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A test of the direction of causation between money and income in Canada, Japan and the United States

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A test of the direction of causation between money and income in Canada, Japan and the United States

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CHAPTER I. INTRODUCTION

The main purpose of this study is to apply Christopher Sims' method (1972) and two other econometric methods to test the direction of causation between money and income in Canada, Japan and the United States.

The importance of Sims' study is the development of a direct test for the existence of unidirectional causality and its application to the money-income relationship. Moreover, the regression results he obtained are surprisingly consistent with the monetarists' position and the form of the lag agrees in general shape with other previous estimates, despite the fact that no a priori restriction was imposed. Noting Sims' "exciting" results, it would be interesting to apply different test methods to different developed economies and to examine whether the test results conform to Sims' findings.

Linear regressions used to test direction of causation require that the assumption of serially uncorrelated residuals be approximately accurate. For this reason Sims transformed all the variables used in the regressions into natural logs and prefiltered them as well. He claimed that his prefiltering made the regression residuals nearly white noise because in practice the filter approximately flattens the spectral density of most economic time series.

To examine whether his method satisfies the assumption of independent regression residuals, Sims used the test on the cumulated periodogram of the residuals described by James Durbin (1969). He also applied the likelihood ratio test for the null hypothesis that the periodogram of the residuals has constant expectation across a number of intervals

(Hannan, 1960). Based on the inconclusive results of his tests, Sims concluded that there is room for doubt about the accuracy of the "F" tests on the regression coefficients.

Unable to determine the structure of his regression residuals, Sims used Hannan's (1963) "inefficient procedure", a frequency domain procedure, to check on the least squares results he obtained. He found close general agreement between the least squares results and the frequency domain results, although the tests for significance of groups of coefficients did not come out in the same way at the same significance levels in the frequency domain estimates.

Notwithstanding the general agreement between the results derived using time domain and frequency domain procedures, this writer thought it desirable to employ not only Sims' method but also other econometric methods to test direction of causation between the variables, especially because Sims was unable to establish the independence of his error structure.[1] Furthermore, Feige and Pierce (1974) in a paper presented before the Midwest Economic Association Conference commented that Sims had unfortunately chosen a poor filter - one which did not flatten the spectral density of the time series he used.

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[1] In a discussion paper written by Sims entitled, "Are There Exogenous Variables in Short Run Production Relations?" and published by The Center for Economic Research of the University of Minnesota, Sims stated that his filter failed to avoid a negative serial correlation in his nondurable investment equation. Consequently, he used a filter different from his standardized one $(1 - 1.5L + .5625 L^2)$.

Three econometric methods were applied to test the direction of causation between money and income in Canada, Japan and the United States. The intent for applying the tests to the three countries mentioned is to examine whether there is a pattern concerning the direction of causation for developed market economies. It has to be admitted that the sample size (number of countries) is too small to be able to make such a generalization. However data limitations, particularly the absence of gross national product data for all but a few countries, has placed a constraint on the number of countries which could be included in the analysis.

The motivation behind this interest may be traced to an article by D. R. Starleaf and R. L. Floyd (1972) concerning the efficacy of Friedman's monetary proposal. The test which they developed supports the hypothesis that countries with stable rates of growth in their domestic money supply also tended to have relatively stable rates of national income growth. Such findings would tend to make one curious about the pattern of the direction of causation for the countries studied.

The results of the tests for the United States would be important because of the ongoing controversy regarding the effectiveness of monetary policy versus fiscal policy. Some economists accuse M. Friedman of claiming that changes in the stock of money are the principal cause of changes in money income. J. Tobin (1970) for example states that Friedman in his less guarded and more popular expositions comes close to asserting that the money stock is the unique cause of changes in income. W. Heller argues that the issue is not whether money matters but whether only money matters, as some Friedmanites put it (Friedman and Heller, 1969). However, to say that only money matters or money is the principal cause, it is first of all, necessary to show that money affects income and secondly, that it is the major determinant of changes in money income.

On this point, it is important to note that the existence of a significant statistical relationship between money and income does not necessarily imply or indicate a causal relationship between the two variables. But since the monetarists usually argue that the money stock has been determined exogenously[2], i.e., the money supply has been determined independently of the values of the other variables in the economic system, it follows that the existence of a significant statistical relationship must be assumed to reflect the causal influence of changes in the money stock on income (Goodhart and Crockett, 1970). The monetarists support their position with case studies based on American economic history (Friedman and Schwartz, 1963) and also by examining the lead lag relationship between money and income at turning points of the business cycle (Friedman and Schwartz, February, 1963).

Is the money stock statistically exogenous such that one can infer from the statistical relationship that changes in the money stock is the cause and changes in money income, the effect?

This paper does not attempt to examine whether only money matters or how much it matters. Neither does it attempt to elucidate on the question of monetary policy versus fiscal policy as tools for economic stabilization. What this paper attempts is simply to determine whether

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[2]In passing it should be pointed out that a policy variable is not "ipso facto" an exogenous variable.

the money stock affects money income, or vice versa, or whether both influence each other or whether both are independent of each other. In other words, this paper endeavors to trace the direction of causation.

In the analysis which follows, emphasis is given to determining the direction of causation and to comparing the findings derived from the methods used with respect to the consistency of their results in each of the countries studied. The purpose for comparing the findings is to determine the sensitivity of the results to the methodology used. If the results of all the methods for each country are consistent, greater reliance could be placed on the test results. However, if the results vary, this would indicate problems of methodology. Consequently the question of what is the appropriate method would arise.

Significance of this Study

Studies of this nature are important for several reasons. Economics is both a science and an art. As a science, economics is concerned with building models applicable to the real world. From the definitions and assumptions of the model, an hypothesis about the relationships among economic variables is logically derived. An hypothesis or a theory is but a generalization concerning the relationships among economic variables.

Data are then gathered, systematically arranged, and analyzed in order to test whether the model sufficiently explains and predicts the real world. If the predictions of the model are in harmony with the real world, then the theory is said to be confirmed (not verified, for a theory can never be regarded as absolutely true). Thus testing the relationships, particularly causal relationships among variables, is an integral part of economics.

Economic theories or models are but simplifications and abstractions of reality. They are intended to illuminate on the phenomenon or phenomena of interest. The real world is too complex for the human mind to comprehend in all detail. For this reason, the need for simplification and abstraction arises.

Aside from facilitating the understanding of reality, economic theories are useful because they are the basis on which policies are formulated to solve economic problems. This is the applied part of economics. It is in this area, where economists determine what variables to manipulate or what strings to push or pull in order to achieve the desired results. Hence, a knowledge of causal relationships is of crucial importance. And in the case of money and income, the knowledge of causal relationships is important because of the fact that monetary and fiscal policy are presently considered as the major tools for economic stabilization.

It is the practice among economists, especially monetary economists, to interpret distributed lag regressions of income on money as causal relationships.[3] Is this practice invalidated by the existence of a feedback from income to money?

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[3]For example, the St. Louis Federal Reserve Bank study on the relative importance of monetary and fiscal actions in economic stabilization assumes that monetary and fiscal actions have unidirectional causal impact on nominal GNP. This assumption is invalid and likewise the use of distributed lags unless it can be shown that the right hand side variables are truly exogenous.

> [I]f the consensus view that there is some influence of business conditions on money is correct, if the influence is of significant magnitude, and if current dollar GNP is a good index of business conditions, then distributed lag regressions treating money as strictly exogenous are not causal relations (Sims, 1972).

Therefore, it is important to test the assumption of causal priority on which they rest.

From the point of view of econometrics, Sims (1972) points out that most efficient estimation techniques for distributed lags are invalid unless causality is unidirectional.

CHAPTER II. METHODOLOGY: TESTING THE DIRECTION OF CAUSATION BETWEEN TWO VARIABLES

Sims' method as well as two other econometric procedures were applied to the data. Each of these methods is explained in detail in this chapter. All these methods are intended to minimize if not to eliminate autocorrelation in the regression residuals. The rule stated below describes how the "F" test was used to determine causal priority.

The Rule and its Rationale

The test developed by Christopher A. Sims is:

> If and only if causality runs one way from current and past values of some list of exogenous variables to a given endogenous variable, then in a regression of the endogenous variable on past, current and future values of the exogenous variables, the future values of the exogenous variable should have zero coefficients (Sims, 1972).

This rule or statement is the basis for determining causal ordering.

Following the above statement, in order to test the direction of causation between two variables, for example X and Y, and in the case of this dissertation, the variables are money and income, Y is regressed on past, current, and future values of X; similarly X is regressed on past, current, and future values of Y. The "F" test is used to determine whether the coefficients of the future values of the exogenous variable, as a group, are significantly or not significantly different from zero. If in the regression of Y on X, the coefficients of the future values of X (as a group) are not significantly different from zero, that is the "F" statistic is not significant, and if in the regression of X on Y, the "F" statistic on the coefficients of the future values of Y are significant, then the conclusion is that the evidence tends to indicate that the direction of causation is from X to Y. If the reverse were true, that is significant for the regression of Y on X but not of X on Y, the implication is Y causes X. Other possible outcomes of the test could be that in both regression equations, Y on X and X on Y, the "F" statistics are significant, then the test indicates that the direction of causation is two way or bidirectional. Finally, no cause and effect relationship can be imputed if the "F" statistics in both regression equations are not significant.

Table 1 summarizes the nature of the test.

Table 1. Conditions for direction of causality using F tests on future coefficients

Direction of Causality	Regression Equations	F Tests on Future Coefficients
1. Y causes X	Y on past, current and future values of X	significant
	X on past, current and future values of Y	not significant
2. X causes Y	X on past, current and future values of Y	significant
	Y on past, current and future values of X	not significant
3. Bidirectional causation between Y and X	Y on past, current and future values of X	significant
	X on past, current and future values of Y	significant
4. No implication about causal relationship	Y on past, current and future values of X	not significant
	X on past, current and future values of Y	not significant

The rationale underlying this approach is a sophisticated "Post Hoc Ergo Propter Hoc" type of reasoning. Because event A precedes event B, therefore, A is the cause of B. To argue solely on the basis of temporal precedence is fallacious, unless one can explain the causal mechanism linking the events. What gives validity to this approach in tracing the direction of causation between money and income is the various theories, Quantity, Neo Quantity, Keynesian, Neo Keynesian, etc., linking money with economic activity. Those who claim that the direction of causation is from money to income, assume that the money supply or the monetary base is exogenously determined. On the other hand, there are economists who believe that there is a two-way relationship between movements in the money stock and in money income, with causal influences running in both directions. To illustrate the feedback from economic activity to money, they point out that the immediate determinants of the money supply (e.g. deposit to reserve ratio, deposit to currency ratio, etc.) and therefore the money supply, are influenced by economic variables in the system. "Underlying each 'proximate determinant' are many economic and institutional factors which may be viewed as ultimate determinants" (Andersen, 1967). They also cite as an example the possibility of the monetary authorities altering the money supply/monetary base in response to income changes as when the monetary authorities follow a policy of "leaning into the wind". This is the case when the Federal Reserve is concerned with maintaining an orderly pattern of interest rates (Goodhart and Crockett, 1970). In principle, the mere fact that central banks exist with the goal of stabilizing economic conditions, would imply some response of monetary variables to changes in economic activity.

An additional point to be noted about the test is that it implies a lagged relationship between the variables. If money causes income, then it would be expected that changes in the money supply should precede changes in income, and vice versa.

The Specification of the Model: The Choice of the Variables and the Form of the Regression Equations

Since this paper is concerned with tracing the direction of causation between money and economic activity, a decision has to be made with regard to what variables to use to represent the money supply and economic activity. Regarding economic activity, nominal gross national product (GNP) was chosen as a proxy variable for economic activity. The choice of GNP is based both on logical grounds as well as convention. It is to be expected that changes in economic activity will be reflected in changes in real output and/or prices, both of which are components of money GNP. Furthermore, an examination of the literature will reveal that studies analyzing the relationship between money and economic activity use GNP as a surrogate for economic activity.

What assets make up the money supply is still a question being debated both on a priori and empirical grounds. The lack of agreement is due to the differing degree of emphasis on the various functions of money (medium of exchange as opposed to temporary abode of purchasing power) and also because of the difference in interest between monetary theory and monetary policy (Johnson, 1962). Some of the different measures are:

a) Currency plus demand deposits;

b) Currency, demand deposits and time deposits in commercial banks only;

c) Currency, demand deposits and savings-type accounts in commercial banks, mutual savings banks, saving and loan associations and post offices;

d) Total amount of credit outstanding, and

e) Highly liquid financial assets with a high degree of substitutability among them.

This paper does not attempt to resolve this issue nor suggest an ideal definition for money. The choice of the first measure above was based mainly on the availability of the data. The same reason accounts for the fact why Canada, Japan and the United States were included in the analysis.

The data used were raw quarterly data uncorrected for trend and seasonality. The reason for starting with raw data is because Sims warns that spurious seasonal variation is likely to appear in the estimated lag distribution if, in distributed lag regressions relating two variables, the variables have been deseasonalized by procedures with different assumed rates of shift in the seasonal pattern (Sims, 1972).

Regarding the form of the regression equations, Sims (1972) states that prefiltering may produce a perverse effect on approximation error when lag distributions are subject to prior "smoothness" restrictions. He suggests that no Koyck, Almon or rational lag restrictions should be imposed a priori and the length of the estimated lag distributions should be kept generous. Based on this, linear regressions were applied on the logs of the variables which were first prefiltered. Each regression equation consisted of the current, leading and lagging values of the independent variable, a constant term, a linear trend term and three seasonal dummies. In the case of Method II (First Difference Iterative Estimation Procedure) the constant term was eliminated from the regression equations.

If the variables are prefiltered, Durbin-Watson statistics are of little use in detecting serial correlation. Thus certain steps have to be taken to ensure that the residuals are not autocorrelated. This becomes especially important if one would like to make precise use of the "F" test. For this reason, Method I uses a two stage regression procedure, Method II employs a reiterative procedure and Method III uses Sims' filter.

Detailed Summary of the Test Procedures

<u>Method I (two-stage regression procedure)</u>

1. The raw quarterly observations of the variables were transformed into logs. Y and X are used to represent the logged variables.

2. Estimates for the model below were derived using ordinary least squares:

$$Y_t = \rho_1 Y_{t-1} + \rho_2 Y_{t-2} + \rho_3 Y_{t-3} + \rho_4 Y_{t-4} + B_1 T_t + B_2 D_{1t} + B_3 D_{2t} + B_4 D_{3t} + e_t$$

where T represents the linear trend term and the Di's are the seasonal dummies.

3. The significance of each ρ was tested using the "t" test with critical region equal to .10.

H_o: $\rho_i = 0$

H_A: $\rho_i \neq 0$

4. Based on the "t" test, if not all the ρ's turn out to be significant, the equation in step 2 was refitted by regressing the equation on the same variables, omitting those Y_{t-i} (i = 1, 2, 3, 4) whose coefficients are not significant. For example if $\hat{\rho}_3$ and $\hat{\rho}_4$ turn out not to be significant, the regression equation to estimate the values of ρ_1 and ρ_2 is given below:

$$Y_t = \rho_1 Y_{t-1} + \rho_2 Y_{t-2} + B_1 T_t + B_2 D_{1t} + B_3 D_{2t} + B_4 D_{3t}$$

In those instances when the $\hat{\rho}_i$'s which were found to be significant in step 3 turn out not to be significant after the model was refitted,[4] resort was made to the use of "all possible regressions" (Draper and

[4]For example if $\hat{\rho}_1$, $\hat{\rho}_2$ and $\hat{\rho}_4$ are significant based on the "t" test (step 3) and when the model is refitted by omitting Y_{t-3} from the regression equation, the coefficient of Y_{t-1} or Y_{t-2} may turn out not to be significant.

Smith, 1966), to determine the appropriate model and the estimates for the ρ_i's.[5]

5. Depending on the estimates of the ρ_i's derived in step 4, both variables Y and X were transformed as well as the trend, seasonal dummies and the constant term. Following the example in step 4, the transformation would involve:

$$\overset{*}{Y}_t = Y_t - \hat{\rho}_1 Y_{t-1} - \hat{\rho}_2 Y_{t-2}$$

$$\overset{*}{X}_t = X_t - \hat{\rho}_1 X_{t-1} - \hat{\rho}_2 X_{t-2}$$

where the left hand side variables with stars on top are the transformed variables.

6. After having done the transformation, the following regressions were run:

a) $$\overset{*}{Y}_t = \overset{*}{B}_0 + B_1\overset{*}{X}_t + B_2\overset{*}{X}_{t-1} + B_3\overset{*}{X}_{t-2} + B_4\overset{*}{X}_{t-3} + B_5\overset{*}{X}_{t-4} + B_6\overset{*}{X}_{t-5} + B_7\overset{*}{X}_{t-6} + B_8\overset{*}{X}_{t-7} + B_9\overset{*}{X}_{t-8} + B_{10}\overset{*}{X}_{t+1} + B_{11}\overset{*}{X}_{t+2} + B_{12}\overset{*}{X}_{t+3} + B_{13}\overset{*}{X}_{t+4} + B_{14}\overset{*}{T}_t + B_{15}\overset{*}{D}_{1t} + B_{16}\overset{*}{D}_{2t} + B_{17}\overset{*}{D}_{3t}$$

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[5] "All possible regressions" is a procedure for selecting the "best" regression equation, i.e. choosing the least number of regression variables which would best explain the variation in the dependent variable. The procedure requires the fitting of every possible regression equation involving any number of variables, e.g. $X_1,\ldots,X_k$. The first set of regression equations would contain only one independent variable. The second set would contain all possible combinations of two independent variables, and the last set would be the regression containing k variables.

Given all the possible regressions, the best regression equation is chosen on the basis of some criterion or criteria, for example by examining the R^2s, the standard errors of estimate, the significance of the coefficients, the correlation matrix, etc. Here a great deal of personal judgment is necessary.

b) $\overset{*}{X}_t = \overset{*}{B}_0 + B_1\overset{*}{Y}_t + B_2\overset{*}{Y}_{t-1} + B_3\overset{*}{Y}_{t-2} + B_4\overset{*}{Y}_{t-3} + B_5\overset{*}{Y}_{t-4}$
$+ B_6\overset{*}{Y}_{t-5} + B_7\overset{*}{Y}_{t-6} + B_8\overset{*}{Y}_{t-7} + B_9\overset{*}{Y}_{t-8} + B_{10}\overset{*}{Y}_{t+1}$
$+ B_{11}\overset{*}{Y}_{t+2} + B_{12}\overset{*}{Y}_{t+3} + B_{13}\overset{*}{Y}_{t+4} + B_{14}\overset{*}{T}_t + B_{15}\overset{*}{D}_{1t}$
$+ B_{16}\overset{*}{D}_{2t} + B_{17}\overset{*}{D}_{3t}$

7. To check if the original transformation was satisfactory:

a) An estimate of the true error structure, $\tilde{e}$, was made

$\tilde{e} = Y - \tilde{Y}$

Y = untransformed Y's (original Y's: step 1)

$\tilde{Y} = \hat{B}X$ where the $\hat{B}$'s were derived from the regressions carried out in step 6

X = untransformed X's (step 1)

$\hat{B}X = \hat{B}_0 + \hat{B}_1X_t + \hat{B}_2X_{t-1} + \ldots + \hat{B}_9X_{t-8} + \hat{B}_{10}X_{t+1}$
$+ \ldots + \hat{B}_{13}X_{t+4} + \hat{B}_{14}T_t + \hat{B}_{15}D_1 + \hat{B}_{16}D_2 + \hat{B}_{17}D_3$

b) After the $\tilde{e}_t$'s have been calculated, $(\tilde{e}_t - \hat{\rho}_1\tilde{e}_{t-1} - \hat{\rho}_2\tilde{e}_{t-2})$ was regressed on $\tilde{e}_{t-1}$, $\tilde{e}_{t-2}$, $\tilde{e}_{t-3}$, $\tilde{e}_{t-4}$, i.e. $(\tilde{e}_t - \hat{\rho}_1\tilde{e}_{t-1} - \hat{\rho}_2\tilde{e}_{t-2}) = P_1\tilde{e}_{t-1} + P_2\tilde{e}_{t-2} + P_3\tilde{e}_{t-3} + P_4\tilde{e}_{t-4}$. Note $\hat{\rho}_1$ and $\hat{\rho}_2$ are the same ρ's used to transform all the variables and which were found to be significant in step 3.

c) The significance of the coefficients as a group was tested using the "F" test with level of significance equal to .10.

H_0: $P_1 = P_2 = P_3 = P_4$
H_A: $P_i \neq 0$.

If the "F" statistic is not significant, the direction of causality could be tested by directly applying Sims' rule to the regression equations in step 6. This will be the end of the procedure.

d) If on the other hand, the "F" statistic turns out to be significant, this indicates that the proper transformation was not made. Therefore, a new set of P's has to be calculated.

8. The new set of P's is derived from the regression:

$$\tilde{e}_t = P_1\tilde{e}_{t-1} + P_2\tilde{e}_{t-2} + P_3\tilde{e}_{t-3} + P_4\tilde{e}_{t-4}$$

9. Again the individual P's were tested using the "t" test with the critical region equal to .10.

$$H_0: \; P_i = 0$$

$$H_A: \; P_i \neq 0.$$

10. If not all of P's are significant, the model was refitted by eliminating from the regression equations those $\tilde{e}_{t-k}$ (k = 1, 2, 3, 4) whose coefficients are not significant. This section repeats the same procedure used in step 4.

11. Depending on which P's are significant, all the original variables (not the transformed variables) were transformed.

12. After transforming the variables, regressions similar to step 6 were carried out, and Sims' rule was applied to test the direction of causality.

13. Finally "Chow Test" (Huang, 1969) was used to test the stability of the structure.

Rationale for the two-stage regression procedure

The procedure described above is similar to the two-stage regression procedure suggested by J. Durbin (1960). Durbin's procedure is applicable to more than one explanatory variable and to higher autoregressive schemes in the error structure. Moreover the estimates have asymptotically the same properties as the least squares estimates obtained by direct minimization of the Σe^2 (Johnston, 1972).

The rationale for the use of Method I is that the transformations carried out on the variables, such as logging and prefiltering, are designed to make the residuals as white noise as possible, i.e., uncorrelated or independent. Then regressions are run on the transformed variables to get estimates of the parameters, B's. This is the first stage in the procedure.

If the proper transformation was not made, a new set of ρ's has to be estimated, (step 8) and used to transform the original variables. Then the regressions are carried out using the transformed variables. This makes up the second stage.

To check whether the proper transformation was made, the following steps were taken. First, an estimate of the true error terms, $\tilde{e}_t$'s, was made. This was done by subtracting from the original (not transformed) Y_t's, $\tilde{Y}_t$'s (step 7). Note that the $\tilde{Y}_t$'s are not the usual $\hat{Y}_t$'s obtained in ordinary regression procedures. The $\tilde{Y}_t$'s were estimated by multiplying the $\hat{B}$'s, obtained in the first stage, on the original X_t's not the prefiltered X_t's. By subtracting $\tilde{Y}_t$'s from Y_t's, an estimate of the e_t's, which is $\tilde{e}_t$'s is obtained. Again note that the $\tilde{e}_t$'s are different from the residuals of the regression on the transformed variables. Once an approximation of the true error terms is derived, a test of its structure is carried out (step 7). If the test shows no autocorrelation exists, then one can proceed to carry out the test to determine the direction of causality. On the other hand, if the test indicates autocorrelation, a new set of correlation coefficients has to be estimated and used to transform the original variables, including trend, seasonal dummies and the constant term (steps 8, 9, and 10). Then regressions are run on the transformed variables in order to test causal ordering.

Method II (first difference iterative estimation procedure)

The steps involved in Method II consisted of the following:

1. As in Method I, the variables were transformed into natural logs. Y and X are used to represent the logged variables.
2. The first differences of the logged variables were obtained, i.e., $Y_t - Y_{t-1}$, $Y_{t-1} - Y_{t-2}$, etc.; $X_t - X_{t-1}$, $X_{t-1} - X_{t-2}$, etc.
3. Linear regressions were applied on the first differences of the variables. Each regression equation consisted of the current, leading, and lagging values of the independent variable, a linear trend term, and three seasonal dummies. Note that the regression equations did not contain a constant term. Nevertheless the trend term which was added in place of the constant term is still linear in the log of the first difference, but not in the log of the variables (see Appendix B).

4. The regression residuals of each equation were tested for autocorrelation using the autoregressive scheme of the form:

$$\hat{e}_t = \rho_1 \hat{e}_{t-1} + \rho_2 \hat{e}_{t-2} + \rho_3 \hat{e}_{t-3} + \rho_4 \hat{e}_{t-4}$$

5. The significance of each $\hat{\rho}$ was determined using the "t test" with the critical region equal to .10.
6. Based on the results of step 5, the equation in step 4 was refitted by dropping those e_t's whose $\hat{\rho}$'s were not significant. The refitting would give new estimates for the ρ's. In those cases where the $\hat{\rho}$'s found to be significant in step 4 but which were no longer significant after the equation was refitted, the method of "all possible regressions" was employed to determine what e_t's would be included in the equation and the values of their respective ρ's.
7. Given the values of the new $\hat{\rho}$'s, the first differences of all the variables, the trend and the seasonal dummies were transformed and linear regressions were applied on the transformed variables.

This method is subject to iteration by obtaining the new set of regression residuals and testing for serial correlation (steps 4, 5, and 6). Depending on the results of the test, the transformed variables could be further transformed and a new set of regressions could be derived. The reiteration could continue until the regression residuals have been reduced to white noise.

8. Sims' rule to test causality was applied on the regression results.
9. Finally, "Chow Test" was also used to determine the stability of the structural parameters.

The author thought it appropriate to experiment with this method because the first difference reflects changes in the variable from one period to the next. Economists attribute changes in the money supply as causing changes in GNP. Regressions involving the first differences of money and GNP is widespread in the economic literature. Furthermore, employing first differences is a method to correct for serial correlation of the first order when the correlation coefficient is close to unity. Also, the use of first differences in distributed lag models involving only exogenous variables on the right hand side of the equation tends to minimize the problem of multicollinearity.

Method II is a form of generalized least squares where the variables are transformed using the estimated ρ's derived from the regression residuals. This procedure could be iterated several times by calculating new ρ's from the new regression residuals and retransforming the transformed variables and then regressing them until the researcher becomes satisfied that his regression residuals have become uncorrelated.

In the case of this paper, only one transformation was made because of certain constraints, especially computer money. Because of this and the possible problem of multicollinearity in estimating the ρ's of the regression residuals and also in estimating the regression coefficients of the distributed lag structure, the "F test" to determine causality may not be accurate.

Method III (Sims' method)

Sims' method consists of transforming all the variables into natural logs and prefiltering each of them using the filter

$$1 - 1.5\ L + .5625\ L^2, \text{ i.e.,}$$

$$Y_t - 1.5\ Y_{t-1} + .5625\ Y_{t-2},\ X_t - 1.5\ X_{t-1} + .5625\ X_{t-2}.$$

Linear regressions were then applied on the logged and filtered variables, together with a constant term, trend and seasonal dummies. Finally, the rule to test causality was applied on the regression results.

The reason why Sims logged and prefiltered the variables used in the regression is because he claims that this procedure tends to flatten the spectral density of most economic time series and he hoped that the regression residuals would be transformed to nearly white noise.

The filter Sims used was derived from Nerlove's work on seasonal adjustment (Nerlove, 1964). Sims experimented with this filter on various economic time series, and in the regressions involving logged and filtered variables, he was satisfied that serial correlation was avoided, except in one case. He detected negative serial correlation in his nondurable investment equation (Sims, 1971).

Summary

Three econometric procedures were used to test causal ordering. All these methods are intended to generate independent regression residuals in order to make precise use of the "F" test. It is for this reason that the variables were logged and transformed using filters. One difference among the methods used is that Sims (Method I) applies a standard filter on all the time series he used. On the other hand, Methods I and II attempt to estimate the filter by which to transform the variables. One problem inherent in the two methods is the estimation of the filter because of the possible problem of a high degree multicollinearity which affects the test of significance and estimates of the correlation coefficients.

The basic problem in all these methods is determining what is the appropriate filter to use.

CHAPTER III. EMPIRICAL RESULTS AND CONCLUSIONS

The Data

Quarterly data were used which covered the following periods: Canada, 1951 to 1970; Japan, 1955 to 1972; and the United States, 1951 to 1970. The figures for Canada and Japan were provided directly by their respective central banks while those for the United States were obtained through Data Resources, Inc. (1972).

"F" Tests on Four Future Quarters' Coefficients

Table 2 gives the "F" values of the tests on the four future quarters' coefficients for each of the three methods and for each of the three countries. For Canada, none of the "F" values were significant at a level of significance of 5 percent. This means that no causal influence could be inferred between money and income. Methods I and III tended to give larger "F" values for the regression of M_1 on GNP as compared to GNP on M_1 while Method II gave the opposite results.

In the case of Japan, Method II indicated that the direction of causation is from GNP to M_1. This "F" value was significant even at a level of significance of 1 percent. On the other hand, the "F" values derived from Methods I and III were not significant, implying no causal influence in either direction. The "F" values obtained from Methods I and II tended to be larger for the regression of GNP on M_1 relative to the regression of M_1 on GNP. The reverse was true for Method III.

Table 2. "F" tests on four future quarters' coefficients

	Method I	Method II	Method III
<u>Canada</u>			
GNP on M_1	$F_{4,46}$ = .943	$F_{4,45}$ = 1.829	$F_{4,48}$ = .107
M_1 on GNP	$F_{4,46}$ = 1.514	$F_{4,49}$ = 1.647	$F_{4,48}$ = 1.619
<u>Japan</u>			
GNP on M_1	$F_{4,38}$ = 2.231	$F_{4,37}$ = 6.165[a]	$F_{4,40}$ = .517
M_1 on GNP	$F_{4,38}$ = .897	$F_{4,39}$ = 1.932	$F_{4,40}$ = 1.744
<u>United States</u>			
GNP on M_1	$F_{4,46}$ = 1.408	$F_{4,49}$ = 2.117	$F_{4,48}$ = 1.720
M_1 on GNP	$F_{4,47}$ = 3.197[b]	$F_{4,49}$ = 1.437	$F_{4,48}$ = 4.416[a]

[a]Significant at the 1% level
[b]Significant at the 5% level

Concerning the United States, Methods I and III indicated that the direction of causation is from M_1 to GNP at a 5 percent level of significance. Method II did not give any indication about the direction of causation. However, if the level of significance were increased to 10 percent, Method II would show an income to money causal relationship.

One final thing to note about Table 2 is that Method II consistently gave larger "F" values for the regression of GNP on M_1 while the opposite was true for Methods I and III, except in one case.

The test results concerning the direction of causation for the countries is therefore ambiguous except in the case of Canada. The results obtained for Canada are consistent with what one might expect, i.e. no significant causal influence between money and income in either direction. It is a known fact that the United States is Canada's dominant trading partner. Moreover, the U.S. dollar is widely used as a medium of exchange in Canada and deposits denominated in U.S. dollars are accepted by Canadian banking institutions. It may be worthwhile to mention other features concerning Canada's situation. There are no controls on capital movements, thus debt and equity capital flow freely between Canada and the United States. Long term borrowing and lending occur between the two countries on a much larger scale than is common between pairs of countries in other parts of the world. A substantial proportion of business enterprises in Canada are owned or controlled directly or indirectly by U.S. corporations or U.S. based corporations. "Much of their investment in Canada is made to supply U.S. demand, and much of their financing takes the form of direct inflows of equity capital" (Freeman, 1973). This explains why Canada's price and cost experience over the last 20 years closely parallel those of the United States. The overall implication here is perhaps Canadian money GNP is more responsive to financial conditions in the United States rather than to the Canadian money supply.[6]

In the case of the United States and Japan, one would expect to find some relationship between money and income. It is unfortunate that the test results were ambiguous concerning the direction of causation.

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[6] In a speech by M. Friedman at the Federal Reserve Bank of Chicago in December, 1973, he stated that the study done by one of his Canadian students showed that on average, Canadian income is more responsive to the U.S. money supply than it is to the Canadian money supply.

"F" Values to Test Eight Lagged Coefficients

Table 3 gives the "F" values to test eight lagged coefficients. The only significant "F" value for Canada at a 5 percent level of significance is the regression of M_1 on GNP using Method I. It also appears from the table that the "F" values for the regression of M_1 on GNP tend to be relatively larger than those for the regression of GNP on M_1.

For Japan, all the "F" values for the regression of GNP on M_1 tended to be significant except in the case of Method III. Likewise, all the "F" statistics for the regression of M_1 on GNP were significant for all methods. The levels of significance is shown on the table.

In the case of the United States, only in one instance was the "F" statistics significant and that was for the regression of M_1 on GNP using Method III.

Table 3. "F" values to test eight lagged coefficients

	Method I	Method II	Method III
Canada			
GNP on M_1	$F_{8,50} = 1.468$	$F_{8,49} = 1.418$	$F_{8,52} = .384$
M_1 on GNP	$F_{8,50} = 2.922^a$	$F_{8,53} = 1.730$	$F_{8,52} = 1.148$
Japan			
GNP on M_1	$F_{8,42} = 5.226^a$	$F_{8,41} = 2.500^b$	$F_{8,44} = 1.033$
M_1 on GNP	$F_{8,42} = 2.436^b$	$F_{8,43} = 6.540^a$	$F_{8,44} = 2.731^b$
United States			
GNP on M_1	$F_{8,50} = 1.148$	$F_{8,53} = 1.115$	$F_{8,52} = .995$
M_1 on GNP	$F_{8,51} = 1.509$	$F_{8,53} = 1.805$	$F_{8,52} = 2.233^a$

[a] Significant at the 1% level
[b] Significant at the 5% level

Estimated Regression Coefficients by Countries

Tables 4, 5 and 6 give the estimated regression coefficients by country for all the methods used.[7] They provide the estimated regression coefficients for the four future, current and eight lagged coefficients. In addition, the estimated coefficients for the regressions on the current and eight lagged values of the independent variable are also presented.

These tables also provide the squares of the coefficients of multiple correlation (R^2s), the largest and smallest standard errors of coefficients, indication of those regression coefficients which are significant, and the sum of the current and eight lagged coefficients.

There are a few things to note in connection with these tables. First, the standard errors of coefficients seem large relative to the estimated regression coefficients. Consequently, only a few of the coefficients turn out to be significant. Large standard errors of coefficients is one indication of possible serious multicollinearity. Second, negative signs[8] appear in some regression coefficients. This

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[7]The tables containing the estimated regression coefficients by method for all the countries analyzed are found in Appendix A.

[8]Friedman (1961) provides a possible explanation to such occurrence. He says the effects may change sign after a time because the original effects of changes in the money supply set up forces that tend to produce not merely a reversal (feedback effects of business on money) but an overshooting. This explanation is possibly true but it does not account for why negative signs sometimes appear on the first, second and/or third lagged periods as shown in the tables.

Table 4. Estimated regression coefficients, Canada: 1951-1970

	GNP on M_1					
	Method I		Method II		Method III	
t	w/future	current & past	w/future	current & past	w/future	current & past
4	-.165	--	.078	--	.178	--
3	.091	--	.226	--	-.051	--
2	-.330	--	-.206	--	-.074	--
1	.323	--	.474[a]	--	.081	--
0	.111	.197	.313	.283	.234	.202
-1	.261	.340	.536[a]	.416[a]	.429	.422
-2	-.172	-.028	-.020	-.065	-.100	-.101
-3	.021	-.028	.275	.040	.131	.113
-4	.528	.459	.711[b]	.564[b]	.229	.235
-5	.049	.094	.047	.028	.163	.203
-6	.006	.077	.238	.184	.295	.258
-7	-.049	-.080	.209	.039	.065	.028
-8	.174	.156	.322	.280	.003	.036
Sum of current and eight lagged coefficients	.929	1.187	2.631	1.769	1.449	1.396
R^2	.94	.93	.96	.95	.96	.96
Standard errors of coefficients						
Largest S. E.	.275	.268	.229	.215	.364	.334
Smallest S. E.	.217	.217	.194	.193	.332	.314

[a]Significant at 5% level

[b]Significant at 1% level

	M_1 on GNP					
	Method I		Method II		Method III	
t	w/future	current & past	w/future	current & past	w/future	current & past
4	.236	--	.169	--	.203	--
3	.083	--	.096	--	.185	--
2	-.020	--	-.024	--	.066	--
1	.145	--	.170	--	.206	--
0	.144	.230	.131	.122	.154	.042
-1	.162	.225	.059	.133	.091	.107
-2	-.062	-.080	-.098	-.106	-.057	-.050
-3	-.211	-.278[a]	-.133	-.113	-.114	-.072
-4	-.321[a]	-.302[a]	-.245[a]	-.216[a]	-.233	-.153
-5	-.092	-.169	-.155	-.202[a]	-.168	-.172
-6	.179	.139	.081	.032	.082	.017
-7	.093	.094	.031	.074	.053	.037
-8	.044	.140	.093	.166	.098	.141
Sum of current and eight lagged coefficients	-.064	.001	-.236	-.110	.016	-.103
R^2	.78	.75	.90	.90	.93	.81
Standard errors of coefficients						
Largest S. E.	.164	.144	.113	.105	.149	.143
Smallest S. E.	.125	.122	.087	.088	.104	.010

Table 5. Estimated regression coefficients, Japan: 1955-1972

	GNP on M_1					
	Method I		Method II		Method III	
t	w/future	current & past	w/future	current & past	w/future	current & past
4	-.394	--	.468[a]	--	-.267	--
3	.019	--	.573[a]	--	-.624	--
2	.048	--	-.254	- --	-.238	--
1	-.079	--	.480	--	.544	--
0	-.298	-.364	.180	.582[a]	.583	.496
-1	.566	.551	-.096	-.017	-.076	-.156
-2	.425	.407	-.373	-.363	-.819	-.827
-3	.433	.505	-.495	-.500	.732	.766
-4	-.856	-.871	.452	.555	-.257	-.318
-5	.292	.185	-.150	.265	.075	-.142
-6	.123	.107	-.206	-.213	-.280	-.471
-7	.147	.180	-.277	-.266	-.296	-.102
-8	-.670[a]	-.554[a]	.517[a]	.594[a]	.420	.652
Sum of current and eight lagged coefficients	.162	.146	-.448	.637	.082	-.102
R^2	.96	.94	.98	.97	.98	.98
Standard errors of coefficients						
Largest S.E.	.624	.494	.265	.309	.647	.570
Smallest S.E.	.263	.257	.201	.240	.549	.501

[a]Significant at 5% level

[b]Significant at 1% level

	M_1 on GNP					
	Method I		Method II		Method III	
t	w/future	current & past	w/future	current & past	w/future	current & past
4	-.064	--	.018	--	.031	--
3	.027	--	-.010	--	.181	--
2	.067	--	.019	--	.126	--
1	.318	--	.100[b]	--	.242	--
0	.337	.497[b]	.096[a]	.842[a]	.245[a]	.054
-1	.066	.230	.189[b]	.175[b]	-.004	-.073
-2	-.069	-.127	.215[b]	.192[b]	-.026	-.141
-3	-.275	-.304	.098[a]	.145[b]	-.194	-.269[a]
-4	-.079	-.109	.072	.081[a]	-.063	-.138
-5	.299	.213	.005	-.012	.221	.104
-6	.172	.176	-.002	.000	.129	.029
-7	.082	.193	-.057	.072[a]	.143	.105
-8	.088	.026	.025	.028	.138	.084
Sum of current and eight lagged coefficients	.621	.795	.641	1.523	.589	-.245
R^2	.95	.95	.97	.96	.98	.98
Standard errors of coefficients						
Largest S.E.	.208	.173	.039	.039	.126	.100
Smallest S.E.	.155	.145	.033	.033	.074	.073

Table 6. Estimated regression coefficients, United States: 1951-1970

	GNP on M_1					
	Method I		Method II		Method III	
t	w/future	current & past	w/future	current & past	w/future	current & past
4	-.632[a]	--	-.782[a]	--	-.673[a]	--
3	.128	--	.071	--	.159	--
2	-.029	--	-.025	--	.070	--
1	.188	--	.125	--	.212	--
0	.292	.559[a]	.215	.509	.300	.500
-1	.202	.176	.150	.129	.246	.147
-2	.381	.310	.329	.254	.441	.309
-3	.378	.327	.325	.272	.410	.316
-4	-.238	.018	-.393	-.145	-.321	-.127
-5	-.040	-.111	-.096	-.186	-.032	-.151
-6	-.279	-.321	-.273	-.335	-.217	-.299
-7	.413	.269	.378	.180	.363	.168
-8	.321	-.225	-.355	-.342	-.430	-.385
Sum of current and eight lagged coefficients	.788	1.002	.280	.336	.760	.478
R^2	.59	.51	.82	.78	.94	.93
Standard errors of coefficients						
Largest S.E.	.306	.289	.305	.294	.283	.269
Smallest S.E.	.283	.272	.268	.264	.269	.255

[a]Significant at 5% level

[b]Significant at 1% level

	M_1 on GNP					
	Method I		Method II		Method III	
t	w/future	current & past	w/future	current & past	w/future	current & past
4	.051	--	.002	--	.054	--
3	.131	--	.062	--	.129[a]	--
2	.183[b]	--	.095	--	.171[b]	--
1	.160[a]	--	.078	--	.162[b]	--
0	.189[b]	.117	.078	.091	.182[b]	.167[a]
-1	.098	.009	-.017	-.036	.091	.055
-2	.105	.015	-.013	-.043	.098	.069
-3	.093	.025	-.011	-.039	.096	.071
-4	-.018	-.043	-.107	-.096	.003	.027
-5	.012	-.016	-.603	-.058	.024	.051
-6	-.002	-.027	-.088	-.087	-.006	.026
-7	.092	.083	.031	.034	.098	.125
-8	.140[a]	.158[a]	.082	.107	.149	.203[b]
Sum of current and eight lagged coefficients	.708	.321	-.108	-.127	.735	.794
R^2	.69	.69	.82	.80	.95	.93
Standard errors of coefficients						
Largest S.E.	.070	.069	.066	.064	.063	.068
Smallest S.E.	.059	.063	.059	.060	.057	.062

could be implying misspecification of the model, perhaps the lag structure. Third, there is no discernible pattern concerning the lag structure. Evidences from many economic studies involving distributed lags tended to favor lag structures of two different types: weights which follow an "inverted v" distribution and a geometrically declining weight structure. Finally, Sims (1972) found the pattern of a short run elasticity exceeding unity and a long run elasticity below unity. This result was not obtained in this study.

It is reasonable to assume that the impact of one variable on another would be distributed over time. For example, this month's expenditure on advertisement would be expected to affect not only this month's sales but also the sales for the succeeding months. An econometric formulation allowing for the current as well as the past values of one variable to affect another could be written as:

$$Y_t = B_0 X_t + B_1 X_{t-1} + \dots + B_s X_{t-s} + U_t.$$

This regression equation together with the relevant assumptions is called a distributed lag model.

The model can be estimated if the B's have a finite sum ($\sum_{i=0}^{s} B_i < \infty$). Furthermore least squares estimate will still give the best linear unbiased estimates provided the model has been correctly specified, and the usual assumptions about the distribution of U and the independence of X and U are satisfied (Johnston, 1972). However, the estimation poses two problems, namely: the form of the lag and second, the danger of serious multicollinearity because of the lagged X_s. Concerning the form of the lag, theory in many cases would not be of much help. Consequently statistical procedures have to be relied upon to determine the appropriate form.

In practice, distributed lag models of the form described above are rarely estimated without some restrictions placed on the regression coefficients. The two most common types of restrictions imposed are that the B's should be declining in a geometric progression or the B's should first be increasing and then declining ("inverted v" or a polynomial of low degree). Adaptive expectation models and partial adjustment models are examples in economics of the use of geometrically declining weighted average. On the other hand, de Leew (Johnston, 1972) in a study of capital investment found evidence in favor of the weights following an "inverted v" distribution. Friedman (1961) alludes to this form of lag distribution concerning the effects of an instantaneous monetary change on money income.[9]

In all the test methods used in this paper, no a priori restriction was imposed on the form of the lag structure other than the length of the lag. Nevertheless the length of the lag distribution was kept generous. The reason for this is because Sims (1972) warns that pre-filtering may produce a perverse effect on approximation error when lag distributions are subject to prior "smoothness" restrictions. He

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[9]Friedman (1961) states "Suppose the effect on, say national income of a single instantaneous monetary change could be isolated in full from the surrounding matrix. The effect would no doubt be found to begin immediately, rise to a crescendo, then decline gradually, and not disappear fully for an indefinite time."

therefore suggests that no Koyck, Almon or rational lag restrictions should be imposed and the length of the lag should be kept generous.

This writer suspects that the relatively large standard errors of coefficients, the negative signs and the failure to observe any discernible pattern concerning the lag structure may be due to the lack of a priori restrictions on the lag distribution and also because of the possible danger of a high degree of multicollinearity.

Sims (1972) found in his study that the short run elasticity of income with respect to changes in the money supply exceeded unity while the long run elasticity was below unity. Since Sims transformed his data to natural logs, the regression coefficients may be viewed as elasticities, i.e. the degree of responsiveness of changes in money income to changes in the money supply. His study showed that the lag distribution was positive at first and became mostly negative beyond the fourth lag. The sum of the initial positive coefficients was greater than one but the sum of all the coefficients was less than one. Sims interpreted this finding to mean that in the short run, money income is highly responsive to changes in the money supply but not in the long run. He claims that this agrees with Friedman's (1961) theoretical specification concerning the demand for money. As previously stated, this result was not found in this study.

It should also be pointed out that using Method I on U.S. data, a second transformation was not necessary. The tests on the residuals, $\tilde{e}_t$'s, indicated that the initial transformation was the proper transformation. The same thing was true for the regression of Canadian GNP on Canadian M_1 using Method I.

The above observation was always the case whenever those variables which were significant prior to refitting the equation to estimate the correlation coefficients (ρ's) turn out also to be significant after refitting.

"F" Values for Comparison of Subperiods

The "F" statistics for comparison of subperiods (Chow Test) is provided by Table 7. The tests showed some structural changes for Canada and more so for Japan but none for the United States. The subperiods covered were as follows: Canada and the United States, 1951 to 1960 and 1961 to 1970; Japan, 1955 to 1963 and 1964 to 1972.

Table 7. "F" values for comparison of subperiods; U.S. and Canada: 1951 to 1960 and 1961 to 1970; Japan: 1955 to 1963 and 1964 to 1972

	Method I	Method II	Method III
Canada			
GNP on M_1	$F_{19,26} = 1.812$	$F_{18,26} = 1.503$	$F_{19,28} = 2.702^a$
M_1 on GNP	$F_{19,26} = 1.682$	$F_{18,26} = 1.020$	$F_{19,28} = 1.115$
Japan			
GNP on M_1	$F_{19,18} = 3.126^a$	$F_{18,18} = 1.642$	$F_{18,20} = 3.299^a$
M_1 on GNP	$F_{19,18} = 7.810^a$	$F_{18,18} = 2.590^b$	$F_{18,20} = 1.512$
United States			
GNP on M_1	$F_{19,26} = 1.114$	$F_{18,30} = 1.257$	$F_{19,28} = 1.274$
M_1 on GNP	$F_{19,26} = .763$	$F_{18,30} = .885$	$F_{19,28} = .831$

[a]Significant at 1% level

[b]Significant at 5% level

CHAPTER IV. CONCLUSION

Since the three methods used do not give consistent results when applied to each country, the major conclusion of this paper is the results of the tests to determine causal ordering are highly sensitive to the methodology used. To illustrate this point, the findings for the United States is that Methods I and III indicate that the direction of causation is from money to income at a level of significance of 10 percent. On the other hand, Method II points to income as the cause and money, the effect. If the level of significance were reduced to 5 percent, Methods I and III would still give the same results but in the case of Method II, money and income would become independent.

Feige and Pierce (1974) used the Box Jenkins method to determine the values of the filters they applied on U.S. data. After prefiltering the variables, running the regressions, and carrying out the "F" tests on the future quarters' coefficients, they reported that their study indicates that money and income are statistically independent.

The Feige and Pierce study (1974) is another approach to test causal priority. Taking this study into account, there are now four methods applied on U.S. data, two of which give contrary results to the other two. Moreover, the test results for Japan in this paper are also ambiguous. All these results support the conclusion of this paper.

Given this conclusion, the question which logically follows is which among the several methods mentioned is the appropriate method to use.

It should be noted that econometric methods to test causal direction require that the assumption of serially uncorrelated residuals be approximately accurate. If this assumption is not satisfied, least squares estimates are still unbiased and consistent (provided no lagged endogenous variables appear on the right hand side of the equation) but no longer efficient. More important for this study is the fact that when the regression residuals are correlated, the conventional formulas for carrying out tests of significance or constructing confidence intervals with respect to the regression coefficients lead to incorrect statements (Kmenta, 1971).

Autocorrelation refers to the interdependence of successive disturbances. Autocorrelation of first and higher order can arise because of misspecification of the model such as faulty functional form and the omission of certain variables in the model. In addition, the persistence of observation errors in economic variables, the estimation of missing data by either averaging or extrapolating, and the lagged effects of temporary shocks distributed over a number of time periods can give rise to autocorrelation in the disturbances (Huang, 1969).

There are various tests for departure from the assumption of independence. The tests vary depending upon the suspected structure of the residuals. For example, the Durbin-Watson statistics is applicable only to first order autoregressive disturbance when the regression equation contains a constant term and no lagged endogenous variables appear on the right hand side of the equation. For disturbances suspected of belonging to higher order autoregressive schemes, some tests which could be applied are the Durbin test on the cumulated periodogram (1969), likelihood ratio test (Hannan, 1960), spectral analysis, etc.

To correct or minimize autocorrelation, most procedures use linear transformations on all the variables in the regression. This technique is a form of generalized least squares. But in order to transform the variables, values of the linear transformation have to be estimated. How to calculate the values of the filter is the key question.

To illustrate the importance of accurately estimating the filter, the writer experimented with two sets of filters. For the regression of U.S. GNP on U.S. M_1 the transformation used was $1 - 1.253L + .341\ L^2$, i.e., $Y_t - 1.253\ Y_{t-1} + .341\ Y_{t-2}$ and $X_t - 1.253\ X_{t-1} + .341\ X_{t-2}$. For the regression of M_1 on GNP, the filter used was $1 - 1.726\ L - .970\ L^2$. The second set of filters were $1 - 1.464\ L + .463\ L^2$ and $1 - 1.605\ L + .605\ L^2$ for the regressions of GNP on M_1 and M_1 on GNP respectively. Using the first set of filters, the "F" tests indicated that money and income were independent while the "F" tests using the second set of filters pointed to a money income causal relationship. Noting that the numerical differences between the sets of filter are "small" and yet different results were obtained, this experiment indicates the sensitivity of the test results to the filter used and therefore the importance of accurately estimating the filters.

Sims' (1972) method uses a standardized filter equal to $1 - 1.5\ L + .5625\ L^2$ because he claims his studies show that this filter tends to flatten the spectral density of most economic time series and the hope was that the residuals would be reduced to white noise. Method I estimates the filter initially by autoregressive procedures applied on the endogenous variable and then checks the residuals ($\tilde{e}_t$'s) whether further transformation is necessary. If a second transformation is necessary, another autoregressive procedure is used to determine the filter but this time the residuals ($\tilde{e}_t$'s) are used instead of the endogenous variable. Method II calculates the correlation coefficients from the regression residuals ($\tilde{e}_t$'s) through the autoregressive equation of the form $\hat{e} = \rho_1 \hat{e}_{t-1} + \rho_2\hat{e}_{t-2} + \rho_3\hat{e}_{t-3} + \rho_4\hat{e}_{t-4}$. The estimates for the ρ's are then used to transform the variables. One basic problem in calculating the filters using an autoregressive scheme is selecting the best regression equation containing for example, those $\hat{e}_{t-i}$ which are highly correlated with e_t. Once the best regression equation has been determined, estimates for ρ_i's are automatically derived. The author for example regressed e_t on $\hat{e}_{t-1}$, $\hat{e}_{t-2}$, $\hat{e}_{t-3}$ and $\hat{e}_{t-4}$ and tested the significance of each regression coefficient ($\hat{\rho}_i$). The equation was then refitted by eliminating those $\hat{e}_{t-i}$ whose ρ_i's were not significant. After refitting the equation and testing the significance of the remaining $\hat{\rho}_i$'s, it was observed that some ρ_i's which were significant in the first equation were no longer significant after refitting. This phenomenon gives rise to the problem of determining which variables enter the regression equation. Considerable judgment is required in analyzing the summary statistics of the possible regressions in order to answer this question.

Realizing the difficulty of estimating the ρ_i's necessary to correct for autocorrelation, Rao and Miller (1971) warn that correcting for serial correlation does not always give "better" results unless the parameter of serial correlation is known, which he claims is rarely the case.

Finally, the possibility of a high degree of multicollinearity in the regressions of GNP on M_i and vice versa should not be discounted. The problem of multicollinearity concerns the degree to which multicollinearity becomes harmful and not whether it exists or does not exist. There are various ways to measure the degree of multicollinearity (Kmenta, 1971). However, the degree to which multicollinearity becomes harmful is still being debated by the econometric profession. Multicollinearity is one problem, of which not much can be done without a priori knowledge of the model and the variables. On this point Rao and Miller (1971) suggests that the tendency to blame all econometric problems on multicollinearity may often be largely a theoretical nightmare rather than an empirical reality.

All these problems may contribute to explaining why the methods used give conflicting results in each country. To ascertain which method is more accurate than the other, additional work has to be done, some of which are suggested in the next section.

Suggestions for Further Study

The conclusion of this paper is the results of tests to determine causal direction is highly sensitive to the methods used. Therefore, the question to be resolved is which among the several methods is the appropriate one. The suggestions below are intended to elucidate on this question.

1. Since the results of Method II differ most from the others, perhaps Method II could be modified and the results analyzed. Method II may be modified by prefiltering the first difference of all the variables including the trend and seasonal terms prior to carrying out the regressions. Then the regression residuals could be analyzed for autocorrelation and the remaining steps of the methods could be carried out. In addition, a constant term should be tried in lieu of a trend variable.

2. One way to discriminate among the several methods is to test the regression residuals in each of the methods for autocorrelation. Some tests which could be applied is the Durbin (1969) test on the cumulated periodogram, likelihood ratio test (Hannan, 1960), the use of spectral analysis, etc. Sims used the first two tests on his regression residuals. One problem however with these tests is that they require a large number of observations. For instance, Granger (1964) suggests that the ideal number of observations is 200 and the minimum number should be 100 to use spectral analysis.

3. Another way to compare the different procedures is to use frequency domain procedures such as Hannan's (1963) "inefficient"

procedure to check on the least squares results. This is how Sims justified his procedure.

4. Cross spectral analysis could be applied on the two series in order to study the lead and lag relationship between them. The leads and lags could indicate causal ordering.

5. Path analysis has been a procedure used for sometime in the social sciences, particularly sociology, to determine causal ordering. Path analysis could be applied to the two series to test for direction of causation (see Kerlinger and Pedhazer, 1973).

6. Finally, one practical approach to evaluating the different methods is to take time series observations of two variables whose cause and effect relationship is a priori known, for example, temperature and mercury. By applying the methods on the two series, their results could be compared as to whether they are consistent with the a priori knowledge.

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APPENDIX A. ESTIMATED REGRESSION COEFFICIENTS BY METHODS

Table 8. Estimated regression coefficients: Method I

t	GNP vs M_1 Canada	GNP vs M_1 Japan	GNP vs M_1 United States	M_1 vs GNP Canada	M_1 vs GNP Japan	M_1 vs GNP United States
4	-.165	-.394	-.632	.236	-.064	.051
3	.091	.019	.128	.083	.027	.131
2	-.330	.048	-.029	-.020	.067	.183[a]
1	.323	-.079	.188	.145	.318	.160[b]
0	.111	-.298	.292	.144	. 37	.189[a]
-1	.261	.566	.202	.162	.066	.098
-2	-.172	.425	.381	-.062	-.069	.105
-3	.021	.433	.378	-.211	-.275	.093
-4	.528	-.856	-.238	-.321	-.079	-.018
-5	.049	.292	-.040	-.092	.299	.012
-6	.006	.123	-.279	.179	.172	-.002
-7	-.049	.147	.413	.093	.082	.092
-8	.174	-.670[b]	-.321	.044	.088	.140[b]
Sum of current and 8 lagged coefficients	.929	.162	.788	.064	.621	.708
R^2	.94	.96	.59	.78	.95	.69
Standard errors of coefficients						
Largest S.E.	.275	.624	.306	.164	.208	.070
Smallest S.E.	.217	.263	.283	.125	.155	.059

[a]Significant at 1% level
[b]Significant at 5% level

Table 9. Estimated regression coefficients: Method II

t	GNP vs M_1 Canada	GNP vs M_1 Japan	GNP vs M_1 United States	M_1 vs GNP Canada	M_1 vs GNP Japan	M_1 vs GNP United States
1	.078	.468[a]	-.782[b]	.169	.018	.002
2	.226	.573[a]	.071	.096	-.010	.062
3	-.206	-.254	-.025	-.024	.019	.095
4	.474	.480	.125	.170	.100[b]	.078
0	.313	.180	.215	.131	.096[a]	.078
-1	.536[a]	-.096	.150	.059	.189[b]	-.017
-2	-.020	-.373	.329	-.098	.215[b]	-.013
-3	.275	-.495	.325	-.133	.098[a]	-.011
-4	.711[b]	.452	-.393	-.245[a]	.072	-.107
-5	.047	-.150	-.096	-.155	.005	-.063
-6	.238	-.206	-.273	.081	-.002	-.088
-7	.209	-.277	.378	.031	-.057	.031
-8	.322	.517[a]	-.355	.093	.025	.082
Sum of current and 8 lagged coefficients	2.631	-.448	.280	-.236	.641	-.108
R^2	.96	.98	.82	.90	.97	.82
Standard errors of coefficients						
Largest S.E.	.229	.265	.305	.113	.039	.066
Smallest S.E.	.194	.201	.268	.087	.033	.059

[a]Significant at 5% level

[b]Significant at 1% level

Table 10. Estimated regression coefficients: Method III

t	GNP vs M_1 Canada	Japan	United States	M_1 vs GNP Canada	Japan	United States
1	.178	-.267	-.673[a]	.203	.031	.054
2	-.051	-.624	.159	.185	.181	.129[a]
3	-.074	-.238	.070	.066	.126	.171[b]
4	.081	.544	.212	.206	.242	.162[b]
0	.234	.583	.300	.154	.245[a]	.182[b]
-1	.429	-.076	.246	.091	-.004	.091
-2	-.100	-.819	.441	-.057	-.026	.098
-3	.131	.732	.410	-.114	-.194	.096
-4	.229	-.257	-.321	-.233	-.063	.003
-5	.163	.075	-.032	-.168	.221	.024
-6	.295	-.280	-.217	.082	.129	-.006
-7	.065	-.296	.363	.053	.143	.098
-8	.003	.420	-.430	.098	.138	.149
Sum of current and 8 lagged coefficients	1.449	.082	.760	.016	.589	.735
R^2	.96	.98	.94	.93	.98	.95
Standard errors of coefficients						
Largest S.E.	.364	.647	.283	.149	.126	.063
Smallest S.E.	.332	.549	.269	.104	.074	.057

[a]Significant at 5% level

[b]Significant at 1% level

APPENDIX B. DETERMINING THE FORM OF THE TREND USED IN METHOD II

Let: $L_n G_t = Y_t$

$$L_n M_t = X_t$$

$$\Delta Y_t = Y_t - Y_{t-1}$$

$$\Delta X_t = X_t - X_{t-1}$$

The regression equation consisted of the following:

$$\Delta Y_t = B_1 \Delta X_t + B_2 \Delta X_{t-1} + B_3 \Delta X_{t-2} + \ldots + B_9 \Delta X_{t-8} + B_{10} \Delta X_{t+1}$$

$$+ \ldots + B_{13} \Delta X_{t+4} + \delta T_t + B_{14} D_1 + B_{15} D_2 + B_{16} D_3$$

Note:

1. The regression equation does not contain a constant term;
2. $T_t = t$ where $t = 1, 2, 3,$ etc.

ΔY_t could be written as

$$\Delta Y_t = Y_t - Y_{t-1} = A_t + \delta^t$$

where A_t is equal to the sum of all the other terms in the regression equation other than the trend term.

$$L_n G_t - L_n G_{t-1} = L_n \left(\frac{G_t}{G_{t-1}}\right)$$

$$L_n \frac{G_t}{G_{t-1}} = A_t + \delta^t$$

$$\frac{G_t}{G_{t-1}} = e^{A_t + \delta^t}$$

$$G_t = G_{t-1} e^{A_t + \delta^t}$$

Let G_0 = initial value

$$G_{t-1} = G_{t-2}\, e^{A_{t-1} + \delta(t-1)}$$

$$G_{t-2} = G_{t-3}\, e^{A_{t-2} + \delta(t-2)}$$

$$G_1 = G_0\, e^{A_1 + \delta(1)}$$

$$G_t = G_0\, e^{A_t + \delta t}\, e^{A_{t-1} + \delta(t-1)} \cdots e^{A_1 + \delta}$$

$$= G_0\, e^{\sum_{i=1}^{t} A_i + \delta \sum_{i=1}^{t} i}$$

$$= G_0\, e^{a_t + \delta \frac{t(t+1)}{2}}$$

where

$$a_t = \sum_{i=1}^{t} A_i$$

$$\sum_{i=1}^{t} i = \frac{t(t+1)}{2}$$

$$G_t = G_0\, e^{a_t + \delta \frac{t(t+1)}{2}}$$

$$Y_t = l_n G_t$$

$$= l_n G_0 + a_t + \delta \frac{t(t+1)}{2}$$

Let $B_t = l_n G_0 + a_t$

$$Y_t = l_n G_t = B_t + \frac{\delta t}{2} + \frac{\delta t^2}{2}$$

The above is a polynomial of the second degree.

This implies that the trend with respect to Y_t $(=l_n G_t)$ is a polynomial of the second degree. However, the trend with respect to ΔY_t is linear.

To check on the above result:

$$\Delta Y_t = A_t + \delta t$$

$$\Delta Y_t = Y_t - Y_{t-1}$$

$$\Delta Y_t = A_t + \delta t$$

$$Y_t = B_t + \frac{\delta t}{2} + \frac{\delta t^2}{2}$$

$$Y_{t-1} = B_{t-1} + \frac{\delta(t-1)}{2} + \frac{\delta(t-1)^2}{2}$$

Subtracting Y_{t-1} from Y_t:

$$Y_t - Y_{t-1} = \Delta Y_t = B_t - B_{t-1} + \delta t$$

$$B_t = \ln G_0 + a_t$$

$$B_{t-1} = \ln G_0 + a_{t-1}$$

$$\Delta Y_t = B_t - B_{t-1} + \delta t$$

$$= a_t - a_{t-1} + \delta t$$

$$= A_t + \delta t$$

since $$a_t - a_{t-1} = \sum_{i=1}^{t} A_t - \sum_{i=1}^{t-1} A_t = A_t$$