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SAID ALKHATIB
Yarmouk University, Irbid, Jordan

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THE GRANGER-CAUSALITY FROM MONEY TO OUTPUT

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SAID ALKHATIB*
Yarmouk University, Irbid, Jordan

Abstract

This study examines the Granger causality from money to output in Jordan for the sample period from 1969 to 1991 on the basis of implementation of a FPE approach. The criteria used in this context for determining the lag lenght are R2-adjusted, Akaike's Information criterion (AIC), and schwarz's criterion (SC). The FPE statistics suggest that both M1 and M2 measures turn out to Granger-cause output. These results confirm the importance of monetary policy in affecting output. The results also confirm the null hypothesis that money does not react passively to output. Interestingly, the results turn out to be insensitive to the money measures used in this study

Introduction

During the last two decades, macroeconomists have renewed their interest in seeking an explanation for business cycles. Renewed interest in business cycles research has resulted in a substantial number of theories. Many of these theories are equilibrium theories in Hayek's sense (Norrbin and Schlagenhauf, 1988). Perhaps the most publicized theory of the business cycle is the Lucas (1972, 1979), Sargent and Wallace (1975), and Barro (1976) rational expectations general equilibrium model which stresses the role of nominal shocks in the presence of imperfect information.

The purpose of this paper is to investigate empirically the Granger-causality from money to output using Jordanian annual data on the basis of implementation of a final prediction error - henceforth FPE - methodology. The interrelationship between

* Assistant Professor, Department of Economics, Faculty of Economics and Administrative Sciences, Yarmouk University, Irbid, Jordan.

money and output provides important information on two main sets of competing hypotheses. The first set emphasizes the active role of changes in money in affecting output, while the second set emphasizes a passive response of money to output.

The first hypothesis is basically based on both equilibrium and disequilibrium models. The former assume full price flexibility. Proponent of these models are likely to see changes in money as autonomous and generally precede movements in output. Rational expectations versions of these models tend to distinguish between anticipated and unanticipated changes in money. It is hypothesized that anticipated changes in money have no effects on real output, while unanticipated monetary changes are assumed to have non-neutral effects on output.

On the other hand, disequilibrium models involve some type of price stickiness, and /or market imperfections (Leiderman, 1984). These setups generally yield hypotheses similar to those above, except that the distinction between anticipated and unanticipated monetary changes becomes less relevant. Changes in money are mostly regarded as non-neutral in terms of their short-run effects on output. Some of these non-neutralities of money may involve a transmission mechanism very different from the one of unanticipated money equilibrium models.

Proponents of disequilibrium models generally emphasize the existence of capital market segmentation, production lags, and the implied of liquidity constraints on the economy's supply sector. Under these conditions, increases in money lead to an outward shift of both aggregate demand and supply schedules. Thus, these models hypothesize stronger output effects of monetary changes than models in which money does not directly affect the economy's supply.

The second hypothesis states that money reacts passively to output (Taylor, 1981). The passive role of money rests on several assumptions. First, the authorities may want to smooth output fluctuations in an economy subject to dominant supply shocks. If that is the case, and to the extent that monetary policy is effective, then a rule of monetary accommodation of supply shocks will be observed. Second, changes in output may alter the government's budget deficit and this, in turn, may lead to changes in the monetary base and the money supply. Third, changes in money may reflect induced balance of payments effects of output shocks, especially under a fixed exchange rate regime (Leiderman, 1984). In this case, however, there can still be an autonomous monetary policy instrument, namely through changes in the domestic credit components of the monetary base.

The organization of the rest of the paper is as follows. The next section reviews the most recent studies that are tightly linked to the nature of money output dynamics. Section three presents the empirical methodology used in the paper. Section four discusses the empirical findings. Section five reports the conclusions.

Literature Review

There has been a substantial amount of research regarding the nature of money-output dynamics. It has been found (Genberg et al., 1987) that the impact of monetary forces on real magnitude depends on: (a) the structure of the economy, (b) the formation of expectations, and (c) the reactions of policymakers to changing economic circumstances. Consequently, the impact of monetary policy on output can only be determined empirically.

Genberg et al. (1987), as an example, argue that the relative importance of domestic and foreign shocks for domestic macroeconomic performance depends critically on the prevailing exchange rate regime. Fixed rates make for a great deal of interdependence and imply transmission of disturbances from country to country. Flexible rates, in contrast, minimize interdependence, provide policy autonomy, and insulate economies from disturbances originating abroad. In a nut-shell form, the response pattern of output to monetary shocks depends on the prevailing exchange rate regime.

Huizinga and Leiderman (1987) examine empirically the link between money supply announcements and interest rates. Announcements of unexpected changes in monetary base are shown to have a statistically significant impact on interest rates above and beyond the impact of announcements of unexpected changes in the money supply. It is also shown that the response of interest rates to both money supply and monetary base announcements diminishes as time goes on. Since many firms depend on bank loans to finance working capital requirements of the production process, then the arise in the interest component of variable costs will, in turn, adversely affect output. This channel suggests that anticipated changes in money turn to have less impact on output than those of unanticipated.

Christiano and Ljungqvist (1988) yield evidence showing that the relationship between money and output reflects causation running from money to output when data are measured in log levels, but not when they are measured in first difference of the logs. They argue that the most likely explanation of this puzzle is that the small F-statistic based on the difference data reflects not the data's lack of Granger-causality from money to output, but rather the test's lack of power to detect it. They concluded that the reason for the lack of power of the first difference F-statistic is that log first differencing both time series prior to doing the Granger-causality test appears to give rise to the specification error.

Leiderman (1984) examines the dynamic interrelationship among money growth, inflation rate, and output growth for Columbia and Mexico on the basis of implementation of a vector autoregression technique. The results for Columbia generally show autonomous output growth and money growth behavior, and an important role money shocks in accounting for variation in inflation. In contrast, the results for Mexico provide clear support for two way feedbacks among growth and inflation, and less autonomous output growth behavior than Columbia.

Burbidge and Harrison (1985) attempt to assess the relative role of monetary factors in the great depression using U.S. monthly data covering 1919 to 1941. They show that a significant proportion of the fall in prices and output after early 1931 remains unexplained. By contrast, they find much firmer evidence of monetary impact on the recovery between 1938 and 1941.

MODELING MONEY-INCOME CAUSALITY

3.1 GRANGER CAUSALITY

This section describes the FPE approach which is used here to examine the Granger-causality from money to output using bivariate time series data. To examine the nature of money-output dynamics, we consider the bivariate stationary stochastic process $z_t = (m_t, y_t)$, where m_t and y_t denote money and output at time t measured in logarithm levels, respectively. Suppose that, at time t-1, we try to predict next-period output, y_t. If y_t is better predicted by adding the past money supply time series to the past output time series than by using the past output time series alone, then money is said to Granger-cause output (Granger, 1969). Similarly, output is said to Granger-cause money if next-period money, m_t, is better predicted by adding the past output time series to the past money series than by using the past money series alone. More specifically, let $\bar{y}_{t-1}$, $\bar{m}_{t-1}$, and $\bar{z}_{t-1}$ represent the set of past values of y_t, m_t, and z_t, respectively, so that

$$\bar{y}_{t-1} = (y_{t-1}, y_{t-2}, \ldots)$$
$$\bar{m}_{t-1} = (m_{t-1}, m_{t-2}, \ldots)$$

and

$$\bar{z}_{t-1} = (y_{t-1}, y_{t-2}, \ldots, m_{t-1}, m_{t-2}, \ldots)$$

let $\sigma^2(y_t \mid \bar{z}_{t-1})$ denotes the error in predicting period-t output based on the information set that includes both the past output and the past money supply time series. By contrast, let $\sigma^2(y_t \mid \bar{z}_{t-1} - \bar{m}_{t-1})$ denotes the error in predicting period-t output based on the information set that excludes past money supply time series, m_t. In the present case, money is said to Granger-cause output if $\sigma^2(y_t \mid \bar{z}_{t-1}) <$ $\sigma^2(y_t \mid \bar{z}_{t-1} - \bar{m}_{t-1})$. This inequality implies that money causes output if next period output, y_t, is better predicted by the bivariate time series than by the univariate output series alone. However, if the inequality in the definition does not hold, then money is said not to Granger-cause output. Likewise, we can define $\sigma^2(m_t \mid \bar{z}_{t-1})$ and $\sigma^2(m_t \mid \bar{z}_{t-1} - \bar{y}_{t-1})$ to be the errors in predicting future money, where the prediction is based on the bivariate information set or the information set excluding past output, respectively. Output is said to Granger-cause money if $\sigma^2(m_t \mid \bar{z}_{t-1}) <$ $\sigma^2(m_t \mid \bar{z}_{t-1} - \bar{y}_{t-1})$; otherwise, output does not cause money.

Finally, if $\sigma^2(y_t \mid \bar{z}_{t-1}) < \sigma^2(y_t \mid \bar{z}_{t-1} - \bar{m}_{t-1})$ and $\sigma^2(m_t \mid \bar{z}_{t-1}) < \sigma^2(m_t \mid \bar{z}_{t-1} - \bar{y}_{t-1})$, then feedback is said to occur between money and output.

3.2 The Model to be Estimated

A more conventional way to investigate the Granger-causality from money to output is to estimate the autoregressive model based on the bivariate time series $z_t = (y_t, m_t)$. A regular full rank stationary stochastic process, $z_t = (y_t, m_t)$ can be represented in the polynomial form:

$$y_t = c_1 + F_{11}(L)y_t + F_{12}(L)m_t + e_{1t} \quad \text{......(1)}$$

$$m_t = c_2 + F_{21}(L)y_t + F_{22}(L)m_t + e_{2t} \quad \text{......(2)}$$

where c_1 and c_2 are constants, $F_{ij}(L)$ is the lag polynomial $\sum_{k=1}^{n} F_{ijk}L^k$, where L^k denotes the lag operator ($L^k m_t = m_{t-k}$), and (e_{1t}, e_{2t}) are conventional zero-mean error terms with constant variance-covariance matrix. Equations (1) and (2) state that the current output, y_t, and current money supply, m_t, can be represented as a linear function of the past output and the past money.

Causal relationships would appear to enter in this model in the following way. If $F_{12}(L) = 0$ (i.e., $F_{12k} = 0$ for all k), then it is clear from equation (1) that past money turns to have no effect on future output; that is money does not cause output. Similarly, if $F_{21}(L) = 0$, output does not cause money. The causal relationships between money and output could be determined by fitting equations (1) and (2) by ordinary least squares yielding estimates that are consistent and a symptotically normally distributed and then testing to see whether $F_{ij}(L) = 0$, for $i \neq j$.

Hsiao (1979, 1981) shows that the test of $F_{ij}(L) = 0$ is quite sensitive to the order of the lags of $F_{ij}(L)$. If, for example, the lag structure is prespecified, the test results may be simply a result of the imposed lag specification rather than of the data showing causality. To overcome this potential problem, we let the data determine the lag structure rather than imposing some arbitrary lag structure on the model. Hsiao's suggested procedure for obtaining the optimal order of the lags for each of the $F_{ij}(L)$ in each of equations (1) and (2) is to employ the FPE criterion introduced by Akaike (1969). Consider first the output variable y_t. The FPE of y_t is defined to be the mean squared prediction error.

$$E(y_t - \hat{y}_t)^2 \quad \text{(3)}$$

where $\hat{y}_t$ is the predicted output in period t, and E(.) is the expectations operator. The predicted output value $\hat{y}_t$ is determined by regressing equation (1) using ordinary least squares for a given lag structure of order r and q on $F_{11}(L)$ and $F_{12}(L)$, respectively. In other words, $\hat{y}_t$, is the least-squares estimate:

$$\hat{y}_t = \hat{c}_1 + \hat{F}^r{}_{11}(L)y_t + \hat{F}^q{}_{12}(L)m_t \quad \text{(4)}$$

where $\hat{c}_1$ is an estimated constant, $\hat{F}^r{}_{11}(L)$ are the estimated parameters of $F_{11}(L)$ assuming a lag structure of order r, and $\hat{F}^q{}_{12}(L)$ are the estimated parameters of $F_{12}(L)$ assuming a lag structure of order q. Akaike estimates the FPE by

$$FPE_y(r,q) = \frac{(T+r+q+1)}{(T-r-q-1)} \; \frac{1}{T} \sum_{t=1}^{T} (y_t - \hat{y}_t)^2 \quad \ldots\ldots (5)$$

where $\sum_{t=1}^{T} (y_t - \hat{y}_t)^2$ is the residual sum of squares, and T is the total number of observations after subtracting the presample values (Since the number of observations in the original sample is 23, then T = 23 - the maximum lag length). Akaike's FPE criterion is to choose the lag structure (r,q) that minimizes the FPE given by equation (5). Similarly, we can estimate equation (2) by ordinary least squares to obtain an estimated value $\hat{m}_t$ for money. The estimated FPE for money would then be

$$FPE_m(r,q) = \frac{(T+r+q+1)}{(T-r-q-1)} \; \frac{1}{T} \sum_{t=1}^{T} (m_t - \hat{m}_t)^2 \quad \ldots\ldots (6)$$

The FPE approach for determining causality yields a number of distinct benefits in terms of identifying the model (Bar-Yosef et al., 1987). First, as it has already been pointed out, the data are used to determine the lag structure of the model rather than imposing some arbitrary lag order specification. Second, the FPE criterion does not constrain the lag structure of each variable to be identical; i.e., r is not constrained to be necessarily equal to q. Third, it can be shown that the FPE criterion is equivalent to choosing the model specification on the basis of an F-test with varying significant levels.

To minimize the computational difficulties, Hsiao (1979) has suggested the following sequential procedure.

1. An upper bound on the maximal lag order is specified, say n.
2. The FPE criterion is used to determine the optimal order of the one-dimensional autoregressive process for output alone. Call this order r(≤n), so that the resulting $FPE_y(r,0)$.
3. Fix the lag structure for output at r and use the FPE criterion to specify equation (1). Let q > 0 denote the potential lag order for the money lag operator $F_{12}(L)$, so that the FPE is $FPE_y(r,q)$. To select q, equation (1) is

estimated with money lags of 1 through the maximum lag n. Thus, q minimizes $FPE_y(r,q)$ for money lags up to n.

4. Holding the order of the lag operator $F_{12}(L)$ at q, let the order of the lag operator $F_{11}(L)$ vary from 1 to n. Choose the order of $F_{11}(L)$ that gives the smallest FPE, say s, thereby yielding $FPE_y(s,q)$.

If $FPE_y(r,0) \leq FPE_y(s,q)$, then output is best predicted by a one-dimensional autoregressive process, so that money does not cause output. Conversely, if $FPE_y(r,0) > FPE_y(s,q)$, then money causes output. A similar approach can be used on equation (2) to investigate whether output causes money.

3.3 The Data

The basic data cited throughout the work consist of (a) money supply narrowaly defined (M1), (b) money supply broadly defined (M2), and (c) real GNP for the sample period from 1969 through 1991 using 1985 as the base year. Information about these series come from the International Financial Statistics. Output and money series used in estimating causality models are measured in logarithm levels. The use of different money measures will allow us to compare the robustness of the results across different money measures, and to see which one of monetary aggregates is more tightly linked to output.

4. Empirical Findings

There are two potential problems in estimating equations (1) and (2). First, in practice the lag length r is unknown. If the lag length r is replaced by some upper bound n and r > n, then the least squares estimators are inefficient since the regression model is over fitted (Griffiths et al., 1993). If this is the case, then tests of significance become invalid. By contrast, the least squares estimators are biased if n < r. A second difficulty is that the regressors may exhibit multicollinearity. It may be worth noting that collinear variables do not provide enough information to estimate their separate effects, even though economic theory, and their total effect, may indicate their importance in the relationship.

In order to choose the optimal lag length, three procedures are used. The first procedure of choosing the lag length r such that the adjusted R^2 ($\overline{R}^2$) is maximized. The $\overline{R}^2$ measure for the present case is defined as

$$\overline{R}^2 = 1 - \frac{(T-1)\,\sigma^2}{TSS} \qquad (7)$$

where TSS is the total sum of squares. Of course, $\bar{R}^2$ reaches its maximum when σ^2 assumes a minimum.

The other two criteria used in this context for determining the lag length are Akaike's (1981) information criterion (AIC),

$$AIC(r) = Ln\frac{RSS_r}{T} + \frac{2r}{T} \qquad (8)$$

and Schwarz's (1978) criterion (SC)

$$SC(r) = Ln\frac{RSS_r}{T} + \frac{rLn(T)}{T} \qquad (9)$$

here RSS_r is the residual sum of squares resulted from estimating the regression model using a lag length of r. For both criteria the lag length estimate r is chosen so as to minimize the criterion used.

In this study, five was set to be the maximum number of potential lags for each univariate time series. The ordinary least squares results are reported in appendix A. As table 1 shows, the lag length of r = 2 is chosen for output, r = 3 for money supply M1, and r = 4 for money supply M2. Interestingly, the optimal lag lengths selected on the basis of using different criteria turn out to be the same in all cases.

Table 1

Estimation results for univariate time series[a]

Lag Length r	Output y $\bar{R}^2$	Output y AIC(r)	Output y SC(r)	Money supply m1 $\bar{R}^2$	Money supply m1 AIC(r)	Money supply m1 SC(r)	Money supply m2 $\bar{R}^2$	Money supply m2 AIC(r)	Money supply m2 SC(r)
1	0.947	-4.703	4.654	0.993	-5.102	-5.052	0.996	5.260	-5.210
2	0.956[b]	-4.933[c]	-4.833[c]	0.995	5.549	5.450	0.998	-6.100	6.001
3	0.946	-4.786	-4.637	0.996[b]	-5.742[c]	-5.593[c]	0.998	-6.269	6.120
4	0.934	4.665	-4.467	0.996	-5.536	5.536	0.999[b]	-6.425[c]	-6.226[c]
5	0.938	4.914	-4.666	0.995	5.557	5.309	0.998	-6.249	-6.002

a R-square adjusted, AIC, and SC are computed on the basis of the least squares results reported in appendix A.

b refers to the highest value of R-square adjusted

c refers to the lowest values of AIC and SC

Equations (1) and (2) were estimated as described above. The univariate and bivariate time series models were estimated using all four steps of the Hsiao sequential time series procedure. Table 2 lists the FPE statistics computed on the basis of the univariate time series in which each dependent variable is predicted by its past alone. In light of the results obtained by estimating the univariate time series, the FPE statistics show that real GNP is better predicted when the order of lag operator $F_{11}(L)$ is estimated at $r = 2$ (i.e.; $FPE_y(2,0) = 0.00794$). The same procedure is used to estimate the smallest FPE for each money measure. The results show that money supply M1 is better predicted at $r = 3$, while money supply M2 is better predicted at $r = 4$.

Table 2

Results of the FPE test based on univariate time series model FPE statistics[d]

Regression model	r = 1	r = 2	r = 3	r = 4	r = 5
$y/c, y_{t-1} - y_{t-r}$	0.00993	0.00794[e]	0.00927	0.01059	0.00843
$m1/c, m1_{t-1} - m1_{t-r}$	0.00667	0.00429	0.00357[e]	0.00364	0.00443
$m2/c, m2_{t-1} - m2_{t-r}$	0.00570	0.00247	0.00210	0.00182[e]	0.00222

d FPE statistics are computed on the basis of the least squares results reported in appendix A

e refers to the smallest FPE statistics

We now turn to select q. Equation (1) is estimated holding the order of lag operator $F_{11}(L)$ at $r = 2$ with money lags of 1 through the maximum lag 5 for M1 and M2. Likewise, equation (2) is estimated holding the order of lag operator $F_{22}(L)$ at $r = 3$ for M1 and $r = 4$ for M2 with output lags of 1 through the maximum lag 5. Table 3 lists the FPE statistics based on bivariate time series results listed in appendix B. The smallest FPE is achieved at $q = 1$ in all cases.

Table 3

Results of the FPE based on bivariate time series FPE statistics[f]

Regression model	r	q = 1	q = 2	q = 3	q = 4	q = 5
$y/c, y_{t-1}, y_{t-2}, m1_{t-q}$	2	0.00721[g]	0.00793	0.00930	0.01088	0.01230
$y/c, y_{t-1}, y_{t-2}, m2_{t-q}$	2	0.00785[g]	0.00839	0.00867	0.01051	0.01162
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-q}$	3	0.00380[g]	0.00411	0.00459	0.00471	0.00587
$m2/c, m2_{t-1} - m2_{t-4}, y_{t-q}$	4	0.00189[g]	0.00212	0.00240	0.00230	0.00252

f FPE statistics are computed on the basis of the least squares results reported in appendix B.

g see footnote e at table 2.

Holding the order of the lag operator $F_{12}(L)$ at q = 1 with the order lag operator $F_{11}(L)$ vary from 1 to 5. As shown in table 4, the FPE statistics suggest that the smallest FPE is achieved at s = 2 and q = 1 for output when past M1 or past M2 are included to explain the behavior of output. On the other hand, the smallest FPE statistics are found at s = 3 and q = 1 for M1, and s = 4 and q = 1 for M2 when past output is used to explain the behavior of M1 and M2, respectivly.

In more precise words, the bivariate time series results show that output is better predicted at s = 2 and q = 1 (i.e. $FPE_y(2,1)$ for each money measure. By contrast, the smallest FPE for money supply M1 is found at s = 3 and q = 1, while the smallest FPE for money supply M2 is found at s = 4 and q = 1.

Table 4

Results of the FPE based on bivariate time series

FPE statistics[h]

Regression model	q	s = 1	s = 2	s = 3	s = 4	s = 5
$y/c, y_{t-s}, m1_{t-1}$	1	0.00968	0.00721[i]	0.00847	0.00902	0.00925
$y/c, y_{t-s}, m2_{t-1}$	1	0.01054	0.00786[i]	0.00926	0.01097	0.00947
$m1/c, m1_{t-s}, y_{t-1}$	1	0.00628	0.00458	0.00380[i]	0.00391	0.00474
$m2/c, m2_{t-s}, y_{t-1}$	1	0.00592	0.00243	0.00204	0.00189[i]	0.00236

h FPE statistics are computed on the basis of the least squares results reported in appendix C

i see footnote e at table 2.

To determine whether money Granger-causes output, we compare the smallest FPE's achieved in tables 2 and 4. The smallest FPE statistic based on the bivariate time series in which past money supply M1 is used to explain the behavior of output is found at s = 2, and q = 1 which is smaller than the smallest FPE when past money supply M1 is excluded (i.e., $FPE_y(2,1) = 0.00721$ while $FPE_y(2,0) = 0.00972$). This implies that output is better predicted when past money supply M1 is used to explain the behavior of output, suggesting that M1 Granger-causes output. Likewise, money supply M2 turns to affect the behavior of output, because the $FPE_y(2,1)$ is smaller than the $FPE_y(2,0)$ (i.e., $FPE_y(2,1) = 0.00786$, while $FPE_y(2,0) = 0.00794$). This result suggests that money supply M2 Granger-causes output.

To examine whether money reacts passively to output, we compare the FPE statistics based on the bivariate time series in which past output is used to explain the behavior of money supply M1 or M2 with the FPE statistics based only on the past money measures. The FPE statistics suggest that money supply M1 does not react passively to output when past output is used to explain the behavior of money supply M1. That is because the $FPE_{m1}(3,1) = 0.0038$ while the $FPE_{m1}(3,0) = 0.00357$. The same result is achieved when past output is used to explain the behavior of money supply M2.

Table 5 reports the OLS estimates of the models represented in table 4. With respect to the impact of money on output, the results yield evidence showing that only $m1_{t-1}$ turns out to have an impact which is positive and statistically significant only at the 10% significance level. On the other hand, y_{t-1} appears to have no impact on money measures. This result supports the previous results found on the basis of using FPE approach. As was shown above, it becomes difficult to identify the separate effects of the collinear variables involved precisely.

Interestingly, the results obtained throughout this study appear to be consistent with those obtained by Christiano and Ljungqvist (1988) using U.S. data. This does not, however, mean that the relationship between money and output always exhibits causation running from money to output. It is obvious that such relation may change as a result of changes in the structure of the economy, the formation of expectations, and the reaction of policymakers to changing economic circumstances.

Table 5

Ordinary least squares results based on bivariate time series models reported in table 4

$$\hat{y}_t = 1.911 + 1.107y_{t-1} - 0.505y_{t-2} + 0.160m1_{t-1} \quad R^2=0.968$$

(2.50) (5.40) (-2.61) (1.91)

$$\hat{y}_t = 1.743 + 1.186y_{t-1} - 0.516y_{t-2} + 0.099m2_{t-1} \quad R^2=0.965$$

(1.94) (5.83) (-2.38) (1.40)

$$\hat{m1}_t = 0.689+1.716m1_{t-1}-0.967m1_{t-2}+0.266m1_{t-3}+0.097y_{t-1} \quad R^2=0.996$$

(1.26) (7.85) (-2.49) (1.27) (-0.81)

$$\hat{m2}_t = 0.763+1.349m2_{t-1}-0.136m2_{t-2}-0.340m2_{t-3}+0.124m2_{t-4}-0.089y_{t-1}$$

(0.18) (5.26) (-0.27) (-0.69) (0.54) (-1.02)

$R^2=0.999$

Figures in parentheses are t-ratios

5. Conclusions

This study examines the Granger-causality from money to output in Jordan for the sample period from 1969 through 1991 on the basis of implementation of a FPE methodology. In addition to the FPE criterion, several criteria are also used to determine the lag structure that appears to be sufficient to reflect the interdependence between money and output. Interestingly, the lag structure is found to be the same across different criteria.

Money supply M1 and money supply M2 are used to compare the robustness of the results across different monetary measures. The FPE statistics reveal strong evidence supporting the hypothesis that money Granger-causes output, while the hypothesis that money reacts passively to output is rejected in all cases.

APPENDIX A

Ordinary least squares results based on univariate time series

Regression model	T	r	q	RSS	$\bar{R}^2$
$y/c, y_{t-1}$	22	1	0	0.18213	0.9471
$y/c, y_{t-1} - y_{t-2}$	21	2	0	0.12507	0.9563
$y/c, y_{t-1} - y_{t-3}$	20	3	0	0.12362	0.9462
$y/c, y_{t-1} - y_{t-4}$	19	4	0	0.11742	0.9335
$y/c, y_{t-1} - y_{t-5}$	18	5	0	0.07586	0.9380
$m1/c, m1_{t-1}$	22	1	0	0.12224	0.9925
$m1/c, m1_{t-1} - m1_{t-2}$	21	2	0	0.06752	0.9949
$m1/c, m1_{t-1} - m1_{t-3}$	20	3	0	0.04754	0.9955
$m1/c, m1_{t-1} - m1_{t-4}$	19	4	0	0.04029	0.9958
$m1/c, m1_{t-1} - m1_{t-5}$	18	5	0	0.03988	0.9946
$m2/c, m2_{t-1}$	22	1	0	0.10441	0.9961
$m2/c, m2_{t-1} - m2_{t-2}$	21	2	0	0.03893	0.9982
$m2/c, m2_{t-1} - m2_{t-3}$	20	3	0	0.02806	0.9984
$m2/c, m2_{t-1} - m2_{t-4}$	19	4	0	0.02021	0.9985
$m2/c, m2_{t-1} - m2_{t-5}$	18	5	0	0.01996	0.9979

RSS = sum of squared errors; $\bar{R}^2$ = the adjusted coefficient of determination;

T = total number of observations after subtracting the presample values; r and q denote the lag lengths of F_{ii} and F_{ij} for $i \neq j$, respectively.

APPENDIX B

Ordinary least squares results based on bivariate time series: holding r constant and varying q

Regression model	T	r	q	RSS	$\bar{R}^2$
$y/c, y_{t-1} - y_{t-2}, m1_{t-1}$	21	2	1	0.10297	0.9619
$y/c, y_{t-1} - y_{t-2}, m1_{t-1} - m1_{t-2}$	21	2	2	0.10243	0.9598
$y/c, y_{t-1} - y_{t-2}, m1_{t-1} - m1_{t-3}$	20	2	3	0.10173	0.9494
$y/c, y_{t-1} - y_{t-2}, m1_{t-1} - m1_{t-4}$	19	2	4	0.09537	0.9370
$y/c, y_{t-1} - y_{t-2}, m1_{t-1} - m1_{t-5}$	18	2	5	0.08512	0.9166
$y/c, y_{t-1} - y_{t-2}, m2_{t-1}$	21	2	1	0.11221	0.9585
$y/c, y_{t-1} - y_{t-2}, m2_{t-1} - m2_{t-2}$	21	2	2	0.10844	0.9574
$y/c, y_{t-1} - y_{t-2}, m2_{t-1} - m2_{t-3}$	20	2	3	0.09338	0.9535
$y/c, y_{t-1} - y_{t-2}, m2_{t-1} - m2_{t-4}$	19	2	4	0.09219	0.9391
$y/c, y_{t-1} - y_{t-2}, m2_{t-1} - m2_{t-5}$	18	2	5	0.08044	0.9212
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-1}$	20	3	1	0.04557	0.9953
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-1} - y_{t-2}$	20	3	2	0.04426	0.9951
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-1} - y_{t-3}$	20	3	3	0.04415	0.9947
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-1} - y_{t-4}$	19	3	4	0.03649	0.9938
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-1} - y_{t-5}$	18	3	5	0.03519	0.9910
$m2/c, m2_{t-1} - m2_{t-4}, y_{t-1}$	19	4	1	0.01871	0.9985
$m2/c, m2_{t-1} - m2_{t-4}, y_{t-1} - y_{t-2}$	19	4	2	0.01860	0.9983
$m2/c, m2_{t-1} - m2_{t-4}, yt-1 - y_{t-3}$	19	4	3	0.01860	0.9982
$m2/c, m2_{t-1} - m2_{t-4}, yt-1 - y_{t-4}$	19	4	4	0.01558	0.9983
$m2/c, m2_{t-1} - m2_{t-4}, yt-1 - y_{t-5}$	18	4	5	0.01298	0.9979

APPENDIX C

Ordinary least squares results based on bivariate trime series: holding q constant and varying s.

Regression model	T	s	q	RSS	R^2
$y/c, y_{t-1}, m1_{t-1}$	22	1	1	0.16181	0.9505
$y/c, y_{t-1} - y_{t-2}, m1_{t-1}$	21	2	1	0.10297	0.9619
$y/c, y_{t-1} - y_{t-3}, m1_{t-1}$	20	3	1	0.10158	0.9528
$y/c, y_{t-1} - y_{t-4}, m1_{t-1}$	19	4	1	0.10002	0.9390
$y/c, y_{t-1} - y_{t-5}, m1_{t-1}$	18	5	1	0.07322	0.9348
$y/c, y_{t-1}, m2_{t-1}$	22	1	1	0.17626	0.9461
$y/c, y_{t-1} - y_{t-2}, m2_{t-1}$	21	2	1	0.11221	0.9585
$y/c, y_{t-1} - y_{t-3}, m2_{t-1}$	20	3	1	0.11113	0.9484
$y/c, y_{t-1} - y_{t-4}, m2_{t-1}$	19	4	1	0.10840	0.9339
$y/c, y_{t-1} - yt\text{-}5, m2_{t-1}$	18	5	1	0.07500	0.9332
$m1/c, m1_{t-1}, y_{t-1}$	22	1	1	0.10493	0.9932
$m1/c, m1_{t-1} - m1_{t-2}, y_{t-1}$	21	2	1	0.06541	0.9948
$m1/c, m1_{t-1} - m1_{t-3}, y_{t-1}$	20	3	1	0.04557	0.9953
$m1/c, m1_{t-1} - m1_{t-4}, y_{t1}$	19	4	1	0.03865	0.9944
$m1/c, m1_{t-1} - m1_{t-5}, y_{t-1}$	18	5	1	0.03752	0.9922
$m2/c, m2_{t-1}, y_{t-1}$	22	1	1	0.09890	0.9961
$m2/c, m2_{t-1} - m2_{t-2}, y_{t-1}$	21	2	1	0.03472	0.9983
$m2/c, m2_{t-1} - m2_{t-3}, y_{t-1}$	20	3	1	0.02453	0.9985
$m2/c, m2_{t-1} - m2_{t-4}, y_{t-1}$	19	4	1	0.01871	0.9985
$m2/c, m2_{t-1} - m2_{t-5}, y_{t-1}$	18	5	1	0.01867	0.9978

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