Reexamination of Empirical Studies Using Granger Causality – "Causality" Between Money Supply and Nominal Income –*

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I. Introduction

The causal relationship between money and nominal income has always attracted interest as one of the most important empirical issues in macroeconomics. Numbers of studies have appeared in the literature since 1970.

Of these, Sims (1972) has had the most significant impact. Sims tests between money and income presented in his paper depend upon the concept of "Granger Causality". The tests have stimulated the introduction of various new analytical methodologies, including the variance decomposition, and relative power contribution analysis. However, Granger Causality itself is a concept merely based on "predictability". While Granger Causality is an important concept, the notion can lead to paradoxical conclusions if it is interpreted as causality in the usual sense. Granger himself has given appropriate warning regarding the conceptualization of this term. Still, analyses are often performed by regarding Granger Causality as simply one of the necessary conditions for usual causality.

This paper is an attempt to ascertain the significance and limitations of an empirical test which incorporates "Granger Causality" as in recent analyses of the

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"causal relationship" between money and income, especially in the U.S. and Japan. The present paper is comprised of four sections (II-V).

In II, the empirical analyses of money-income causality conducted since the late 1960s are reviewed. After introducing the debate between Tobin (1970) and Friedman (1970) on the intuitive content of Granger Causality, Granger's own reservation are introduced. Then, in III, we discuss the Sims Test (1972), which led Sims to maintain unidirectional causality running from money to nominal income in the U.S. economy. In IV, we examine Sims' later work (1980) based on a method known as "variance decomposition," which led to a rejection to the earlier conclusions.

In Sections III and IV, two types of problems found in studies employing the concept of Granger Causality are evaluated: first, the difficulties of interpretation arising from conceptual problems in III, and the robustness of test results under alternative procedures in IV. In III, we clarify some of the conceptual difficulties involved in Granger Causality by using hypothetical simple models. In IV, in examining the robustness of Granger Causality test, the results of Feige and Pearce (1979) are briefly reviewed. In that study, it is indicated that Granger Causality between the two variables is significantly influenced by:

1) Selection of the test procedures (either the Sims Test or Granger Test, etc.);
2) Selection of a filter required for stationarity;
3) Selection of the lag length of variables;
4) Choice between seasonally-adjusted and original data.

In Section V, empirical tests of Granger Causality between money and nominal income in the Japanese economy are reviewed. The empirical results are indeed subject to the influence of the testing procedures, as claimed in Section IV. This is illustrated by: (1) comparing empirical studies which employed a bivariate time series model and (2) comparing the two empirical results which employed a VAR methodology.

The conclusion can be found in Section VI. We argue that it is necessary to consider the nature of the statistical assumptions and of the null hypotheses when interpreting tests of Granger Causality.

II. Empirical Tests of Causality Between Money and Nominal Income — Review since the End of the 1960s —

The causal relationship between money and nominal income has attracted broad attention, ever since competing Keynesian and monetarist approaches divided the theoretical framework of macroeconomics.

Since Sims (1972) first utilized bivariate stationary time series in studying causality, analyses based on the concept of Granger Causality have predominated among studies of the money-income nexus. Prior to Sims' work, attention focused on the turning points of money and income (or their rates of change) in a time series. The Tobin-Friedman controversy of 1970 based on this approach is considered first in this section, followed by the studies of Granger (1969) and Sims (1972), and subsequent developments.

(1) Tobin-Friedman Controversy

Friedman and his associates, for example, Friedman and Schwartz (1963) turned their attention to the leads and lags between the turning points of money stock and those of nominal income. Much of their efforts were devoted to show that "the turning points in the rate of change of money supply show a long lead and turning points in the money stock itself (relative to trend), a shorter lead over the turning points of nominal income." Assuming that Friedman and others regard this as the basis for claiming that "changes in the supply of money are the principal cause of changes in money income," Tobin (1970) made the following criticisms:

1) The discovery of such a timing evidence does not constitute a proof of the monetarist-type of causality. This is because identical timing evidence is consistent with the adoption by authorities of an accommodating policy designed to maintain a fixed level of interest rates.[1]

2) Conversely, it is possible to demonstrate that this sort of timing evidence would not emerge from the Friedman model.

Friedman (1970) cited the following reasons in rejecting Tobin's criticisms:

1) Since there is no unambiguous way to count causes, the only way to assure that changes in the supply of money are the "principal cause," with no further qualification, would be for them to account for more than half of the variance of all changes in money income — from minute to minute, day to day, month to month, and so on — for periods of all durations. Friedman argued that changes in the supply of money have accounted for more than half the variance of money income for reasonably long periods and for changes measured over intervals of a year or more, but not for all periods and all intervals.

2) Friedman agreed that timing evidence is limited as "empirical proof" of the independent influence of money.

3) Friedman argued that while timing relations do not provide decisive evidence on the direction of influence, they are important for determining policy effects. If, for example, money exerts an independent influence on income, the use of that proposi-

1. To demonstrate this point, Tobin constructed what he calls the "ultra-Keynesian" model in which the money supply endogenously changes to maintain interest rates at a fixed level. Tobin uses this model to investigate the correlation between the turning points of the related variables.

tion for either policy or prediction depends critically on knowing what the relation between money and income is, and especialy on that lags are involved. Similarly, the lag between monetary changes and their effects is critical for the kind of monetary policy that is possible and desirable. Friedman argued against discretionary policy on the belief that the lags are long and variable. He also indicated that failure to allow for lags between monetary changes and income changes would bias any estimates of relations between the two and give a misleading impression of the closeness of the relation.

4) Friedman argued that (Tobin's) examples are largely irrelevant and that the results were achieved by caricaturizing his views and employing inappropriate specifications. What is noteworthy about the Tobin-Friedman debate is that both (a) demonstrate the importance of the model in interpreting the timing evidence and (b) express necessary reservations against regarding the timing relation as decisive evidence of causality.

(2) Granger Causality

The year before the Tobin-Friedman debate, Granger (1969) advanced the "causality" concept known as Granger Causality. Granger's definition of "causality" is as follows:

"If A_t is a stationary stochastic process, let $\bar{A}_t$ represent the set of past values $\{A_{t-j}, j = 1, 2, \ldots, \infty\}$ and $\bar{\bar{A}}_t$ represent the set of past and present values $\{A_{t-j}, j = 0, 1, \ldots, \infty\}$.

Denote the optimum, unbiased, least-squared predictor of A_t using the set of values B_t by $P_t(A|B)$. Thus, for instance, $P_t(X|\bar{X})$ will be the optimum predictor of X_t using only past X_t. The predictive error series will be denoted by $\varepsilon_t(A|B) = A_t - P_t(A|B)$. Let $\sigma^2(A|B)$ be the variance of $\varepsilon_t(A|B)$. Let U_t be all the information in the universe accumulated by time $t-1$ and let $U_t - Y_t$ denote all this information apart from the specified series Y_t. We then have the following definitions.

Definition 1: Causality. If $\sigma^2(X|U) < \sigma^2(X|\overline{U-Y})$, we say that Y is causing X, denoted by $Y_t \overset{G}{\rightarrow} X_t$.[2] We say that Y is causing X if we are better able to predict X using all available information than if the information apart from Y had been used.

Definition 2: Feedback. If

$$\sigma^2(X|\bar{U}) < \sigma^2(X|\overline{U-Y}),$$
$$\sigma^2(Y|\bar{U}) < \sigma^2(Y|\overline{U-X}),$$

2. Instead of $Y_t \overset{G}{\rightarrow} X_t$ and $Y_t \overset{G}{\leftrightarrow} X_t$, $Y_t \Rightarrow X_t$ and $Y_t \Leftrightarrow X_t$ are used in the original paper.

we say that feedback is occurring, which is denoted $Y_t \overset{G}{\leftrightarrow} X_t$, i.e., feedback is said to occur when X_t is causing Y_t and also Y_t is causing X_t (Granger (1969) P.428).

In proposing these concepts, Granger (1969) noted a number of important reservations. Let us cite four of Granger's caveats and comment upon them.

(i) The definitions have assumed that only stationary series are involved. In the nonstationary case, $(X|\overline{U})$ etc. will depend on time t and, in general, the existence of causality may alter over time (op. cit. p.429). In fact, almost all economic data are nonstationary. Therefore, the choice of pre-filtering technique becomes very important in practice.

(ii) The one completely unreal aspect of the above definitions is the use of the series U_t, representing all available information. The large majority of the information in the universe will be quite irrelevant, that is, will have no causal consequence. Suppose that all relevant information is numerical in nature and belongs to the vector set of time series $Y_t^D = \{ Y_t^i, i \in D \}$ for some integer set D. The definition of causality is now relative to the set D. If relevant data has not been included in this set, then spurious causality could arise. For instance, if the set D was taken to consist only of the two series X_t and Y_t, but in fact there was a third series Z_t which was causing both within the enlarged set $D' = (X_t, Y_t, Z_t)$, then for the original set D, spurious causality between X_t and Y_t may be found. This is similar to spurious correlation and partial correlation between sets of data that arise when some other statistical variable of importance has not been included (op. cit. p.429). This implies that we must distinguish "true Granger Causality" from "D-dependent Granger Causality".

(iii) It has been pointed out already that instantaneous causality, in which knowledge of the current value of a series helps in predicting the current value of a second series, can occasionally arise spuriously in certain cases. Suppose $Y_t \overset{G}{\rightarrow} X_t$ with lag one unit but that the series are sampled every two time units. Then although there is no real instantaneous causality, the definitions will appear to suggest that such causality is occurring. This is because certain relevent information, the missing readings in the data, have not been used. Due to this effect, one might suggest that in many economic situations an apparent instantaneous causality would disappear if the economic variables were recorded at more frequent time intervals (op. cit. p.430).

(iv) The definition of causality used above is based entirely on the predictability of some series, say X_t. If some other series Y_t contains information in past terms that helps in the prediction of X_t and if this information is contained in no other series used in the predictor, then Y_t is said to cause X_t. It also follows from the definitions that a purely deterministic series, that is, a series which can be predicted exactly from its past terms such as a nonstochastic series, cannot be said to have any causal influences other than its own past. (op. cit. p.430).

These reservations introduced by Granger[3] will be examined in this paper in the context of a survey of empirical tests of causality between money and income.

(3) Test of the Monetarist Hypothesis by Sims (1972)

In testing the monetarist hypothesis (that causality is unidirectional from money to income), Sims (1972) adopted a procedure involving the use of bivariate stationary time series (consisting of money supply and nominal income). Known today as the Sims Test, Sims' research was based on the following theorem:

> "Theorem: Consider the jointly covariance-stationary, linearly indeterministic, pair of stochastic processes X and Y. Then, when $\begin{bmatrix} X \\ Y \end{bmatrix}$ has an autoregressive representation, Y can be expressed as a distributed lag function of current and past X with a residual which is not correlated with any values of X, past or future, if and only if, Y does not cause X in Granger's sense (op. cit. pp.544-545)".

On the basis of this theorem, after prefiltering data to remove the nonstationary features of money stock (M) and nominal income (Y), Sims estimated ($n_1=4$, $n_2=8$) the following regression equations;

$$M_t = \sum_{i=-n_1}^{n_2} \alpha_1 Y_{t-1} + u_t$$

$$Y_t = \sum_{i=-n_1}^{n_2} \beta_1 M_{t-1} + v_t$$

As a result, since the F value of future coefficients of nominal GNP in the money regression equation was significant but that of money stock in the nominal GNP equation is not (Table 1). Sims concluded, "the evidence agrees quite well with a null hypothesis that causality runs entirely from money to GNP without a feed-back."

Sims (1972) spawned a number of similar studies. In Japan, for example, Oritani (1979) obtained comparable results using Sims' filter for seasonally-adjusted M2 and nominal GNP (see V for details).

Criticisms on Sims (1972) can be roughly divided into two categories. The first line of criticism, conceptual in nature, involved problems related to the selection of information set D a la Granger (1969). For example, Ando (1977) insisted that the causal relationships among economic variables are so complicated that nothing substantial could be said by formulating a bivariate time series.

The second line of criticism, admitting the basic assumption of the causal relationship between money and income can be discussed within the context of a bivariate time series set-up, concerns the robustness of the Sims' result with respect to

3. In his interpretation of correlation coefficients in a simultaneous equation system, Simon (1954) reached conclusions similar to these.

Table 1 F-Tests on Four Future Quarters' Coefficients

Regression Equation	F
GNP on M1	0.36
GNP on MB	0.39
M1 on GNP	4.29*
MB on GNP	5.89*

Note: * Significant at 0.05 level
All tests apply to regressions run over the full sample and are assumed distributed as F(4, 60).
Source: Sims (1972)

testing procedure. Feige and Pearce (1979) presented this line of argument, which will be discussed later. In what follows, the results of the variance decomposition methodology used by Sims (1980) are introduced in response to the first line of criticism.

(4) Investigating Granger Causality with Variance Decomposition

First, the idea of variance decomposition used in Sims (1980) is explained in a tri-variate vector autoregressive model.

Consider the following stationary stochastic process.

$$\begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} = A_1 \begin{bmatrix} x_{t-1} \\ y_{t-1} \\ z_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} x_{t-2} \\ y_{t-2} \\ z_{t-2} \end{bmatrix} \cdots\cdots + A_m \begin{bmatrix} x_{t-m} \\ y_{t-m} \\ z_{t-m} \end{bmatrix} + \begin{bmatrix} u_t^x \\ u_t^y \\ u_t^z \end{bmatrix}$$

As (s = 1, ..., m) is the 3 × 3 coefficient matrix and u_t^j (j = x, y, z) is an i.i.d. disturbance term. Assuming that the process is invertible, the following moving average representation is obtained:

$$\begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} = \begin{bmatrix} u_t^x \\ u_t^y \\ u_t^z \end{bmatrix} + B_1 \begin{bmatrix} u_{t-1}^x \\ u_{t-1}^y \\ u_{t-1}^z \end{bmatrix} + B_2 \begin{bmatrix} u_{t-2}^x \\ u_{t-2}^y \\ u_{t-2}^z \end{bmatrix} + \cdots\cdots$$

By converting to a moving average representation, the realized value of a variable can be decomposed into a "weighted sum of the past innovations of all other variables" and a "weighted sum of the past and current innovations of the variable concerned". Then, the prediction root mean squared errors of a variable generated by this model can be decomposed into the innovation variances unique to that variable and those due to other variables. If the prediction errors are mainly attributable to the former, we may be able to interpret that the variable is not caused by other variables in the Granger's sense. In contrast, if most of the prediction errors of the variable in question are explained by the innovation variance of other variables, they may have substantial influence on the former variable in the Granger's sense.

In actual estimation, Sims used two lists of variables; first, a list consisting of 3 variables — production, M1 and WPI; and second list, consisting of four variables including short-term interest rates. The results are shown in Tables 2 and 3. Looking at the variance decomposition using the 3 variables in the first list (Table 2), it is apparent that the exogenity of M1 is extremely high both in inter- and post-war periods, and also, M1 is causing production in the Granger's sense. However, in the list of variables including interest rates (Table 3), a completely different image emerges: whereas the exogenity of M1 declines significantly and its influence on production sharply declines, the exogenity of interest rates is high and both M1 and production are "caused" by them.

Sims (1980), confronted with this result, attempted a number of monetarist interpretations but decided that they were all unfeasible and abandoned the monetarist approach, concluding:

"While there are potential monetarist explanations for such an observation,

Table 2 Three-Variable Innovation Accounting: Percentages of 48-Month Forecast-Error Variance Explained (Interwar/Postwar)

Variables Explained	By Innovations in		
	M1	IP	WPI
M1	92/97	4/2	4/1
IP	66/37	28/44	6/18
WPI	38/14	19/7	43/80

Note: M1=Money Stock; IP=Industrial Production;
WPI=Wholesale Price Index.

Source: Sims (1980)

Table 3 Four-Variable Innovation Accounting Percentages of 48-Month Forecast-Error Variance Explained (Interwar/Postwar)

Variables Explained	By Innovations in			
	R	M1	WPI	IP
R	63/50	28/19	7/4	1/28
M1	39/56	58/42	1/1	1/1
WPI	1/2	54/32	43/60	3/6
IP	16/30	58/4	7/14	18/52

Note: See Table 2 R = Short-Term Interest Rate.
Source: Sims (1980)

none of them seem to fit comfortably the estimated dynamics. A nonmonetarist explanation of the dynamics, based on the role of expectations in investment behavior, seems to fit the estimated dynamics better. That this explanation, which is consistent with a passive role for money, could account for so much of the observed postwar relation between money stock and income may raise doubts about the monetarist interpretation even of the interwar date." (Sims op. cit. p.250)

However, a comparison of Table 2 and Table 3 reveals that; 1) although the exogenity of M1 has declined considerably as a result of adding the independent variable of interest rates, the influence of M1 on WPI is actually increasing; 2) it is, therefore, premature to jump to the conclusion that the importance of money is spurious and that the monetarist hypothesis that "money causes nominal income" should be abandoned. What is noteworthy here is the reconfirmation that results differ significantly, depending on whether variables are added or removed from a system. In other words, the selection of variables (a la Granger, information Set D) is of crucial importance in using the concept of Granger Causality to detect the causality of an economic system.

III. Economic System and Granger Causality

In this section, as a matter of convenience, we call the model in which interest rates cause income "Keynesian", and the model in which money stock causes income "monetarist". According to this line of thought, the development from Sims (1972) to Sims (1980) can be interpreted as a case where the nature of alternative hypothesis (the Keynesian hypothesis in which interest rates should be included in the system) was not explicitly taken into account in testing. In other words, the selected information set inappropriately excluded a variable which is important in an alternative hypothesis.

The problems resulting from the use of the concept of Granger Causality, including the selection of an appropriate information set, can be distinguished into the following four categories:

(1) Selection of an Information Set and Granger Causality

First, the world of a simple "non-monetarist model" is assumed; where the transmission mechanism is,

Money supply → Interest rates → Income

(Case 1)

$$M_t = u_t \quad (1)$$
$$r_t = bM_{t-1} + v_t \quad (2)$$
$$Y_t = ar_{t-1} + w_t \quad (3)$$

where,

M_t : Money in period t

r_t : Interest rates in period t

Y_t : Nominal income in period t

u_t, v_t, and w_t are assumed to be mutually independent white noise (also, M, r, and Y are assumed to be stationary). By eliminating the interest rates from (2) and (3), the system would be

$$Y_t = a\,b\,M_{t-2} + a\,v_{t-1} + w_t \quad (4)$$
$$M_t = u_t \quad (1)$$

In this system, since the past value of the money supply increases the predictability of income, while the reverse is not the case,

$$M_t \overset{G}{\rightarrow} Y_t$$
$$Y_t \overset{G}{\nrightarrow} M_t$$

it appears that "the unidirectional causality runs from money to income is recognized (the monetarist hypothesis is supported)".

However, it is apparent that information concerning the past values of the money does not increase the accuracy of income prediction when information on the past values of interest rates is available:

$$r_t \overset{G}{\rightarrow} Y_t$$
$$M_t \overset{G}{\nrightarrow} Y_t$$

Also,

$$Y_t \overset{G}{\nrightarrow} M_t$$
$$Y_t \overset{G}{\nrightarrow} r_t$$

Thus, Granger Causality testing in this case depends substantially on whether the interest rates are added to the system or not. The "monetarist hypothesis" stresses the importance of the relationship between money and income. If we regard the alternative "Keynesian hypothesis" to be a hypothesis which attaches importance to interest rates, it should be obvious that the test of a "monetarist hypothesis", which omits interest rates from its system, does not take proper account of the alternative "Keynesian hypothesis".

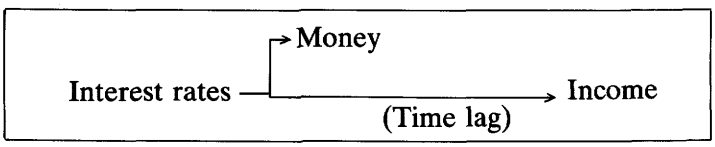
(2) Distinction between "Indirect Causes" and "Spurious Causes"

There is another point that should be noted from the example of the model just presented; while money supply does not cause income in the Granger's sense on the basis of a trivariate system, money does "cause" income indirectly.

To further this understanding, consider the world of an "anti-monetarist model":

$$r_t = v_t \qquad (2)'$$
$$M_t = br_{t-1} \qquad (1)'$$
$$Y_t = ar_{t-2} + w_t \qquad (3)'$$

where the real transmission mechanism is



(Case 2)

If the interest rates are omitted from (1)′ and (3)′ ,

$$Y_t = ab\, M_{t-1} + w_t \qquad (4)'$$

Therefore, if attention is directed only to the relation between income and money,

$$M_t \overset{G}{\rightarrow} Y_t$$
$$Y_t \overset{G}{\nrightarrow} M_t$$

By contrast, if (1)′ − (3)′ is considered,

$$r_t \overset{G}{\rightarrow} Y_t$$
$$M_t \overset{G}{\nrightarrow} Y_t$$
$$Y_t \overset{G}{\nrightarrow} r_t$$
$$Y_t \overset{G}{\nrightarrow} M_t$$

so that, the direction of Granger Causality here is exactly the same as in Case 1. However, in this hypothetical case, money does not cause income in the usual sense. In this case, causality is completely spurious and does not reflect usual causality. In other words, Case 1 (non-monetarist model) and Case 2 (anti-monetarist model) are completely different in terms of their true transmission mechanisms, but the direction of Granger Causality turns out to be quite similar. Obviously, the distinction between "direct", "indirect", and "spurious" causes is important in evaluating the Granger Causality between variables and the essence of the system may be lost unless this is taken into account.

There are several studies which attempt to distinguish "spurious causality" from "direct/indirect causality", such as Hsiao (1982), Lütkepol (1980), Kunitomo and Yamamoto (1985).

Let us examine the points made in these papers by using a classical model based on Hsiao (1982).

Consider the hypothetical macroeconomic model,

$$Y_t = a(M_{t-1} - E_{t-2} M_{t-1}) + w_t$$
$$M_t = a\, r_{t-1} + v_t$$
$$r_t = w_t$$

The income equation is a variant of the Lucas-Barro type, while the money equation can be interpreted as a reaction function designed to stabilize interest rates (E_t is expectation operator). Assuming rational expectations, we get $E_{t-1} M_t = a\, r_{t-1}$. In this system, only innovations of income and money affect income, despite the fact that income is caused by money, which is, in turn, caused by the interest rates. This point becomes clear by using the MA representation of the system.

$$\begin{aligned} Y_t &= a\, v_{t-1} + u_t \\ M_t &= a\, w_{t-1} + v_t \\ r_t &= w_t \end{aligned}$$

However, the AR representation of the system,

$$\begin{aligned} Y_t &= a\, M_{t-1} - a^2 r_{t-2} + u_t \\ M_t &= a\, r_{t-1} + v_t \\ r_t &= w_t \end{aligned}$$

suggests that the interest rates cause income. This is because the interest rates are useful to "estimate" the innovation of money. In other words, the unidirectional Granger Causality running from the interest rates to income in this system is spurious in the usual sense.

Hsiao formally introduced the notions of "indirect causality" and "spurious causality" in the trivariate system to distinguish among these phenomena. However, it is difficult to develop the typology of causality which Hsiao proposed, if a system consists of more than 3 variables. Instead of pursuing this line of investigation, Kunitomo and Yamamoto (1985) proposed a more practical approach for the general multi-variate time series model; to estimate the model with both the AR representation and the MA representation. They argue that if we do not have any conflicts from the 2 different representations of the estimated time series model with respect to some variables in the system, then it is appropriate to use the term of causality for that variable in particular.

Kunitomo and Yamamoto applied this testing procedure to the analysis of a set of Japanese macroeconomic (quarterly) data. As might be expected, the estimated multi-variate time series model for the Japanese macroeconomy illustrates the possibility of conflict between the AR representation and the MA representation.

(3) Policy Rules and Granger Causality

Policy rules further affect the interpretation of causality tests.

Consider a model in which the authorities will act to maintain a certain interest rate. If the rate is a function of the ratio of nominal income to money,

$$i_t = f(M_t / Y_t) \tag{5}$$

Then, a policy maintaining the interest rates at a fixed level i* would be,

$$\frac{M_t}{Y_t} = f^{-1}(i^*) \tag{5$'$}$$

From this, the policy rule that the monetary authorities take would be,

$$M_t = mY_t \qquad \text{(where } m = f^{-1}(i^*)) \qquad (5)''$$

But, if the reaction of authorities has some lags and if its control over money supply is not complete,

$$M_t = mY_{t-1} + u_t \qquad (5)'''$$

is a more realistic description of this system.

Meanwhile, assuming that a monetarist type of relationship exists between income and money as shown below,

$$Y_t = bM_t + w_t, 0<b<1. \qquad (6)$$

In this case, information concerning the past value of income improves predictions of money supply, but since the reverse is not obtained,

$$M_t \overset{G}{\not\rightarrow} Y_t$$
$$Y_t \overset{G}{\rightarrow} M_t$$

Table 4 Granger Causality and Transmission Mechanism – Trivariate Macroeconomic System (Hypothetical)

	Case 1. Non-monetarist	Case 2. Anti-monetarist	Case 3. Fixed Interest Policy
Structure of Hypothetical Economy	$M_t = u_t$ $r_t = bM_{t-1} + v_t$ $Y_t = ar_{t-1} + w_t$	$r_t = v_t$ $M_t = \frac{1}{b} r_{t-1} + u_t$ $Y_t = ar_{t-2} + w_t$	$M_t = mY_{t-1} + u_t$ (Policy Rule) $Y_t = bM_t + w_t$ (0<b<1)
Transmission Mechanism	$M \rightarrow r \rightarrow Y$	$r \rightarrow M$ $r \longrightarrow Y$ (Time Lag)	$M \rightarrow Y$
Granger Causality With Two Variables (Y and M)	$M \overset{G}{\rightarrow} Y$ (Indirect Cause)	$M \overset{G}{\rightarrow} Y$ (Spurious Cause)	$M \overset{G}{\leftarrow} Y$
Granger Causality With Three Variables (Y, M and r)	$M \overset{G}{\rightarrow} r$, $r \overset{G}{\rightarrow} Y$	$r \overset{G}{\rightarrow} M$, $r \overset{G}{\rightarrow} Y$	
Notes	$\rightarrow$: Transmission Mechanism $\overset{G}{\rightarrow}$: Granger Causality		Policy makers control M to maintain interest rates at a certain level

Namely, income in this system causes money when considered from the perspective of Granger Causality.[4]

Table 4, which summarizes the discussion, clearly shows that, even in a hypothetical trivariate system consisting only of income, money and the interest rates, it is necessary to exercise extreme caution interpreting Granger Causality of the system.

(4) Granger Causality in an Efficient Market

While the concept of Granger Causality was initially applied to the relation between money and nominal GNP, it has been employed recently, in the analysis of asset prices, such as exchange rates. In this section, we indicate why extreme caution must be paid to interpret Granger Causality tests regarding asset prices, taking exchange rates as an example.

If the foreign exchange market is efficient and market participants are risk neutral, a rise in the expected future exchange rate should be accompanied by an increase in the spot rate, due to arbitrage. In other words, we have uncovered interest parity;

$$E_t e_{t+s} - e_t = i_t - i_t^*, \quad s > 0 \tag{13}$$

Where e_j: logarithum of yen-denominated exchange rate at j
i_t: Japanese interest rates in t
i_t^*: foreign interest rates in t

In this case, the innovation with respect to the exchange rate,

$$u_{t+s} = e_{t+s} - E_t\tilde{e}_{t+s} \tag{14}$$
$$(\text{where } E_t\tilde{e}_{t+s} = \tilde{e}_t + i_t - i_t^*)$$

should be unpredictable, given the information set at time t. Otherwise, an unexploited profit opprtunity would exist, contradicting the assumption of an efficient market. In this case, then, even if the exchange rate level is affected by the purchasing power parity and other factors, future spot exchange rates may be predicted merely by noting the current spot exchange rate and the interest rates. This means that exchange rates would become exogenous in the Granger's sense, against other factors.

4. A detailed study of policy rules based on a more general multi-variate rational expectation model is found in Buiter (1984).

These possibilities have already been pointed out by Sims (1977) in the context of the analysis of durable goods prices. Sims (1977) pointed out the possibility that, even if prices of durable goods were to pass Sims and other exogenity tests, that may be indicative of spurious exogenity brought about by the nature of the efficient market, and proposed the following checking procedure: If a market is of a type where arbitrage works perfectly, prices should not only be exogenous but should also meet the arbitrage conditions unique to an efficient market. If those conditions are not met, the market is not efficient and it is possible to interpret that the exogenity of the price variable is not spurious.

However, Sims' procedure would be inappropriate if the risk premium ignored in (13) is of significant importance. Imagine that while the exchange market is efficient, its participants are risk averse and require risk premiums. Then, the interest arbitrage condition including the risk premium becomes,

$$E_t e_{t+s} - e_t = i_t - i_t^* + \phi_t(\cdot) \qquad (13)'$$

(where, $\phi_t(\cdot)$ is the risk premium for t)

Even in this case, since all unexploited profit opportunity are eliminated by arbitrage, it should also be impossible to predict innovation u_t, given the information set at time t.

But, the interest arbitrage condition (13) has not been satisfied here. When (13) is rejected, it is difficult to determine whether this was the result of the efficient market hypothesis being rejected or because risk neutrality does not hold. Consequently, it is extremely difficult to determine the relationship between the exchange rates and other variables on the basis of Granger Causality.

The above categories, (1) – (4) demonstrate the importance of;

1) the range of variables included in a system,
2) the distinction between indirect and spurious cases,
3) the policy rules,
4) the interpretation of the market mechanism included in a system.

IV. The Robustness of Granger Causality under Alternative Testing Procedure

In the previous section, the conceptual problems of Granger Causality are discussed. In this section, the robustness of Granger Causality under alternative testing procedures is examined.

(1) Feige and Pearce (1979)

After accepting Sims (1972) assumption that the causality of money and nominal GNP can be investigated within the bivariate time series framework, Feige and Pearce (1979) raised the following questions:

1) To what extent are the results of the Sims test different from those of the direct Granger test and the Pierce and Haugh test?[5]

2) When Sims uses pre-filter $(1 - kL)^2$ in generating a stationary time series, he a priori selects the value k = 0.75. To what extent does the selection of this pre-filtering affect the result?

3) In the distributed-lag-type regression equation;

$$M_t = \sum_{l=-n_1}^{n_2} \alpha_l Y_{t-l} + u_t$$

$$Y_t = \sum_{l=-n_1}^{n_2} \beta_l M_{t-l} + v_t$$

which serves as the basis of the Sims Test, Sims selects the values $n_1 = 4$ and $n_2 = 8$. To what extent is Granger Causality testing affected by the selection of the length of the lags (or leads) among these variables?

4) Sims used seasonally-adjusted data. To what extent are the results of the analysis affected by the adjustment of seasonality?

Feige and Pearce (1979) compared the test results of Granger Causality between money and nominal GNP on the basis of various alternative assumptions. Their results can be roughly summarized as follows:

1) The Pierce and Haugh test consists of two steps. First, an ARIMA model is estimated for each series and then used to compute the sample innovations. Second, these estimated innovations are used to calculate a sample cross-correlation function from which inferences about the population cross-correlation function are made. The test results are summarized in Table 5 and 6. Because the S-statistic exceed the critical χ^2 value at the 5% significance level in only one case, Feige and Pearce could not reject the hypothesis that the income and money aggregates are independent.

2) The direct Granger Test uses the autoregressive representation given by

$$X_t = \sum_{i=1}^{T} \alpha_i X_{t-i} + \sum_{i=1}^{T'} \beta_i Y_{t-i} + u_t$$

Under the null hypothesis that Y does not cause X, $\beta_i = 0$ for all i. The test involves

5. See Feige and Pearce (1979) for the details of the direct Granger Test and the Pierce and Haugh Test.

estimating the model, and testing the hypothesis that all β_i are jointly equal to zero. X and Y are then reversed and second regression estimated to see if X causes Y. The results of the test (Table 7) performed with various lag lengths yielded only one instance in which the F-statistic exceeds the critical value at the 5% level. Thus, the general inferences are that money does not "Granger cause" income and that income does not "Granger cause" money.

3) Next, Feige and Pearce adopt Sims Test using an alternative method of pre-filtering based on seasonally unadjusted data. The estimated F-statistics (Table 8) indicate that the empirical results are highly sensitive to the use of seasonally adjusted data as well as to the particular filter chooses for prewhitening. Table 9 indicates the same effects even with the use of the GLS procedure . Feige and Pearce (1979) concluded that the relationship between money and income appears to be casual rather than causal. "We are left with the uncomfortable conclusion that an essentially arbitrary choice left to the discretion of individual researchers can significantly affect the nature of the economic conclusions derived from the test procedures." (op. cit. p.532)

Several recent developments respond to these problems of Granger Causality tests. A Monte Carlo comparison of the power of the tests (Geweke, Meese, and Dent (1983)), cast doubt on the reliability of the Sims Test, especially when using a pre-filter of $(1 - 0.75L)^2$. The direct Granger Test or Sims Tests with own lags are considered to be more reliable. Mehra (1977) has proposed a method designed to reduce the arbitrariness of pre-filtering by selecting an "optimum" k of pre-filter $(1 - kL)^2$. This is taken up in the next section.

(2) Analysis Based on Relative Power Contribution

A development of the empirical analysis of Granger Causality unique to Japan may be found in the extensive use of "Relative Power Contribution" (hereinafter abbreviated as RPC), which was proposed by Hirotsugu Akaike.

RPC represents the mutual influence of the multivariate feedback system in a frequency domain, and as such as a method originally developed for applications in the control engineering field. A comparison of the RPC between money and real income observed in different studies reveals considerable variations. The RPC decomposition of real GNP by Sakakibara and others (1980) and a similar analysis by Kunitomo and Yamamoto (1985) reveal considerable differences in the influence of interest rates on real GNP. This is because,

1) there are differences in the concept of the variables (difference between WPI and GNP deflator in price variables, difference between GNP and GDP, etc.);
2) there are differences in the estimation periods;
3) there are differences in the orders of the AR model;
4) there are differences in the pre-filter employed;

5) in Sakakibara (1980), two variables — nominal GNP in the U.S. and the government nominal expenditure — are added;

Of these, the difference between the information sets is not important since the contribution of U.S. nominal GNP and the nominal government expenditure are insignificant. Statistical problems covered by 1) - 4) are presumably more significant. These statistical problems such as pre-filtering and seasonal adjustments cannot be ignored. In the next section, these points are examined briefly by returning to the principles behind Granger Causality.

Table 5 Estimated Quarterly ARIMA Models 1947I–1969IV

Time Series	ARIMA Model	Test of Residuals Q	D.F.
GNP (seasonally adjusted)	$(1-B)(1-.539B) \ln GNP_t = .007 + e_t$	27.6	28
GNP (seasonally unadjusted)	$(1-B)(1-B^4)(1-.298B)(1+.456B^4) \ln GNP_t = e_t$	21.9	28
M1 (seasonally adjusted)	$(1-B)^2 \ln M1_t = (1-.389B^4-.294B^5) e_t$	12.9	28
M1 (seasonally unadjusted)	$(1-B)(1-B^4)(1-.541B) \ln M1_t = (1-.578B^4) e_t$	19.3	27
MB (seasonally adjusted)	$(1-B)(1-.477B) \ln MB_t = .003 + (1+.411B^4) e_t$	28.9	27
MB (seasonally unadjusted)	$(1-B)(1-.274B^2)(1-.892B^4) \ln MB_t = e_t$	24.3	28

Notes: Q refers to revised χ^2 test for white noise residuals,
D.F. is degrees of freedom for Q-statistic.

Ljung and Box report that for small data samples, the appropriate χ^2 statistic with which to test the hypothesis that "the time series of interest is white noise" is,

$$Q = n(n+2) \sum_{k=1}^{m} (n-k)^{-1} r_k^2 \sim \chi_m^2$$

where,

n = number of observations on the time series
m = number of autocorrelations considered
r_k = sample autocorrelation coefficient for lag k.

All Q-statistics reported in this study are computed using this formula.

Source: Feige and Pearce (1979)

Table 6 Haugh-Pierce χ^2 Tests for Independence

	Seasonally Adjusted Data		Seasonally Unadjusted Data	
Degrees of Freedom	GNP and M1	GNP and MB	GNP and M1	GNP and MB
9	8.99	7.09	16.77	13.71
17	19.37	15.77	29.09*	23.82
25	22.73	25.54	32.75	32.35

Note: * Significant at 5% level.
Source: Feige and Pearce (1979)

Table 7 Results of Direct Granger Test for Causality

Dependent Variable (no. of lags)	Independent Variable (no. of lags)	Box-Ljung Q	F	Type of Data
M1 (4)	GNP (4)	19.84	0.88	Seas. Unadj.
M1 (8)	GNP (4)	21.24	0.34	Seas. Unadj.
M1 (4)	GNP (4)	22.10	0.35	Seas. Adj.
M1 (8)	GNP (4)	21.50	0.54	Seas. Adj.
MB (4)	GNP (4)	22.71	0.16	Seas. Unadj.
MB (8)	GNP (4)	21.40	0.31	Seas. Unadj.
MB (4)	GNP (4)	14.08	0.82	Seas. Adj.
MB (8)	GNP (4)	18.55	0.40	Seas. Adj.
GNP (4)	M1 (4)	12.81	1.19	Seas. Unadj.
GNP (8)	M1 (4)	16.13	1.12	Seas. Unadj.
GNP (4)	M1 (4)	24.05	1.95	Seas. Adj.
GNP (8)	M1 (4)	19.30	2.47	Seas. Adj.
GNP (4)	MB (4)	14.77	0.48	Seas. Unadj.
GNP (8)	MB (4)	16.66	0.94	Seas. Unadj.
GNP (4)	MB (4)	29.57	2.22	Seas. Adj.
GNP (8)	MB (4)	24.32	3.42*	Seas. Adj.

Notes: F-statistics are calculated for the hypothesis tht all coefficients on lagged independent variables are jointly zero.
Q-statistic is the revised Q of Ljung and Box (1976) with 25 degrees of freedom.
* Significant at 5% level.
Source: Feige and Pearce (1979)

Table 8 Sims Causality Tests with Alternative Filters and Seasonally Unadjusted Data

Regression	(1) Sims' Reported Results $(1-.75B)^2$ Filter	(2) Replication of Sims' Results $(1-.75B)^2$ Filter	(3) (1−B) Filter	(4) ARIMA Filter
M1 on GNP	N.A.	2.50 (43.75*)	2.06 (41.02*)	1.11 (28.68)
MB on GNP	N.A.	4.79* (26.33)	1.36 (29.65)	1.90 (17.38)
GNP on M1	N.A.	0.42 (33.17)	0.27 (14.07)	1.46 (22.22)
GNP on MB	N.A.	0.21 (52.46*)	0.20 (23.85)	1.57 (22.54)

Note: N.A. = not available.
* Significant at 5% level.
Source: Feige and Pearce (1979)

Table 9 Sims Causality Tests Using GLS Estimation Technique and Seasonally Unadjusted Data

Regression	Sims' Filter	(1−B) Filter	ARIMA Filter
M1 on GNP	4.79*	1.98	1.60
MB on GNP	10.84*	1.60	2.52
GNP on M1	0.38	0.37	2.62*
GNP on MB	0.25	0.26	2.23

Note: * Significant at 5% level.
Source: Feige and Pearce (1979)

V. Granger Causality between Money Supply and Nominal Income in the Japanese Economy

There are a large number of studies purporting to test Granger Causality between money and nominal GNP in the Japanese economy. In this section, these studies are surveyed and their implications explored.

(1) Oritani (1979)

Oritani (1979) was the first economist to test Granger Causality between money and nominal GNP in the Japanese economy. After generating a stationary time series for seasonally-adjusted M2 and nominal GNP using the same pre-filter that Sims used, Oritani conducted the Sims Test by following Sims' procedure and obtained results similar to Sims (1972) (See Table 10).

However, even if the framework of bivariate time series model is accepted, the power of Sims Test using Sims' pre-filter is not high. Tests that take this point into account have been carried out by Komura (1982, 1984), Ram (1984), Okubo (1983), etc.

Table 10 F-value for the Money supply (M) and Nominal Income (GNP)

(I) GNP = f (M)

	future value	current and past value
Japan	0.809	2.404*
U.S.	0.36	1.89*

(II) M = f (GNP)

	future value	current and past value
Japan	2.280*	0.793
U.S.	4.29**	n.a.

Note: Money; M2 for Japan, M1 for U.S.
* significant at 10% level
** significant at 5% level
Source: Oritani (1979), Sims (1972)

(2) Other Tests in the Bivariate Framework

Komura (1982), following Mehra, made a search for an appropriate value of k in the pre-filter $(1 - kL)^2$. The procedure is as follows; (i) pre-filter the logarithm of the original data in any given equation with an arbitary value of $k(0<k<1)$ and apply ordinary least squares to the pre-filterd data to estimate the lag profile of that equation, (ii) calculate the residuals of the relevant equation estimated in step i, and run an autoregression on these least squares residuals, (iii) systematically changing the value of k between 0 and 1, select the value of k which removes the serial correlation in the autoregression of residuals, (iv) if, however, there is no appropriate k, then repeat steps i to iii with third order filtering of the form $(1 - kL)^3$ as suggested by Nerlove. After finding the proper value of k, the significance of the future values of the explanatory variables can be examined.

The results of the Sims Test carried out following the above procedure are shown in Table 11, and accordingly, even the Japanese data show that the Granger Causality between money and nominal GNP was strongly affected by the selection of k, and that of the lead and lag.

Komura finds that the influence of GNP on M2 is generally strong and, unidirectional Granger Causality from GNP to M2 exists in the period beginning in 1972, when the floating exchange rate system became dominant.

In contrast, Ram (1984), regarding the power of the Sims Test itself as problematic, used the direct Granger Test in place of the Sims Test and conducted a follow-up of Komura's (1982) tests using the same data set as well as another data set in which M2 was changed to M1. The equation used for the test was,

$$x_t = \sum_{j=1}^{J} a_j x_{t-j} + \sum_{j=1}^{J} b_j y_{t-j} + \alpha + \beta t + u_t$$

Here, βt is a trend, and seasonal dummies are added to the equation, avoiding the use of a pre-filter. As shown in Table 12, while Ram's results are consistent with those of Komura (1982) to the extent causality from money to nominal income is stronger, the further back in time the test is conducted, Ram finds the relationship between GNP and money supply is weak under the floating exchange rate sytem. In response to this, Komura (1984) carried out a supplementary test on the causal relationship between M1 and GNP using Mehra's procedure. In analysing the results thus obtained, Komura (1984) expressed the following view:

> "These results indicate that one needs to be careful in interpreting the findings of one test procedure since the power of the Sims and Granger tests is not very high. Evidence common to both procedures would suggest a fairly strong causal relationship between the variables involved (op. cit. p.1223)".

Table 11 F-ratios of the Future Values of GNP and M2

(i) 1955I–1964IV

	M2 on GNP		GNP on M2	
Lag Form	F-ratio	k[a]	F-ratio	K
4 future 8 past	3.14*	0.95	0.04**	0.40
8 future 4 past	2.68*	0.70	13.86**	0.10
6 future 4 past	3.61**	0.70	1.87	0.20
4 future 4 past	6.04**	0.70	3.80**	0.20
2 future 4 past	4.08**	0.70	0.20	0.20

(ii) 1955I–1971II

	M2 on GNP		GNP on M2	
Lag Form	F-ratio	k	F-ratio	k[b]
4 future 8 past	1.73	0.75	2.66**	0.10
8 future 4 past	1.72	0.77	3.23**	0.25
6 future 4 past	1.90	0.77	2.91**	0.25
4 future 4 past	2.80**	0.77	4.98**	0.25
2 future 4 past	2.21	0.77	0.37	0.15

(iii) 1971III–1980IV

	M2 on GNP		GNP on M2	
Lag Form	F-ratio	k	F-ratio	k
4 future 8 past	1.00	0.25	8.14**	0.45
8 future 4 past	2.45	0.60	5.00**	0.05
6 future 4 past	1.47	0.60	3.81**	0.05
4 future 4 past	1.19	0.60	2.16	0.65
2 future 4 past	1.02	0.60	1.89	0.05

Notes: ** Significant at 5 percent level.
* Significant at 10 percent level.
(a) The value of k is for the second-order filtering of the form $(1-kL)^2$ unless otherwise specified.
(b) The value of k is for the third-order filtering of the form $(1-kL)^3$.
(c) There remains autocorrelation significant at 10 percent level in the residuals.

Source: Komura (1982)

Table 12 F-Statistics for the "Joint Significance" of the Coefficients

Direction of Causality	1955I-1964IV			1955I-1971II			1971III-1980IV		
	J=4*	J=6*	J=8*	J=4*	J=6*	J=8*	J=4*	J=6*	J=8*
	(4, 22)	(6, 16)	(8, 10)	(4, 48)	(6, 42)	(8, 36)	(4, 20)	(6, 14)	(8, 8)
1. M1 to GNP**	6.26*	4.73*	3.82*	5.39*	4.14*	3.44*	0.90	1.84	0.83
2. GNP to M1	1.26	2.18	2.76	3.19*	4.18*	2.80*	2.33	0.52	0.29
3. M2 to GNP	7.68*	3.43*	3.30*	6.66*	3.82*	3.94*	1.58	1.92	1.07
4. GNP to M2	1.09	1.43	3.47*	3.83*	4.56*	2.62*	3.11*	2.45	2.54
5. M1 to RGNP	1.93	4.11*	2.66	1.85	2.32*	2.03	2.05	1.38	0.65
6. RGNP to M1	1.10	1.86	2.56	2.89*	3.36*	2.46*	1.32	0.47	0.14
7. M2 to RGNP	4.12*	2.42	2.62	3.42*	2.35*	2.22	4.05*	2.10	1.01
8. RGNP to M2	1.39	1.67	2.34	5.00*	5.51*	3.09*	1.60	4.05*	2.28
9. M1 to PGNP	7.52*	2.93*	4.94*	5.56*	3.75*	3.66*	1.25	1.38	0.68
10. PGNP to M1	1.16	1.88	2.13	2.51*	3.19*	2.50*	2.28	0.18	0.50
11. M2 to PGNP	4.64*	2.01	2.41	5.75*	2.71*	2.34*	2.01	1.41	1.30
12. PGNP to M2	0.62	1.07	2.45	1.57	2.56*	2.47*	4.11*	1.13	1.08

Notes: 1. The number in "J=" indicates the lag length in quarters, and the numbers in the parentheses below give the degrees of freedom (of F) for the numerator and the denominator, respectively, for the column.

2. As equation (1) in the text would show, the expression "M1 to GNP" means that GNP is regressed on its own lagged values and on the lagged values of M1, and the F-test consists of verifying whether the coefficients of lagged M1 are "jointly significant."

* Significant at (at least) 5% level.

Source: Ram (1984)

Table 13 shows that results of the Komura-Ram Test on the relation between money and the GNP deflator (PGNP) and real GNP (RGNP), which were prepared by Komura (1984). These results indicate that the causality between money and prices and that between money and nominal income seems to be weak throughout the 1970s.

Kama (1982) applied the Pierce-Haugh Test to money (M1, M2) and GNP (both real and nominal), using both seasonally adjusted data and seasonally unadjusted data. The results indicate that M1 unidirectionally causes nominal GNP and that there exists a feedback relationship between nominal GNP and M2, regardless of the treatment of seasonality.[6]

On the other hand, based on the data since the First Oil Crisis, Okubo (1983) applied the RPC procedure to money and nominal income using the seasonally-adjusted first log difference, and insisted on the existence of unidirectional causality from M2 + CD to nominal GNP.

These results are consistent with those of Feige and Pearce in that the Granger Causality tests are very sensitive to the selection of the testing procedure.

(3) Variance Decomposition and RPC Based on the VAR Model

Ito (1982) applied Sims' (1980) method of variance decomposition to Japan and compared two systems: one consisting of three variables — M1, production index, and the WPI — and the other consisting of four variables — call rate, M1, production index, and the WPI (Table 14). According to this analysis, the results are nearly parallel with Sims' (1980) results for the U.S. econony in that the exogenity of M1 is high in the trivariate system while low in the quadrivariate system. But in both cases, the influence of financial variables (call rate and M1) on the elements of nominal GNP (real output and prices) is extremely weak, and this result is not significantly affected by the selection of the sample period.[7]

In contrast, the results of RPC by Okubo (1983) based on a VAR model of four variables — M2 + CD, real interst rates, real GNP, and the GNP deflator — using seasonally-adjusted log differences from the previous quarter is quite different from those in Ito (1982). Okubo claims that M2 + CD and real interest rates have considerable influence on real GNP and the GNP deflator. These examples indicate that even with tests using the VAR model based on identical AIC criteria, may lead to completely different results by using different unit data periods or different seasonality adjustments.

6. However, the relationship between money and real GNP is subject to change.

7. There is very little difference between the results over the entire sample period and those obtained prior to the First Oil Crisis period.

Table 13 A Comparison of Causality Test Results between Granger-Sargent Test and Sims Test

(i) 1955I - 1964IV

Granger	Sims	Granger	Sims
M2 ⇒/← GNP	M2 ⇒/⇐ GNP	M1 ⇒/← GNP	M1 ⇒/← GNP
M2 → RGNP	M2 →/⇐ RGNP	M2 →/⇠ RGNP	M1 →/⇠ RGNP
M2 →/⇠ RGNP	M2 ⇒/⇠ PGNP*	M1 ⇒ PGNP	M1 ⇒/⇐ PGNP

(ii) 1955I - 1971II

Granger	Sims	Granger	Sims
M2 ⇒/⇐ GNP	M2 →/⇐ GNP	M1 ⇒/⇐ GNP	M1 ⇒ GNP
M2 ⇒/⇐ RGNP	M2 ⇐ RGNP	M1 →/← RGNP	M1 ⇢ RGNP
M2 ⇒/⇐ PGNP	M2 ⇠ PGNP	M1 ⇒/⇐ PGNP	M1 ⇒/⇠ PGNP

(iii) 1971III - 1980IV

Granger	Sims	Granger	Sims
M2 ← GNP	M2 ⇐ GNP	M1 GNP	M1 GNP
M2 →/← RGNP	M2 RGNP	M1 RGNP	M1 RGNP
M2 ← PGNP	M2 ⇢/⇠ PGNP	M1 ⇠ PGNP	M1 PGNP

Notes: ⇒ F-ratio is significant at 5% level at least for two types of lag specification
→ F-ratio is significant at 5% level at least for one type of lag specification
⇢ F-ratio is significant at 10% level at least for one type of lag specification
* Although F-ratio of future PGNP is significant at 5% level for two types of lag specification it was no confirmed by the reverse regression explaining M2 with lagged PGNPs.
Source: Komura (1984)

(4) Summary of Empirical Studies of the Japanese Economy

The results of the above analyses of Granger Causality between money and nominal GNP for the Japanese economy have led to various contradictory conclusions concerning the direction of causality (Table 15). From the results of these analyses, the following points may be made as an agenda for future studies:

1) These empirical studies suggest that some structural change must have occured in the Japanese economy in the first half of the 1970s. A glance at the actual changes in money supply, nominal GNP, and real GNP reveals that the variance of money supply and GNP has declined significantly since the second half of the 1970s.

Table 14 Variance Decomposition:
Percentages of 48-month Forecast-Error Variance Explained by Innovations in a three-variable (M1, IP, WPI) system.

1956-81 (monthly)

Variables Explained	By Innovations in		
	M1	IP	WPI
M1	75	12	13
IP	14	54	32
WPI	5	46	49

1956-81 (Monthly)

Variables Explained	By Innovations in			
	R	M1	WPI	IP
R	42	10	30	18
M1	10	54	3	33
WPI	3	6	41	50
IP	4	5	15	76

Feb. 1956 – Oct. 1973

Variables Explained	By Innovations in			
	R	M1	WPI	IP
R	58	1	28	13
M1	13	23	9	55
WPI	2	7	60	31
IP	7	1	33	59

Notes: M1 = Money Stock (M1); IP = Industrial Production Index; WPI = Wholesale Price Index each variables in the log-form; R= the call market rate. Monthly data without seasonal adjustment for Japan. The system is estimated with 13 lags of each variable and seasonal dummies.

Source: Ito (1983)

Table 15 Granger Causality between Money and Nominal Income in Japan: Some Examples

bivariate	Test Method	Choice of Pre-filter	Sample period and Seasonal Adjustment	Test Results
Oritani (1979)	Sims Test	Sims Filter $(1-0.75L)^2$	S.A. (1962/I–1976/III)	M2 → GNP
Komura (1982)	Sims Test	Mehra's Filter $(1-kL)^2 (0<k<1)$	Original (Seasonal Dummies are used) (1971/III–1980/IV)	GNP ⇒ M2
Ram (1984)	Direct Granger Test	linear trend is included in right hand side of regression	"	GNP → M2
Kama (1982)	Pierce-Haugh Test	(1–L)	S.A. (1965/II–1978/III)	GNP ⇔ M2
Okubo (1983)	RPC	(1–L)	S.A. (1965/II–1982/I)	Strong influence from M2+CD on GNP

multivariate

multivariate	Test Method	Choice of Pre-filter	Sample period and Seasonal Adjustment	Test Results
Ito (1983)	Variance Decomposi-	linear trend is included in right hand side of regression	Original (Seasonal Dummies are used) (1956-1981)	M1 does not have significant influence on WPI and production
Okubo (1983)	RPC	(1–L)	S.A. (1965/II–1982/I)	influence from M2+CD to GNP

Notes: ⇒ unidirectional causality can not be rejected at 5%
→ unidirectional causality can not be rejected at 10%
⇔ feed-back relation can not be rejected at 5%
*This table shows only part of the results and should not be interpreted as exhaustive.

However, many factors can be considered as a main source of such structural changes, including (a) the First Oil Crisis, (b) the shift to the floating exchange rate system, and (c) changes in monetary policy rules (more emphasis is paid on prices and exchange rates), and therefore the point of dividing the sample period of empirical tests has been suggested alternately as 1971 (Komura and Ram) and 1973 (Ito and Okubo). Further examination is necessary to determine whether to include the 1971-1973 period as part of the recent sample, because there is good reason to believe that this will have a significant effect on the test results.[8]

2) It can be expected that financial deregulation and changes in the financial structure would gradually change the relationship between nominal GNP and money supply. This will become an increasingly important problem for future study as the changes in the financial structure accelerate.

3) The most significnat lesson gained from the empirical results thus far obtained is that the analyses are extremely sensitive to the elements of test procedure: adjustment of seasonality and trends, pre-filtering to eliminate non-stationality, testing methods, and unit data period (monthly or quarterly).

VI. Conclusion

In this paper an attempt was made to organize and examine the points to be kept in mind when interpreting the causal relationships between money supply and income using the concept of Granger Causality. The points in question were grouped into: 1) The conceptual problem of interpreting Granger Causality in economic systems, and 2) The statistical problems presented by the testing procedure for detecting Granger Causality (robustness issue).

Next, empirical analyses of Granger Causality between money and nominal income in the Japanese economy were surveyed in line with the points reflected in 1) and 2) above.

Granger Causality is a fundamental concept for investigating causality among various economic variables. The proper use of Granger Causality will no doubt be further elaborated as the test procedure become widely adopted.

In fact, there are several interesting developments in this area. For example, Kunitomo (1984, 1985) provided a synthesis and generalization of the measures of Granger Causality in a multivariate time series model and, as mentioned before, Hsiao (1982) and Kunitomo and Yamamoto (1985) have attempted to distinguish spurious causality from indirect causality. Kitagawa and Gersch (1984) and Naniwa (1985) discuss a new approach to deal with trend and seasonality simultaneously,

8. Parkin (1984) has insisted that the seasonality patterns have changed since the onset of the 1970s, and this point should also be examined in future studies.

using the state space representation of the stochastic process. This multiplicity of approaches makes it all the more important to clearly indicate, prior to interpreting the results, what is assumed in the analysis, and which theoretical hypotheses are being tested against which alternative hypotheses. The test results have been mutually contradictory and robustness has yet to be established for any particular procedure. Insufficient attention to these points may cause misleading conclusions to be drawn in the short run. And in the long run, risking the danger of undermining the trust in the usefulness of the concept itself.

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