Causality Tests Among High-powered Money, Money Supply and Nominal GNP: the US, 1871–1975 and the UK, 1874–1975*

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I. Introduction

This paper reports some fact findings which are detected by the statistical methods of causality test among high-powered money, money supply and nominal GNP in the US and the UK cases.

We have recently tested the causal relationships among high-powered money, money supply, bank loan and nominal GNP by means of Granger test, Sims test and the decomposition of variance (using VAR model) in the Japanese case. In that case the causal relationship running from money supply to high-powered money was detected by using quarterly data, and it appeared to be the composition of the causal relationship running from money supply to nominal GNP which was asserted by monetarism and that running from nominal GNP to high-powered money of which the most part consisted of cash in circulation, which showed the demand for cash by the public due to the transaction motive.

For the US and the UK some studies about the similar causality tests have been published by other scholars. For example, for the US Moore [11], using quarterly data since the middle of 1960s, found that “Increases in money wage rates... will

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thus lead directly to an increase in the quantity of bank credit demanded, and so to a corresponding increase in bank deposits and in the money stock" (p. 546). Feige and McGee [1] conducted Sims test using weekly data of total reserve and M1 transformed by Box-Jenkins filter for the seven years immediately preceding the 1968 amendments to Regulation D and the seven years immediately following the transition to LRA (the lagged required reserve accounting conventions). And they found that "With respect to the causality issue, for the preamendment period, an examination of columns 1 and 3 shows that we cannot reject, at the 5 percent level, both the hypothesis that money does not cause reserves and the hypothesis that reserves do not cause money... Examination of columns 2 and 4 for the postamendment period reveals that the money supply is exogeneous with respect to total reserves and that money causes reserve" (p.547). On the other hand, Meltzer [10] stated, for the time period from March 1947 to March 1965, that "Evidence from past periods suggests that the monetary base is the most important determinant of the money supply and that there is a high degree of association between the base and the money stock... In the past, 85 percent of the variance of the monthly change in money—currency and demand deposits—resulted from changes in the monetary base and changes in Treasury deposits at commercial bank in the current and previous month" (p. 18). Sims [13] detected the causal relationship running from monetary base to nominal GNP and that running from M1 to nominal GNP for the period 1949 III-1968 IV. In his paper all the variables used in regressions were prefiltered using Nerlove filter 1−1.5L+.5625L2.

For the UK Goodhart [4] analyzed the causal sequence of the equilibrating mechanism of gold standard with monthly data (in Chap. 14) and with weekly data (in Chap. 15). And he stated that "The inference of this finding is that movements in the money supply were adapted, and accommodated, to movements in money incomes, so that the direction of causation ran from increase in incomes to increases in money balances, not vice versa" (p. 11). Williams, Goodhart and Gowland [14] tried Sims test with quarterly data transformed by GLS filter for 1958 I-1971 III and they found some evidence of unidirectional causality running from nominal income to narrow money.

2) For M2 case Meltzer [10] stated "The relation between monthly changes in the monetary base and money plus time deposits is not as good. Nevertheless, more than 75 per cent of the variance of the monthly changes in this monetary aggregate can be controlled by using the base as a target and estimating Treasury deposits as accurately as in the past" (p.19)
These results as so far reviewed were all detected by using short period data such as weekly data, monthly data and quarterly data.

Now we can utilize the long series of the relevant annual data for the US and the UK published in Friedman and Schwartz [2], so that in this paper we will test the causal relationships among high-powered money, money supply and nominal GNP using those annual data for the US and the UK and examine the validity of the monetarist assertion that the causal relationships are running from high-powered money to money supply and from money supply to nominal GNP. Since the data published in Friedman and Schwartz [2] cover the period from the middle of the 19th century to recent time (1869-1975 for the US and 1871-1975 for the UK), we conduct the tests for the whole period, for the period of gold standard system (until 1933 for the US and until 1931 for the UK) and for the succeeding period, that is, the period of managed currency system.

We utilize the data as transformed into the rate of change as compared with the preceding year (See Figure 1 and 2).

The statistical methods of causality test used in this paper are only Granger test and Geweke test. Statistical method of Sims test is not used here. Reference should be made to some comparative studies of the various methods of causality test. Nelson and Schwert [12] found that the most powerful test was Granger test. Geweke, Meese, and Dent [3] found that Granger test and Geweke test were preferred to Sims test. Guilkey and Salemi [6] found that both Granger test and Geweke test were more powerful than Sims test, and they recommended Granger test because this test was computationally the least expensive of the three and resulted in the fewest degrees of freedom lost from formation of lags and leads. Therefore we use only Granger test and Geweke test and don’t use Sims test. And we don’t use the method of decomposition of variance, either. Because the result of that method is very likely to be affected by the change of arrangement order of variables in the decomposition of variance when using annual data which has large coefficients of correlation among contemporaneous residuals.

The length of the lag in Granger test and Geweke test is determined by AIC.

3) Friedman and Schwartz [2] 1982, Table 4.8, pp.122-129 for the US and Table 4.9, pp.130-137 for the UK.
4) Geweke test is a lagged dependent variable version of Sims test introduced in Geweke et al. [3] 1983. But we call it “Geweke test” in this paper.
5) Indeed this time we conducted the method for some cases and found that the results were affected by the change of arrangement order of variables. See also Kobayashi [9] 1987b.
Figure 1. High-powered money, Money Supply and Nominal GNP in the US
(Annual Rate of Change)

Figure 2. High-powered money, Money Supply and Nominal GNP in the UK
(Annual Rate of Change)
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(Akaike’s Informations Criterion). By the method, however, the lag has proved generally not to be so long and 1 period for the lead is used in all cases of this paper.

In Section II the process deriving Sims test from Granger test is explained and in this process Geweke test is explained. In Section III the results of causality test in the US case and in Section IV the results of causality test in the UK case are reported, respectively. And Section V summarizes our findings.

II. The relation among Granger test, Sims test and Geweke test

To begin with, Granger test is conducted as follows.

Consider the simple causal model

\[
\begin{align*}
  x_t &= a_1 x_{t-1} + \ldots + a_p x_{t-p} + b_1 y_{t-1} + \ldots + b_p y_{t-p} + u_{1t} \\
  y_t &= c_1 x_{t-1} + \ldots + c_p x_{t-p} + d_1 y_{t-1} + \ldots + d_p y_{t-p} + u_{2t}
\end{align*}
\]

Under the assumption that \( u_{1t} \) and \( u_{2t} \) are two uncorrelated white-noise series, the definition of Granger causality implies that \( y_t \) is causing \( x_t \) provided that some \( b_k \) is not zero in the first equation of (1). Similarly \( x_t \) is causing \( y_t \) if some \( c_k \) is not zero in the second equation of (1). Therefore in F test of the null hypothesis \( H_0 : b_1 = b_2 = \ldots = b_p = 0 \) against alternative hypothesis \( H_1 : b_k \neq 0 \) for some \( k \) in (1), if the null hypothesis is rejected, it is said that \( y_t \) is causing \( x_t \) and it is denoted as \( y_t \rightarrow x_t \). If the null hypothesis is not rejected, it is said that \( y_t \) is not causing \( x_t \) and it is denoted as \( y_t \not\rightarrow x_t \).

On the other hand, Sims test is based on a distributed lag model

\[
y_t = \sum_{k=0}^{p} h_k x_{t-k} + \epsilon_t \tag{2}
\]

where \( E(x_t, \epsilon_t) = 0 \) must be satisfied for all \( s \) and \( t \) in order that (2) should be a regression model.

Now if we postulate Granger causality \( y_t \rightarrow x_t \), (1) becomes as follows.

\[
\begin{align*}
  x_t &= a_1 x_{t-1} + \ldots + a_p x_{t-p} + u_{1t} \\
  y_t &= c_1 x_{t-1} + \ldots + c_p x_{t-p} + d_1 y_{t-1} + \ldots + d_p y_{t-p} + u_{2t} 
\end{align*}
\]

Generally, however, \( E(u_{1t}, u_{2t}) = \sigma_{12} \neq 0 \), so that \( E(x_t, u_{2t-k}) \neq 0 \). Therefore \( u_{2t-k} (k > 0) \) affects \( x_t \), so that it is inconsistent with the assumption \( y_t \rightarrow x_t \). Hence the model must be change so as to eliminate the correlation between contemporaneous residuals.

If the lower triangle matrix \( T = \begin{bmatrix} 1 & 0 \\ -\sigma_{12}/\sigma_{11} & 1 \end{bmatrix} \) is multiplied to the covariance matrix

\[
\Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{bmatrix}
\]

from right and left hands, we have

\[
T \Sigma T' = \Sigma^* = \begin{bmatrix} \sigma_{11}^* & 0 \\ 0 & \sigma_{22}^* \end{bmatrix}
\]

where \( \sigma_{11}^* = \sigma_{11} - \sigma_{12}^2/\sigma_{11} \).

Multiplying the matrix \( T \) to (3) from left hand, we have

\[
\begin{align*}
\mathbf{x}_t &= \mathbf{a}_1 \mathbf{x}_{t-1} + \cdots + \mathbf{a}_p \mathbf{x}_{t-p} + \mathbf{u}_{1t} \\
-\mathbf{c}_0^* \mathbf{x}_t + \mathbf{y}_t &= \mathbf{c}_1^* \mathbf{x}_{t-1} + \cdots + \mathbf{c}_p^* \mathbf{x}_{t-p} + \mathbf{d}_1 \mathbf{y}_{t-1} + \cdots + \mathbf{d}_p \mathbf{y}_{t-p} + \mathbf{u}_{2t}^* \\
\end{align*}
\]

where

\[
\begin{align*}
-\mathbf{c}_0^* &= -\frac{\sigma_{12}}{\sigma_{11}} \\
\mathbf{c}_1^* &= -\mathbf{c}_0^* \mathbf{a}_1 + \mathbf{c}_1 = -\frac{\sigma_{12}}{\sigma_{11}} \mathbf{a}_1 + \mathbf{c}_1 \\
\mathbf{u}_{2t}^* &= -\frac{\sigma_{12}}{\sigma_{11}} \mathbf{u}_{1t} + \mathbf{u}_{2t}.
\end{align*}
\]

Here we have \( T \mathbf{U}_t = \begin{bmatrix} \mathbf{u}_{1t} \\ \mathbf{u}_{2t}^* \end{bmatrix} = \mathbf{U}_t \), where \( \mathbf{U}_t = \begin{bmatrix} \mathbf{u}_{1t} \\ \mathbf{u}_{2t}^* \end{bmatrix} \).

Now we have

\[
\text{var} \mathbf{U}_t^* = \text{E}((\mathbf{U}_t^*)^T \mathbf{U}_t^*) = T \Sigma T' = \Sigma^*.
\]

There is no correlation between contemporaneous residuals in this case, so that

\[
\text{E}(\mathbf{x}_t \mathbf{u}_{2t}^*) = 0 \text{ for all } s \text{ and } t.
\]

Rearranging the second equation in (4), we have

\[
\begin{align*}
\mathbf{y}_t &= \mathbf{c}_0^* \mathbf{x}_t + \mathbf{c}_1^* \mathbf{x}_{t-1} + \cdots + \mathbf{c}_p^* \mathbf{x}_{t-p} \\
&\quad + \mathbf{d}_1 \mathbf{y}_{t-1} + \cdots + \mathbf{d}_p \mathbf{y}_{t-p} + \mathbf{u}_{2t}^* \\
&\quad + \mathbf{u}_{2t}^* \\
\end{align*}
\]

\[
\begin{align*}
(1 - \sum_{k=1}^{p} \mathbf{d}_k \mathbf{L}^k) \mathbf{y}_t &= \sum_{k=0}^{p} \mathbf{c}_k \mathbf{L}^k \mathbf{x}_t + \mathbf{u}_{2t}^* \\
\mathbf{d}(\mathbf{L}) \mathbf{y}_t &= \mathbf{c}^*(\mathbf{L}) \mathbf{x}_t + \mathbf{u}_{2t}^* \\
\mathbf{y}_t &= \mathbf{d}(\mathbf{L})^{-1} \mathbf{c}^*(\mathbf{L}) \mathbf{x}_t + \mathbf{d}(\mathbf{L})^{-1} \mathbf{u}_{2t}^* \\
\mathbf{y}_t &= \mathbf{h}(\mathbf{L}) \mathbf{x}_t + \mathbf{w}_t
\end{align*}
\]

where

\[
\begin{align*}
(1 - \sum_{k=1}^{p} \mathbf{d}_k \mathbf{L}^k) &= \mathbf{d}(\mathbf{L}), \quad \sum_{k=0}^{p} \mathbf{c}_k \mathbf{L}^k = \mathbf{c}^*(\mathbf{L}) \\
\mathbf{d}(\mathbf{L})^{-1} \mathbf{c}^*(\mathbf{L}) &= \mathbf{h}(\mathbf{L}) = \sum_{k=0}^{p} \mathbf{h}_k \mathbf{L}^k \\
\mathbf{d}(\mathbf{L})^{-1} \mathbf{u}_{2t}^* &= \mathbf{w}_t
\end{align*}
\]

Now \( \mathbf{w}_t \) is expressed by \( \mathbf{u}_{2t}^* \) and \( \mathbf{u}_{2t}^* \) is obviously not correlated to \( \mathbf{x}_t \) by (5).

Therefore (7) is a distributed lag model (a regression model). Hence

if \( \mathbf{y}_t \rightarrow \mathbf{x}_t \), it is expressed by \( \mathbf{y}_t = \sum_{k=0}^{p} \mathbf{h}_k \mathbf{x}_{t-k} + \mathbf{w}_t \).

Then since \( \mathbf{w}_t \) generally has a serial correlation, it is necessary that the data be
appropriately prefiltered by \( d(L) \) to eliminate the serial correlation in Sims test\(^9\). Hence

\[
d(L)y_t = y_t^*, \quad d(L)x_t = x_t^*\]

In this case (7) is transformed into

\[
y_t^* = h(L)x_t^* + u_{t+1}\]

(8)

Then it is Sims test that examines Granger causality by F test on whether added future values of \( x_t^* \) are significant or not in (8). On the other hand, it is Geweke test that examines Granger causality by F test on whether added future values of \( x_t \) are significant or not in (6)\(^{10}\). In both tests if the added future values are not significant, it is said that \( y_t \) does not cause \( x_t \) in the sense of Granger causality \((y_t \rightarrow x_t)\). Geweke test is different from Sims test in respects of the needlessness of prefiltering and the presence of lagged values of the explained variable as explaining variables. And (6) resembles to the second equation in (3), but (6) is different from it in respect of the presence of \( x_t \) as an explaining variable.

### III. Results of causality tests in the US case

1) For the whole period, the results of causality tests in the US case are as follows. (See Table 3.1 and 3.2)

First, as to the causal relationships between high-powered money and money supply, the hypothesis that high-powered money does not cause money supply is rejected at the 5% significance level by Granger test (F value = 3.3942) and at almost

<table>
<thead>
<tr>
<th>Table 3.1 Results of Granger Test for the Whole Period in the US Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis</td>
</tr>
<tr>
<td>F value</td>
</tr>
<tr>
<td>Prob&gt;F</td>
</tr>
<tr>
<td>( \chi^2 )</td>
</tr>
</tbody>
</table>

| Lag | 2 | 2 | 2 |

Notes. H, M and Q denote high-powered money, money supply and nominal GNP, respectively.

** shows that null hypothesis \((y_t \rightarrow x_t)\) is rejected at the level of 1% significance.

** shows that null hypothesis \((y_t \rightarrow x_t)\) is rejected at the level of 5% significance.

* shows that null hypothesis \((y_t \rightarrow x_t)\) is rejected at the level of 10% significance.

9) The appropriate filter is usually detected by some methods so that \( u_t \) becomes a white noise. But it seems that we can directly use \( d(L) \) which is estimated on (1).

the 10% significance level by Geweke test (F value=2.6962). On the other hand, the hypothesis that money supply does not cause high-powered money is rejected at the 10% significance level by Granger test (F value=2.9663), but not rejected even at the 10% significance level by Geweke test (F value=1.6323). Hence the bidirectional causality is detected. However, the causality running from high-powered money to money supply is stronger than the reversed causality with respect to the significance level.

Next, as to the causal relationships between money supply and nominal GNP, the hypothesis that money supply does not cause nominal GNP is rejected at the 5% significance level by both of Granger test (F value=4.5496) and Geweke test (F value=5.2232). On the other hand, the hypothesis that nominal GNP does not cause money supply is rejected at the 10% significance level by Granger test (F value=2.4849) but not rejected even at the 10% significance level by Geweke test (F value=2.4579). Hence the bidirectional causality is detected. However, the causality running from money supply to nominal GNP is stronger than the reversed causality with respect to the significance level.

Lastly, as to the causal relationships between high-powered money and nominal GNP, neither the hypothesis that high-powered money does not cause nominal GNP nor the hypothesis that nominal GNP does not cause high-powered money is rejected even at the 10% significance level, that is, the independent relationship is detected both by Granger test and Geweke test.

The figures of $\chi^2$ row in the tables are $n \cdot R^2$ values for the Breusch-Goodfey test which is the method for testing autocorrelation of residuals over 4th order\(^{11}\). In the test we refer $n \cdot R^2$ values to the $\chi^2$ distribution for 4 degree of freedom and reject the null hypothesis that there is no autocorrelation over 4th order in residuals if a significantly large $n \cdot R^2$ value is found. By the test there is no autocorrelation

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over 4th order in residuals in any cases, because 1% critical value in $\chi^2$ distribution for 4 degrees of freedom is 13.277.

The lags which are determined by AIC are all two periods.

The tests periods are 1872-1975 in Granger test and 1872-1974 in Geweke test.

2) For the period of gold standard system, the results of causality test in the US case are as follows. (See Table 3.3 and 3.4)

Table 3.3 Results of Granger Test for the Period of Gold Standard System in the US Case

<table>
<thead>
<tr>
<th>Ho: H→M</th>
<th>Ho: M+H</th>
<th>Ho: M+Q</th>
<th>Ho: Q→M</th>
<th>Ho: H+Q</th>
<th>Ho: Q→H</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>1.0720</td>
<td>1.1344</td>
<td>4.1529**</td>
<td>0.8236</td>
<td>0.6634</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.3491</td>
<td>0.3288</td>
<td>0.0460</td>
<td>0.3578</td>
<td>0.4186</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>3.4916</td>
<td>3.2480</td>
<td>2.9618</td>
<td>3.7878</td>
<td>0.3245</td>
</tr>
<tr>
<td>Lag</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>1872-1933</td>
<td>1871-1933</td>
<td>1871-1933</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.4 Results of Geweke Test for the Period of Gold Standard System in the US Case

<table>
<thead>
<tr>
<th>Ho: H→M</th>
<th>Ho: M+H</th>
<th>Ho: M+Q</th>
<th>Ho: Q→M</th>
<th>Ho: H→Q</th>
<th>Ho: Q→H</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>1.2361</td>
<td>1.3995</td>
<td>4.6643**</td>
<td>1.9740</td>
<td>0.6452</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.2711</td>
<td>0.2419</td>
<td>0.0349</td>
<td>0.1654</td>
<td>0.4251</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>3.4278</td>
<td>2.2272</td>
<td>4.1890</td>
<td>4.0533</td>
<td>5.5224</td>
</tr>
<tr>
<td>Lag, Lead</td>
<td>2, Lead 1</td>
<td>Lag 1, Lead 1</td>
<td>Lag 1, Lead 1</td>
<td>1972-1933</td>
<td>1871-1933</td>
</tr>
<tr>
<td>Period</td>
<td>1872-1933</td>
<td>1871-1933</td>
<td>1871-1933</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First, as to the causal relationships between high-powered money and money supply, the independent relationship is detected both by Granger test and Geweke test.

Next, as to the causal relationships between money supply and nominal GNP, while the hypothesis that money supply does not cause nominal GNP is rejected at the 5% significance level both by Granger test (F value = 4.1529) and Geweke test (F value = 4.6643), the hypothesis that nominal GNP does not cause money supply is rejected neither by Granger test (F value = 0.8236) nor by Geweke test (F value = 1.9740) even at the 10% significance level. Hence the unidirectional causality running from money supply to nominal GNP is detected.

Lastly, as to the causal relationships between high-powered money and nominal GNP, the hypothesis that high-powered money does not cause nominal GNP is rejected neither by Granger test (F value = 0.6634) nor by Geweke test (F value = 0.6452)
even at the 10% significance level. On the other hand, the hypothesis that nominal GNP does not cause high-powered money is rejected at the 10% significance level by Granger test (F value=2.8713) but not rejected even at the 10% significance level by Geweke test (F value=1.7925). Hence the unidirectional causality running from nominal GNP to high-powered money is detected.

According to the Breusch-Godfrey test there is no autocorrelation over 4th order in residuals in any cases, because 1% critical value in $\chi^2$ distribution for 4 degrees of freedom is 13.27713.

The lags which are determined by AIC are two periods in the cases between high-powered money and money supply and one period in the other cases. Therefore the tested periods of the former cases are 1872-1933 both in Granger test and Geweke test and the tested periods of the latter cases are 1871-1933 both in Granger test and Geweke test.

3) For the period of managed currency system, the results of causality tests in the US case are as follows. (See Table 3.5 and 3.6)

First, as to the causal relationships between high-powered money and money supply.

### Table 3.5 Results of Granger Test for the Period of Managed Currency System in the US Case

<table>
<thead>
<tr>
<th>Ho: $H \rightarrow M$</th>
<th>Ho: $M \rightarrow H$</th>
<th>Ho: $M \rightarrow Q$</th>
<th>Ho: $Q \rightarrow M$</th>
<th>Ho: $H \rightarrow Q$</th>
<th>Ho: $Q \rightarrow H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>4.9054**</td>
<td>0.6788</td>
<td>0.6734</td>
<td>2.6375</td>
<td>2.2498*</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.0321</td>
<td>0.4156</td>
<td>0.4168</td>
<td>0.1124</td>
<td>0.0612</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>5.4348</td>
<td>10.1944</td>
<td>10.7122</td>
<td>5.1832</td>
<td>12.2356</td>
</tr>
<tr>
<td>Lag</td>
<td>Lag 1</td>
<td>Lag 1</td>
<td>Lag 1</td>
<td>Lag 1</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3.6 Results of Geweke Test for the Period of Managed Currency System in the US Case

<table>
<thead>
<tr>
<th>Ho: $H \rightarrow M$</th>
<th>Ho: $M \rightarrow H$</th>
<th>Ho: $M \rightarrow Q$</th>
<th>Ho: $Q \rightarrow M$</th>
<th>Ho: $H \rightarrow Q$</th>
<th>Ho: $Q \rightarrow H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>0.5117</td>
<td>0.8314</td>
<td>1.3368</td>
<td>1.3816</td>
<td>0.0731</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.4760</td>
<td>0.5679</td>
<td>0.2552</td>
<td>0.2475</td>
<td>0.7892</td>
</tr>
<tr>
<td>Lag, Lead</td>
<td>Lag 1, Lead 1</td>
<td>Lag 1, Lead 1</td>
<td>Lag 1, Lead 1</td>
<td>Lag 1, Lead 1</td>
<td>Lag 1, Lead 1</td>
</tr>
</tbody>
</table>

12) Since this test should be conducted for the large sample, it may be useless for the period of gold standard system and for the period of managed currency system, respectively.
supply, the hypothesis that high-powered money does not cause money supply is not rejected even at the 10% significance level by Geweke test (F value = 0.5117) but rejected at the 5% significance level by Granger test (F value = 4.9054). On the other hand, the hypothesis that money supply does not cause high-powered money is rejected neither by Granger test (F value = 0.6788) nor by Geweke test (F value = 0.8314) even at the 10% significance level. Hence the unidirectional causality running from high-powered money to money supply is detected.

Next, as to the causal relationships between money supply and nominal GNP, the independent relationship is detected both by Granger test and Geweke test.

Lastly, as to the causal relationships between high-powered money and nominal GNP, by Granger test the hypothesis that high-powered money does not cause nominal GNP is rejected at the 10% significance level (F value = 2.2498) and the hypothesis that nominal GNP does not cause high-powered money is rejected at the 5% significance level (F value = 3.0084), but by Geweke test the independent relationship is detected. Hence the bidirectional causality is detected. However, the causality running from nominal GNP to high-powered money is stronger than the reversed causality with respect to the significance level.

According to the Breusch-Godfrey test there is no autocorrelation over 4th order in residuals in any cases except Geweke tests of causalities running from nominal GNP to money supply, from high-powered money to nominal GNP and from nominal GNP to high-powered money, because 1% critical value in $z^2$ distribution for 4 degrees of freedom is 13.277.

The lags which are determined by AIC are seven periods in the cases between high-powered money and nominal GNP and one period in the other cases. The tested periods are 1934-1975 in Granger test and 1934-1974 in Geweke test. These results in the US case are compactly depicted in Figure 3.

### IV. Results of causality tests in the UK case

<table>
<thead>
<tr>
<th>Table 4.1 Results of Granger Test for the Whole Period in the UK Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0 : H \rightarrow M$</td>
</tr>
<tr>
<td>F value</td>
</tr>
<tr>
<td>Prob&gt;F</td>
</tr>
<tr>
<td>$z^2$</td>
</tr>
<tr>
<td>Lag</td>
</tr>
</tbody>
</table>
1) For the whole period, the results of causality tests in the UK case are as follows. (See Table 4.1 and 4.2)

<table>
<thead>
<tr>
<th></th>
<th>Ho: H→M</th>
<th>Ho: M→H</th>
<th>Ho: M→Q</th>
<th>Ho: Q→M</th>
<th>Ho: H→Q</th>
<th>Ho: Q→H</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>1.4014</td>
<td>14.3183***</td>
<td>15.0337***</td>
<td>1.0417</td>
<td>6.3436**</td>
<td>3.0129*</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.2395</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.3101</td>
<td>0.0138</td>
<td>0.0865</td>
</tr>
<tr>
<td>x²</td>
<td>4.9179</td>
<td>9.8746</td>
<td>1.8624</td>
<td>1.2125</td>
<td>1.3156</td>
<td>5.8236</td>
</tr>
<tr>
<td>Lag, Lead</td>
<td>Lag 2</td>
<td>Lead 1</td>
<td>Lag 2</td>
<td>Lead 1</td>
<td>Lag 7</td>
<td>Lead 1</td>
</tr>
</tbody>
</table>

First, as to the causal relationships between high-powered money and money supply, while the hypothesis that high-powered money does not cause money supply is rejected neither by Granger test (F value = 2.0544) nor by Geweke test (F value = 1.4014) even at the 10% significance level, the hypothesis that money supply does not cause high-powered money is rejected at the 1% significance level both by Granger test (F value = 9.4202) and Geweke test (F value = 14.3183). Hence the unidirectional causality running from money supply to high-powered money is detected.

Next, as to the causal relationships between money supply and nominal GNP, the hypothesis that money supply does not cause nominal GNP is rejected at the 1% significance level both by Granger test (F value = 6.2478) and Geweke test (F value = 15.0337). On the other hand, the hypothesis that nominal GNP does not cause money supply is rejected at the 5% significance level by Granger test (F value = 3.3194), but not rejected even at the 10% significance level by Geweke test (F value = 1.0417). Hence the bidirectional causality is detected. However, the causality running from money supply to nominal GNP is stronger than the reversed causality with respect to the significance level.

Lastly, as to the causal relationships between high-powered money and nominal GNP, the hypothesis that high-powered money does not cause nominal GNP is rejected at the 1% significance level and the 5% significance level by Granger test (F value = 5.0204) and Geweke test (F value = 6.3436), respectively. On the other hand, the hypothesis that nominal GNP does not cause high-powered money is rejected at the 10% significance level by Geweke test (F value = 3.0129) but not rejected even at the 10% significance level by Granger test (F value = 1.7328). Hence the bidirectional causality is detected. However, the causality running from high-powered money to nominal GNP is stronger than the reversed causality with respect to the significance level.
According to the Breusch-Godfrey test there is no autocorrelation over 4th order in residuals in any cases.

The lags which are determined by AIC are seven periods in the cases between high-powered money and nominal GNP and two periods in the other cases. Therefore the tested periods of the former cases are 1879-1975 in Granger test and 1879-1974 in Geweke test and the tested periods of the latter cases are 1874-1975 in Granger test and 1874-1974 in Geweke test.

2) For the period of gold standard system, the results of causality tests in the UK case are as follows. (See Table 4.3 and 4.4)

### Table 4.3 Results of Granger Test for the Period of Gold Standard System in the UK Case

<table>
<thead>
<tr>
<th>Case</th>
<th>( H_0 : H + M )</th>
<th>( H_0 : M + H )</th>
<th>( H_0 : M + Q )</th>
<th>( H_0 : Q + M )</th>
<th>( H_0 : H + Q )</th>
<th>( H_0 : Q + H )</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>7.8845***</td>
<td>1.0958</td>
<td>7.3111***</td>
<td>4.0839**</td>
<td>12.6338***</td>
<td>1.9165*</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.0002</td>
<td>0.3596</td>
<td>0.0004</td>
<td>0.0114</td>
<td>0.0001</td>
<td>0.0938</td>
</tr>
<tr>
<td>( z^2 )</td>
<td>4.7435</td>
<td>2.2737</td>
<td>9.2273</td>
<td>1.9239</td>
<td>3.7877</td>
<td>4.0120</td>
</tr>
<tr>
<td>Lag</td>
<td>1875-1931</td>
<td>1875-1931</td>
<td>1879-1931</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>Lag 3</td>
<td>Lag 3</td>
<td>Lag 7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4.4 Results of Geweke Test for the Period of Gold Standard System in the UK Case

<table>
<thead>
<tr>
<th>Case</th>
<th>( H_0 : H + M )</th>
<th>( H_0 : M + H )</th>
<th>( H_0 : M + Q )</th>
<th>( H_0 : Q + M )</th>
<th>( H_0 : H + Q )</th>
<th>( H_0 : Q + H )</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>13.2081***</td>
<td>1.0026</td>
<td>28.9326***</td>
<td>0.2457</td>
<td>17.6747***</td>
<td>2.9747*</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.0007</td>
<td>0.3217</td>
<td>0.0001</td>
<td>0.6224</td>
<td>0.0002</td>
<td>0.0932</td>
</tr>
<tr>
<td>( z^2 )</td>
<td>9.6248</td>
<td>10.4903</td>
<td>1.0759</td>
<td>8.7768</td>
<td>3.4349</td>
<td>6.1201</td>
</tr>
<tr>
<td>Lag, Lead</td>
<td>Lag 3, Lead 1</td>
<td>Lag 3, Lead 1</td>
<td>Lag 7, Lead 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>1875-1931</td>
<td>1875-1931</td>
<td>1879-1931</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First, as to the causal relationships between high-powered money and money supply, while the hypothesis that high-powered money does not cause money supply is rejected at the 1% significance level both by Granger test (\( F \) value = 7.8845) and Geweke test (\( F \) value = 13.2081), the hypothesis that money supply does not cause high-powered money is rejected neither by Granger test (\( F \) value = 1.0958) nor by Geweke test (\( F \) value = 1.0026) even at the 10% significance level. Hence the unidirectional causality running from high-powered money to money supply is detected.

Next, as to the causal relationships between money supply and nominal GNP, the hypothesis that money supply does not cause nominal GNP is rejected at the 1%
significance level both by Granger test (F value = 7.3111) and Geweke test (F value = 28.9326). On the other hand, the hypothesis that nominal GNP does not cause money supply is rejected at the 5% significance level by Granger test (F value = 4.0859) but not rejected even at the 10% significance level by Geweke test (F value = 0.2457). Hence the bidirectional causality is detected. However the causality running from money supply to nominal GNP is stronger than the reversed causality with respect to the significance level.

Lastly, as to the causal relationships between high-powered money and nominal GNP, the hypothesis that high-powered money does not cause nominal GNP is rejected at the 1% significance level both by Granger test (F value = 12.8339) and Geweke test (F value = 17.6747) and the hypothesis that nominal GNP does not cause high-powered money is rejected at the 10% significance level both by Granger test (F value = 1.9165) and Geweke test (F value = 2.9747). Hence the bidirectional causality is detected. However, the causality running from high-powered money to nominal GNP is stronger than the reversed causality with respect to the significance level.

According to the Breusch-Godfrey test there is no autocorrelation over 4th order in residuals in any cases.

The lags which are determined by AIC are seven periods in the cases between high-powered money and nominal GNP and three periods in the other cases. Therefore the tested periods of the former cases are 1879–1931 both in Granger test and Geweke test and the tested periods of the latter cases are 1875–1931 both in Granger test and Geweke test.

3) For the period of managed currency system, the results of causality tests in the UK case are as follows. (See Table 4.5, 4.6)

First, as to the causal relationships between high-powered money and money supply, the hypothesis that high-powered money does not cause money supply is

<p>| Table 4.5 Results of Granger Test for the Period of Managed Currency System in the UK Case |
|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|</p>
<table>
<thead>
<tr>
<th>F value</th>
<th>Prob &gt; F</th>
<th>X^2</th>
<th>F value</th>
<th>Prob &gt; F</th>
<th>X^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ho: H → M</td>
<td>2.6197*</td>
<td>3.9520</td>
<td>Ho: H → Q</td>
<td>0.0991</td>
<td>2.9697*</td>
</tr>
<tr>
<td>0.0856</td>
<td>0.0001</td>
<td>0.0011</td>
<td>0.9422</td>
<td>0.5246</td>
<td>0.8650</td>
</tr>
<tr>
<td>14.0126***</td>
<td>3.6880</td>
<td>0.6840</td>
<td>0.6558</td>
<td>7.7600</td>
<td>4.8880</td>
</tr>
</tbody>
</table>
Table 4.6 Results of Granger Test for the Period of Managed Currency System in the UK Case

<table>
<thead>
<tr>
<th>Ho: H→M</th>
<th>Ho: M→H</th>
<th>Ho: M→Q</th>
<th>Ho: Q→M</th>
<th>Ho: H→Q</th>
<th>Ho: Q→H</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>2.2496</td>
<td>26.1949***</td>
<td>2.1612</td>
<td>0.6084</td>
<td>0.1396</td>
</tr>
<tr>
<td>Prob&gt;F</td>
<td>0.1424</td>
<td>0.0001</td>
<td>0.1502</td>
<td>0.3743</td>
<td>0.7108</td>
</tr>
<tr>
<td>χ²</td>
<td>11.6454</td>
<td>8.5998</td>
<td>5.3703</td>
<td>14.6289</td>
<td>8.0418</td>
</tr>
</tbody>
</table>

Lag. Lead Period
Lag 2 Lead 1 1932–1974
Lag 2 Lead 1 1932–1974
Lag 1 Lead 1 1932–1974

rejected at the 10% significance level by Granger test (F value=2.6197) but not rejected even at the 10% significance level by Geweke test (F value=2.2496). On the other hand, the hypothesis that money supply does not cause high-powered money is rejected at the 1% significance level both by Granger test (F value=14.0126) and Geweke test (F value=26.1949). Hence the bidirectional causality is detected. However, the causality running from money supply to high-powered money is stronger than the reversed causality with respect to the significance level.

Next, as to the causal relationships between money supply and nominal GNP, the independent relationship is detected both by Granger test and Geweke test.

Lastly, as to the causal relationships between high-powered money and nominal GNP, the hypothesis that high-powered money does not cause nominal GNP is rejected neither by Granger test (F value=0.0091) nor by Geweke test (F value=0.1396) even at the 10% significance level. On the other hand, the hypothesis that nominal GNP does not cause high-powered money is rejected at the 10% significance level by Granger test (F value=2.9897) but not rejected even at the 10% significance level by Geweke test (F value=0.8943). Hence the unidirectional causality running from nominal GNP to high-powered money is detected.

According to the Breusch-Godfrey test there is no autocorrelation over 4th order in residuals in any cases except Geweke test of causality running from high-powered money to nominal GNP.

The lags which are determined by AIC are one period in the cases between high-powered money and nominal GNP and two periods in the other cases.

The tested periods are 1932–1975 in Granger test and 1932–1974 in Geweke test. These results in the UK case are compactly depicted in Figure 4.

V. Summary

The summary of the results as presented in Sections III and IV above is as follows.

First, in the US case we find for the period of gold standard system that the
Figure 3. Results of the causality tests in the US Case

<table>
<thead>
<tr>
<th>Period</th>
<th>Causality Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>the Whole Period</td>
<td>H ←→ M, M → Q, H → Q</td>
</tr>
<tr>
<td>the Period of Gold Standard</td>
<td>H → M, M → Q, H ← Q</td>
</tr>
<tr>
<td>System</td>
<td></td>
</tr>
<tr>
<td>the Period of Managed</td>
<td>H → M, M → Q, H ← Q</td>
</tr>
<tr>
<td>Currency System</td>
<td></td>
</tr>
</tbody>
</table>

Notes. →→ denotes that the null hypothesis is rejected both by Granger test and Geweke test.

→ denotes that the null hypothesis is rejected by one of them.

→→→→→→→→ denotes that the independent relationship is detected.

→ denotes that null hypothesis is rejected at the 1% significance level.

→→ denotes that the null hypothesis rejected at the 5% significance level.

→→→→→→→→→→ denotes that the null hypothesis is rejected at the 10% significance level.

Figure 4. Results of the causality tests in the UK Case

<table>
<thead>
<tr>
<th>Period</th>
<th>Causality Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>the Whole Period</td>
<td>H ←→ M, M → Q, H → Q</td>
</tr>
<tr>
<td>the Period of Gold Standard</td>
<td>H → M, M → Q, H ← Q</td>
</tr>
<tr>
<td>System</td>
<td></td>
</tr>
<tr>
<td>the Period of Managed</td>
<td>H → M, M → Q, H ← Q</td>
</tr>
<tr>
<td>Currency System</td>
<td></td>
</tr>
</tbody>
</table>

causality is running from money supply to nominal GNP (M→Q) and for the period of managed currency system that it is running from high-powered money to money supply (H→M). Therefore we find for the whole period that the causality is running from high-powered money to money supply and from money supply to nominal GNP (H→M, M→Q) which is the causal relationship asserted by monetarism. In the UK case we find for the period of gold standard system that the causality is running from high-powered money to money supply and from money supply to nominal GNP.
(H→M, M→Q) which is the causal relationship asserted by monetarism, and we find for the period of managed currency system that the causality is running from money supply to high-powered money (M→H). As for the relationship between high-powered money and money supply, F values in the tests of causality running from money supply to high-powered money for the period of managed currency system (M→H) are higher than those in the tests of causality running from high-powered money to money supply for the period of gold standard system (H→M). Therefore we find for the whole period that the causality is running from money supply to high-powered money and from money supply to nominal GNP (M→H, M→Q).

Secondly, as to the relationships between high-powered money and money supply, it is the period of managed currency system in the US case and the period of gold standard system in the UK case when we have causality running from high-powered money to money supply which is asserted by monetarism. The US and the UK had the dominant position in the world economy for the period of managed currency system and for the period of gold standard system, respectively. This suggests that only a country in such a dominant position might be able to control its money supply by autonomously controlling its high-powered money. However, we can’t be sure that such a suggestion holds true without examining into the details. So we will attempt at such an examination in the future.

Thirdly, for the cases in which we detect the causality running from money supply to high-powered money (the whole period in US case, the whole period and the period of managed currency system in UK case), if the significance level is loosened to the 15% level (for the first and third cases), we can have the causality running from money supply to nominal GNP and that running from nominal GNP to high-powered money. Therefore the causality running from money supply to high-powered money, which is detected in this paper, might be explained by the composition of the two causalities, that is, the causality running from money supply to nominal GNP which is asserted by monetarism and that running from nominal GNP to high-powered money of which the most part consists of cash in circulation, which shows the demand for cash by the public due to the transaction motive.

Lastly, in common to both the US and the UK cases we find the causality running from money supply to nominal GNP which is asserted by monetarism for the whole period and for the period of gold standard system, but we cannot find this causality for the period of managed currency system. However, our tests do not cover the most recent periods of the Reagan administration in the US and the Thatcher
government in the UK of which both are said to have adopted the policy of monetarism. The causality tests for those periods are very interesting, so we will conduct them in near the future.

References


