of employment with an arduous but important task. A wide range of studies *of individual firms* is required before we will be able to understand the nature of these dynamic costs and to use that knowledge to infer the impact of policies that may alter them.

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THE EFFECTS OF INSIDE AND OUTSIDE MONEY ON INDUSTRIAL PRODUCTION ACROSS SPECTRAL FREQUENCY BANDS

Mark A. Thoma*

Abstract—This paper examines money–income causality using band spectral filtering techniques. The paper's central finding is that relatively low frequency movements in outside money are responsible for the relationship between money and economic activity. This result is inconsistent with theoretical models in which unanticipated changes in money are responsible for movements in real activity. Reverse causality is also examined. The results are not supportive of a strong feedback relationship from income to inside money. However, there is evidence of strong feedback from income to outside money.

I. Introduction

The question of whether money causes real activity has been debated extensively in the economics literature.[1] This paper examines money–income causality in a novel way by using band spectrum filtering techniques to determine the bands of frequencies in measures of inside and outside money and real activity responsible for money–income causality results. The paper's central finding is that relatively low frequency movements in outside money—movements that are highly predictable over horizons of up to a year and a half—are responsible for the relationship between money and economic activity. This finding is provocative because it is inconsistent with theoretical models in which changes in money that are unanticipated at fairly short horizons cause temporary deviations from the natural rate of real activity.

The findings reported in the paper also bear on the reverse causality debate. The findings are not supportive of a strong feedback relationship from income to inside money. However, there is evidence of a strong feedback relationship from income to outside money. These findings are provocative because they are inconsistent with models where changes in income bring about endogenous changes in inside money to accommodate changes in the transactions demand for money.

II. The Model and Baseline Results

I begin by obtaining money–income causality and reverse causality results in a baseline model. Then, the effects of money on real income as well as reverse causality from income to money are examined across various frequency bands.

A. The Baseline Causality Results

Obtaining the baseline results is relatively straightforward. The data used are monthly and cover the

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[1] Contributions to this literature include Sims (1972, 1980), Litterman and Weiss (1985), Stock and Watson (1989), and more recently Krol and Ohanian (1990) and Friedman and Kuttner (1990).

TABLE 1.—BASELINE CAUSALITY RESULTS

Definitions of Money (M)				
	Inside			Outside
$M1$	Base	Curr	Res	DD
		A. $M \to Y$		
2.61[a]	3.13[a]	3.62[a]	1.55	2.12[b]
		B. $Y \to M$		
1.73	2.00[b]	2.16[a]	2.29[a]	1.53

[a] Significant at the 5% level ($F_{.05}(6,335) = 2.13$).
[b] Significant at the 10% level ($F_{.10}(6,335) = 1.79$).

sample period 1959:2 to 1989:12. The measure of aggregate activity is industrial production. Money is measured as $M1$, outside money as currency, reserves, and the monetary base, and inside money as demand deposits. The interest rate is for three month T-bills, and the price level is the CPI. All data are from the *Citibase Data Bank*.

To obtain stationary representations of the data, unit roots are removed from the logs of the money measures, output, and the price level and from the level of the interest rate. The basic model is

$$Z_t = \sum_{j=1}^{J} A_j Z_{t-j} + u_t \tag{1}$$

where $Z_t = [Y_t, M_t, P_t, R_t]^T$, Y_t is the growth rate of industrial production, M_t is the growth of money, the base, currency, reserves, or demand deposits, P_t is the inflation rate, R_t is the change in the interest rate, the A_j are coefficient matrices, u_t is the column vector of disturbances, and J, the lag length of the VAR, is 6.

Causality from Money to Output: In table 1, the baseline results in the first row are the F-statistics for whether lags of innovations to the measures of money help to predict output.[2] As can be seen in table 1, money significantly causes income at the 5% level for $M1$, the base, and currency, and at the 10% level for demand deposits. Causality from reserves to income is not significant. Money–income causality is most significant for two of the measures of outside money, the base and currency.

Causality from Output to Money: The feedback statistics for income causing money are also presented in table 1. Table 1 indicates that reverse causality from income to money is significant at the 5% level for currency and reserves, and at the 10% level for the base. The feedback statistics are not significant for $M1$ and demand deposits. Thus, reverse causality is significant for measures of outside money, but not for measures of inside money.

III. Causality Results Across Spectral Frequency Bands

Which frequency movements in the measures of money and real activity lie behind the money–income causality and feedback results? The procedure used to answer this question is to transform the data to the frequency domain, zero out some of the frequencies, transform the data back to the time domain, perform causality tests, and compare the tests to the baseline, unfiltered results. Following Engle (1974, 1978), define the row vector w_k as

$$w_k = (1, e^{i\theta_k}, e^{2i\theta_k}, \dots, e^{(T-1)i\theta_k}) \tag{2}$$

where $\theta_k = 2\pi k/T$. Now, consider a particular element of the vector Z_t, say Y_t. Let

$$Y = [Y_0, Y_1, \dots, Y_{T-1}]^T,$$

and define $\tilde{Y} = WY$ where $W = [w_0, w_1, \dots, w_{T-1}]^T$. $\tilde{Y}$ is a T element vector with complex entries, each of which corresponds to a different frequency. The objective is to exclude some of the frequencies from $\tilde{Y}$. To accomplish this, construct a $T \times T$ matrix S, where S has ones on the diagonal elements corresponding to included frequencies and is zero elsewhere, and obtain $S\tilde{Y}$. Finally, define $Y^* = W^{\dagger}SWY = W^{\dagger}S\tilde{Y}$ where $\dagger$ means the complex conjugate of the transpose. This is the inverse Fourier transform of $S\tilde{Y}$.

The next step is to let $Z_t^{Y^*} = [Y_t^*, M_t, P_t, R_t]^T$. Then write the new VAR model:

$$Z_t^{Y^*} = \sum_{j=1}^{J} A_j Z_{t-j}^{Y^*} + u_t. \tag{3}$$

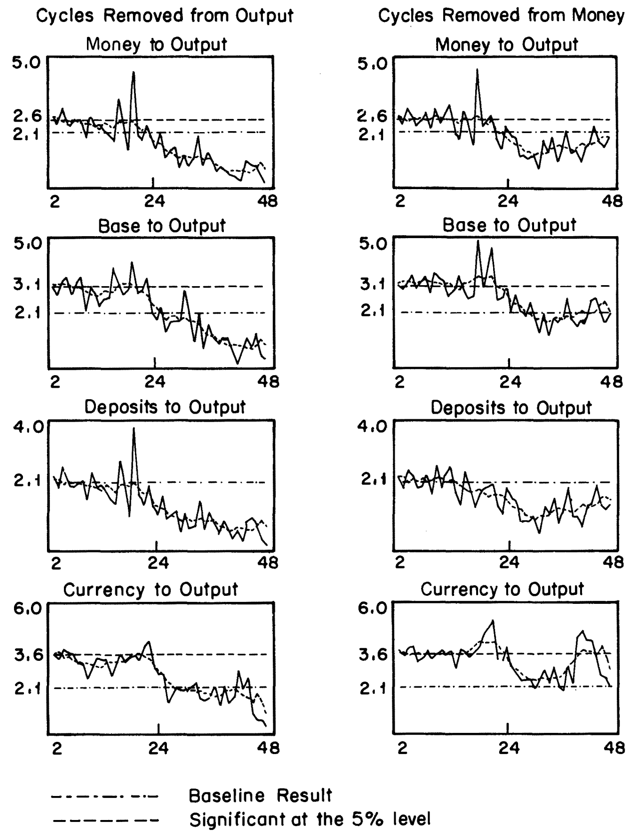
This is the VAR model with designated frequencies removed from one of the variables, in this case from Y. This model is estimated with cycles from 2 to 48 months removed from money or income[3] and the F-statistics for causality are compared to the baseline results from model (1).[4] If the excluded frequencies are responsible for the causality results, the F-statistics

[2] As in Stock and Watson (1989) and Friedman and Kuttner (1990), F-statistics rather than variance decompositions and impulse response functions are used to assess causality. This is so that the results here can be compared directly to the results of Stock and Watson, Friedman and Kuttner, and others. The limitations inherent in the use of F-statistics to assess causality in multivariate VAR models (i.e., with more than two variables) are acknowledged.

[3] The bandwidth of the excluded frequencies is 0.01 of a cycle. Both the fundamental and harmonic frequencies are excluded.

[4] Geweke (1984) presents a decomposition of directional linear feedback by frequency. The procedures used here, which are similar to Engle (1974, 1978), are much easier to apply.

FIGURE 1.—*F*-STATISTICS FOR MONEY–INCOME CAUSALITY



from model (3) should drop below the baseline results from model (1).[5]

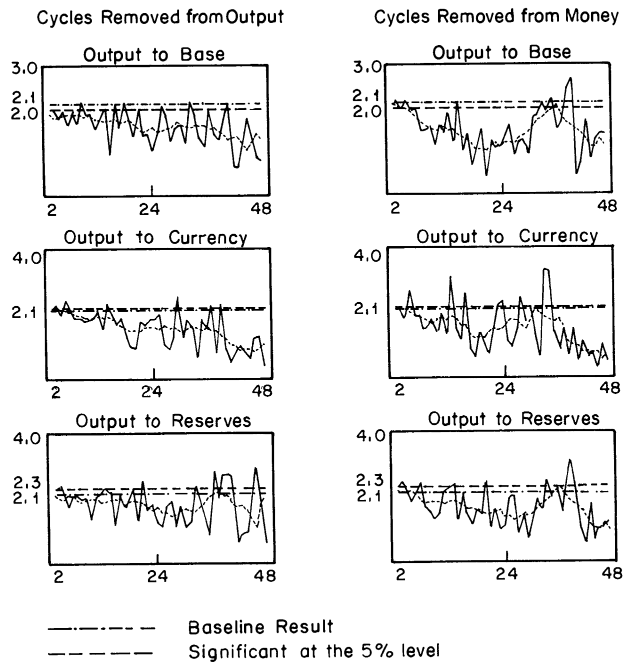
Causality from Money to Output: The causality statistics are presented in figures 1 and 2 where cycles from 2 to 48 months in duration are removed one at a time from output and the measures of money. The results are then plotted on a diagram with the *F*-statistics for causality on the vertical axis, and the period of the cycle removed on the horizontal axis (the baseline and 5% significant lines are also shown in the diagrams).[6] The effects of removing cycles from output, shown on the left-hand side of figure 1, are clear and are consistent across the various measures of money. In each of the four diagrams on the left-hand side of figure 1, the results are similar. There is not much change in the *F*-statistics from the baseline results when cycles between 2 and 17 months in duration are removed. There is a consistent decline in the *F*-statistics when 18 to 48 month cycles are removed, except for currency where there is a leveling off of the statistics from 31 to 48 months. Thus, cycles of length 18–48 months in income are behind the money to income causality results.

The *F*-statistics corresponding to the removal of money cycles are presented on the right-hand side of figure 1. Once again, the effects are clear and consistent across the various definitions of money. When cycles of duration 2 to 17 months are removed, the *F*-statistics hover at the baseline level. The *F*-statistics then show a sharp decline from 18 to 30 months. After that, when cycles from 31 to 48 months are excluded, the *F*-statistics begin increasing back towards baseline.

[5] Monte Carlo simulations show that filtering cycles from the data in this manner does not affect the distribution of the test statistics for causality under the null hypothesis. Details are available upon request.

[6] The *F*-statistics shown in figures 1 and 2 are smoothed using a symmetric rectangular window of width five. The smoothed statistics are superimposed upon the raw statistics to give an indication of the local movement in the *F*-statistics. To save space, only the figures for the cases where the baseline results are significant at the 10% level are shown.

FIGURE 2.—*F*-STATISTICS FOR REVERSE CAUSALITY



Thus it is clear that money to income causality is due to cycles in money of duration 18–30 months.

Causality from Output to Money: Figure 2 details the reverse causality statistics. The removal of cycles from 2–48 months in duration from output, shown on the left-hand side of the figure, produces a slight fall in the *F*-statistics below baseline. However, the results are fairly noisy and it is difficult to identify a particular set of frequencies responsible for the results.

On the right-hand side of figure 2, the *F*-statistics for the removal of cycles from the money measures between 2 and 48 months are plotted. For causality from output to money, there is a decline in the *F*-statistics from 2 to 18 months for the base and currency, and a decline from 2 to 27 months for reserves. The results are clear for the base, but are fairly noisy for currency and reserves. This is followed by an increase in the *F*-statistics and a return to baseline at about 36 months for all three money measures, followed by a sharp decline from 37 to 48 months. This evidence suggests that output causes cycles in money from 2–18 months long for the base, and from 37–48 months long for the base, currency, and reserves.

Summary of the Results Across Spectral Frequency Bands: Summarizing, the results are that 18–30 month cycles in money measured as $M1$, the base, currency, and demand deposits cause 18–48 month cycles in output. In the reverse direction, from output to money, the results indicate that cycles in output at all frequencies cause both high (2–18 months) frequency cycles in the base and intermediate (37–48 months) frequency cycles in the base, currency, and reserves.[7]

IV. Conclusions

The impact of aggregate demand shocks on measures of real activity is usually examined through the use of impulse response functions. Very little attention has been focused on the frequency of the aggregate demand shocks responsible for the movements in measures of real activity. That is, are movements in money

[7] Several checks on the robustness of the results were performed. First, across sample periods, the results concerning the frequency bands responsible for the causality results were consistent, but the strength of the results did vary. The results were stronger when the sample period used by Stock and Watson, 1959:2 to 1985:12, was used but weaker for the entire postwar sample, 1947:2 to 1989:12. However, several of the money measures show a clear break around 1959 making the 1947:2 to 1989:12 results subject to questions of misspecification. Second, removing a trend from the money measures as in Stock and Watson strengthens the results substantially for all sample periods. The conclusions are unaffected. Third, using unemployment rather than industrial production as the measure of real activity weakened the results somewhat, but again did not alter the conclusions. Fourth, extending the number of lags in the VAR model to 12 produced weaker but generally consistent results, perhaps indicating a reduction in the power of the tests. Fifth, broader filtering of cycles in two groups, those less than 18 months and those greater than or equal to 18 months resulted in similar conclusions. Thus, although these changes affected the strength of the conclusions, the conclusions themselves were generally unaffected.

at particular frequencies primarily responsible for aggregate fluctuations? Similarly, are money driven movements in output clustered at particular frequencies?

The evidence from band spectrum filtering techniques shows that money–income causality is predominantly a relationship between cycles in outside money and real activity greater than 18 months. Cycles of this duration in money growth measures cause similar cycles in the growth rate of industrial production. This finding is provocative because although the results of this study support the conclusions of earlier writers that demand shocks affect real activity, the result that money–income causality is due to business cycle frequency movements in outside money is inconsistent with the commonly held view that it is relatively high frequency cycles in money that induce cycles in output. For example, in new classical models movements in output are often driven by expectational errors concerning the money growth rate, a result supported by the work of Barro (1977, 1978). It is difficult to imagine that such errors could persist for as long as 18–30 months.

This paper also examines reverse causality from income to money used by real business cycle theorists to explain observed correlations in money and income. The results are that cycles in output at all frequencies cause cycles from 2–18 months and from 37–48 months in outside money growth. The result that outside money is involved in the feedback relationship differs from King and Plosser (1984) who find that income is more highly correlated with inside money than with outside money. Thus, the results of this paper imply a lack of robustness in the real business cycle view of an endogenous response of inside money to changes in the transactions demand for money. It is worth noting, however, that evidence for a feedback relationship from income to outside money is consistent with many demand-side models.

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