand for bank loans. Liability management with such a high degree of asset substitutability between bills and parallel money-market assets makes monetary control highly problematic. The results here are preliminary but they represent a useful first-step in an area where it is difficult to obtain any sensible empirical results at all.

FOOTNOTES

(1) Note that 'adding up' and symmetry imply homogeneity. (Although homogeneity and 'adding up' do not imply symmetry.)

(2) If the disequilibrium term for asset 1 is excluded then the estimated adjustment matrix is:

$$L = (\underline{l}_2, \underline{l}_3, \ldots \underline{l}_k) \qquad kx(k-1)$$

The dynamics of the full model may be written

$$s_t = (I_k + l^*)s_{t-1}$$

Where
s_t is kxl
$L^* = (i, \underline{l}_2, \underline{l}_3, \underline{l}_4)$ is (kxk)
$i = (1,0...0)$ is (kxl)
I_k = kxk identity matrix

One of the eigen values of $(I_k + L^*)$ is unity and stability requires that the other (k-1) eigenvalues have negative real parts.

(3) Shares cannot be random walks since the latter process is unbounded. However, shares may be a non-stationary series (but with a non-Gaussian error near the boundaries). Since all models are approximations, the practical question is whether the data should be modelled utilising the unit root literature. We find that shares are I(1) rather than I(0) and therefore any modelling strategy must embrace the unit root literature.

TABLE 1 - DICKEY FULLER TEST'S OF MODEL VARIABLES [1]

HIGHER LEVEL AGGREGATE CAPITAL CERTAIN. CC: CAPITAL UNCERTAIN, CU.

	I(0)		I(1)	
Shares	DF	ADF	DF	ADF
CC	-0.5	-0.1	-7.3	-3.9
Prices				
CC	()	-1.5	-4.8	-3.9
CU	-2.0	-2.4	-10.7	-7.5
Real Wealth	-1.7	-1.2	-6.9	-4.4
LOWER LEVEL CAPITAL CERTAIN				
NC	-1.6	+0.3	-8.8	-5.5
BL	-0.9	+2.7	-8.2	-3.2
PM	-2.6	+0.9	-6.1	-4.1
Real Wealth	-1.1	-0.8	-7.2	-4.6
Prices				
NC	-2.3	-2.5	-10.5	-6.9
BL	-2.3	-2.3	-10.7	-7.7
PM	-2.3	-2.4	-10.8	-7.5
LOWER LEVEL CAPITAL UNCERTAIN				
Shares				
PSL	-1.1	-0.2	-8.7	-5.2
CS	-1.3	-1.0	-8.2	-5.4
PC	-0.5	-0.2	-6.4	-3.7
Real Wealth	-0.5	-0.7	-7.0	-4.2
Inflation	-1.3	-1.0	-8.2	-5.4
Prices				
PSL	-2.0	-1.9	-10.2	-10.0
CS	-2.7	-2.5	-9.8	-9.6
FC	-1.2	-1.7	-8.7	-8.3

1 The critical values at a 5 per cent significance level for the DF and ADF statistics are -2.9 (Dickey and Fuller 1979).

TABLE 2A - CAPITAL CERTAIN ASSETS: LONG-RUN SHARES[1]

(i) Unrestricted Γ matrix

	$\ln p^T_{1t}$	$\ln p^T_{2t}$	$\ln p^T_{3t}$	RW_t	x_{1t}	x_{2t}
1 NC	-0.46	-14.67	-14.01	-0.18	0.09	0.01
	(0.50)	(1.4)	(1.4)	(3.8)	(4.3)	(8.1)
2 BL	5.05	-72.35	65.57	-0.24	0.28	0.03
	(1.3)	(1.6)	(1.5)	(3.4)	(5.5)	(9.0)
3 PM	-4.59	57.68	-51.56	0.42	-0.37	-0.04
	(1.1)	(1.2)	(1.1)	(5.3)	(6.59)	(9.6)

(ii) Symmetry imposed on Γ

	$\ln p^T_{1t}$	$\ln p^T_{2t}$	$\ln p^T_{3t}$	RW_t	x_{1t}	x_{2t}
1 NC	0.02	5.14	-5.16	-0.17	0.08	0.05
	(0.02)	(1.5)	(1.4)	(10.3)	(8.6)	(6.5)
2 BL		-71.1	65.9	-0.24	0.25	0.03
		(1.7)	(1.6)	(3.4)	(5.2)	(9.5)
3 PM			-60.8	0.42	-0.33	-0.04
			(1.5)	(5.3)	(6.6)	(10.2)

(iii) Preferred long-run equation ($\gamma_{22} = \gamma_{33}$, imposed)[2]

	$\ln p^T_{1t}$	$\ln p^T_{2t}$	$\ln p^T_{3t}$	RW_t	x_{1t}	x_{2t}
1 NC	0*	0*	0*	-0.17	0.08	0.004
				(10.3)	(8.5)	(6.4)
2 BL		-51.2	51.2	-0.25	0.27	0.03
		(1.3)		(3.4)	(5.8)	(10.1)
3 PM			-51.2*	0.42	-0.35	-0.04
				(5.4)	(7.0)	(10.7)

(1) x_{it} = CCC dummy, x_{2t} = proxy for the post-1981 monetary control provisions.

t-statistics are in parentheses but are not distributed as a Student's t-distribution. They are at best indicative of the relative contribution of each independent variable to movements in the dependent variable.

(2) A star * indicates an imposed coefficient.

TABLE 2B - CAPITAL CERTAIN: SHORT-RUN COEFFICIENTS[1]

	Δlnp^I_{1t}	Δlnp^I_{2t}	Δlnp^I_{3t}	ΔRW_t	Δx_{1t}	Δx_{2t}
1 NC	0*	0*	0*	-0.18	0.06	0.005
				(5.0)	(3.6)	(1.3)
2 BL		-36.03	36.03	-0.16	-0.003	0.03
		(0.7)		(1.14)	(0.03)	(2.2)
3 PM			-36.03	0.34	0.06	-0.04
				(2.4)	(0.6)	(2.5)

	Adjustment matrix: L		Diagnostics	
	$(s_2-s_2^*)_{t-1}$	$(s_3-s_3^*)_{t-1}$	R^2	BP(4)
1 NC	-	-	0.37	7.6
2 BL	-2.65	-1.98	0.51	4.1
	(4.4)	(3.7)		
3 PM	1.81	1.22	0.49	4.8
	(3.0)	(2.3)		

(1) Symmetry of price matrix C, equality of own price effects of BL and PM, and zero restrictions on first row of C matrix imposed. t-statistics in parentheses.

(2) x_{1t}, x_{2t} are defined in table 2A.

TABLE 3A - CAPITAL UNCERTAIN ASSETS: LONG-RUN SHARES

(i) Unrestricted Γ matrix

	$\ln p_1^T$	$\ln p_2^T$	$\ln p_3^T$	RW_t	x_{1t}	g_z (2)	x_{2t}
1 PSL	-1.15	-0.2	0.03	-0.18	0.02	3.0	0.00
	(1.6)	(0.6)	(0.1)	(5.5)	(0.8)	(1.8)	(1.7)
2 CS	0.03	-0.43	0.46	-0.24	0.12	-1.7	-0.005
	(0.09)	(1.3)	(1.5)	(7.4)	(0.5)	(1.1)	(3.5)
3 FC	1.12	0.66	-0.49	0.43	-0.07	-1.25	0.005
	(1.1)	(1.3)	(1.1)	(8.5)	(0.2)	(0.5)	(2.4)

(ii) Symmetry imposed on Γ

	$\ln p_1^T$	$\ln p_2^T$	$\ln p_3^T$	RW_t	x_{1t}	g_z (2)	x_{2t}
1 PSL	-0.49	-0.2	0.69	-0.17	-0.02	0.8	-0.002
	(1.1)	(0.10)	(2.4)	(5.1)	(1.0)	(0.6)	(2.6)
2 CS		-0.12	0.3	-0.2	-0.05	-2.48	-0.006
		(0.6)	(1.5)	(6.9)	(2.3)	(1.9)	(4.4)
3 FC			-1.00	0.4	0.08	1.67	0.008
			(2.8)	(7.8)	(2.1)	(0.8)	(3.5)

(iii) Preferred long-run equation (γ_{22} = 0.4, γ_{23} = 0.3 imposed) (1)

	$\ln p_1^T$	$\ln p_2^T$	$\ln p_3^T$	RW_t	x_{1t}	g_z (2)	x_{2t}
PSL	-0.95	0.1*	0.85	-0.16	-0.03	1.34	0.001
	(3.4)		(3.1)	(4.9)	(1.1)	(0.9)	(4.3)
CS		-0.4*	0.3*	-0.24	-0.06	-2.9	-0.011
				(8.4)	(3.1)	(2.3)	(5.4)
FC			-1.15	0.4	0.08	1.59	0.01
			(4.2)	(8.2)	(2.5)	(0.7)	(3.8)

(1) A star * indicates an imposed coefficient. See notes to table 2A.

(2) Quarterly inflation rate.

TABLE 3B - CAPITAL UNCERTAIN: SHORT-RUN COEFFICIENTS (1)

	$\Delta \ln p_1^T$	$\Delta \ln p_2^T$	$\Delta \ln p_3^T$	ΔRW	Δx_{1t} (2)	Δg_z (3)	Δx_{2t} (2)
PSL	-0.41 (1.1)	0.1	0.31 (0.8)	-0.1 (1.3)	0.02 (0.9)	-1.49 (0.6)	-0.002 (0.4)
CS		-0.38*	0.28*	-0.15 (2.1)	-0.04 (1.5)	0.3 (0.1)	-0.005 (1.3)
FC			-0.59 (1.5)	0.24 (2.3)	0.01 (0.4)	1.2 (0.36)	0.007 (1.1)

		Adjustment Matrix: L		**Diagnostics**	
		$(s_2-s_2^*)_{t-1}$	$(s_3-s_3^*)_{t-1}$	R^2	BP(4)
1	PSL	-	-	0.29	7.2
2	CS	-0.75 (1.7)	-0.22	0.31	9.1
3	FC	0.26 (1.2)	-0.22	0.33	9.5

Notes:

(1) Symmetry of short-run price coefficients imposed. A star * indicates an imposed coefficient. t-statistics in parentheses.

(2) x_{1t} and x_{2t} are defined in table 2A.

(3) g_z = Quarterly inflation rate.

TABLE 4 - HIGHER LEVEL MODEL RESULTS

Shares of capital certain assets (ie asset 1)

Symmetry imposed on Γ matrix

	$\ln p_1^T$	$\ln p_2^T$	RW_t	x_{1t} (1)	x_{2t} (2)	BP(4) (3)
(a) Long-run (4)	-0.5 (1.7)	0.5 (-)	-0.01 (0.2)	0.01 (0.4)	0.01 (2.5)	4.2
	$\Delta \ln p_1^{*T}$	$\Delta \ln p_2^{*T}$	ΔRW_t	Δx_{1t}	Δx_{2t}	l_{11}
(b) Short-run	-0.6 (1.1)	0.6 (-)	-0.2 (1.4)	-0.01 (0.2)	+0.01 (1.5)	-0.2 (0.8)

(1) x_{1t} = ccc dummy variable.

(2) x_{2t} = post-1981 'New' monetary control provisions.

(3) BP(4) is the Box-Pierce statistic for residual serial correlation asymptotically distributed as χ^2 under the null of no serial correlation in the error term. The critical value at a 5 per cent significance level is 8.1.

(4) The t-statistic quoted for each of the long-run equilibrium models are not distributed as a Student's t-distribution although they do give a purely mechanistic indication of the importance of each variable in reducing the residual sum of squares.

DATA APPENDIX

Asset stocks are taken from a specially constructed, consistent stock-flow matrix (Barr and Cuthbertson 1989) although most of the 'raw' flow data may be obtained from published sources.

Basic assets[1]

NCM	Notes and coin
TBM	Treasury bills
PSLM	Public sector liabilities (long-term)
CSM	Company securities (net)
CDLB	Certificates of deposit (liabilities of banks)
CDAB	Certificates of deposit (assets of banks)
BEDB	Bank of England deposits
CBB	Commercial bills held by banks
LABB	Local authority bills held by banks
LADB	Local authority deposits held by banks
BSCDB	Building society CDs and time deposits held by banks
CDAD	CD's held by discount houses
CBD	Commercial bills held by discount houses
LABDH	Local authority bills held by discount houses
LADDH	Local authority deposits held by discount houses
BSCDDH	Building society CDs held by discount houses
UKFLBG	Foreign currency lending to government
UKFLBPV	Foreign currency lending to nbps
UKFLBO	Foreign currency lending to overseas
UKFDBG	Foreign currency deposits from government
UKFDBPV	Foreign currency deposits from nbps
UKFDBO	Foreign currency deposits from overseas

(1) 'Banks' here refers to the monthly reporting institutions.

DATA APPENDIX (CONTINUED)

Aggregation for the estimated model

NC	= NCM + BEDB
BL	= TBM + CBB + CBDH + LABB + LABDH
PM	= CDAB - CDLB + CDADH + LADB + LADDH + BSCDB + BSCDDH
PSL	= PSLM
CS	= CSM
FC	= (UKFLBG + UKFLBPV + UKFLBO) - (UKFDBG + UKFDBPV + UKFDBO)

Prices

AJND	Rate on commercial bills
AJNB	Rate on Treasury bills
CDRATE	Rate on CD's
RUKG	Rate of UK gilts
AJMD	Rate on UK equities
AJIB	Rate of fc assets

Source: Financial Statistics

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