A Time Series Analysis Of the Control of Money

By Jack L. Rutner

In recent years the Federal Reserve System has come to place somewhat greater emphasis on monetary aggregates as policy variables and somewhat less emphasis on money market conditions, i.e., interest rates. As a result of this shift in emphasis, there has been a great deal of research done within and without the System on how to control the money stock.[1]

One approach to money stock control, originally suggested some years ago by Milton Friedman and Anna J. Schwartz,[2] relates the stock of money to the monetary base, which is defined as member bank balances at the Federal Reserve plus all commercial banks' vault cash and currency held by the nonbank public.[3] In this approach, the determination of the money stock is symbolized by the identity $M = mB$. In the identity, the money stock (M) is decomposed into the monetary base (B)—the portion of the money stock controlled by the monetary authorities—and the multiplier (m)—the uncontrolled portion of the money stock.[4]

An important assumption underlying this multiplier-base approach is that the Federal Reserve can control the monetary base rather closely and thereby control the money stock. There is little reason to doubt this assumption because the monetary base is almost exclusively a liability of the Federal Reserve. Even with close

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1/See, for instance, ***Controlling Monetary Aggregates II: The Implementation,*** Proceedings of a Conference sponsored by the Federal Reserve Bank of Boston, February 1973; and ***Monetary Aggregates and Monetary Policy,*** Federal Reserve Bank of New York, October 1974.

2/Milton Friedman and Anna I. Schwartz, ***A Monetary History of the United States 1867-1960,*** (Princeton: Princeton University Press for the National Bureau of Economic Research, 1963), Appendix B.

3/This analytical framework begins by dividing the stock of money into a currency component (C) and a deposit component (D) as, for example:

$$M = C + D.$$

Similarly, it divides the monetary base (B) into a reserve component (R), where reserves are member bank balances at the Federal Reserve plus all commercial banks' vault cash, and a currency component, as in the following equation:

$$B = C + R.$$

By dividing M by B, the following identity is obtained:

$$\frac{M}{B} = \frac{C + D}{C + R},$$

and by dividing the numerator and denominator of the right side of the last equation by D and multiplying both sides of the equation by B, the following multiplier-base identity is obtained:

$$M = \left[\frac{\frac{C}{D} + 1}{\frac{C}{D} + \frac{R}{D}}\right] B.$$

The quantity in the brackets, called the money multiplier, expresses that part of the money stock outside the control of the Federal Reserve, while B expresses that part of the money stock said to be controlled by the Federal Reserve.

4/Since the appearance of the Friedman-Schwa framework, there have been several studies which have examined the relationship between the monetary base and the money stock. Two of these are Allan Meltzer, "Controlling Money," Federal Reserve Bank of St. Louis ***Review,*** May 1969; and Albert E. Burger, "Money Stock Control," ***Controlling Monetary Aggregates II.***

control of the monetary base, however, there is reason to question whether the money stock can be controlled because variations in the multiplier might cause the money stock to fluctuate in an undesirable manner. If this occurs, money stock control might still be achieved if the monetary authorities were to offset fluctuations in the multiplier through variations of the monetary base. This presupposes, however, some knowledge about the interaction between the base and the multiplier, a matter which has not been the subject of extensive research.

Complicating an analysis of the multiplier-base approach is that some recent studies have employed a concept of the base adjusted for changes in reserve requirements and shifts of deposits between different classes of deposits. This concept, hereafter referred to as the adjusted base, was developed by Karl Brunner and popularized by the Federal Reserve Bank of St. Louis.[5] Their adjustments, however, tend to overstate the case for the control of money through variations in the base because the adjustments reduce the observable effect the multiplier has on the money stock and thereby amplify the effect of the adjusted base.

This article examines the statistical relationship between the money stock and the adjusted base as well as the unadjusted base.[6] The article also examines the interaction between the base and the multiplier and the effect the multiplier has on the money stock. In these examinations, some relatively new statistical techniques are employed, including spectral analysis. The money stock concepts that are related to the base are the narrowly defined money stock, M1 (currency held by individuals plus demand deposits), and the more broadly defined money stock, M2 (M1 plus time deposits at commercial banks less large negotiable certificates of deposit).

RELATIONSHIP BETWEEN MONEY AND THE BASE

One of the problems encountered in examining the relationship between the money stock and the base is that both have strong upward trends. When relationships between variables with a strong upward trend are estimated by ordinary statistical tools, the resulting estimates tend to be biased toward acceptance of the hypothesis that the variables are related when indeed they may not be. Thus, before the relationship between the money stock and the base can be estimated properly, the trend must be removed from each series.

Panel A of Chart 1 shows the strong upward trend that exists in the original monthly observations for M1. To remove the trend from such a series, one technique commonly employed is to convert the original series showing levels into a series showing changes in levels. This technique, however, is frequently defective in removing the trend. Panel B, which contains a series on changes (A) in M1, shows clearly that there still exists an upward trend in the series. A second technique for removing the trend is to remove that part of the series that can be predicted from its own past history.[7] Panel C shows the results of applying this technique to the M1 series. As can be seen, this technique is far superior in removing the trend and, consequently, it is employed in this article.[8]

5/See Karl Brunner, "A Schema for the Supply Theory of Money," *International Economic Review,* Vol. 2, No. 1, January 1961, pp. 79-108; and Leonall C. Anderson and Jerry L. Jordan, "The Monetary Base Explanation and Analytical Use," Federal Reserve Bank of St. Louis *Review,* August 1968.

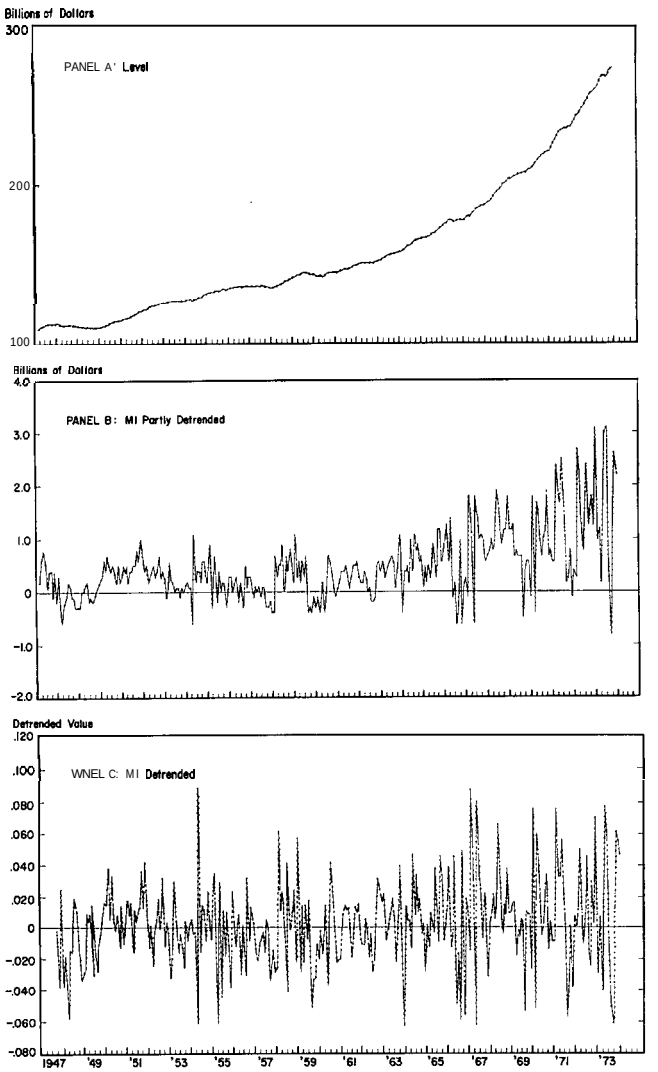
Two exceptions to the use of the St. Louis adjusted base are Friedman and Schwartz, *A Monetary History of the United States;* and Philip Cagan, *Determinants and Effects of Changes in the Stock of Money 1875-1960* (New York: Columbia University Press for the National Bureau of Economic Research, 1965).

6/Data for the unadjusted base, i.e., not adjusted for reserve requirement changes, etc., were kindly furnished by Anna J. Schwartz of the National Bureau of Economic Research.

7/Essentially this is accomplished by regressing a variable on its past values. The significant lags are retained and the regression is rerun. Inasmuch as significant lags sometimes become insignificant on the rerun, it is necessary to run the regressions several times until a set of lags are found whose coefficients maintain their significance. The residual from the regression in which all remaining lags are significant is then used as the new series to run the statistical tests. In the tests run here, all variables were first converted to natural logarithms. A reference to the technique used here may be found in Marc Nerlove, "A Comparison of a Modified 'Hannan' on the BLS Seasonal Adjustment Filters," *Journal of American Statistical Association,* June 1965, pp. 442-91.

8/Note, too, that there is some evidence of increasing variance for the more recent figures.

Chart 1
LEVEL, PARTLY DETRENDED, AND TOTALLY DETRENDED VALUES OF M1
(Monthly, 1947-73)



NOTE: The detrended value is not in the same scale as the level and first differences See footnote 7 for derivation of tho detrended value.

The pitfalls of incorrect trend removal can be found in Table 1. This table shows the correlation coefficients (R^2's) between various measures of money and the base when each series is correctly and incorrectly detrended.[9] In the case of the inadequately detrended adjusted base, there appears to be a strong relationship--evidenced by the relatively high R^2—between it and the money stocks. By itself, the high R^2 would confirm the hypothesis that the money stock is correlated with the adjusted base; not unexpectedly the relationship for the unadjusted base is somewhat weaker than for the adjusted base. When the more effective method of trend removal is used, however, virtually no relationship is found between the base and the money stock. Thus, the use of the more effective trend removal technique would appear to lead to rejection of the hypothesis that the money stock is correlated with the base be it the unadjusted or the adjusted base.

Table 1
A COMPARISON OF THE R^2 IN REGRESSIONS OF ADEQUATELY DETRENDED DATA AND INADEQUATELY DETRENDED DATA

Adequately Detrended			Inadequately Detrended		
	B*	B_A*		ΔB	ΔB_A
M1*	.0097	.0399	ΔM1	.1642	.3268
M2*	.0143	.0508	ΔM2	.2894	.4893

NOTES:
1. The asterisk (*) indicates that the data have been detrended by a regression on the natural logarithm of the original data. This removes the portion of the variable which can be predicted from its own past history. The delta (Δ) indicates that the variable has been detrended by first differencing, which is accomplished by subtracting the past value of the variable from the current value (i.e., $\Delta B_t = B_t - B_{t-1}$).
2. B is the unadjusted base, while B_A is the adjusted base.

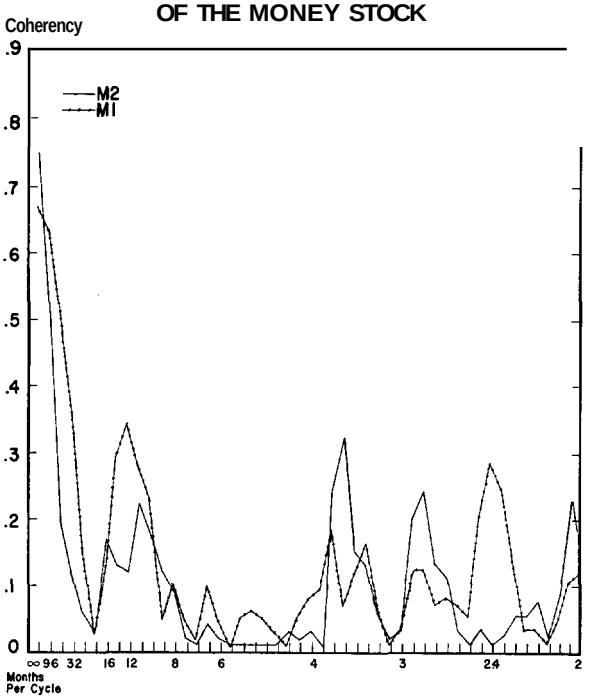
Despite the apparent rejection by the regression technique of the hypothesis that the monetary base and the money stock are related, it is possible that a significant relationship may still exist for particular periods of time. To examine this possibility, a more powerful tool called spectral analysis is employed. Spectral analysis, unlike the regression technique, has the

9/ In each case these are the R^2's from a regression of the form $y = a + bx$. Since it made no difference which was the independent and which was the dependent variable, only one R^2 is reported for each combination of money and base variables. For all tests conducted, monthly data were used beginning in January 1947 and terminating December 1973. The Durhin-Watson statistic, a measure of trend (actually serial correlation) in the errors of the regression, indicated no trend in the adequately detrended variables. In the case of first differences, significant trend remained in the errors of the regression except for AM1 and AB_A.

advantage of being able to simultaneously determine the correlation between variables for different lengths of time, or cycle lengths. The statistical measure which reveals the correlation for different lengths of time is the "coherency," which is similar to the R^2 of regression analysis. A coherency of 1 signifies complete association of the two series, while a coherency of 0 signifies no association. In practice, the coherency may be high for some cycle lengths and low for others. The spectral technique also produces a statistic which indicates the degree to which one series leads or lags another series.

The correlation, or coherency, between the unadjusted base and the M1 and M2 definitions of the money stock for various cycle lengths is illustrated in Chart 2.[10] In general, the results of this chart confirm the findings of the regressions made with the adequately detrended data. For most cycle lengths there is no significant relationship between the monetary base and either definition of the money stock.[11] Unlike the regression results, however, Chart 2 reveals a high coherency for very long cycle lengths between the base and both definitions of the money stock, with the coherency being somewhat higher for the M2 definition.

Chart 2
COHERENCY BETWEEN THE UNADJUSTED BASE AND TWO DEFINITIONS OF THE MONEY STOCK



AN INTERPRETATION OF THE RESULTS OF THE RELATIONSHIP OF THE UNADJUSTED BASE WITH THE MONEY STOCK

The relatively high correlation between money and the unadjusted base for the longer cycles indicates a very long-run stable relationship between the two variables. In shorter cycles, however, the absence of any significant correlation between the two variables suggests that no short-run stable relationship exists between them. The absence of any relationship might, of course, be explained in several ways. One is that the base is not, in fact, related to the money stock, except in the very long run, and that the multiplier is the primary determinant of the stock of money. A second possibility is that both the base and the multiplier are determinants of the money stock, but they interact in a manner to offset each other. If the second possibility were true, it would be difficult to discern a statistical relationship between the base and the money stock. To investigate these two possibilities, it is useful to look at the relationship of the multiplier to the money stock and at the interaction of the base with the multiplier.

Chart 3 illustrates the coherency of the multiplier (of the unadjusted base) with the two definitions of the money stock, while Chart 4 illustrates the coherency of the multiplier (of the unadjusted base) with the unadjusted base. It is apparent from Chart 3 that for cycles shorter than about 2½ months the money stock is determined primarily by the actions of the multi-

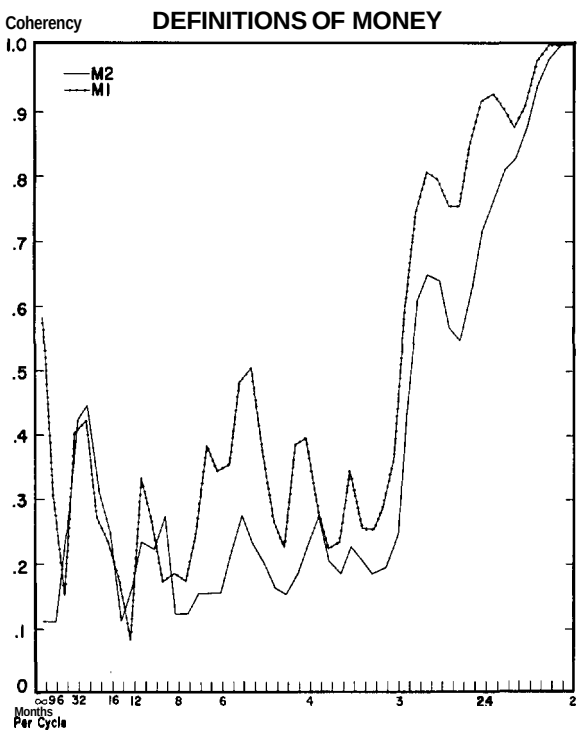
10/In estimating the cross-spectrum, Parzen weighting was used. The cross-spectrum was estimated on 60 lags and 48 frequency bands.
11/For this and succeeding charts, the coherency must he at least .4 to he statistically significant, except for very long-run cycles (marked ∞) where it must he at least .6.

plier. This is supported by evidence that showed a low coherency between the base and the money stock in short cycles (Chart 2) and a low coherency between the base and the multiplier in short cycles (Chart 4).

For cycle lengths in excess of about 2% months, relationships begin to reverse themselves. In Chart 3, the coherency of the multiplier and the money stock decreases dramatically, while in Chart 4, the coherency of the multiplier and the unadjusted base increases just as dramatically. These results suggest that, between the very long run and the very short run, the base and the multiplier must be neutralizing one another so that neither is determining the money stock.

If the base and the multiplier offset one another during intermediate cycle lengths, the question arises whether the base is countering the effects of the multiplier or the multiplier is countering prior movements in the base. For clarification of this point it is necessary to determine which of these two variables leads and which lags. From information furnished by lead-lag figures between the base and the multiplier, it appears the multiplier leads the base by a half-cycle length for most cycles.[12] In other words, for cycles in which the base and the multiplier are offsetting, it is the base that is countering the effects of past changes in the multiplier.[13] This suggests that, for the period 1947-73, the policies pursued by the monetary authorities—through variations in the unadjusted base—have had the effect of neutralizing the impact the multiplier exerts on the money stock during cycles of more than 2% months. It can be inferred from this evidence that the unadjusted base could be a powerful instrument to control money because the authorities could vary the unadjusted base in such a way as to offset fluctuations in the multiplier, while simultaneously achieving the desired growth in money.

Chart 3
COHERENCY OF THE MULTIPLIER OF THE UNADJUSTED BASE WITH TWO DEFINITIONS OF MONEY



THE ADJUSTED BASE

Thus far, the discussion has centered on the unadjusted base. An examination of the synthetically constructed adjusted base, by comparison, paints a related but somewhat different picture.

Chart 5 illustrates the coherency of the

12/The following table lists the lag of the unadjusted base behind the multiplier:

Lag of Unadjusted Base Behind Unadjusted Multipliers of M1 and M2 At Points of Highest Coherency

m1 and B			m2 and B		
Cycle Length (months)	Months	Cycle Fraction	Cycle Length (months)	Months	Cycle Fraction
2.40	.33	.14	2.67	.69	.26
3.10	1.03	.33	3.00	.91	.30
4.57	1.89	.41	4.17	1.82	.44
6.00	2.26	.40	6.00	2.44	.41
13.71	5.91	.43	13.71	7.56	.55
24.00	10.09	.33	32.00	10.89	.34

NOTE: Cycle fraction is number of months of lag divided by cycle length; m1 and m2 are the M1 and M2 multipliers, respectively, of the unadjusted boss.

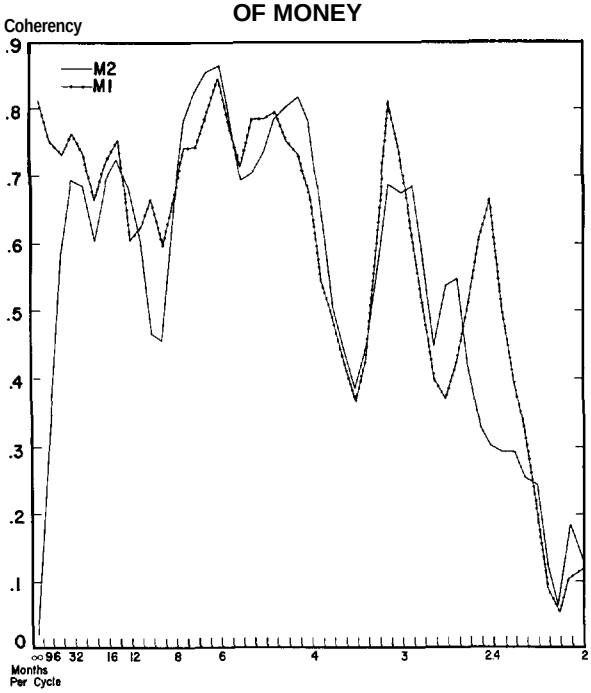
13/The high coherency between MI and its multiplier for very long cycles presents somewhat of a puzzle. In this case, the multiplier and the base may be enhancing each other because they both have some correlation with the money stock in these very long cycles.

adjusted base with both M1 and M2. For cycles shorter than 16 months, there is virtually no relationship between the adjusted base and money. For cycles 16 months or more, however, money and the adjusted base are highly correlated

It is somewhat surprising that the adjustments that have been made on this synthetic construct still leave the adjusted base uncorrelated with the money stock for cycles shorter than 16 months, as is the unadjusted base. One would have expected the adjustments to have made it appear that the base and the money stock were highly correlated. For cycle lengths 16 months or more, though, the adjustments on the base have had the very definite impact of raising its correlation with the money stocks.[14]

The higher correlations between the adjusted base and the money stock for longer cycles would appear to suggest that the adjusted base is a more appropriate instrument for monetary control than the unadjusted base. A number of factors, however, would point to the opposite conclusion. First, for some cycles where the adjusted base and the money stock are highly correlated, the money stock ***leads*** the adjusted base.[15] If, however, the adjusted base is to be used to control the money stock, the adjusted base must lead the money stock. Second, the adjusted base and the adjusted multiplier are significantly correlated for cycles shorter than about a year, and more importantly, for these cycles the adjusted base ***leads*** the adjusted multiplier. This means that changes in the adjusted multiplier are offsetting changes in the adjusted base, which would make it difficult to control the money stock through the adjusted base. The opposite, it will be recalled, was the case for the unadjusted base and the unadjusted multiplier. That is, the unadjusted multiplier leads the unadjusted base, suggesting that the Federal Reserve has exercised control over money by changing the unadjusted base to offset prior movements in the unadjusted multiplier.[16]

Chart 4
COHERENCY OF THE UNADJUSTED BASE WITH ITS MULTIPLIER FOR TWO DEFINITIONS OF MONEY



14/Comparing the coherency results in Chart 5 with the R^2 of the regressions of the adequately detrended variables of the adjusted base and the money stock in Table 1 again indicates the power of the spectral technique. The regression does not indicate the source of the R^2, whereas the spectral diagram indicates that it comes from the cycles of 16 months or more.

Curiously, the highest coherency for the adjusted base was found with M2 + CD (M2 plus large negotiable certificates of deposit). This appears to contradict other studies which appear to indicate that M1 is more highly correlated with the adjusted base than other monetary aggregates.

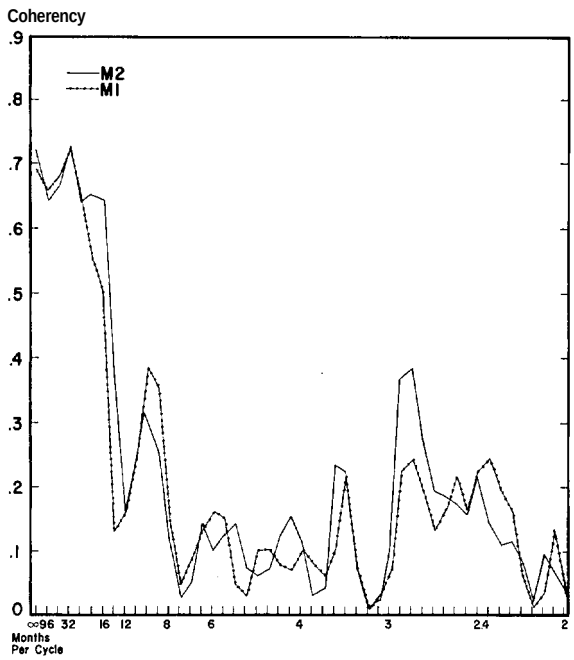
15/The following table lists the lead-lag relationship of the adjusted base with M1 and M2 for cycles in which there is a high coherency between the base and the two money stock definitions.

Cycle Lengths (months)	M1	M2
	(months)	
16.0	-4.09	-4.29
19.2	-2.84	-3.65
24.0	-1.15	-2.87
32.0	.16	-1.95
48.0	3.48	.44
96.0	11.14	7.28

NOTE: A positive number indicates that the monetary base leads the money stock; a negative number indicates that the money stock leads the bore. All figures are months, or fractions thereof.

16/Another factor is that. for some cycles, the coherency between the adjusted multiplier and money is higher than between the unadjusted multiplier and money. A high coherency between the multiplier and money suggests that the multiplier exerts considerable influence on money. This would indicate weak monetary control since the Federal Reserve has little control over the multiplier.

Chart 5
COHERENCY OF THE ADJUSTED BASE WITH TWO DEFINITIONS OF MONEY



Apart from statistical considerations, it is not entirely clear that the monetary authorities can control the adjusted base as well as they can control the unadjusted base. In calculating the adjusted base, the effects of shifts between deposit classes are netted out of the multiplier in an ***ex post*** fashion and put into the base. Inasmuch as the Federal Reserve has no direct control over the composition of deposits, it has no control, at least in the short run, over the adjusted base.[17] In the extreme case, one could also net out the effects of shifts between currency and deposits. This would make it appear as if the money stock and the base were perfectly related and that the Federal Reserve had precise control over money when indeed the opposite could be equally true.

CONCLUSION

An important finding of this study is that, in the short run, there is no significant relationship between the money stock and either the unadjusted or adjusted monetary base. For intermediate time lengths, though, money is highly correlated with the adjusted base; and, in the very long run, money is highly correlated with both the adjusted and the unadjusted base. The finding that money and the base are unrelated in the short run is at great variance with most previous research. An important reason for the different conclusion is that the results of this article are based on adequately detrended data; while in previous research on this subject, the trend in the data was inadequately removed.[18]

Despite evidence that the adjusted base is somewhat better correlated with money for certain time periods than the unadjusted base, other evidence suggests the unadjusted base is a better instrument to control money. One reason is that, for some time periods, variations in money lead the adjusted base. This means it would be difficult to control money by first altering the adjusted base. Another reason is that in some time periods variations in the adjusted base are neutralized by movements in the multiplier, while the opposite is true for the unadjusted base. This, too, suggests it would be more difficult to control money with the adjusted base than with the unadjusted base. And, finally, for definitional reasons, the unadjusted base can probably be controlled more easily than the adjusted base. All these factors clearly call into question the ability of the monetary authorities to control the money stock with the adjusted base.

17/One way to acquire control over the adjusted base. however. would be to subject all deposit classes to the same reserve requirement or possibly have no reserve requirements. In the case of no reserve requirements, the determination of the multiplier would be purely behavioristic and that might be easier to determine than when deposits flow between different classes of deposits.

18/While previous tests would appear to suggest one-way causality from money to the base because money was regressed on past values of the base, they probably would have indicated causality from money to the base if the base were run on past values of the money stock. The reason for this is the trend element common in both variables.