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DYNAMICS OF THE DEMAND FOR MONEY AND UNCERTAINTY: THE U.S. DEMAND FOR MONEY REVISITED***

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Abstract

The purpose of the paper is to revisit the demand for money specifications by using U.S. quarterly data over the sample period 1951:1 - 1983:4. Utilizing the so-called threshold models suggested by Tong and Lim (1980) we first demonstrate the unsatisfactory performance of standard linear partial adjustment type specifications. Then we turn to compare error correction type models; the generalized error correction type demand for money model seems to outperform other specifications, but suffer from heteroscedasticity of residuals. Finally, an attempt is made with some success to account for this heteroscedasticity by augmented variables - variance of nominal interest rate and inflation and covariance between nominal interest rate and inflation - which attempt to measure changes in uncertainty over time. The resulting specification passes all standard diagnostic checks and shows also otherwise reasonable properties.

Keywords: demand for money, threshold models, error correction mechanisms

CONTENTS

1 INTRODUCTION

It is now commonly agreed that the standard demand for money function suffers from several problems. In particular, this seems to be the case if it is fitted to U.S. data. At the empirical level these problems boil down to parameter instability of the standard demand for money function (see e.g. Judd and Scadding (1982) and Roley (1985) for surveys). In the search to account for parameter instabilities in an empirically satisfactory way one should be able to find a satisfactory solution to many problems like how to measure the relevant concept of money in the light of developments in the financial markets, how to distinguish between exogenous and endogenous variables in the demand for money function and how to specify the functional form and dynamics. While redefining the demand for money concept may to some extent alleviate instability problems, it is hard to argue that the problem lies only in the measurement of the money concept. Anyway in what follows we ignore measurement aspects and concentrate on some modelling issues associated with the demand for money. We use U.S. quarterly data over the period 1951:1 - 1983:4.

Typically, the stability of the standard demand for money equation a lá Goldfeld has been evaluated by using tests for the stability of the whole regression relationship over time so that the source of instability has not been identified. A way to conduct stability tests, which make it possible to identify particular sources of instabilities is to use the so-called threshold models, which have been recently proposed by Tong and Lim (1980). The idea is to scrutinize the parameter constancy by specifying the switching model, where for instance the parameters of the demand for money equation take different values depending on whether the driving "threshold" variables happen to be above or below the (fixed) "threshold" values to be estimated simultaneously with the parameters of the demand for money equation. The first purpose of

the paper is to apply threshold specifications to the standard demand for money equation.

Given the well-documented instability of the Goldfeld demand for money function it is not surprising that the threshold specifications turn out to outperform the standard one. This raises the question of how it should be respecified to take into account the instabilities in such a way that the resulting specifications could be regarded as an approximation to the threshold models. For various reasons an obvious candidate for such a model is the generalized error correction specification (GECM) proposed by Kloek (1984). The second purpose of the paper is to compare GECM with the simple error correction mechanism (ECM) and with the partial adjustment mechanism (PAM). Though GECM dominates both ECM and PAM, it still suffers from some problems, particularly from heteroscedasticity of residuals. In the presence of uncertainty and risk aversion, however, inflation and interest rate risk may play an important role. Finally, we make an attempt to account for uncertainties associated with these variables as additional explanatory variables in the demand for money function. The resulting uncertainty corrected demand for money functions with GECM outperform the other specifications and - unlike them - passes all standard diagnostic tests.

We proceed as follows: Section 2 presents the specifications to be estimated, while the estimation results are reported in section 3. Finally, there is a brief conclusion.

2 MODELLING THE DEMAND FOR MONEY

2.1 Partial adjustment and threshold specifications

The standard way of modelling the demand for money is to use a simple (transactions) demand for money model as a starting point and write

$$(1) \qquad m_t^* = a_0 + a_1 y_t^e + a_2 r_t^e + u_t,$$

where m* denotes the "desired" real money balances, y the real GNP, r the nominal interest rate and u the error term. Because the values of y and r are not necessarily known at (the beginning of) period t, it is preferable to use the "expected" values y^e and r^e instead of actual values y and r.

Usually at this point people start thinking about dynamics of (1) and the conventional response is to make use either of a partial adjustment mechanism or an error correction mechanism a lá Hendry. Starting with the former if we substitute the actual values of y and r for y^e and r^e respectively and postulate the real partial adjustment mechanism (RPAM) in log terms $m_t = \lambda m_t^* + (1-\lambda)m_{t-1}$, then we end up with

$$(2) \qquad m_t = b_0 + b_1 y_t + b_2 r_t + b_3 m_{t-1} + u_t,$$

where all the variables are expressed in log terms and m refers to the actual real money balances. According to RPAM economic agents display an instantaneous response to the change in the price level, while a non-instantanous response to changes in income and interest rate. A more natural assumption is to allow for a non-instantaneous reaction also to the change in the price level; after all economic agents adjust nominal balances. The nominal partial adjustment

mechanism (NPAM) is $M_t = \lambda M_t^* + (1-\lambda)M_{t-1}$, where M refers to the log of the actual nominal balances and M* to its "desired" value, and it can be rewritten as $m_t = \lambda m_t^* + (1-\lambda)m_{t-1} - (1-\lambda)p_t$, where p_t refers to the log of the inflation rate. Substituting y and r for y^e and r^e respectively and using NPAM yields

$$(3) \qquad m_t = c_0 + c_1 y_t + c_2 r_t + c_3 p_t + c_4 m_{t-1} + u_t,$$

where we have the parameter restriction $c_4 = -c_3$ if the inflation rate results from NPAM.

Another way of justifying the inflation rate as an explanatory variable in addition to the nominal interest rate in the demand for money function goes as follows: If money serves as a substitute for real assets and neither the Fisher equation - according to which the nominal interest rate changes one-to-one with respect to the expected inflation rate - nor the "inverted" Fisher equation - according to which the real interest rate changes inversely one-to-one with respect to the expected inflation rate - hold, then both the nominal interest rate and the inflation rate will affect m* so that

$$(1') \qquad m_t^* = a_0 + a_1 y_t^e + a_2 r_t^e + a_3 p_t^e + u_t.$$

Assuming the adaptive expectations hypothesis $x_t^e - x_{t-1}^e = \theta(x_t - x_{t-1}^e)$ for the expected variables and the same expectations coefficient $0 < \theta < 1$ gives with $m_t^* = m_t$ the specification which is equivalent to (3) with two exceptions; given (1') the error term is now $v_t = u_t - (1-\theta)u_{t-1}$ and the interpretation of the coefficients c_i is different.

In all the specifications presented thus far the parameters have been assumed to be stable. For various reasons this may not be the case, however. First, in the partial adjustment case it can be shown that if the actual cash balance is not directly a choice variable under stochastic cash flows, but economic agents revise their cash monitoring practices in response to exogenous variables, we can wind

up with the nominal adjustment specification, where the parameters of the demand for money function do depend on exogenous variables (see Milbourne and Buckholtz and Wasan (1983), and Smith (1986) for details).[1)]

Second, in the case of the adaptive expectations interpretation of (3) there is no compelling reason to suppose a constant adaptations coefficient θ. In fact, by allowing for certain (realistic) elements of uncertainty one can derive an adaptive model with a time-varying adaptations coefficient from a situation, where economic agents form their predictions by using a Bayesian sampling procedure. Under the circumstances where the observations about the variable to be forecasted are composed of two, separately unidentifiable parts, the 'permanent' and 'transient' components, the adaptation coefficient depends on the relative precision of the degree of belief and the interpretation of observations; with high degree of belief and very "transient" observations θ is close to zero, while with low degree of belief and very "permanent" observations θ is close to one (for details, see Turnovsky (1969) and particularly, Lawson (1980)).[2)]

In the face of various potential explanations for parameter instability one should obviously carry out stability tests. Standard stability tests are not necessarily very helpful, however, because they are based on the assumption that instability is somehow related to time so that they do not allow for the identification of the sources of instability. From the point of view of the identification of the sources of instability the so-called threshold models are an obvious candidate. They are based on the assumption that the parameters of the explanatory variables change according to some threshold variable, which can be just time, or explanatory variables themselves. For instance in the case of specification (3) using a threshold specification means fitting the following type non-linear equation into the data

$$
(4)\quad
\begin{aligned}
&\text{(a)}\ m_t = c_0 + c_1 y_t + c_2 r_t + c_3 p_t + c_4 m_{t-1} + u_t \\
&\qquad\qquad \text{for all } t \text{ with } q_t \leq \bar{q} \\
&\text{(b)}\ m_t = c_0^* + c_1^* y_t + c_2^* r_t + c_3^* p_t + c_4^* m_{t-1} + u_t^* \\
&\qquad\qquad \text{for all } t \text{ with } q_t > \bar{q},
\end{aligned}
$$

where u_t and u_t^* are error terms and were q is a threshold variable and $\bar{q}$ is its corresponding (fixed) threshold value. If the error variances are equal, then one can find out a modified threshold model of the form

$$
(5)\quad m_t = c_0 + c_1 y_t + c_2 r_t + c_3 p_t + c_4 m_{t-1} + c_0' d + c_1' y_t' + c_2' r_t' + c_3' p_t' + c_4' m_{t-1}' + u_t',
$$

where u_t' is an error term and d=1 for all t with $q_t \leq \bar{q}$ and 0 otherwise, $y_t' = y_t$ for all t with $q_t \leq \bar{q}$ and 0 otherwise and similarly for r_t', p_t' and m_{t-1}'. The advantage of (5) over (4) is that it allows for testing the equality of parameters in the two regimes by means of testing the significance of the additional variables d, y_t', r_t', p_t' and m_{t-1}' (for further details of the methodology of threshold models, see the seminal paper by Tong and Lim (1980)).

Except that threshold models provide a way of testing for stability of the specifications, they can be justified on two other grounds. First, they provide a rough approximation to more general linear structures in the lack of knowledge of precise parameterization; in particular, they provide an approximation to varying-parameter specifications, which may result from the earlier presented reasons. Second, threshold models are a natural way to evaluate the so-called "multi-geared adaptive expectations hypothesis" presented by Flemming (1976). This is a sort of synthesis between rational expectations and adaptive expectations to avoid the strong assumptions of the former and (in some cases) the systematic errors of the latter; for instance if the price-level variable has exhibited no trend in recent years, then this is the variable to

which economic agents will apply the adaptive expectations hypothesis. However, if the price-level variable has revealed a trend, while its rate of change variable, the inflation rate, has not then the adaptive schema will be used to predict the inflation rate variable.[3] And analogously for other expected variables.

2.2 Generalized error correction specification

If the threshold models of type (4) or (5) outperform standard linear specifications like (2) and (3), then either the non-linear threshold specification gets support and/or the outperformance can be interpreted as showing parameter instability of standard linear models. In the latter case the question of how the linear specifications should be modified in order to account for instabilities has to be faced.

An obvious way to proceed is to make use of the generalized error correction mechanism (GECM) proposed and discussed by Kloek (1984). In this connection it may be specified as follows

$$(6) \qquad \Delta m_t = b_0 + b_1(m-y)_{t-1} + b_2(m-y)_{t-2} + b_3\Delta y_t + b_4\Delta y_{t-1} + b_5\Delta r_t + b_6\Delta r_{t-1} + b_7\Delta p_t + b_8\Delta p_{t-1} + u_t,$$

where Δ refers to the first differences of the variables and where $(m-y)_{t-1}$ and $(m-y)_{t-2}$ are the so-called error correction terms. According to (6) the change in the real money balances depends on the change in the current and lagged values of the explanatory variables and on the lagged discrepancies between the real money balances and the real income, the so-called error correction terms.[4]

The specification (6) have several attractive features. First, by dropping the error correction term $(m-y)_{t-2}$ and the lagged differences of the explanatory variables we wind up with the simplest example of the error correction mechanism (ECM)

$$(7) \qquad \Delta m_t = b_0 + b_1(m-y)_{t-1} + b_2\Delta y_t + b_3\Delta r_t + b_4\Delta p_t + u_t.$$

Second, the specification (6) represents an approximation to threshold models presented earlier in the sense that excluding the error correction terms the right-hand side variables can be written in terms of first and second differences (a "gear shift") and threshold models provide a way to evaluate "gear shifts" in the explanatory variables.[5] Third, the specification allows for varying velocity of money in the long run (for an analysis of the circumstances in which the specifications of type (6) or (7) represent optimal response of economic agents in a dynamic environment, see Nickell (1985)).

Specifications of the demand for money presented earlier, while differing in details, have one common characteristic: they have the certainty equivalence property in the sense that even though we have referred to uncertainties as a reason for varying parameter models, the expectation variables have been formulated by means of the expected values only. It is obvious, however, that changes in the degree of uncertainty may play an important role as a factor affecting the pattern of money holdings by risk-averse economic agents.

First, for well-known portfolio theoretic reasons uncertainty about nominal rate of returns, inflation and covariance between nominal rate of return and inflation may affect money holdings as additional explanatory variables (for various ways of justifying this, see Buiter and Armstrong (1978), Fischer (1975) and Boonekamp (1978)). Second, as suggested earlier, one can derive a time-varying and uncertainty sensitive specification from a situation, where economic agents form their predictions under uncertainty by using a Bayesian sampling procedure (see Turnovsky (1969), and particularly Lawson (1980)). Moreover, Walsh (1984) has recently suggested how the parameters of the demand for money function - derived from portfolio theoretic framework in the presence of nominal interest rate and inflation uncertainty - can themselves depend on stochastic properties of interest rate and inflation.[6] For both of these

reasons, changes in uncertainty may affect via parameters of the explanatory variables.

In practice it is very difficult, if not impossible, to distinguish between the two channels of influence of uncertainty variables. In this paper we do not try to tackle this issue, but introduce uncertainty variables additively as additional explanatory variables into the GECM specification (6).

More specifically, we introduce the nominal rate of return uncertainty variable - measured by the variance of the interest rate v_r - the inflation rate uncertainty variable - measured by the variance of the inflation rate v_p - and the hedging variable - measured by the covariance between the nominal rate of return and the inflation rate, cov - as augmented variables. Denoting the expected values by supscript e we end up with the following uncertainty-corrected GECM specification:

$$(8) \qquad \Delta m_t = b_0 + b_1(m-y)_{t-1} + b_2(m-y)_{t-2} + b_3\Delta y_t + b_4\Delta y_{t-1}$$

$$b_5\Delta r^e_t + b_6\Delta r^e_{t-1} + b_7\Delta p^e_t + b_8\Delta p^e_{t-1} + b_9\Delta v_{rt} +$$

$$b_{10}\Delta v_{rt-1} + b_{11}\Delta v_{pt} + b_{12}\Delta v_{pt-1} + b_{13}\Delta cov_t +$$

$$b_{14}\Delta cov_{t-1} + u_t.$$

The purpose of the empirical part of the paper is to estimate and compare the relative performance of the specifications (2) - (8) by using the U.S. quarterly data over the sample period 1951:1 - 1983:4.

3 EMPIRICAL RESULTS

The U.S. data over the period 1951:1 - 1983:4 to be used are quarterly, seasonally adjusted - with the exception of nominal interest rates, which are seasonally unadjusted - and derived mainly from Business Conditions Digest. The money stock is the conventional M1, GNP is used as a proxy for y and the respective price deflator as the relevant price series. As the proxy for the opportunity cost of holding money we used the three-month Treasury bill rate (RTB).[7)]

3.1 The Goldfeld specification and threshold models of the demand for money

It is well-known that the real partial adjustment demand for money function (2) has shown a rather poor performance, particularly, when the data from the 1970s and 1980s has been used in estimations (Judd and Scadding (1982), see also Koskela and Virén (1986)). The estimation results of (2) and (3) indicate clearly that the inflation rate serves as an important explanatory variable in the demand for money function.

Using quarterly U.S. data over the period 1951:1 - 1983:4 yields a standard error .00824 for specification (2) and .00686 for the specification (3) with the t-value of the inflation rate being 7.59. Moreover, we cannot reject the NPAM $c_4 = -c_3$ ($F(1,128) = .56$) over the whole estimation period. If we go a bit further and estimate the following unrestricted model in terms of the inflation rate

$$(3') \qquad m_t = c_0 + c_1 y_t + c_2 r_t + c_3 P_t + c_4 P_{t-1} + c_5 m_{t-1} + u_t$$

where P_t indicates the log of the price level, then the hypothesis that $c_3 = -c_4$ cannot be rejected either ($F(1,127) = 2.26$) in conformity

with NPAM. But using the fact $M = m + P$ (3') can be rewritten as $M_t - c_5M_{t-1} = c_0 + c_1y_t + c_2r_t + (1+c_3)P_t + (c_4-c_5)P_{t-1} + u_t$ and assuming $c_3 = -1$ and $c_4 = c_5 = 1$ yields $M_t - M_{t-1} = c_0 + c_1y_t + c_2r_t + u_t$. Unfortunately, we cannot reject the coefficient restrictions leading to this specification either so that over the whole estimation period the change in the nominal money balances seems to depend on the real GNP and the nominal interest rate; this is clearly a finding that is not consistent with any standard theoretical analysis of the demand for money.[8] This last result is a kind of artifact, which does not hold over subsamples. For instance in the case of subsamples 1951:1 - 1967:2 and 1967:3 - 1983:4 the parameter restrictions $c_3 = -1$ and $c_4 = c_5$ can clearly be rejected (the chi square statistic is 6.6 in both cases).

In the light of the above mentioned weaknesses of specifications (2) and (3) it is appropriate to seek for a better alternative. Next we turn to consider threshold models of the demand for money (4) and (5), which were presented in section 2.

The test procedure consists of fitting the linear model (3), the threshold model (4) and the modified threshold model (5), where the inflation rate was decomposed into price level components, into the data sample by using p_t, r_t, rate of growth of y_t, time and inflation variance v_p alternatively as threshold variables. The estimation results with the inflation rate p as the threshold variable are presented in Table 1 both over the whole estimation period and across two sub-periods. The values of the threshold were determined by using the Schwartz Bayesian information criterion (SBIC).[9] The threshold models were estimated by non-linear LS using the program by Luukkonen (1983).

Both on the basis of the Schwartz Bayesian information criterion and of the value of the LR-statistic (calculated for the modified threshold model) the linear specification (3) is outperformed by threshold specifications. Moreover, the particular choice of the threshold variable did not to seem to matter; e.g. for the whole sample period almost the same data points were chosen by the threshold variables p, rate of change of y, time and inflation

Table 1. Estimation Results with Threshold Specifications

1951.2 - 1883.4

Constant	m_{-1}	y	r	P	P_{-1}	SEE	$\bar{p}$	SBIC
-.283	1.010	.057	.500	-.695	.664	.0046	p<3.86	-686.6
(2.50)	(40.15)	(3.43)	(4.84)	(3.87)	(3.68)		n=66	
.134	.942	.030	-.089	-1.298	1.296	.0074	p>3.86	-613.3
(0.70)	(19.07)	(1.44)	(1.84)	(6.74)	(6.80)		n=65	

SBIC = -1286.25 z = 19.96

1951.2 - 1967.2

.633	.855	.149	-.326	-.699	.502	.0042	p<2.54	-478.7
(1.64)	(11.87)	(3.49)	(2.68)	(3.48)	(2.36)		n=46	
1.174	.669	.218	-1.115	-.212	.020	.0019	p>2.54	-207.9
(5.99)	(16.89)	(8.54)	(5.89)	(1.39)	(0.12)		n=18	

SBIC = -679.7 z = 16.82

1967.3 - 1983.4

.078	1.055	-.082	-.271	-.572	.623	.0056	p<6.88	-412.7
(0.34)	(20.42)	(1.65)	(3.90)	(1.87)	(2.12)		n=42	
2.403	.266	.392	.148	-1.402	1.153	.0072	p>6.88	-208.2
(2.42)	(1.00)	(2.89)	(1.34)	(3.42)	(2.54)		n=23	

SBIC = -616.5 z = 18.69

---

m = log(MIP), y = log(GNPQ), r = RTB/100, $\bar{p}$ indicates the value of the inflation threshold, SBIC the value of the Schwartz information criterion for a linear model, and finally z an chi square test statistic (with 6 degrees of freedom) for the hypothesis that the coefficients above and below the threshold are equal. This statistic is computed assuming that error variances for the both model structures (above and below the threshold) are equal.

variance v_p.[10] All in all, threshold models clearly outperform linear specification (3). An unattractive feature of threshold estimation is that time works roughly as well as other threshold variables. Therefore, we turn to consider specifications which would account for these instabilities.

3.2 Error correction specifications for the demand for money without and with uncertainty variables

In this section we first compare the error correction specifications (6) and (7) with the NPAM specification (3). The OLS estimation results are reported in Table 2 together with a number of test statistics. The following features of results merit attention.

First, the "generalized" ECM seems to outperform both the nominal partial adjustment version (3) and the simple ECM (7) in almost all respects. The better performance of (6) is displayed by the standard error of equations, Godfrey's LM autocorrelation statistics, Jarque-Bera test for normality of residuals, and various types of CUSUM tests. Second even though (6) outperforms (3) and (7) in terms of most diagnostics, it suffers from heteroscedasticity of residuals. This is indicated by the CUSUMQ test statistic, which for (6) - as well as for (3) and (7) - exceed the standard levels of significance. A more direct evidence is provided by Engle's Autoregressive Conditional Heteroscedasticity (ARCH) test statistic, which in all cases exceeds the standard levels of significance (for details of ARCH-methodology, see Engle (1982)).

A way to try to interpret the finding that residuals of the demand for money equations suffer from heteroscedasticity is to pay attention to the possibility that changes in uncertainty over time have played an important role as a factor affecting the pattern of money holdings by risk-averse economic agents. Let us now return to estimation results obtained by using the GECM augmented with various uncertainty variables, i.e. the specification (8).[11]

Table 2. OLS Estimation Results for Equations (3), (6) and (7)

A Coefficient Estimates

(3) $\hat{m}_t = -.051 + .979m_{t-1} + .026y_t - .113r_t - .931p_t$
(0.55) (47.15) (5.28) (2.81) (7.59)
(0.53) (45.93) (5.29) (2.60) (5.95)

(7) $\Delta\hat{m}_t = -.003 - .001(m-y)_{t-1} + .323\Delta y_t + .025\Delta r_t - .496\Delta p_t$
(0.76) (0.40) (4.49) (0.29) (3.87)
(0.72) (0.34) (4.42) (0.22) (3.21)

(6) $\Delta\hat{m}_t = -.003 + .442(m-y)_{t-1} - .443(m-y)_{t-2} + .217\Delta y_t$
(1.03) (6.37) (6.40) (3.77)
(1.10) (5.55) (5.58) (3.64)

$+ .492\Delta y_{t-1} - .008\Delta r_t - .540\Delta r_{t-1} - .680\Delta p_t - .100\Delta p_{t-1}$
(6.13) (0.12) (8.37) (6.21) (0.97)
(5.36) (0.08) (5.44) (6.72) (1.15)

B Test Statistics

Equation	(3)	(7)	(6)	5 % critical value
R^2	.983	.228	.613	..
100*SEE	.686	.805	.579	..
D-W	1.484	1.296	2.205	1.57/1.78
LM1	3.008	4.327	1.704	1.645
LM2	.606	1.118	.266	1.645
LM3	.846	1.759	.170	1.645
LM4	.956	0.778	.350	1.645
J-B	19.257	17.594	5.389	5.991
ARCH4	18.30	17.28	24.96	9.49
Chow 67:4	4.467	1.748	1.540	1.96
F-H	5.853	1.558	2.266	1.96
Homogeneity	2.108	1.314	.962	1.57
Cusum(b)	.710	1.141	.702	.948
Cusum(f)	.862	.636	.208	.948
Cusumsq(b)	.267	.276	.228	.145
Cusumsq(f)	.403	.335	.362	.145

$m = \log(M/P)$, $y = \log(GNPQ)$, $r = RTB/100$, $p = \log(P_t/P_{t-1})$, Δ indicates first differences, numbers in parentheses immediately below the coefficient estimates are standard t-ratios; below them are White's heteroscedasticity adjusted t-ratios. LMi's denote Godfrey's LM autocorrelation statistics, J-B is the Jarque-Bera test for normality of residuals, ARCH4 is Engle's autocorrelation conditional heteroscedasticity statistic with 4 lags, Chow 67:4 is the Chow stability test statistics for the period 1967:4, F-H is the Farley-Hinich (F) test for the hypothesis that parameters follow a linear trend, Homogeneity is a F test for parameter stability w.r.t. 6 nonoverlapping periods (with 20 observations in each of them), and finally Cusum and Cusumsq are the Cusum squares stability statistics which are computed both backward (b) and forward (f). The critical values are based on the number of degrees of freedom of equation (6).

In order to check roughly whether the augmented variables play any role in alleviating the heteroscedasticity problems of (6) we proceeded as follows: First we constructed time-series proxies for the expected inflation and the interest rate by using simple univariate AR(4) models. Then the one-period ahead predictions were used for expected values, the squared prediction errors for the variance terms and the covariance terms were derived by using the corresponding cross-products of the prediction errors. The AR(4) models were estimated recursively so that the expected values were conditional only to the information which was available at the moment the predictions have been made. Finally, the constructed variance and covariance terms were introduced into the specification (6) taking into account its "generalized" ECM type. The corresponding OLS estimation results are presented in Table 3, where the variance and covariance terms are denoted by v_r, v_p and cov respectively.

On the basis of estimation results presented in Table 3 one can readily conclude that introducing the additional variance and covariance terms into the specification (6) and using the predicted values for r and p instead of their actual values clearly helps to improve the performance of the underlying demand for money function; comparing the estimation results with those in equation (6) of Table 2 indicates that both the standard error of the estimate is now considerably smaller and the specifications now pass all standard diagnostic checks including ARCH test statistic.[12] Moreover, according to F-test statistics the hypothesis that the variance and covariance terms are equal to zero can be rejected at standard significance levels.

Turning to economics of the money demand specifications presented in Table 3 we should point out first, that the so-called error-correction terms will cancel each other out; this means that in the long run the model does not reduce to a constant level of velocity or to a constant growth level of velocity which would be independent of nominal interest rate, inflation rate and real income.[13] Second,

Table 3. Estimation Results with Uncertainty Corrected Demand for Money Specifications

(9) Δm_t = -.003 + .439$(m-y)_{t-1}$ - .440$(m-y)_{t-2}$ + .189Δy_t +
(1.19) (5.55) (5.58) (3.40)
(1.29) (5.30) (5.34) (3.77)

.550Δy_{t-1} - .433Δr^*_t - .148Δr^*_{t-1} - .611Δp_t + .148Δp_{t-1}
(6.78) (9.43) (2.89) (4.87) (1.22)
(6.99) (7.12) (2.56) (5.41) (1.33)

-.188Δv_{rt} - .091Δv_{rt-1} - .241Δcov_t - .031Δcov_{t-1}
(3.30) (1.65) (2.06) (0.28)
(2.70) (1.60) (1.87) (0.23)

R^2 = .688, 100*SEE = .530, D-W = 2.075, LM1 = .639,
LM2 = .450, LM3 = .114, LM4 = .678, J-B = .466,
ARCH = 1.77, Chow = .616, F(4) = 4.158.

(19) Δm_t = .004 + .394$(m-y)_{t-1}$ - .396$(m-y)_{t-2}$ + .193Δy_t + .517Δy_{t-1}
(1.36) (4.58) (4.60) (3.20) (5.76)
(1.41) (4.87) (4.91) (3.23) (6.31)

-.500Δr^*_t - .147Δr^*_{t-1} - .373Δp^*_t + .379Δp^*_{t-1} - .377Δv_{pt} -
(10.27) (2.64) (1.15) (1.17) (2.09)
(8.14) (2.59) (0.99) (1.05) (2.11)

.272Δv_{pt-1} - .214Δv_{rt} - .105Δv_{rt-1} - .327Δcov_t - .027Δcov_{t-}
(1.57) (3.51) (1.77) (2.63) (0.22)
(1.55) (3.13) (1.74) (2.74) (0.19)

R^2 = .646, 100*SEE = .570, D-W = 2.119, LM1 = 1.144,
LM2 = .024, LM3 = .732, LM4 = .828, J-B = 1.377,
ARCH4 = 4.96, Chow = .540, F(6) = 3.888.

---

r* (p*) denotes the predicted value of r (p) given by an AR(4) model which is estimated recursively from the beginning of the sample period. v_p, v_r and cov are corresponding variance and covariance terms (which are constructed by using the (squared) prediction errors of the respective variables). The coefficient of v_r is multiplied by 100, and the coefficient of v_p, in turn, is divided by 100. F(4) and F(6) denote F-test statistics for the hypothesis that the variance and covariance terms are equal to zero. Otherwise notation is the same as in Table 2. For computer capacity reasons we could calculate the Cusumsq-test for neither specification (9) nor for specification (10). But keeping the parameters of the error correction terms fixed produced results which passed in terms of the Cusumsq-statistics.

the income elasticity of the demand for money lies on the range .71 - .74, which sounds very plausible.[12] Finally, as far as the signs of the other explanatory variables are concerned, the nominal interest rate and inflation rate are of expected sign, though in the specification (10) the inflation terms will offset each other. On the basis of portfolio theoretic considerations it is reasonable to expect that the variance of nominal interest rate, v_r, affects positively, while the covariance between the prediction errors of the nominal interest rate and inflation, cov, negatively. The latter seems to be the case, while the sign of v_r is "wrong". Thus the estimation results do not completely obey this portfolio theoretic conjecture. But we should keep in mind that these uncertainty terms may also (or solely) affect "multiplicatively" via the coefficients of the demand for money functions from which we have abstracted in our empirical implementation.

4 CONCLUDING REMARKS

In this paper we have revisited the demand for money specifications by using U.S. quarterly data over the sample period 1951:1 - 1983:4. The reasons why we have used U.S. data are first that standard specifications are particularly problematic in this case and second that the demand for money has been so extensively studied with this data that it therefore provides a convenient case for presenting and testing new specifications.

Given the well-known weaknesses of the standard partial adjustment specifications we first estimated the nonlinear threshold models of the demand for money. They are based on the assumption that parameters of the demand for money change according to some threshold variable, which can be just time or explanatory variables themselves. An attractive feature of threshold models is therefore that they provide a way to test for non-linearities in terms of explanatory variables thus making it possible to identify sources of instability in linear models.

The threshold models outperformed linear specification in all cases including the case where time was used as the threshold variable. Therefore we turned to consider more general specifications which could account for instabilities. This led us to the so-called error correction type models; they displayed a better performance than partial adjustment specifications, but suffered from heteroscedasticity of residuals. Finally, we extended the error correction models by introducing uncertainty variables - like variance of nominal interest rate, variance of the inflation rate and covariance between the nominal interest rate and the inflation rate - as augmented variables into the demand for money functions. The resulting uncertainty-corrected generalized error correction specifications passed all standard diagnostic checks including heteroscedasticity test statistics and showed also otherwise

reasonable properties in terms of the size of elasticities and signs of explanatory variables. Though the results are preliminary we feel that modelling uncertainties in the connection of more general dynamics than partial adjustment is a promising area and provides a number of agendas for further both theoretical and empirical and research.

FOOTNOTES:

1) Under slightly different assumptions Santomero and Seater (1981) have presented a model with variable adjustment, where the partial adjustment parameter changes over time in response to exogenous shocks. By presenting a theory of how assets are searched out and how excess balances are worked off, they emphasize money's role as a "shock absorber" during periods of disequilibrium.

2) Lawson (1980) has also presented how this Bayesian procedure could be operationalized in practice.

3) Thus according to this "gear-shift hypothesis" expectations are formed adaptively on the lowest-order difference of the process of variable to have shown no trend in recent years. See Vanderkamp (1972) for an early attempt to implement this idea in the case of the specification of the wage equation.

4) Generally, and here as well co-integration of the error correction part is assumed. Recent work on methods for testing the unit root can be used to test for co-integration (see Granger and Engle (1987) for details).

5) The dynamics featuring in (6) can also be justified in terms of expectations. Thus, assuming for instance adaptive expectations in terms of p_t^e (only) in equation (1') the following model can be derived:

$$(9) \qquad m_t = a_0\theta + a_1 y_t - a_1(1-\theta)y_{t-1} + a_2 r_t - a_2(1-\theta)r_{t-1} + a_3\theta p_t + (1-\theta)m_{t-1} + u_t - (1-\theta)u_{t-1},$$

where θ is the adaptive expectations coefficient specified earlier. By differencing and rearranging terms one obtains the following specification:

(10) $$\Delta m_t = a_1 \Delta y_t + (1-\theta)(1-a_1)\Delta y_{t-1} + a_2 \Delta r_t - a_2(1-\theta)\Delta r_{t-1} + a_3 \theta \Delta p_t + (1-\theta)(m-y)_{t-1} - (1-\theta)(m-y)_{t-2} + u_t - (2-\theta)u_{t-1} + (1-\theta)u_{t-2}.$$

Clearly, this specification is close to the GECM specification (6). It is only that (9) imposes certain parameter restrictions which are not present in (6). However, the estimation results which will be presented in Table 2 correspond fairly closely to this specification.

6) More specifically, after some approximations Walsh presents the following demand for money function

(1) $$m_t = h_0 + h_1(y_t - \bar{y}_t) + h_2(r_t^e - r_t) + u_t,$$

where the demand for money depends positively on the income "innovation" ($\bar{y}_t$ = the trend value of y_t) and negatively on the expected nominal rate of return on bonds, where r_t and r_{t+1} refer to actual and expected bond prices. It is important to stress that the parameters h_i (i = 0, 1, 2) can be interpreted in terms of the variance of the bond price, the covariance between inflation and the price of bonds and the coefficient of relative risk aversion. The parameters will change, when those variables are subject to changes for instance as a result of changes in monetary policy rules. Thus we have here an example of the Lucas critique view extended to account for uncertainties. (See Walsh (1984) for details).

7) A detailed description of the data is available from the authors upon request.

8) By using the U.S. quarterly data over the period 1951:1 - 1983:4 the OLS estimation of the specification (3) gave the following results

$$m_t = \underset{(1.00)}{-.094} + \underset{(40.45)}{1.005}m_{t-1} + \underset{(1.43)}{.013}y_t + \underset{(3.24)}{-.135}r_t - \underset{(7.81)}{.952}P_t + \underset{(7.85)}{.963}P_{t-1}$$

100*SEE = .679, D-W = 1.557, where t-values are in parentheses. Clearly, on the basis of coefficient estimates we can reject neither the hypothesis that the sum of the coefficients of P_t and P_{t-1} is zero, nor the (joint) hypothesis that the coefficient of P_t is -1 and that the coefficient of P_{t-1} is equal to the coefficient of m_{t-1} (in this joint hypothesis case the chi square statistic with 2 degrees of freedom is .4). Moreover, if one tests the joint hypothesis in the context of the specification (3) that $c_5 = c_4 = c_3$, then the same chi square test statistic with 3 degrees of freedom is now 4.8, which fails to exceed standard

levels of significance. Thus we wind up with an equation of the type $M_t - M_{t-1} = c_0 + c_1 y_t + c_2 r_t + u_t$.

9) In their seminal paper Tong and Lim (1980) suggested the use of the Akaike information criterion (AIC) as the main specification criterion of threshold models. In contrast with SBIC it has, however, a tendency to overestimate the dimension of the model particularly in large samples. In the context of threshold models this tendency to overestimate the dimension means selecting a threshold model with a positive probability even asymptotically though the true model is linear (see e.g. Geweke and Meese (1981) and Teräsvirta and Luukkonen (1985)).

10) A complete set of results is available from the authors upon request.

11) The uncertainty variables have been used with some success as augmented variables in the conventional demand for money function in Koskela & Virén (1987), in which it is shown using U.S. quarterly data over the sample period 1952:2 - 1982:4 that the nominal rate of return uncertainty variable tends to have a significantly positive effect and the inflation hedging variable a significantly negative effect on the demand for money.

12) As for the interest rate, we also experimented with the yield on long-term Treasury bonds. The results were qualitatively similar to those presented in the paper. Hence, they have not been reported. A full set of results is available from the authors upon request.

13) Alternatively, one can refer to the adaptive expectations specification (9) presented in fn. 5. Notice, that this specification implies very reasonable parameter values, particularly in terms of the adjustment coefficient θ.

14) Recently, Rose (1985) has also estimated an error correction type specification using M1 money concept for U.S. data, which outperforms the standard partial adjustment specifications when estimated from early 1950s up till 1973. He reports the steady-state income elasticity .57. Unfortunately, however, the extension of the sample till the end of 1981 has the effect of rejecting the stability of his ECM type demand for money model. Taylor (1986) has also estimated ECM type demand for money models for three European countries, West Germany, the Netherlands and France, using M2 money concept. The income elasticity turns out to be 1 for West Germany and the Netherlands, but surprisingly high 1.64 for France. Neither Rose (1985) nor Taylor (1986) use uncertainty variables in their specifications.

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