Real Money Balances: An Omitted Variable from the Production Function?--A Reply

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The Review of Economics and Statistics, Vol. 57, No. 2 (May, 1975), 247-252.

balances faster than individuals, money held by individuals may play a more important role in influencing the aggregate demand.

Using the two components of money separately, we can replace (1) by

$$\ln Q = \ln A + \alpha \ln L + \beta \ln K + \delta_1 \ln M_F$$
$$+ \delta_2 \ln M_C + \lambda_t T + U \qquad (4)$$

where M_F and M_C are the levels of real money held by firms and consumers respectively.

Test B: According to the production factor approach, we expect: $\delta_1 > \delta_2$.
According to the induced innovation approach, we expect: $\delta_2 > \delta_1$.

The empirical tests to distinguish between the two hypotheses that were suggested previously are performed in the following section.

The Empirical Results

We estimated (3) for alternative values of n. The results for $n = 1$ are given as an example.

$$\ln Q = -1.020 + .9917 \ln L = .3346 \ln K$$
$$\quad (4.0) \quad (7.8) \qquad (3.7)$$
$$+ .0086 \, T + .1109 \ln M_{t-1}$$
$$\quad (2.8) \qquad (2.5)$$
$$+ 0.4307 (\Delta M / M)_{t-1}$$
$$\quad (6.0)$$
$$R^2 = .9966 \quad \text{D.W.} = 1.44$$

where the numbers in parentheses are the t values of the coefficients.

The results clearly indicate that rates of change in the real money supply seem to have stronger and more significant effects than the level of real balances. This is clearly consistent with the induced innovation approach, but not with the production function approach.

The results of (2) are given as follows:

$$\ln Q = -0.1988 + 0.6922 \ln L$$
$$\quad (2.8) \qquad (4.7)$$
$$+ 0.5896 \ln K - 0.0223 \ln M_F$$
$$\quad (4.3) \qquad (0.2)$$
$$+ 0.2106 \ln M_C + 0.0018 \, T.$$
$$\quad (3.7) \qquad (0.4)$$
$$R = 0.986 \quad \text{D.W.} = 1.03$$

The results indicate that the real money balances held by firms seem to have no significant effect on output. The level of money held by consumers retains its significance. These results are again consistent with induced innovation approach but not with the production factor approach.

Summary and Conclusion

The main conclusion of this paper is that money as a factor of demand seems to play an important role in explaining "induced technological changes." The results, however, do not support the initially strong conclusion of Sinai and Stokes that money is an important "omitted input" in the aggregate production function.

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REAL MONEY BALANCES: AN OMITTED VARIABLE FROM THE PRODUCTION FUNCTION? — A REPLY

Allen Sinai and Houston H. Stokes*

I. Introduction

The comments by Ben-Zion and Ruttan (1975), Khan-Kouri (1975), Niccoli (1975), and Prais

(1975) are concerned with different aspects of our earlier work, so we address each separately. The main arguments of these authors are faulty; either because of inadequacies in approach, evidence, or theory. We submit that the evidence for the role of

real money balances in production remains sustained.

We answer the comments in reverse alphabetical order, taking first Prais, then Niccoli, Khan and Kouri, and finally Ben-Zion and Ruttan.

II. The Comment by Prais

Prais (1975) contends that the significance of real money balances ". . . was not achieved by regressing the original variables but only after subjecting the data to second order autocorrelation transformation. The regression on the original variables in fact indicates that the *money variables are not significant* (italics ours) but that the error term is autocorrelated." Prais continues, "It is therefore only by transforming the data that money balances appear significant."

These statements are contradicted by the evidence as can be seen in table 1, where we present the un-

TABLE 1. — ESTIMATES OF THE COBB-DOUGLAS PRODUCTION
FUNCTION WITH AND WITHOUT REAL MONEY BALANCES,
1929–1967
NO CORRECTION FOR SERIAL CORRELATION

$\ln Q = \ln A + \alpha \ln L + \beta \ln K + \gamma \ln m + u'$			
	Equation Number		
	(1)	(2) $m1$	(3) $m2$	(4) $m3$
$\ln A$	−3.938	−3.449	−3.852	−4.003
	(.237)	(.301)	(.236)	(.239)
α	1.451	1.155	1.295	1.368
	(.083)	(.145)	(.122)	(.102)
β	.384	.501	.415	.389
	(.048)	(.066)	(.050)	(.048)
γ		.111	.116	.090
		(.046)	(.067)	(.065)
$\alpha + \beta + \gamma$	1.835	1.767	1.826	1.847
$\bar{R}^2$	.9946	.9954	.9951	.9949
S.E.E.	.0347	.0326	.0338	.0343
D.W.	.86	.73	.73	.77

$\ln Q$ = natural log gross private domestic product, quantity index. $\ln L$ = natural log private domestic labor input, quantity index. $\ln K$ = natural log private domestic capital input, quantity index. $\ln m$ = natural log real money balances, m1, m2, m3. Standard errors of regression coefficients in parentheses. $\bar{R}^2$ = adjusted coefficient of multiple determination. S.E.E. = standard error of estimate. D.W. = Durbin-Watson statistic.

corrected (for serial correlation) estimates of the Cobb-Douglas production function with real money balances.[1]

The regression coefficients for $m1$ and $m2$ are statistically significant at the 2.5% and 5% levels, respectively, for a one-tailed test to the right. Only the coefficient of $m3$, with a t-value of 1.39, was not significant at any of the usual levels of confidence.

[1] See Sinai and Stokes (1972, p. 292) for the results after a correction for autocorrelation. Also see footnotes 6 and 11, p. 292.

Prais then argues "The transformation of the variables introduces lagged values of all the variables into the specification and the resulting estimates may be due to these variables directly rather than to the autocorrelation specification of the error term." A test developed by Sargan (1964) and applied by Hendry (1973) (1974) is used to reject a null hypothesis of autocorrelated errors versus the alternative of including lagged values of the variables in the specification. Prais adds lagged values of real money balances to one of our relations and uses the results to reinterpret the role of money in the production function.

There are several errors in this approach. First, the test Prais employed assumes a first order autoregressive process in the residuals, although in our work we used a second order serial correlation specification to correct for the autocorrelation.[2] Therefore, the result of the test does not apply.

Second, even if an appropriate test for misspecification had been performed, the Prais results do not indicate that the specification error is corrected by the lagged variable alternative. Although the resulting D.W. statistics fall within the indeterminate range, the more powerful BLUS test for serial correlation, suggested by Theil (1971, chapter 5), shows that the hypothesis of no positive serial correlation must be rejected in the Prais equations with lagged real money balances.[3] If the lagged variables hypothesis were correct, such a specification should have removed the autocorrelation of the residuals.[4]

Finally, even if Prais' regressions were acceptable, her interpretation of them is incorrect. She asserts that the results "clearly" show the change in real balances, "$M = M_t — M_{t-1}$," not the level of real balances, to be the variable involved. Forgetting her error in describing $\ln M_t — \ln M_{t-1}$ as a change rather than the growth of real balances, the validity of her claim requires that the absolute values of

[2] See Hendry (1973, 1974) and Sargan (1964, pp. 25–27). It is surprising that Prais does not present the details of the test's application in view of the alleged importance of the results to her subsequent argument. Given our inability to reproduce even the regressions that are reported, we remain skeptical.

[3] The modified Von Neumann ratios are 1.207, 1.177, and 1.366, respectively, for the Prais regressions with lagged real money balances. The null hypothesis of no serial correlation is rejected in favor of positive autocorrelation at the 1% level of significance in the first two cases and at the 5% level in the last. The base used for the BLUS transformation minimized the expected sum of BLUS errors.

[4] In contrast, after reestimating our original equations with a second order GLS procedure, the modified Von Neumann ratios from Theil's BLUS test showed no presence of autocorrelation. The figures were 1.58, 1.47, 1.33, 1.30, 1.38, 1.30, 1.38 and 1.41 for equations (3) to (10), respectively, in Sinai and Stokes (1972, pp. 292–293).

the coefficients for ln M_t and ln M_{t-1} be equal. But her results show no such equality.[5] Also, in two of her three regressions the sum of the coefficients for real balances is negative, a result that is unacceptable on a priori grounds regardless of how the basic regression is interpreted.

III. The Comment by Niccoli

Niccoli gives two reasons why our evidence for real balances as a factor input is defective. First, real money balances enter the production function "mainly as a proxy for current investment" and second, "some of the estimated coefficients are unstable, being different over tight and loose money years." Niccoli then presents the empirical results, (tables 1 and 2), that support his views.

In Niccoli's tables, the sequence of regressions does show that the current investment variable is responsible for rendering the coefficient of real balances negative and insignificant. But what is the sense of this result and of the equation specification that produced it?

Since current investment is more highly correlated with output ($r = 0.9756$) than are money balances ($r = 0.6996$), and I, m are highly correlated with each other ($r = 0.7926$), it is not surprising that real balances drop out when current investment is added to the equation. Almost any variable with similar correlative properties could give the same result.[6] Furthermore, the presence of current I and end-of-period K in the same equation makes little sense and has unknown statistical effects, although one result was the unreported (by Niccoli) implausibly low coefficients of 0.207 and 0.189, respectively, for capital and labor. Once the statistical double-counting of capital is eliminated, as in Niccoli's equation (3), the coefficient of real money balances again became statistically significant.

The theoretical content of the Niccoli equations is elusive. Does he really mean to argue that current investment belongs in the production function instead of real money balances? If so, why are lagged values of investment also included, some entering with negative and insignificant coefficients? Although controversial, at least there is a substantial volume of literature that justifies the presence of

real balances in an aggregate production function. We know of no work that hints, argues or attempts to include values of current and lagged investment as measures of productive inputs.

If Niccoli believes the relation between output and money balances is spurious, essentially reflecting an aggregate demand relation between output and investment, then why are capital and labor included in the specification? What meaningful underlying structure would give a real sector equilibrium equation that contains the stocks of capital and labor, is log linear, and omits government expenditures as an explanatory variable? The presence of statistically significant coefficients for capital and labor and the nature of the functional form of the equation identifies the production function. The addition of any category of expenditures creates a meaningless regression.

Finally, Niccoli's evidence on the instability of the regression coefficient for real money balances is faulty, hinging on a rather curious definition of "tight" and "loose" money periods.[7] Niccoli selects as tight money observations those years when the current rate of growth in nominal money is less than a weighted average of $M1$ growth rates for the previous four years. The weights are arbitrarily chosen as 0.5333, 0.2667, 0.1333 and 0.066. By this criterion, the resulting tight money periods are 1932, 1937, 1938, 1944 to 1949, 1953, 1954, 1956, 1957, 1960 and 1967, a total of 15 observations.

What puzzles us about these periods is that many of them would not be classified as "tight" money episodes by almost any other measure. For example, the rates of growth for $M1$ were 17.6%, 16.3% and 9.5% in 1944, 1945 and 1946, hardly indicative of tight money, but categorized as such because of the comparison with "average" rates of $M1$ growth over the previous four years.[8] In 1967, $M1$ grew by 3.9%, a figure that is significantly greater than the $M1$ growth rates in the "loose" money periods of 1961 to 1964. The recession of 1953 to 1954 is universally recognized as an easy money episode, instead of tight money as Niccoli suggests. In addition, some "loose" money years, such as 1956 and 1966, would be viewed as "tight" by most observers.

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[5] Using a test for the difference between two means when the population variance is unknown, the resulting t-values are 1.96, 3.30 and 7.65 for the equations with $M1$, $M2$, and $M3$, respectively.

[6] We substituted the logarithm of real government expenditures for investment in the Niccoli specification and found that the coefficient of real money balances became negative and insignificant.

[7] Unfortunately, Niccoli does not indicate the nature of the test for stability, nor does he determine whether the coefficient of real balances, labor, capital, or time was mainly responsible for rejecting the null hypothesis. Furthermore, for two of his three regressions in table 2, (5) and (6), the null hypothesis was rejected at levels of significance, 10% and 20%, that normally would be regarded as too low to report. Thus, equation (4) would appear to be the only serious candidate for the structural instability hypothesis.

[8] The years 1947 to 1949 are hard to characterize because of the constraints imposed on Federal Reserve policy by the Treasury.

Without including the six periods that are most suspect, Niccoli would have had to estimate his regressions with only nine observations, clearly an impossible task in equations (5) and (6). Even in equation (4), where five coefficients had to be estimated, the resulting small sample would have made the structural stability hypothesis untestable.[9]

Thus, we cannot accept the Niccoli charge that our evidence was defective because of coefficient instability as between "tight" and "loose" money periods. His test for stability is inconclusive for two of the three regressions, but more importantly, the results may well depend on an arbitrary division of the sample.

IV. The Comment by Khan and Kouri

Khan and Kouri estimate the effect of real cash balances on production in a simultaneous equations model. Their findings support our hypothesis that money is a productive input. The only problem they raise is the size of the regression coefficients for $M2$ and $M3$.

We recognized the possibility of simultaneity in our original paper, but did not pursue the matter because the correct specification of the underlying structure was not readily apparent. Also, there were numerous advantages to using the traditional Cobb-Douglas framework.[10]

Thus, we certainly agree that it is appropriate to examine the role of real balances in a multi-equation model; however, we do not think the Khan-Kouri system is the correct framework. Khan and Kouri use a conventional macro-economic demand for money equation to close the model. If real money balances are a factor input, the demand for it should be derived similarly to the demand for capital or labor services.[11] Furthermore, Khan and Kouri assume that capital and labor are exogenous. Since capital and labor services are not the "maximum" available in the economy, but result from producer choices on stocks and utilization rates, an assumption of endogeneity would be better.

Hence, if a simultaneous equations model is attempted, it should contain the production function and factor demand equations for capital, labor, and

money balances.[12] The misspecified structure of Khan-Kouri may very well account for the large regression coefficients on money balances and the surprisingly high marginal productivities that were estimated. It is well-known that full-information methods of estimation are consistent only under a correct model specification.

A final problem is the omission by Khan and Kouri of a measure of disembodied technological change. The high coefficients on real balances may have been due, in part, to omitting a time trend from their specification. In every case, our results showed that the coefficient of real money balances was smaller when the production function was estimated with a time trend. In fact, our single equation estimates provide more plausible estimates of marginal productivities than Khan-Kouri, further suggesting an incorrect specification of their model.[13]

V. The Comment by Ben-Zion and Ruttan

Ben-Zion and Ruttan argue that a particular theory of induced innovation ". . . suggests money affects output and technological change as a demand factor rather than as a factor of production." Upon close examination, however, it is not the theory of induced innovation that suggests the Ben-Zion-Ruttan hypothesis but the authors themselves, through a conjectural line of reasoning between their interpretation of the theory of induced innovation and the hypothesis they put forward.

The theory of induced innovation is said to suggest that "market conditions affect the demand for innovation and the realized technological changes." Market conditions are implicitly equated with aggregate demand or output and money is advanced as a proxy for short-run fluctuations in aggregate demand. The conclusion is that money affects output and technological change as a demand factor thus is quite a leap from the theory of induced innovation initially cited.

Having provided a weak justification for their

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[9] Even if there were sufficient degrees of freedom, Niccoli's proposed test has a serious theoretical flow. The fact that the elasticity of output with respect to an input changes as market conditions vary from "easy" to "tight" is not a valid reason for rejecting an input as a factor of production. Producers will attempt to economize on the relatively more expensive input. The resulting adjustment in production alters the marginal products of all inputs.

[10] See Sinai and Stokes (1972, p. 291).

[11] See Nadiri (1969) for an example of this approach.

[12] See Bodkin and Klein (1967) for a simultaneous equations model in the case of two inputs.

[13] Khan and Kouri are wrong in interpreting the coefficient for real balances as a marginal product. Rather, it is the elasticity of output with respect to real balances. In the sample period used by Khan-Kouri, the mean values of real output and real balances, defined as $M1$ and $M2$, were 369.548, 137.061, and 195.718, respectively. Given the estimated regression coefficients, the implied marginal physical product of real balances was 0.979 and 1.754 for $M1$ and $M2$. Our corresponding estimates, in equations (4) and (5) of table 1, in (Sinai and Stokes, 1972, p. 292) were 0.447 and 0.383. In equations (8) and (9) of table 2 where a time trend was included (Sinai and Stokes, 1972, p. 293), the marginal products for $M1$ and $M2$ were even lower, 0.330 and 0.238.

hypothesis, Ben-Zion and Ruttan derive "appropriate" tests to distinguish between their view and ours. Friedman's work (1971) is used to justify the authors' expectation, that "applied as a basis for the first test . . . changes in the level of *real money balances* (italics ours) would have a stronger influence on induced innovation than that of the level itself." But, Ben-Zion and Ruttan are clearly confused as Friedman's discussion is stated in terms of *nominal* money and *nominal* income. Also, the authors again confuse output, the dependent variable in their equation, with induced innovation. The presumed equality of the two concepts is highly speculative.

Since equation (3) has no foundation in Friedman or anyone else, for that matter, it can hardly serve as a ". . . basic equation to distinguish" between the production factor and induced innovation approaches. The empirical results that are reported for equation (3) simply defy interpretation in terms of the alternative approaches. The regression only shows that current money growth shifts the production function in a manner that is similar to disembodied technical progress.[14] In fact, Ben-Zion and Ruttan never really test their main conclusion that ". . . money as a factor of demand seems to play an important role in explaining induced technological changes." Induced technological change does not appear as a dependent variable in any equation.

The large and highly significant coefficient for the rate of change in real money balances was probably due to reverse causation between the logarithm of output and the monetary growth variable, defined as the current period's percentage change in the money stock. Thus, it is not surprising that last period's level of real balances exhibited a much smaller effect on output than the current growth of cash balances.

Ben-Zion and Ruttan justify a second test by new, unsupported interpretations of the production factor and induced innovation approaches. We never claimed as part of our hypothesis that ". . . money held by firms play a more important role in determining output than money held by individuals." We argued that ". . . the rationale for including real

balances in the production function relates, in part, to the increased 'economic efficiency' of a monetary economy compared to a barter economy." This efficiency is not due solely to real balances held by firms, but to the total stock of real balances.

Further, there is no reason to infer that the demand-induced innovation approach supposes ". . . money held by individuals may play a more important role in influencing the aggregate demand." On the contrary, this approach should be consistent with a positive, significant relation between a firm's cash balances and output, since innovation can occur more quickly in business and liquidity can be adjusted faster. The clear-cut inferences from hypotheses to regression coefficients just do not exist in Ben-Zion and Ruttan no matter what story is woven.[15]

[14] Ben-Zion and Ruttan ignore the potential 18-month lag in the effect of money on aggregate demand found by Friedman. Lags also exist between changes in market conditions and innovations, hence an appropriate interpretation of the induced innovation approach does not necessarily imply a strong relation between current money growth and current output.

A better test would be to estimate the production function with lags in money balances entered as shift parameters. However, when such a production function was estimated for 1931–1967, the coefficients of the money variables were negative and highly significant.

[15] Ben-Zion and Ruttan do not indicate the period of fit for any regression. Our efforts to duplicate their results, for many different choices of period, were futile. The data used in their second test must be regarded with some skepticism, since the money series for consumers was obtained as a residual.

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INTEREST RATE SEASONALITY AND THE SPECIFICATION OF MONEY DEMAND FUNCTIONS

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The discussions that have arisen in the extensive investigations of the demand for money generally have centered on the selection of an appropriate constraint variable (e.g., permanent income, some other measure of wealth, or current income) and the choice between alternative short-term and long-term interest rates.[1] While nearly all formulations of the demand for money do include an interest rate, an area of neglect in the empirical literature has been the question of whether the interest rate variable chosen should be adjusted to account for seasonality. Traditionally, all included variables in the demand function except the interest rate have been seasonally adjusted.[2]

Equation (1) represents the general form of equations estimated by most empirical studies of the demand for money.

$$M^* = a_0 + a_1 Y^* + a_2 R + u_1 \qquad (1)$$

where

M = demand for real cash balances

Y = permanent income or non-human wealth

R = the short-term interest rate

and the asterisks denote that a seasonally adjusted series is employed.[3] The short-term interest rate is used to reflect the opportunity cost of holding cash balances.[4]

The recent work by Diller (1969), Poole and Lieberman (1972), and Smith and Marcis (1972) has shown that the short-term interest rate is affected by seasonal influences. Our work confirms this finding for the three-month Treasury bill rate.[5] If there are substantial seasonals in the demand for funds due, for example, to tax dates and Christmas, the absence of an offsetting seasonal in supply (i.e., seasonal Federal Reserve behavior) will generate a seasonal in R. Given the identification of seasonals in R some important questions are raised about the inconsistent treatment of seasonality in formulations like equation (1). Specifically, the failure of previous investigations to account for seasonality in the interest rate, while doing so for the money stock and other variables in the demand function, may mean that the demand function has been misspecified and, therefore, the estimated interest elasticity biased.[6]

In view of the evidence of seasonality in R and on the simple grounds of specifying an internally consistent function, equation (2) can be offered as

[1] See Laidler (1969) for an extensive review of the literature on the demand for money.

[2] It is not evident that money demand researchers (concentrating on trend-cycle relations) tested for the appropriateness of using adjusted versus unadjusted data. With regard to the interest rate variable it was probably assumed that seasonal Federal Reserve actions mitigated against seasonal patterns in the interest rate. On the other hand, observable seasonal movements in velocity (or similar evidence) probably suggested the need to adjust income and money stock data.

[3] The function is usually estimated in this way because the demand for money is assumed to be homogeneous in dollar values, that is, there is no money illusion in cash balance demand. Further, the equation is generally estimated in log-linear form. See Zarembka (1968) for a discussion of this functional form.

[4] See Laidler (1969, pp. 82–83) for a brief discussion of the rationale behind this choice of interest rates.

[5] The interest rate series was adjusted multiplicatively by the Census X-11 program, which uses a ratio-to-moving average procedure to filter the regular seasonal components (U.S. Department of Commerce, 1967). The seasonally adjusted series as well as the seasonal factors are available from the authors on request. The estimated seasonal factors show that, in general, the bill rate reaches a seasonal peak in December, declines over the first half of the year, reaching a seasonal low in July, and then rises through year end. The substantial seasonality present is evidenced by the seasonal factors which vary between 91 and 112 in some years.

[6] Some researchers, possibly recognizing the problem detailed above, have employed unadjusted data with stationary seasonal dummy variables in their statistical analysis. Unfortunately, this technique does not allow for moving seasonals or for shifting intensity of the seasonals.