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ON THE DETERMINATION OF THE MONEY STOCK: SOME ESTIMATES

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ABSTRACT

This paper presents a framework for the determination of the money stock and interest rate under the monetary base, nonborrowed reserves and interest rate targeting and uses a generalized adjustment mechanism to produce specifications to be estimated. Estimation results from U.S. quarterly data over the period 1951.2-1983.4 indicate instability of all specifications over the whole sample period thus suggesting that a single regime - e.g. interest rate targeting - may not be appropriate for the whole period. Moreover, while the evidence in terms of interest rate versus nonborrowed reserves targeting is not clearcut, our findings tend to support the claim that the standard demand for money function suffers from simultaneity bias. There is finally a modest amount of evidence for the view that the monetary base targeting assumption is not capable of explaining the data. Causality tests are not incompatible with these findings.

1 INTRODUCTION

During the last decade or so the demand for money function has been subject to quite a lot of studies, which were partly stimulated by Goldfeld's (1976) evidence on systematic overprediction of real money balances by the standard demand for money function. Various explanations - like financial innovations, functional misspecification, changes in policy rule(s) (for a survey, see Judd and Scadding (1982), see also Hafer and Hein (1982)) - for the deteriorating performance were given. It seems fair to say that these explanations, while promising, still lack conclusive confirmation. As an aftermath of this a considerable amount of scepticism has arisen in terms of proper modelling of the demand for money (see Cooley and LeRoy (1981)).

Given all these problems we believe it is still useful to examine alternative specifications for the money stock determination. The purpose of this paper to do just that by reconsidering the behaviour of the supply side in the determination of the money stock. Interest rate target on the part of the monetary authority may not only exist, but it may change according to a systematic monetary policy rule. This in turn may give rise to seriously biased policy multipliers from reduced-form estimations, when policy is not solely a function of lagged target variables, but reacts to contemporaneous events (see Goldfeld and Blinder (1972)). It is surprising how little attention in the demand for money literature has been paid to problems arising from endogenous monetary policy.

In what follows we present a framework for the determination of money stock and interest rate under the monetary base, nonborrowed reserves and interest rate targeting respectively and by using a generalized adjustment mechanism we wind up for the specification of the money stock and interest rate changes in terms of exogenous variables, which depend on the targeting regime. Finally, these specifications are estimated from U.S. quarterly data over the period 1951.2-1983.4 and over various subperiods. Moreover, we conduct some 'causality' tests between variables involved in the determination of the money stock and interest rate.

To anticipate results, it turns out that all specifications display instability over the whole estimation period thus suggesting that a single regime may not be appropriate for the whole period.[1)] Second, there is a modicum of evidence for the view that monetary base targeting assumption is not capable of explaining the money stock determination. Finally, while the evidence in terms of interest rate versus nonborrowed reserves targeting is not clearcut our findings support the claim that the standard demand for money estimation suffers from the simultaneity bias.

We proceed as follows. Theoretical considerations and specifications to be estimated are presented in section 2, while section 3 is devoted to empirical results. Finally, there is a brief concluding section.

2 THEORETICAL CONSIDERATIONS

The standard way of modelling the demand for money is to estimate a partial adjustment model for real money balances assuming that the interest rate(s) is exogeneous, due to interest rate targeting, for instance. The corresponding specification takes the form (cf. e.g. Goldfeld (1973)):

$$(1) \qquad \log(M/P)_t = b_0^* + b_1^* \log r_t + b_2^* \log y_t + b_3^* \log(M/P)_{t-1}$$

where M indicates some concept of money, P the relevant price index, r the interest rate and y the real income. As it is well-known (and was mentioned above) this type of money demand specification overpredicted the demand for money balances after 1973. A way to proceed is to allow for various operating procedures for monetary policy and explore their implications for money stock and market interest rate. Depending on the operating procedure of monetary policy we can using Thornton (1982) as frame of reference end up with the following reduced forms for the stock of money, M, and for the market interest rate r:

$$(2) \qquad \begin{cases} M_t^* = a_1 B_t + a_3 Y_t \\ r_t^* = a_3 B_t + a_4 Y_t \end{cases}$$

$$(3) \qquad \begin{cases} M_t^* = b_1 NBR_t + b_2 Y_t + b_3 RD_t \\ r_t^* = b_4 NBR_t + b_5 Y_t + b_6 RD_t \end{cases}$$

$$(4) \qquad M_t^* = c_1 Y_t + c_2 r_t$$

where (2) corresponds to monetary base targeting, (3) nonborrowed reserve targeting and (4) interest rate targeting, and where B indicates the monetary base, Y the nominal income, NBR the nonborrowed reserves, RD the discount rate and variables with (*) refer to long run equilibrium values of the money stock and the market interest rate. Under fairly weak conditions the following sign restrictions can be imposed: a_1, $a_2 > 0$, $a_3 < 0$, $a_4 > 0$, b_1, $b_2 > 0$, $b_3 < 0$, $b_4 < 0$, $b_5 > 0$, $b_6 > 0$, $c_1 > 0$ and $c_2 < 0$ (see Thornton (1982) for further details).[2)] While the nominal income and the discount rate are always exogenous in this framework, the remaining exogenous variable is determined by the operating procedure to be adopted in monetary policy. Under monetary base targeting, the nonborrowed reserves and the interest rate will move endogenously to achieve levels consistent with the monetary base target and the same will be true of the interest rate and monetary base under nonborrowed reserves targeting.[3)] Finally, under the interest rate targeting the equilibrium stock of money is demand-determined (for an analysis of these and other operating procedures for implementing monetary policy in terms of their shock-absorbing properties, see Thornton (1982) and particularly Bryant (1983)).

As mentioned above the equations (2) - (4) represent the long run equilibrium values of the money stock and the market interest rate under various operating procedures. We specify the dynamics very simply by applying the standard partial adjustment mechanism for (4) and the generalized adjustment mechanism (see e.g. Chow (1983)).

$$X_t - X_{t-1} = \Lambda(X_t^* - X_{t-1}) \tag{5}$$

where X is a 1 x k vector of k endogenous variables and Λ is a k x k matrix of adjustment parameters, for (2) and (3). By using (5), and by deflating the money and income variables by the relevant price index, and, finally, by using a log transformation and adding an error term we end up with the following specifications to be estimated.

$$\log(M/P)_t = d_0 + d_1\log(B/P)_t + d_2\log(Y/P)_t + d_3\log(M/P)_{t-1} + d_4RB_{t-1} + u_{1t} \tag{6-a}$$

$$RB_t = l_0 + l_1\log(B/P)_t + l_2\log(Y/P)_t + l_3\log(M/P)_{t-1} + l_4RB_{t-1} + u_{2t} \tag{6-b}$$

$$\log(M/P)_t = f_0 + f_1\log(NBR/P)_t + f_2RD_t + f_3\log(Y/P)_t + f_4\log(M/P)_{t-1} + f_5RB_{t-1} + u_{3t} \tag{7-a}$$

$$RB_t = g_0 + g_1\log(NBR/P)_t + g_2RD_t + g_3\log(Y/P)_t + g_4\log(M/P)_{t-1} + g_5RB_{t-1} + u_{4t} \tag{7-b}$$

$$\log(M/P)_t = h_0 + h_1RB_t + h_2\log(Y/P)_t + h_3\log(M/P)_{t-1} + u_{5t} \tag{8}$$

where RB indicates the market interest variable (the three month Treasury bill rate) to be applied in the subsequent analysis.

As one can see we have ended up with specifications which are fairly closely related to each other. For instance, comparing the equations for the determination of the money stock (6-a), (7-a) and (8) reveals that all these include the real income and the lagged real money stock variables and the current or the lagged interest rate. Moreover, there are some non-overlapping additional variables (the real monetary base, the real nonborrowed reserves and the discount rate). Looking at sign restrictions, however, does not make the task of distinguishing between these specifications easy. For instance, assuming that the cross adjustment coefficient of interest rate 'disequilibrium' in the money stock equations is positive and "large enough" implies, given the sign restrictions for (2) and (3), that d_2, $f_3 > 0$, d_4, $f_5 < 0$ and d_1, e_1, f_2 = ? which is in turn very close to (8) where $h_1 < 0$ and $h_2 > 0$ (in all cases the lagged money affects positively given the positive own adjustment coefficient).

In a similar way the sign of the cross adjustment coefficient of the money stock 'disequilibrium' in the interest rate equation gives sign restrictions for the interest rate determination given the sign restrictions for (2) and (3). With zero cross adjustment coefficient the interest rate equations in (2) and (3) include now the positive lagged value of the interest rate, but the signs of other explanatory variables are unchanged. If the cross adjustment coefficient, however, is negative (positive), then in (6-b) $e_1 < 0$ (= ?), e_2 = ? (> 0), $e_3 > 0$ (< 0), and in (7-b) $g_1 < 0$ (?), $g_2 > 0$ (= ?), g_3 = ? (> 0), $g_4 > 0$ (< 0).

3 ESTIMATION RESULTS

The subsequent empirical analyses make us of quarterly data from the U.S. over the period 1951.2-1983.4. The data are seasonally adjusted and come mainly from Business Conditions Digest (a detailed description of data is available from the authors upon request). As far as the individual time series are concerned, M is proxied by the conventional M1, the GNP deflator is used as the relevant price index.

Turn now to the estimation results of specifications (6) - (8), which are presented in Tables 1 and 2. Table 1 contains results for the entire data sample and one can clearly see from the displayed Chow-statistics that there seems to be a clear structural break in all specifications, particularly corresponding to the change in the operating procedure for implementing monetary policy in October 1979. That the structural instability shows up not only in the monetary base targeting and nonborrowed reserves targeting equations, but in the Goldfeld-type specification as well is not surprising; after October 1979 the determination of money stock may not be solely demand-determined.

The estimation results for the subsamples 1951.2-1979.2 and 1979.3-1983.4 are reported in Table 2. The major difference between the results from these subsamples lies in the coefficient estimates of income and lagged money in the money stock equations; the former is higher and latter lower in the subsample 1979.3-1983.4. Even though all money stock equations display this feature, it is most

Table 1. OLS Estimates of the Real Money Balance and Interest Rate Equations for 1951.2-1983.4

	Constant	log(y)	log(B/P)	log(NBR/P)	RD	RB	M/P_{-1}	RB_{-1}	R^2	100*SEE	D-W	CHOW79	CHOW66	J-B
	.322	.033	.016				.888	-.284	.978	.778	1.211	15.650	7.772	3.631
(1)	(2.97)	(4.85)	(0.86)				(29.81)	(6.68)			(4.540)	(3.549)	(4.370)	(1.730)
	(2.98)	(4.55)	(1.03)				(30.23)	(5.31)						
	.228	.031		-.007	.013		.925	-.300	.978	.782	1.261	20.168	5.233	2.211
(2)	(1.93)	(3.94)		(0.82)	(0.13)		(27.69)	(3.55)			(4.400)	(3.464)	(4.253)	(1.526)
	(2.15)	(4.82)		(0.74)	(0.13)		(32.21)	(3.07)						
	.214	.029				-.230	.925		.975	.821	1.415	6.577	1.249	32.389
(3)	(2.09)	(4.83)				(5.16)	(39.50)				(3.365)	(1.754)	(3.161)	(0.019)
	(2.10)	(4.97)				(4.73)	(40.46)							
	-.163	.012	-.008				.022	.867	.936	.830	1.620	6.488	1.565	351.946
(4)	(1.41)	(1.63)	(0.38)				(0.71)	(19.11)			(2.551)	(3.153)	(1.653)	(1.671)
	(1.30)	(2.06)	(0.65)				(0.69)	(13.29)						
	-.248	-.019		-.009	.977		.075	.136	.981	.450	1.219	10.924	7.716	17.710
(5)	(3.63)	(4.25)		(1.75)	(17.10)		(3.91)	(2.79)			(5.675)	(0.540)	(1.778)	(2.212)
	(3.63)	(5.07)		(2.01)	(11.05)		(4.15)	(1.73)						

The dependent variable in equations (1), (2) and (3) is log(M/P) and in equations (4) and (5) RB, y = Y/P. Numbers in parentheses immediately below the coefficient estimates are t-ratios, below them are White's heteroscedasticity adjusted t-ratios. Numbers in parentheses immediately below the Durbin-Watson (D-W), Chow and Jarque-Bera (J-B) statistics are the LM-test statistics for fourth-order autocorrelation. CHOW79 indicates that parameter stability is tested with respect to the period 1979.3 (for CHOW66 the corresponding period is 1966.3). The distribution of CHOW is F and J-B χ^2_2. The distribution of the LM autocorrelation statistics in N(0,1).

clearly to be seen in the nonborrowed targeting equation. The extremely slow speed of adjustment of real balances has typically been one of the main problems of the demand for money equations (see e.g. column (9) in Table 2, where the coefficient of $(M/P)_{t-1}$ is very close to one). Allowing for the possibility that the interest rate disequilibrium may affect the adjustment of money stock has the effect of making the adjustment of money stock faster (particularly this seems to be the case with the nonborrowed reserves targeting equation). Thus one might speculate that the lagged dependent variable in the real money balance equations does not only reflect the demand side adjustment costs, but also some supply responses or reactions.

This latter hypothesis is also supported by some instrumental variable estimation results obtained by modelling the monetary policy target variables B, NBR and RD, and RB, respectively, in a monetary policy reaction function framework in terms of (mainly lagged final target variables).[4)] Thus there is a modest amount of evidence the conventional demand for money equation suffers from the simultaneity bias.

From the estimation results of Table 1 and Table 2 we are tempted to draw the following further conclusions: First, and related to what has been said above, the adjustment process of real money balances seem to be more complicated than that allowed by the simple partial adjustment mechanism, but the case with the interest rate adjustment is not so clearcut (see the estimated coefficients of RB_{t-1} and $\log(M/P)_{t-1}$).

Table 2. Some Further OLS Estimates of the Real Money Balance and Interest Rate Equations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Constant	-.069 (0.66)	-.898 (0.77)	-.295 (3.24)	-4.773 (1.81)	.216 (1.96)	-2.294 (1.49)	-.218 (2.96)	.098 (0.110)	-.130 (1.26)	-.401 (0.30)
log(y)	.025 (4.56)	.561 (3.04)	.011 (2.16)	.710 (1.69)	.052 (7.86)	.935 (2.93)	-.016 (3.55)	-.103 (0.52)	.025 (4.88)	.287 (1.31)
log(B/P)	.007 (0.51)	.170 (1.23)	-.019 (1.48)	.641 (2.03)						
log(NBR/P)					.054 (4.78)	.089 (1.85)	-.010 (1.38)	-.080 (2.71)		
RD					.010 (0.08)	-.238 (1.25)	.797 (9.62)	1.500 (12.80)		
RB									-.398 (6.48)	-.412 (2.74)
$\log(M/P)_{-1}$	.977 (36.45)	.284 (1.71)	.058 (2.52)	-.598 (1.58)	.863 (27.43)	.134 (0.68)	.066 (3.15)	.155 (1.29)	.996 (45.69)	.696 (4.35)
RB_{-1}	-.426 (7.36)	-.738 (7.74)	.817 (16.38)	.617 (2.84)	-.419 (4.37)	-.802 (6.01)	.296 (4.64)	.002 (0.03)	-	-
R^2	.988	.950	.939	.611	.990	.957	.971	.975	.987	.816
D-W	1.164	2.184	1.268	2.212	1.227	2.274	1.168	2.323	1.206	2.359
Period	1951-79	1979-83	1951-79	1979-83	1951-79	1979-83	1951-79	1979-83	1951-79	1979-83
Dependent variable	log(M/P)	log(M/P)	RB	RB	log(M/P)	log(M/P)	RB	RB	log(M/P)	log(M/P)

Numbers in parentheses are t-ratios.

Second, the fact that the lagged interest rate have a negative effect on money balances both under the monetary base targeting and the nonborrowed reserves targeting means that y will have a positive effect on money balances while the effects of monetary base, nonborrowed reserves and discount rate are ambiguous; this in fact turns out to be a case so that it is very difficult to distinguish between monetary targeting, nonborrowed reserves targeting and interest rate targeting on the basis of the money stock equations. Looking at the interest rate equations, however, suggest that the monetary base targeting equations perform much worse than the nonborrowed reserve targeting equations bot in terms of goodness-of-fit and in terms of sign restrictions implied by the lagged money stock. On this basis one might argue that the monetary base targeting has not been of crucial importance.

Earlier estimations are based on exogeneity assumptions, which vary depending on the assumed operating procedure for implementing monetary policy. It is therefore useful to look at finally, to what extent these exogeneity assumptions are really justified. To do that we adopt the conventional Granger-Sims 'causality' (or predictability) test framework. The corresponding tests were carried out both for the unfiltered, though differenced, data and for the ARIMA innovations in the way proposed by Pierce and Haugh (1977). There were no noticeable differences between these sets of results, which is why only the results with the ARIMA innovations are displayed here.[5] In the light of the clear structural break in October 1979 and of different coefficient estimates before and after October 1979 the test statistics were computed over the subsamples 1951.2-1979.2 and 1951.2-1983.4 in order to see whether there are any changes in the nature of exogeneity-endogeneity of RB (and other variables) after 1979.2 (the remaining sample 1979.3-1983.4 does not allow for a rigorous test of the exogeneity). The results of these 'causality' (predictability) tests based on ARIMA innovations (see Appendix) are reported in Table 3.

Several features of results merit note. First, irrespective of the sample period the monetary base variable does not seem to play any role in causality tests. Second, there seems to be bidirectional causality between money and interest rate for both sample periods.[6)] Third, the exogeneity of the nonborrowed reserves in terms of the market interest rate cannot be rejected, but vice versa is not true over the whole sample period. Finally, there seems to be bidirectional causality between the market interest rate and the discount rate. All these findings, with the exception of the last one, are not incompatible with the estimation results reported earlier.

Table 3. Results of Granger Causality Test Procedure

Sample period 1951.2-1979.2	X	$\Delta\tilde{RB}_t$ = f(8 past ΔRB, 8 past X)	X = f(8 past X, 8 past RB)
	$\tilde{b}$	1.8	1.4
	$\tilde{Y}$	14.4	17.6
	$\tilde{m}$	29.6	31.8
	$\tilde{nbr}$	12.8	14.2
	$\Delta\tilde{RD}$	20.3	21.6
Sample period 1951.2-1983.4			
	$\tilde{b}$	2.4	0.8
	$\tilde{Y}$	19.4	19.8
	$\tilde{m}$	34.8	60.6
	$\tilde{nbr}$	26.8	16.0
	$\Delta\tilde{RD}$	38.2	27.4

Displayed test statistics are LR χ^2-statistics with 8 degrees of freedom; the respective critical values are: $\chi^2_{.05}$ = 15.51 and $\chi^2_{.01}$ = 20.09. All variables denoted by ~ are ARIMA residuals from models reported in Appendix.

4 CONCLUDING REMARKS

In this paper we have presented a framework for the determination of the money stock and the market interest rate under the monetary base, nonborrowed reserves and interest rate targeting procedures respectively and estimated the resulting equations obtained from a generalized adjustment mechanism by using U.S. quarterly data over the period 1951.2-1983.4. It has turned out that all specifications display instability over the whole sample period thus suggesting that a single regime - mostly implicitly assumed to be interest rate targeting - may not be appropriate for the whole period. Moreover, and related, while the evidence in terms of interest rate versus nonborrowed reserves targeting is not clearcut, our findings support the claim that the standard demand for money equation suffers from the simultaneity bias. Finally, there is a modicum of evidence for the view that monetary base targeting assumption is not capable of explaining money stock determination. Causality tests conducted between variables involved in the determination of money stock and interest rate are not incompatible with these findings.

There is a number of directions one might want to go. We mention only two. We have used quarterly data, which may be too crude to cope with lead-lag relationships between variables involved, particularly if think about the role of systematic policy reactions. Second, we have implicity assumed that the ex post data can be used to replace the forecasted values of the GNP, on which the target values of operating variables in turn are based. The ex post data may not, however, measure the forecasts to which monetary policy has reacted.

FOOTNOTES

1) An alternative explanation is of course that the demand for money function is misspecified in one way or another. But we do not pursue this line of inquiry here.

2) Notice that we do not make any distinction between the market rate of interest and the Federal funds rate which might be the appropriate interest rate target variable. During the course of empirical analysis we estimated, however, a simple linear regression model for the Federal Funds rate, RF, on the Treasury bill rate, RB, and obtained the following result:

$$RB_t = \underset{(8.17)}{.649} + \underset{(72.95)}{.806}\ RF \qquad R^2 = .979,\ D\text{-}W = .786,\ T = 1955.1\text{-}1983.4$$

t-ratios being in parentheses. Clearly these two series are closely related, even though there are some systematic deviations, too.

3) Notice that the discount rate appears in the money stock and interest rate equation (3) - when nonborrowed reserves are exogenous - but not in the money stock and interest rate equation (4) - when the monetary base is exogenous. The changes in the discount rate, ceteris paribus alter the spread between the market interest rate and the discount rate and thus the level of bank borrowing. Under monetary base control, however, changes in borrowings would be offset via open market operations in order to maintain the monetary base at its target level. Under nonborrowed reserve targeting this offsetting does not happen unless the monetary authority simultaneously changes its target level of nonborrowed reserves. Here the discount rate change is interpreted as exogenous ("non-technical"), which may not true for all discount rate changes, i.e. some of them may be expected and be thus endogenous ("technical"). In what follows this complication is emitted (for implications of the distinction between exogenous and endogenous discount rate changes and an empirical analysis, see Smirlock and Yawitz (1984)).

4) The estimated reaction functions, however, displayed a considerable amount of instability suggesting that policy targets have changed a number of times. In this respect the results correspond to those of Abrams, Froyen and Waud (1980), Avery (1979), Froyen (1974) and Lombra and Kaufman (1983). A complete set of these results is available from the authors upon request.

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

6) A similar finding is reported in Feige and McGee (1979).

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APPENDIX

ARIMA models for the selected time series

(1) $$(1 - \underset{(4.65)}{.756}L)\bar{b}_t = \underset{(1.43)}{.002} + (1 - \underset{(7.64)}{1.277}L + \underset{(5.82)}{.498}L^2)a_t$$

$SE = .025,\ \chi^2_{24} = 11.67$

(2) $$(1 - \underset{(5.95)}{.439}L)\bar{Y}_t = \underset{(6.23)}{.010} + a_t$$

$SE = .012,\ \chi^2_{25} = 23.52$

(3) $$(1 - \underset{(12.99)}{.927}L)\bar{m}_t = \underset{(1.04)}{.001} + (1 - \underset{(4.17)}{.531}L - \underset{(1.96)}{.206}L^2)a_t$$

$SE = .007,\ \chi^2_{23} = 19.86$

(4) $$\overline{nbr}_t = \underset{(2.66)}{.006} + \underset{(4.57)}{.361}a_t$$

$SE = .019,\ \chi^2_{24} = 23.18$

(5) $$(1 + \underset{(2.37)}{.325}L + \underset{(2.78)}{.270}L^2)\Delta RB_t = \underset{(0.82)}{.087} + (1 + \underset{(5.08)}{.652}L)a_t$$

$SE = .754,\ \chi^2_{23} = 27.09$

(6) $$(1 + \underset{(2.84)}{.410}L)\Delta RD_t = \underset{(0.96)}{.071} + (1 + \underset{(7.77)}{.777}L)a_t$$

$SE = .496,\ \chi^2_{25} = 27.17$

$\bar{b}$ = dlogB, $\bar{Y}$ = dlogGNPV, $\bar{m}$ = dlogM1, $\overline{nbr}$ = dlogNBR, $L^k x_t = X_{t-k}$, a is the white noise error term, SE is the residual standard error and χ^2_p the Box-Pierce test statistics for an ACF with p lags.
The sample period is 1951.2-1983.4.

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