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# THE GOLDFELD DEMAND FOR MONEY EQUATION REVISITED

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## Abstract:

The purpose of this paper is to revisit the demand for money equation, originally suggested by Goldfeld and since then widely used, from various viewpoints by using the U.S. quarterly data over the period 1955.1-1978.4. Results from different estimation methods and specification tests suggest strongly that the Goldfeld demand for money equation suffers from misspecification. Moreover, misspecification does not seem so much to do with omitted variables, but rather with some more general specification errors like inappropriate dynamics and endogeneity of the RHS variables in the demand for money equation.

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## 1. INTRODUCTION

It is now commonly agreed that attempts to explain and forecast the U.S. money demand during the past ten years have met with serious difficulties. The money demand equation, which was suggested by Goldfeld (1973) and which has achieved a certain degree of acceptability, began to overpredict the demand for money in mid-70´s and failed to pass various stability tests (see e.g. Hafer and Hein (1982)). In the search to repair the Goldfeld demand for money equation various lines of inquiries have emerged; instability problems have been tried to overcome among others in terms of redefining the concept of money in the light of developments in the financial markets (see e.g. Garcia and Pak (1979)) and in terms of introducing additional variables like inflation uncertainty (see e.g. Klein (1977)) and money supply shocks (see e.g. Santomero and Seater (1981)). Without going into details one can conclude that these attempts have not been completely successful thus suggesting that there might be a more fundamental specification error in the conventional Goldfeld equation.

Unfortunately, the 'standard' way of estimating the Goldfeld money demand equation makes it very difficult, however, to evaluate the existence and type of a possible specification error. A common practice is namely to estimate this equation by OLS, detect strong autocorrelation and use thereafter the Cochrane-Orcutt (CO) procedure to obtain more efficient estimates. But at least the following objections can be made against this mechanic use of the CO procedure: (1) the efficiency of the CO estimators can be very low just with the Goldfeld demand for money-type stochastic difference equations (see e.g. Harvey (1981), 189-199),

(2) it is not evident that the CO transformation represents the proper specification of the underlying dynamic model (see e.g. Hendry and Mizon (1978) and finally, (3) the CO procedure can produce multiple fixed points - even asymptotically. In fact, Dufour and Gaudry and Hafer (1983) have demonstrated the existence of multiple minima in the case of the Goldfeld demand for money equation (estimated from the U.S. data).

The purpose of this paper is to shed further light on these questions in the following respects: First, we look at the question of whether the results obtained by the CO procedure differ significantly from those obtained by other (more efficient) estimation procedures, second whether the use of AR(1) filtering is indeed appropriate from the point of view of 'correct' dynamic specification of the demand for money equation, and finally, and most importantly, we carry out a set of specification tests with respect to different filterings of the Goldfeld demand for money equation in order to find out the possible existence and nature of a specification error.

## 2. EMPIRICAL RESULTS

Empirical analyses reported below are based on the following demand for money specification originally suggested by Goldfeld

$$(1) \quad m_t = b_0 + b_1 m_{t-1} + b_2 r_{ct} + b_3 r_{dt} + b_4 y_t + u_t$$

where $m = \ln(M/P)$, M = the 'old' M1, P = the implicit GNP price deflator (1972=100), $r_c = \ln(CPR)$, where CPR = the commercial paper rate,

$r_d$ = ln(RTD), where RTD = the commercial bank passbook rate, $y$ = ln(GNPR), where GNPR = the real GNP and $u$ is the error term. We use the quarterly U.S. data over the period 1955.1-1978.4. These data are presented in Dufour and Gaudry and Hafer (1983).

If the error term $u_t$ is assumed to follow a first-order autoregressive process $u_t = \rho u_{t-1} + e_t$, where $e_t$ is uncorrelated white noise, then the equation (1) can be transformed into the following form

$$(2) \quad m_t = b_0(1-\rho) + (b_1+\rho)m_{t-1} - \rho b_1 m_{t-2} + b_2 r_{ct} - \rho b_2 r_{ct-1} + b_3 r_{dt} - \rho b_3 r_{dt-1} + b_4 y_t - \rho b_4 y_{t-1} + e_t$$

Obviously the equation (2) can be estimated directly and this is done below by using the nonlinear least squares estimation method (NLOLS). This and other estimation results - including the OLS estimates, the estimates obtained by Cochrane-Orcutt (CO) and Hildreth-Lu (HL) procedures and by the Hatanaka two-step methods (H2S) - of the Goldfeld demand for money equation are presented in Table 1.

The following features of results merit note. First, like in Dufour and Gaudry and Hafer (1983) the CO procedure yields three minima corrresponding to the following values of $\hat{\rho}$ : .467, .945 and 1.017 (with widely varying magnitudes and significance of coefficient estimates). Second, and more interestingly, the Hatanaka two-step method and the nonlinear least squares method also detect multiple minima! In the case of the Hatanaka two-step method the results are sensitive to the question of whether the "first-step" equation is estimated by OLS or IV method (for details of the IV method, see section 5.6. in Fuller (1976)), while in the case of the

Table 1. Estimation Results with Different Methods of Estimation

|  | Constant | $m_{t-1}$ | $r_{ct}$ | $r_{dt}$ | $y_t$ | $\hat{\rho}$ | Q(12) | Method |
|---|---|---|---|---|---|---|---|---|
| (1) | -.033 | 1.052 | -.022 | .014 | .001 | - | 31.76 | OLS |
|  | (0.71) | (44.18) | (7.57) | (3.21) | (0.11) |  |  |  |
| (2) | -.105 | 1.010 | -.020 | .005 | .017 | .467 | 14.59 | CO |
|  | (1.42) | (26.70) | (5.06) | (0.71) | (1.26) | (5.13) |  |  |
| (3) | -.604 | .627 | -.014 | -.049 | 1.44 | .945 | 15.70 | CO |
|  | (2.50) | (7.34) | (3.13) | (2.55) | (3.70) | (27.98) |  |  |
| (4) | -1.226 | .553 | -.014 | -.046 | .252 | 1.017 | 21.76 | CO |
|  | (3.60) | (6.55) | (3.34) | (2.78) | (4.44) | (.. ) |  |  |
| (5) | -.105 | 1.010 | -.021 | .005 | .018 | .468 | 14.59 | H2SOLS |
|  | (1.37) | (24.32) | (5.19) | (0.69) | (1.17) | (4.39) |  |  |
| (6) | -.561 | .639 | -.013 | -.051 | .137 | .935 | 15.51 | H2SIV |
|  | (2.37) | (6.15) | (3.02) | (2.60) | (3.58) | (17.94) |  |  |
| (7) | -.919 | .583 | -.014 | -.045 | .190 | .980 | 17.94 | HL |
|  | (2.43) | (6.77) | (3.14) | (2.32) | (3.46) | (- ) |  |  |
| (8) | -.100 | 1.006 | -.019 | -.006 | .017 | .470 | 14.53 | NLOLS |
|  | (1.31) | (25.75) | (4.82) | (0.73) | (1.16) | (4.58) |  |  |
| (9) | -1.225 | .554 | -.014 | -.045 | .256 | 1.013 | 21.58 | NLOLS |
|  | (3.14) | (6.51) | (3.35) | (2.50) | (4.38) | (36.44) |  |  |

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All variables are expressed in natural logs, t-ratios are expressed in parentheses, Q(12) is the adjusted Box-Pierce statistics for autocorrelation the number of lags being 12. Equations (2), (3) and (4) represent three different minima given by the Cochrane-Orcutt procedure, equation (5) is given by the Hatanaka two-step method, where OLS estimation was used at the first stage. The estimates presented above correspond to the 7th iteration: the value of $\hat{\rho}$ used at the first iteration was .401. Equation (6) was estimated by the Hatanaka two-step method, but now the IV estimation method was used at the first stage. The value of $\hat{\rho}$ used at the first iteration was .965. Equation (7) is given by the Hildreth-Lu procedure: the value of $\hat{\rho}$ = .980 represents the upper bound in the computer program. Equations (8) and (9), in turn, were obtained by using nonlinear LS (i.e. estimating equation (2) in text). The displayed estimates represent the minima found with different initial values.

nonlinear least squares the estimation results depend crucially on the initial values of the parameters. Thus the fact that there are multiple minima with corresponding huge differences in magnitudes and significance of coefficient estimates not only with the CO method, but also with other estimation procedures, may not tell so much about the weaknesses of the CO procedure, but rather about the weaknesses in the Goldfeld demand for money equation.1)

More specifically, the AR(1) filtering may not be the proper specification of the underlying dynamic model. In fact, comparing the nonlinear least squares estimates with the corresponding unrestricted estimates - which are presented in equation (3) - as a COMFAC-type test (see Hendry and Mizon (1978)) suggests that the parameter restrictions implied by AR(1) filtering can be rejected for both of the detected minima. The F-statistics for equations (8) and (9) of Table 1 are $F_{(8)3,85} = 10.186$ and $F_{(9)3,85} = 3.695$ respectively. Thus it would seem

$$
\begin{array}{llllll}
(3) \quad m_t = & -.003 & +\ 1.413 m_{t-1} & -\ .393 m_{t-2} & -\ .014 r_{ct} & +\ .003 r_{ct-1} \\
 & (0.07) & (15.10) & (3.95) & (3.19) & (0.48) \\
 & & & & & \\
 & -.035 r_{dt} & +\ .043 r_{dt-1} & +\ .129 y_t & -\ .130 y_{t-1} & Q(12) = 23.86^{2)} \\
 & (1.84) & (2.32) & (1.95) & (1.93) &
\end{array}
$$

that the dynamics of the Goldfeld demand for money equation has not been specified in a proper way.3)

But we do not really know what is the true data generation process, so that all the problems mentioned above might result - not from inappropriate specification of dynamics, but - from some other specification errors like misspecification in terms of endogeneity/exogeneity of various RHS variables, or in terms of omitted variables. In order to check these possibilities we carried out experiments a bit further.

First, we estimated the Goldfeld demand for money equation (1) also in the form of first and second differences like Plosser and Schwert (1978) in another context. The idea behind these variations is to use differencing as an (informal) test of model specification; if a model is correctly specified in terms of the levels (the 'first differences') of the variables, then the 'first differences' (the 'second differences') regression should corroborate the levels (the 'first differences') regression. The corresponding OLS estimation results are presented in Table 2[4)] and they indicate that estimating the Goldfeld demand for money equation in the first difference form gives reasonable results. In the light of this it may be tempting to regard the first difference form as the favoured specification like in Hafer and Hein (1982), where the authors argue that estimating the equation (1) does not make sense because of the level shift in the demand for money. If this hypothesis were true, then the equations (1) and (2) of Table 2 might indeed be expected to give widely varying coefficient estimates for the demand for money, but there would then be no reason why the equations (2) and (3) of Table 2 should differ in terms of coefficient estimates. The 'second differences' regression is just an over-differenced model if the 'first differences' model is correctly specified and differencing should thus not affect the values of the regression coefficients. This does not, however, seem to be the case; instead there are huge differences in magnitudes (and even in signs!) of the coefficient estimates of the levels, 'first differences'

Table 2. Effects of Differencing on the OLS Estimates of Equation (1)

| | Constant | $m_{t-1}$ | $r_{ct}$ | $r_{dt}$ | $y_t$ | $R^2$ | D-W | $F_{HW}$ | RESET |
|---|---|---|---|---|---|---|---|---|---|
| (1) | -.033<br>(0.72)<br>(0.89) | 1.052<br>(44.19)<br>(55.43) | -.022<br>(7.57)<br>(8.67) | .014<br>(3.22)<br>(3.93) | .001<br>(0.11)<br>(0.14) | .989 | 1.191 | 10.875 | .636 |
| | LM(4) | t-1 3.997, | t-2 1.641, | t-3 1.206, | t-4 1.415 | | | | |
| (2) | - | 5.85<br>(6.95)<br>(6.39) | -.014<br>(3.17)<br>(2.78) | -.050<br>(2.95)<br>(6.41) | .186<br>(3.92)<br>(3.91) | .537 | 2.083 | 2.748 | 1.423 |
| | LM(4) | t-1 1.029, | t-2 1.116, | t-3 0.997, | t-4 .279 | | | | |
| (3) | - | -.115<br>(1.03)<br>(1.26) | .000<br>(0.02)<br>(0.02) | -.037<br>(1.99)<br>(3.74) | .103<br>(1.81)<br>(1.31) | .099 | 2.029 | 2.261 | .958 |
| | LM(4) | t-1 1.242 | t-2 1.879, | t-3 1.993, | t-4 1.01 | | | | |

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All variables are expressed in natural logs, t-ratios are in parentheses (second row) and below them White's heteroscedasticity adjusted t-ratios (third row). Equation (1) corresponds to the level form, equation (2) the 'first differences' form and equation (3) the 'second differences' form. $F_{WH}$ indicates the Hausman-Wu test statistics computed by using the Davidson-MacKinnon procedure: the number of instruments is three. RESET, in turn, indicates the Ramsey-Schmidt test statistics for three higher order terms of the predicted values of $m_t$. Values of the LM(4) statistics for autocorrelation are distributed according to N(0,1) (see Godfrey (1978) for details).

and 'second differences' regressions, which might be interpreted as signs of misspecification the framework proposed by Plosser and Schwert and White (1983).

Comparing the equations (1), (2) and (3) of Table 2 does not give any clues as for the exact nature of misspecification which is why we secondly applied the Hausman-Wu (see Hausman (1978)) and the Ramsey-Schmidt RESET (see e.g. Thursby and Schmidt (1977)) test procedures to the levels, 'first differences' and 'second differences' regressions. The results can be briefly summarized as follows: The Hausmann-Wu exogeneity test statistics 5) - displaying clear significance in the levels regression and 'just' significance at the 5 per cent level in the 'first differences' regression - suggest that the RHS variables of the Goldfeld demand for money equation may not really be exogenous some contrary claims nothwithstanding (see e.g. Laidler (1980)).

This might result simply from the fact that at least occasionally the monetary authorities have tried to control the supply of money instead of interest rates thus making the interest rates to depend on the demand for money (see Cooley and LeRoy (1981)). On the other hand, as far as the Ramsey-Shcmidt RESET test statistics - intended to detect a nonzero means of the disturbance in a linear regression model as a result of e.g. omitted variables - are concerned, they fail to exceed the standard significance levels thus suggesting that the equation may not suffer from misspecification due to omitted variables after all.

## 3. CONCLUDING REMARKS

All in all, we are inclined to draw the following conclusions on the basis of estimation and test results. First, the multiple minima detected earlier when estimating the Goldfeld demand for money equation by the CO procedure come out with other estimation methods as well thus telling more about the weaknesses in the demand for money equation than about the weaknesses in the CO procedure. Second, even though the Goldfeld demand for money equation gives very reasonable results in the 'first differences' form, the temptation to regard this as the basic specification is unfounded some contrary claims nothwithstanding, because the 'second differences' form of the demand for money equation does not corroborate the coefficient estimates of the 'first differences' form which should be the case if the latter would really represent a correctly specified model. Finally, and related to the first point, the demand for money equation a lā Goldfeld seems to suffer not from misspecification due to omitted variables, but from some more general specification error. This is supported by the results from COMFAC-type tests, Hausmann-Wu exogeneity tests and Ramsey-Schmidt RESET tests. One can even go so far as to argue that there is too much specification uncertainty to allow for the correct specification of the demand for money equation (see Cooley and LeRoy (1981), who from somewhat different viewpoint come to similar conclusions).

## FOOTNOTES:

1) On the basis of multiple minima Dufour and Gaudry and Hafer (1983) argue strongly against the use of the CO procedure. For a more moderate view, see Offenbacher (1981), in which it is concluded that the CO procedure is not really "inferior" to other estimation methods, particularly compared with the Hatanaka two-step method.

2) Absolute values of the t-ratios are in parentheses. Q(12) indicates the Box-Pierce test statistics for autocorrelation. The number of lags is 12.

3) The "common factor restriction" was also tested with a static model (i.e. $m_t = b_0 + b_1 r_{ct} + b_2 r_{dt} + b_3 y_t$). The parameter restrictions implied by the AR(1) filtering could be clearly rejected ($F_{3,87} = 41.115$). Thus, the lagged dependent variable seems to be a necessary incredent of the Goldfeld money demand equation.

4) There were some signs of heteroscedasticity in equations so that they were also estimated by White´s procedure, which adjusts t-ratios for heteroscedasticity (see White (1980) for details).

5) The Hausman-Wu test statistics were computed by instrumenting $r_{ct}$, $r_{dt}$, and $y_t$ with respect to their respective lagged values, the lagged value of $m_t$, the log of the volume of exports, the log of the Federal government expenditure (at 1972 prices), the log of the Federal government receipts (at 1972 prices) and the lagged value of the relative change in P (data source for the new variables: Business Conditions Digest, U.S. Department of Commerance). The instruments were introduced as additional variables into the money demand equation analogously to the Davidson-MacKinnon (1981) J-test procedure. The significance of these variables were evaluated by the standard F-test statistics. See Hausman and Pesaran (1983) for the demonstration that the Davidson MacKinnon J-test can also be viewed as a test of misspecification by Hausman (1978) in the sense that both tests are asymptotically equivalent under standard assumptions.

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