Money, Interest, Income, and Prices

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Thoughts on Intermediate Monetary Targets

I. Introduction

This paper analyzes the causal relations among money supply, interest rates (especially real rates), income (both real and nominal), and prices. As is well known, the major industrialized countries have used money-centered monetary policy since the first oil crisis. This is because nominal interest rates, which had had a relatively stable relationship with real activity in the 1960s, ceased to be an accurate indicator of the strength of monetary impact on real activity, due to the acceleration of inflation during the late 1960s. That is, in times when inflationary expectations are rising, a rise in nominal interest rates does not necessarily indicate tight money; using nominal interest rates as the intermediate target for monetary policy management carries the danger of encouraging higher inflation. In addition to reconsideration of the wisdom of nominal interest rate based monetary policy, there came to be a widespread recognition of the stable and close relationship of money supply and prices. Monetary policy management focusing on money supply thus became dominant in the major industrial countries after the first oil crisis.

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However, in the United States, progress of financial innovation destabilized money damand functions, and hence limits to the usefulness of money supply as an intermediate target were recognized. To replace money as intermediate target, the real interest rate has recently come to the fore. In Japan, the relationships of money, income, and prices have been stable, and the critical problems faced by the United States have not occurred. On the contrary, money supply control is credited with being an important cause of Japan's ability to appropriately control inflationary pressures accompanying the second oil crisis. However, one can also say that the swift and early increases in nominal interest rates raised real interst rates to appropriate levels, and these high real rates were what allowed successful implementation of the policy goal of price stability.

This paper uses time series data from Japan to examine whether money supply or interest rates (particularly real interest rates) is the better intermediate indicator for monetary policy. This is done by examining statistical causality among these monetary indicators, income, and prices. When we consider which intermediate indicator is more appropriate, we must consider factors such as (i) stability and closeness of the intermediate target and final targets and (ii) controllability of the intermediate indicator. This paper focuses on the first of these factors. It is an empirical analysis with the goal of fact finding about the characteristics of causal relations among economic variables.

As the method of analysis, we use the "relative power contribution" (RPC) as applied to time series, in both bivariate and multivariate forms. With this method, we do not rely on any particular theories, but rather analyze objectively what can be read from the actual data.[1]

Section II of the paper introduces the relative power contribution as a way to analyze causality among economic variables. Section III uses new analytical method to examine systematically the bivariate causality relations between observable monetary variables such as money supply and the major target variables of monetary policy such as income and prices. Section IV considers multivariate causality, and adds unobservable real interest rates (see the Appendix for how real rates are calculated) to nominal rates and money supply as indicators which interact with income and prices. This is done to determine which intermediate monetary indicator is best. Section V summarizes results.

1. This analysis is an inductive one, and stands in contrast to decutive analysis, which examines a particular model with actual data. Since we are not considering any particular theoretical model, structural equations are not expressed explicitly. Moverover, judgments on policy implications must be made with caution, since it is difficult to separate clearly the relationships generated by actions of policymakers and those generated by the market mechanism.

II. Methods of Causal Analysis for Economic Variables

The judgmental basis for most statistical analysis of causality is Granger causality, based on notions of forecasting.[2] But there have been several methods for analyzing causality, and we shall briefly review them here.

The simplest method of causality analysis is to compare peaks and troughs of various variables, and then infer causality from their chronological relationships. But movements of ecomomic time series are related, and one must look at movements between the peaks and troughs as well. The most general method in use for this is cross correlation analysis.[3] Cross correlation analysis expresses the chronological responses among variables by the strength of their correlations, and large correlation coefficients will occur when causality in the Granger sence exists. But here, as in the case of peak-trough analysis, the direction of causality is not necessarily clear, and there are other problems such as inability to distinguish cross correlations and autocorrelations. Hence, cross correlation analysis has defects which prevent it from providing sufficient conditions to show existence of causality.

In contrast to these, the Sims' Test method can be used to test directly for causality in the Grangere sense.[4] The Sims' Test is superior to cross correlation analysis in that it distinguishses between autocorrelation and cross correlation effects. But it does not specify any particular time series model, but rather uses a filter to extract the noise from each series, and then uses regression analysis of the noise series to perform F-tests on predictive power. Hence, results will not be uniform if different filters or different numbers of regressors are used.

2. See Granger [31].

3. Cross correlation analysis for two variable $\{x_i\}$, $\{y_i\}$ examines the correlation between one series and the other lagged a given number of periods. We define the cross correlation at lag ℓ between series $\{y_i\}$ lagged ℓ periods behind series $\{x_i\}$ as

$$r_{yx}(\ell) = \frac{R_{yx}(\ell)}{\sqrt{R_{yy}(0)\ R_{xx}(0)}}$$

where $R_{yx}(\ell)$ is the joint covariance defined, with expectations operator E, as

$$R_{yx}(\ell) = E\left\{[y(s+\ell) - m_y]\,[x(s) - m_s]\right\}$$

with $m_x = E\ \{x[s]\}$, $my = E\ \{y[s]\}$. R_{xx} and R_{yy} are the autocovariances of x and y, defined as

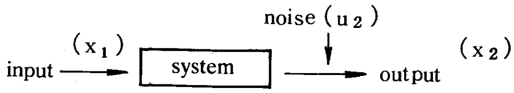
$$R_{xx}(0) = E\left\{[x(s) - m_x]^2\right\},\quad R_{yy}(0) = E\left\{[y(s) - m_y]^2\right\}$$

4. See Sims [48].

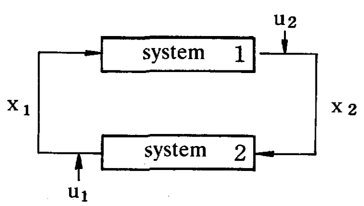
The relative power contribution (RPC) method used in this paper specifies a multivariate time series model, and uses this to extract the noise from variables. Hence, it is a more objective and better method than either the Sims' Test or cross correlation analysis. This RPC method is described as follows.

A multivariate autoregressive model expresses current values of series as the sum of systematic components of stationary time series and noise associated with each series. That is, for the stationary random process of two variables X and Y, an value of X may be used as input and obtain a value of Y; this value of Y is broken into the component linearly dependent on X (explained by X) and the remainder. The variation of Y not explained by X is called the noise of the Y series. When there is a feedback relation between X and Y so that noise from both, u:[x] and u:[y], are used to explain the current values of X and Y, then we have a bivariate time series model. The RPC is a statistic which shows what proportions of the variation of siries X and Y at each frequency depend on u:[X] and u:[Y].[5] We conceive of economic time series as comprising cyclical fluctuations at various periodicities (1/frequencies). For example, the RPC is an index of how u:[x] affects which periodicities of fluctuation of Y. If the effect of u:[x] on Y (the RPC of X onto Y) is large and the effect of u:[y] on X is

5. RPC analysis is an frequency domain technique. Consider the following general time series system.



Without noise (u_2) entering the system, comparison of x_1 and x_2 is all that would be needed to understand the relationship. But it is usual to consider the value of x_2 as the result of u_2 (assumed uncorrelated with x_1) and x_1, so that the influcence of x_1 and u_2 must be separated in analysis. Here we call u_2 the corresponds to the degree to which the economic system is influenced by external factors. In fact it is more natural to consider not simple cases such as this, but rather feedback systems, such as the following.



In this system, u_1 and u_2 are the noise series associated wtih x_1 and x_2 respectively. Contrary to the case of a single noise series, it is natural to think of both x_1 and x_2 being influenced by both u_1 and u_2 (We assume no correlation between x_1 and u_2 and between x_2 and u_1).

The RPC is defined as an index expressing the degree of influcer ce of u_1 and u_2 over the various series. For example the power spectrums of variables x_1 and x_2(P_{x1} (f), P_{x2} (f)) are expressed as the sums of parts depending on u_1 ($P_{xi} \mid U_1$ (f), i =1,2) and on u_2, ($P_{xi} \mid u_2$ (f), i = 1,2). That is, negligibly small, then the effect of X on Y is relatively large, and there may be said to be unidirectional causality form X to Y in the Granger sense.

The reasons to use the RPC in place of previous methods are as follows. (i) Economic phenomena are generated by complex feedback systems among economic variables, and the RPC considers variables as elements of feedback systems. Moreover, in comparison with the Sims' method which uses regressions and F-tests to find direction of causality, the RPC method tests both directions of causality simultaneously. Moreover, the RPC method can treat three or more variables simultaneously, and hence is more inclusive. (ii) To investigate Granger causality, one must separate each variable's white noise through autoregression, and then test for correlations among the random components. The Sims' Test uses a standard filter for these separations, but the RPC extracts the purely random component from application of a time series model. Hence, the RPC method is more objective. (iii) The periodicity of reaction among variables is easily read from the RPC method, and one can separate cross correlation and autocorrelation factors, unlike in the cross correlation method.

III. Causation Among Observable Financial and Economic Variables — Bivariate Model Causality —

This section uses RPC analysis to investigate causal relations between observable financial variables, mainly money supply and nominal interest rates, and the targets of monetary policy, such as prices and income. It is of course true that in an open economy, we cannot ignore the influences of foreign factors, such as foreign interest rates, inflation rates, exchange rates, and the balance of payments. But these factors have been treated elsewhere (see Fukao and Ōkubo[16]), and so this study will limit itself to domestic factors.

But before analysis begins, let us consider the period of investigation. Chart 1

$$P_{xi}(f) = P_{xi} \mid u_1(f) + P_{xi} \mid u_2(f) \qquad (i=1、2)$$

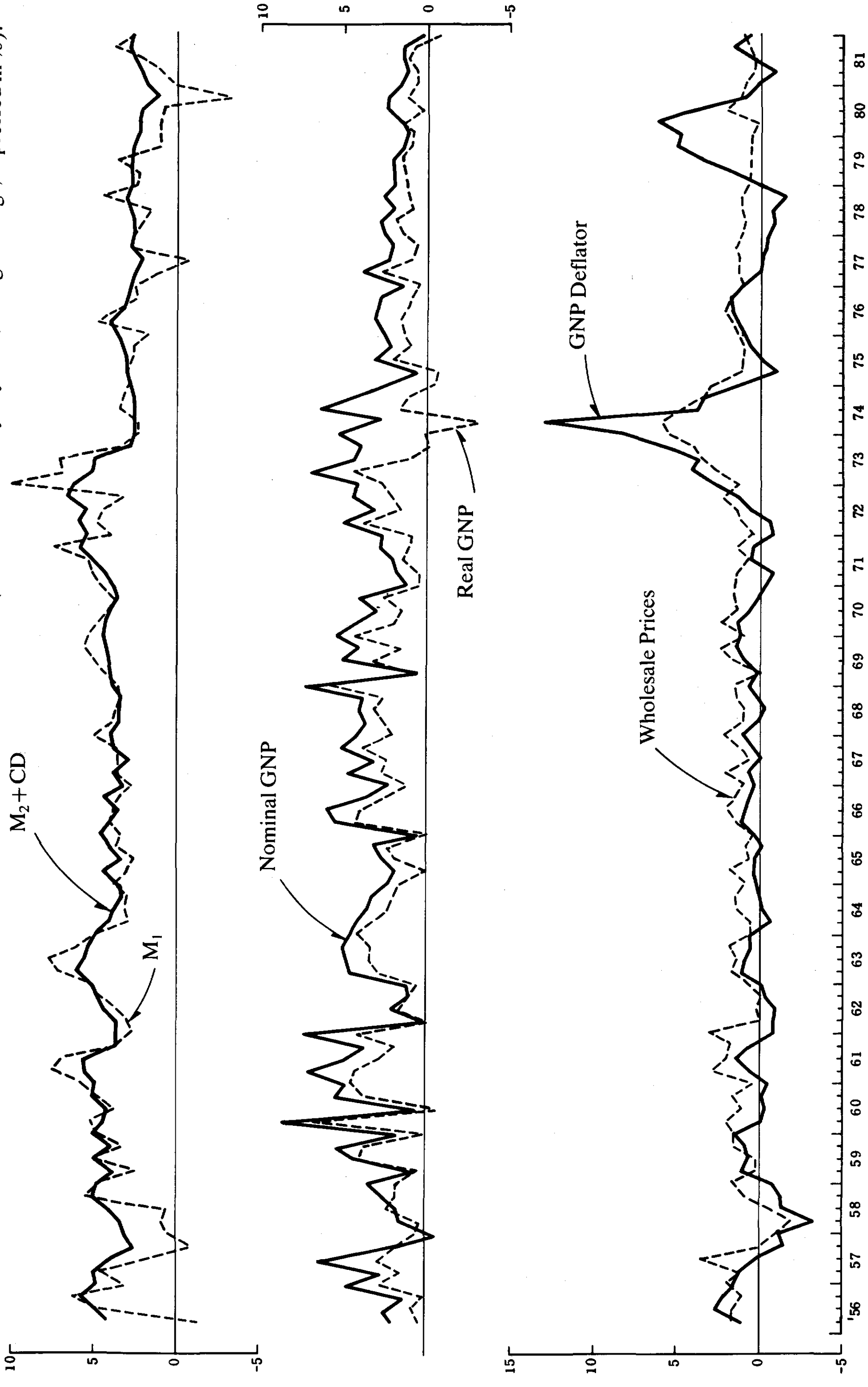
$$RPC_{x_i x_j} = \frac{P_{x_i} \mid u_j(f)}{P_{x_i}(f)} \qquad (i、j=1、2)$$

(See Akaike and Nakagawa [1] for detailed definition of the RPC). The RPC has hiterto been a concept used in optimal control theory, and used as a tool to analyze which variables can be controlled at which frequencies. The economic meaning of applying the RPC to economic analysis is that is enables us to have an indicator of the direction and periodicities of interrelationships among variables in the economic system. One can regard a large RPC from variable A to variable B as indicating existence of Granger causality.

Chart 1

Money Supply, Income, and Prices

(Data are seasonally adjusted, changes in logs, expressed in %).



shows money supply, income, and price movements, and the strong influence of the exogenous shocks of 1973-4 such as the large rise in oil prices can be seen in the movements of wholesale prices. And just at this time (February, 1973) the move to floating exchange rates occurred. If the difference in performance of Japan after the two oil crises depends on the changes in economic structure, it is probable that this is the period at which the changes began. This paper will use three periods for analysis, (A) 1956/II-1981/IV, (B) 1956/II-1973/I, and (C) 1974/IV-1981/IV, and analyze how the periods differ.[6]

Table 1 summarizeds the results of RPC analysis of bivariate pairs of the variables money supply, nominal interest rates, income, and prices.[7] We will now consider the results in detail.

A. Money Supply and Nominal Income

Chart 2 shows causality between money (M_1 and M_2+CD) and nominal GNP. In both cases, there is a strong causality from money to GNP for period A. For period B, that before the first oil crisis, causality from M_1 to GNP is unidirectional, but there appears to be a feedback relation between M_2+CD and nominal GNP. After the first oil crisis, in period C, the causality from M_1 to GNP is questionable, but that from M_2+CD to nominal GNP seems relatively strong. We will consider these results in some detail, along with an explanation of how to interpret RPC diagrams.[8]

For period A, the RPC for M_1 and nominal GNP (upper left diagram) shows that noise in M_1 accounts for about 70% of the cyclical movement in nominal GNP at the longest periods, and that the effect weakens as the periods shorten (as we move

6. When results for periods A, B, and C are highly similar, it is safe to assume no structure change occured. The periods 1973/II to 1974/III between period B and C has been excluded to avoid influence of the disorganized quarters at the time of the first oil crisis. This will not disrupt the period analysis.

   However, there is one technical point that must be noted. Period C contains only seven years of quarterly data, and hence the sample size is extremely small. Results must be interpreted with this in mind. It is not entirely unproblematic to compare the results with those in period B. When the sample is small, confidence in the results for the longest periods (in the vicinity of infinity) are in general low.

7. For multivariate results, see the next section.

8. Let us extend our explanation of how RPC diagrams are interpreted here. Let the RPC for stationary time series X and Y be as follows. (Diagrams are seperated in this note, but those used in reference to the text combine both lines on one diagram.) To see the characteristics of a system, it is sufficient to introduce unbiased noise. The RPC separates effects on X and Y into those linearly forecastable and those that are not (white noise), and then diagrams the strength of effect on the unforecastable portion for each periodicity. For example, in the RPC diagram for X, the effect of Y on X (below the line) reaches a peak at periodicity of 10 quarters. This

Table 1

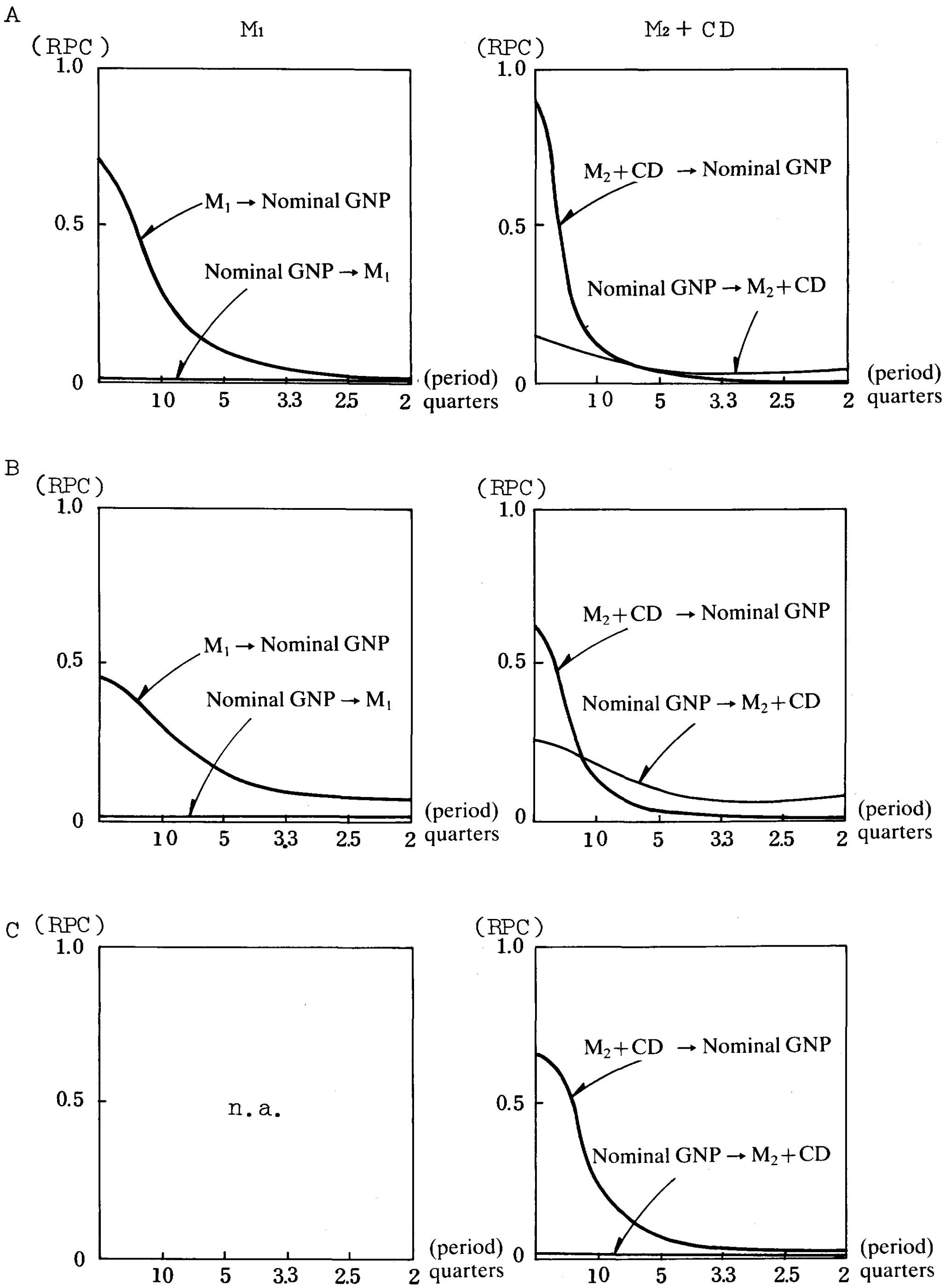
Results of Relative Power Contribution Analysis

	Nominal GNP			Real GNP			Call Rate & Bill Rate Average			NTT Bond Yield			Wholesale Prices			GNP Deflator		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
M_1	↑	↑	n.a.	↑	↑	n.a.	←	←↑	←	←↑	←↑	—	←	←↑	←	↑	↑	—
M_2+CD	↑	←↑	↑	↑	↑	↑	←	←↑	←	←↑	←↑	—	←	←↑	←	←	←↑	↑
Nominal GNP							←↑	←↑	←↑	↑	←↑	←	—	←	←↑	—	n.a.	n.a.
Real GNP							—	←	←	←↑	←↑	←	←	←	←↑	←	n.a.	n.a.
Call Rate & Bill Rate Average													←↑	←↑	←↑	←↑	↑	←
NTT Bond Yield													←↑	←↑	←↑	←↑	←↑	←↑

Notes:
(1) A, B, and C denote sample periods. A: 1956/II-1981/IV, B: 1956/II-1973/I, C: 1974/IV-1981/IV.
(2) Arrows denote direction and strength of causality —denotes lack of causality. n.a. denotes exclusion due to AIC (Akaike's Information Criterion of degree 0.

Chart 2

Money Supply and GNP



rightward on the diagram). As seen before (see Footnote 6), the long periodicities of the RPCs can be expressing relationships of the trends of the series. But even excluding the longest periods, the movements of nominal GNP are explained not only by its own white noise, but also by the white noise of M_1, and hence causality from M_1 to nominal GNP exists. However, as is clear from the diagram, noise in nominal GNP has almost no effect on M_1 (see the RPC of nominal income to M_1), so that M_1 is determined mostly by its own noise. Hence, unidirectional causality from M_1 to nominal GNP exists. Looking at the relation of M_2 +CD to nominal GNP for the same period, we see that M_2 +CD noise explains a fair amount (10%) of the movement of nominal GNP at the 10 quarter periodicity, but the RPC of M_2 +CD on nominal GNP shows very high proportions (90%) at the long periods, and so we may also conclude unidirectional causality to exist here.

Next let us consider the subperiods B and C. For M_1, the results for period B (middle left diagram) are about the same as for period A. Estimates for period C were not possible. For M_2 +CD, however, there were differences; diagrams for period B (middle right) and C (lower right) both show causality from M_2 +CD to nominal

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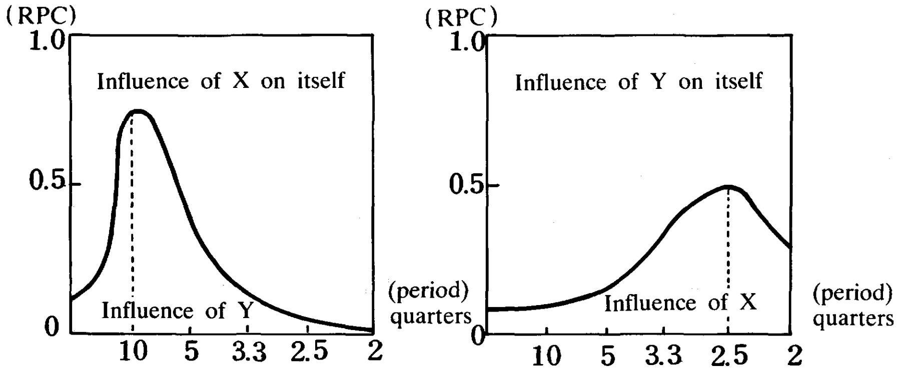
says that 75% of the movements of X at the 10 quarter periodicity are explained by unforecast movement of Y (noise in Y). (This is expressed on the graph as .75 of 1.0.) In contrast, the RPC for Y shows that noise in X accounts for movements of Y most strongly at the 2 quarter periodicity. These RPC diagrams show a feedback relation to exist between X and Y, with X affecting Y at a relatively short period, and Y affecting X at a relatively long one.



There are two points to note here. The first concerns the chronological interpretation of periods. When we say Y affects X at the ten quarter periodicity, we do not mean that a movement in Y will cause a movement in X ten quarters later. As discussed above, determining the timing an strength of effects of Y on X requires a time series model and simulation; these things cannot be determined from the RPC. Second, the analysis in this section is limited to bivariate relations. When movements of X or Y are mostly determined by another variable Z, a comparison of X and Y does have some meaning in its own way, but when determining the relative importance of Y and Z on X, it is the absolute values of the effects that matter. Multivariate analysis enables us to avoid these problems to an extent.

GNP, but for period B there is also a fairly strong (6% to 25%) causality from nominal GNP to M_2 +CD . Hence, there was a feedback relation between the two in this period. But the causality from nominal GNP to M_2 +CD evaporated in period C, so unidirectional causality from money to income existed for this period. In short, these results show that there was clear from income to money existed in the first period, but not in the second. One reason for this is that in the first period, the portfolios of individuals were largely limited to deposits, so that savings-type deposits included in M_2 rose along with income during these years. But for period C, diversification of holding of savings into other assets weakened this relationship.

B. Nominal Interest Rates and Nominal Income

We now consider whether movements of nominal income can be thought to derive from movements of nominal interest rates. Chart 3 shows RPCs of Nippon Telephone and Telegraph (NTT) bond rates (a market determined rate) and nominal GNP. Period B, there is a feedback relation between interest rates and income, with income affecting interest rates at the 10-12 quarter periodicity, and interest rates affecting income at the 2-3 quarter period. That is, interest rates affect income in the short run, and income affects interest rates in the long run, just as Keynesian theory says.[9] But this feedback relation does not come out so clearly in period C, nothing definite can be said about the intermediation function of interest rates. But results here are those for nominal interest rates; results for real interest rates are given in the next section.

9. Sims' Tests performed on NTT bond rates and nominal GNP (with four leads and four lags) show, as seen below, that a feedback relation exists between the two. Let the bond rate be Rntt, and nominal income be GNP. F-test results on exclusions are:

(1) GNP = f(Rntt)

future values	current and past values
3.945*	3.036*

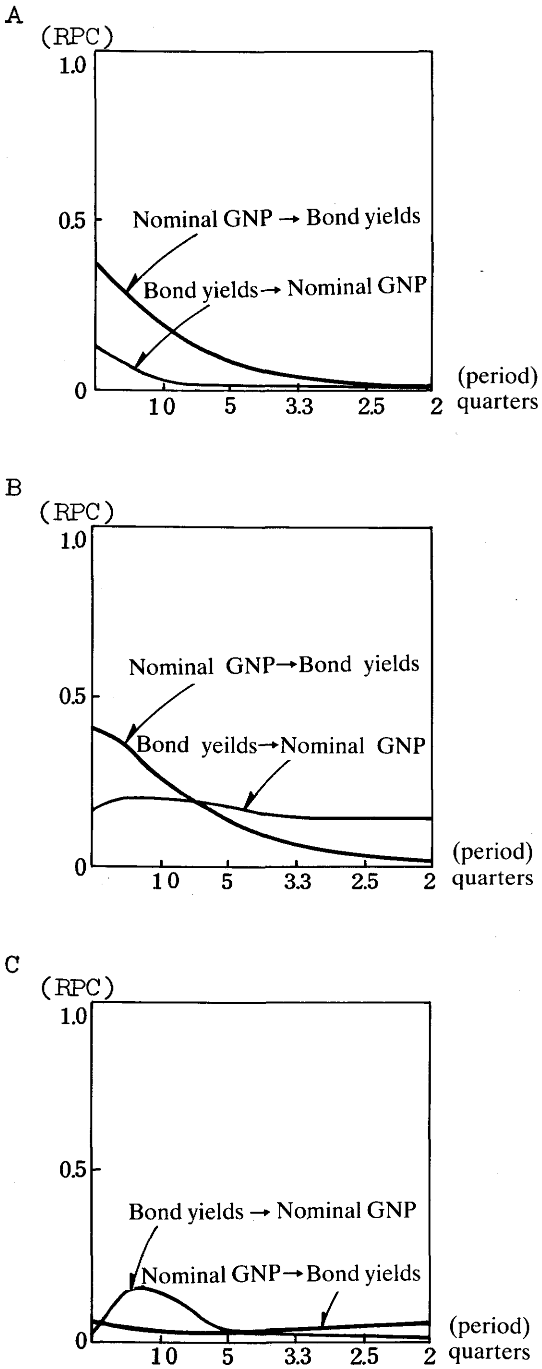
(2) Rntt = f(GNP)

future values	current and past values
2.870*	4.567*

where * indicates significance at the 5% level. Sums of values of future period coefficients for the Rntt equation and the GNP equation are 0.1738 and -0.4215 respectively, implying that the effect of Rntt and GNP is negative and that of GNP on Rntt positive. This corresponds to the mechanism of interest rate declines raising income, and then income increases raising interest rates over time.

Chart 3

Nominal GNP and NTT Bond Yields



C. Money Supply and Prices

Results on the relationship of money to prices differ according to whether we use wholesale prices or the GNP deflator for the price indicator. Let us consider the GNP deflator first (see Chart 4). In Period B there is unidirectional causality from M_1 to the GNP deflator, but this relationship could not be obtained with the method used here for period C. On the other hand, causality between M_2 +CD and the GNP deflator existed in both periods, but for period B the reverse causality from prices to money is too large to ignore. But overall, causality running from money to the GNP deflator existed, and was strong in the period after the first oil crisis.

When the wholeseale price index is used, results differ somewhat. For period B, there is causality from M_2 +CD to prices; but overall, causality from whlesale prices to money is more strongly observed. This is because wholesale prices are strongly influenced by inflationary expectations based on foreign factors such as the rise in oil prices and by cost push factors. The resultant changes in nominal value of transactions invites changes in the money supply. This is the mechanism which seems to be working relatively strongly here (see Chart 5).

D. Nominal Interest Rates and Prices

Here we investigate the Fisher relation, that is the causality between prices and nominal interest rates. Chart 6 shows the PRCs for Nippon Telephone and Telegraph bond rates and prices. In every period, causality from prices to interest rates is apparent, which demonstrates the existence of the Fisher relation. The NTT bond rate is a long rate, and so we have also calculated RPCs using the repurchase rate (three month) and prices, seen in Chart 7. There are differences among periods here, so generalization is difficult. But the existence of causality from prices to the repurchase rate can be seen.

E. Real Income and Prices

The RPCs for real GNP and prices (see Chart 8) show that the causality between the two, while not exactly nil, is extremely small in every period. Particularly in period C, the curves are very low at every periodicity, and this may be interpreted to mean that the Phillips curve for Japan is nearly vertical.

F. Policy Interest Rates and the Money Supply

To investigate whether monetary control is carried out through interest rate

Chart 4

Money Supply and the GNP Deflator

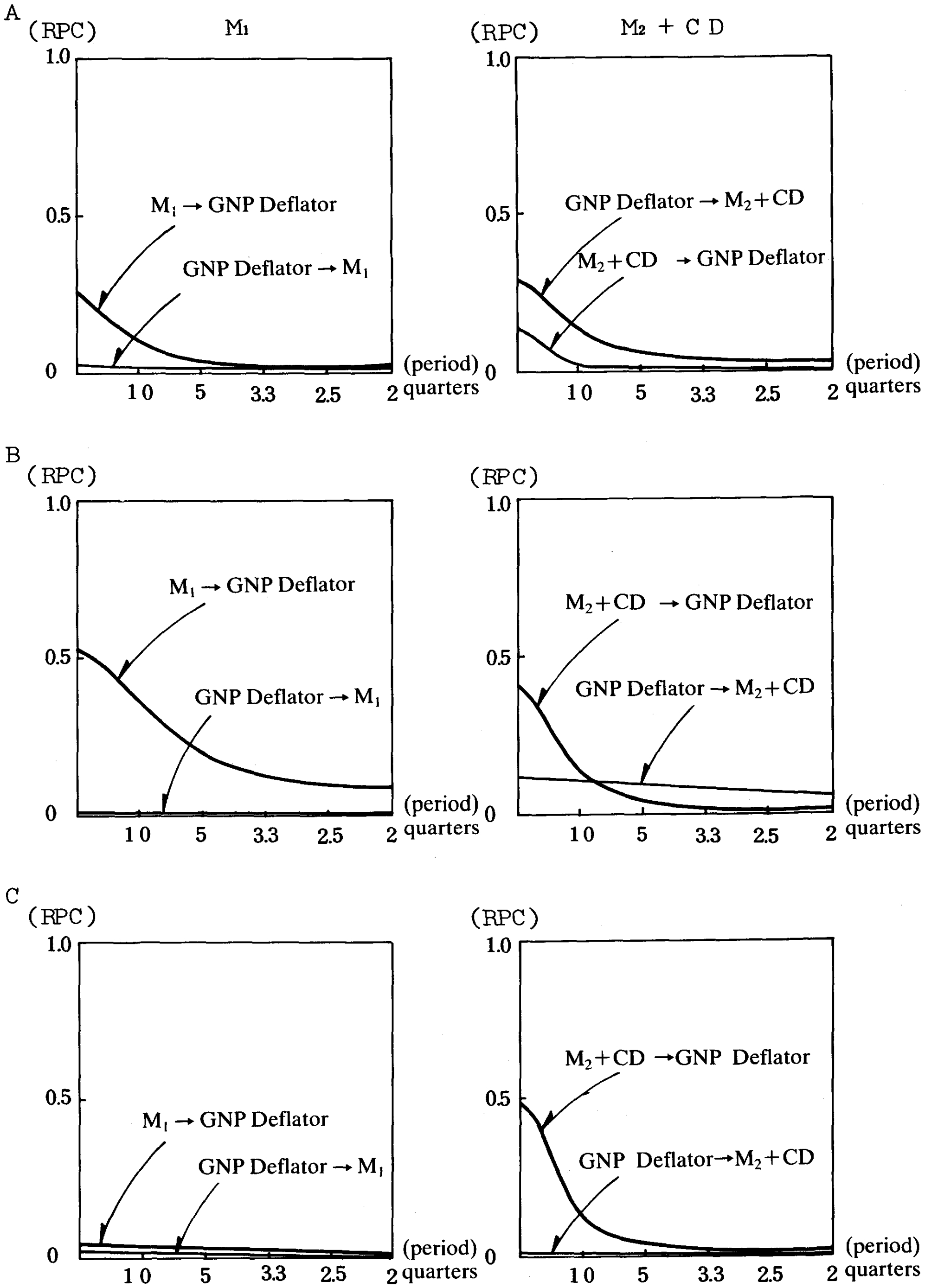


Chart 5

Money Supply and Wholesale Prices

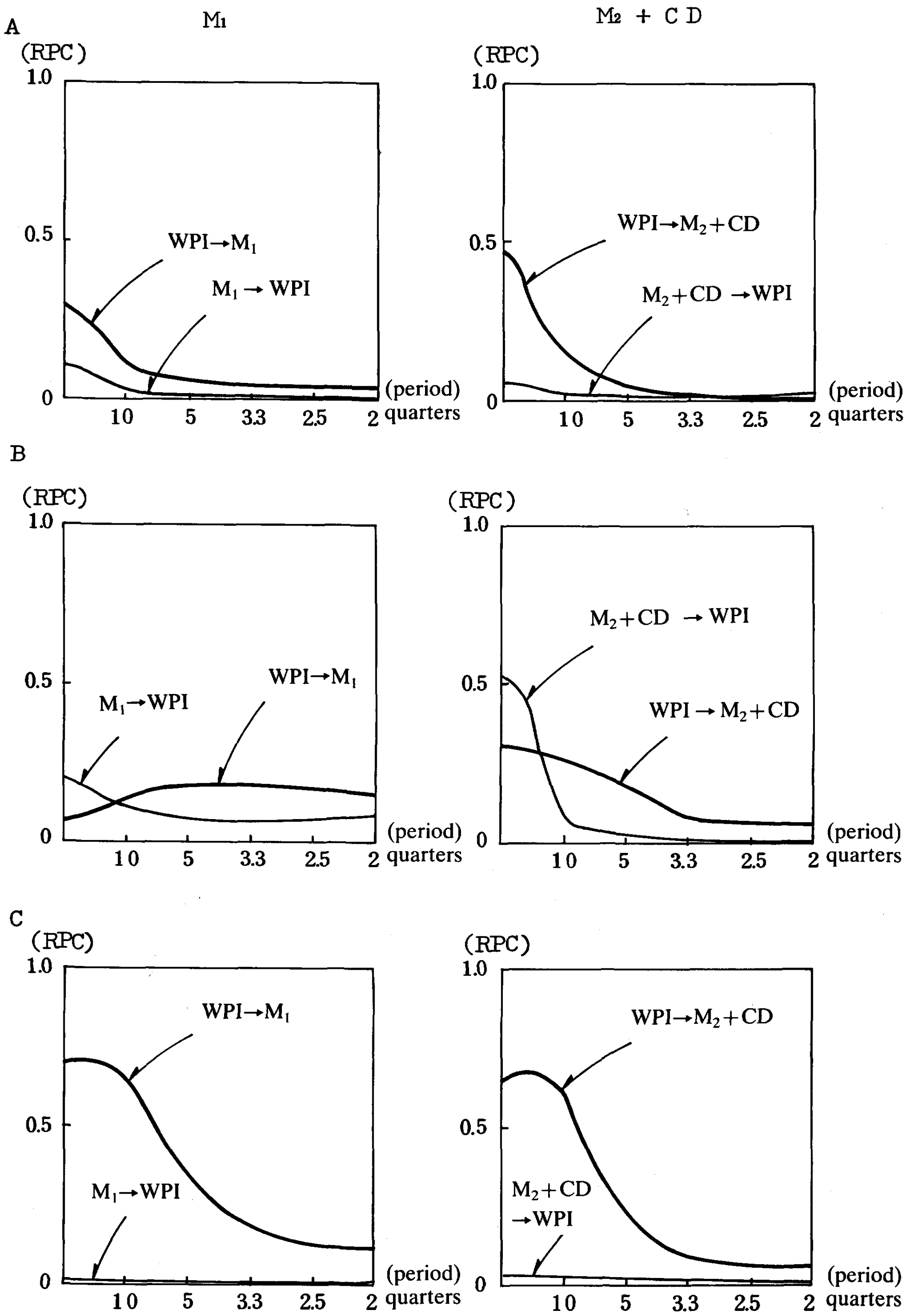


Chart 6

Bond Yields and Prices

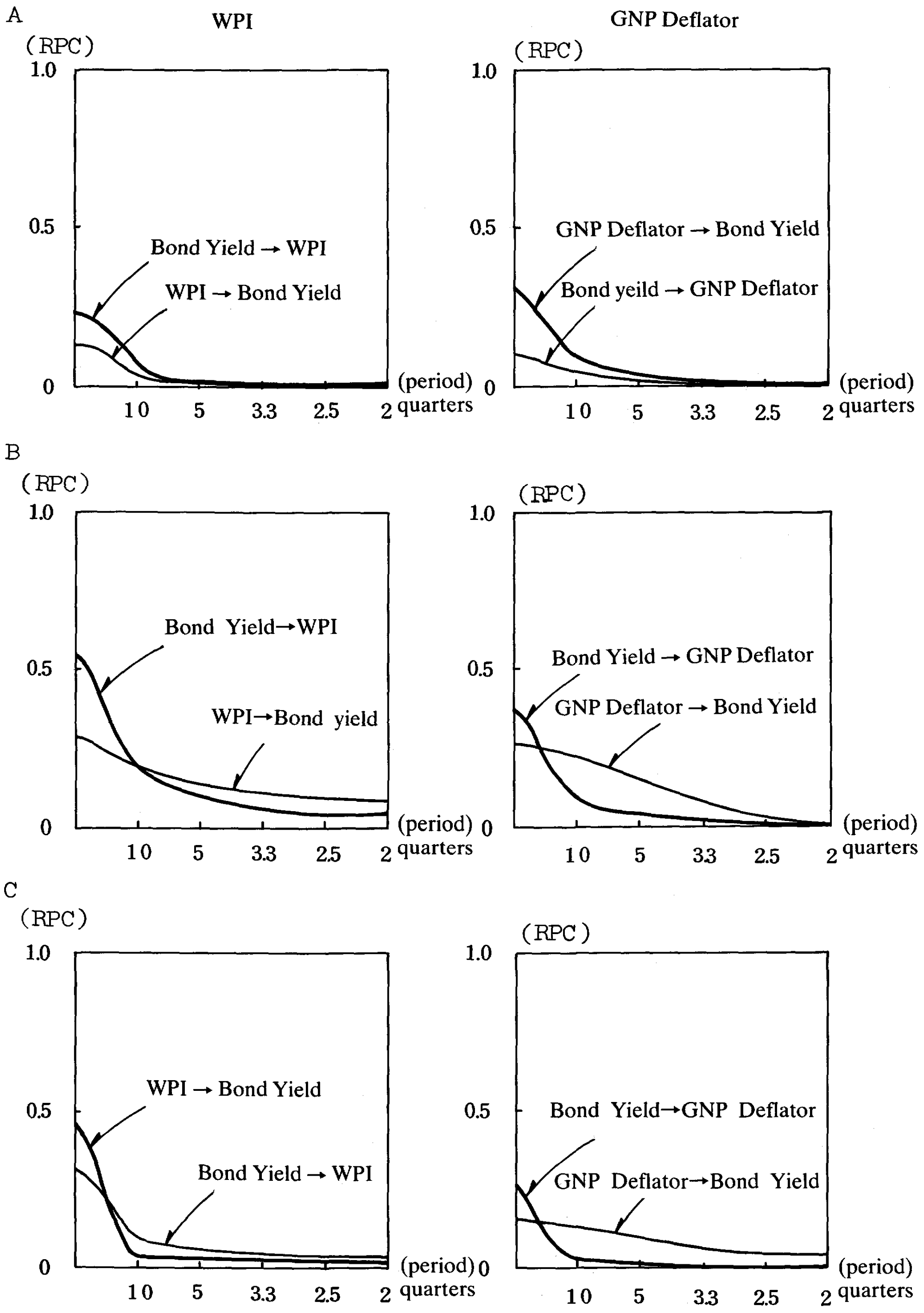


Chart 7

The Repurchase Rate and Prices

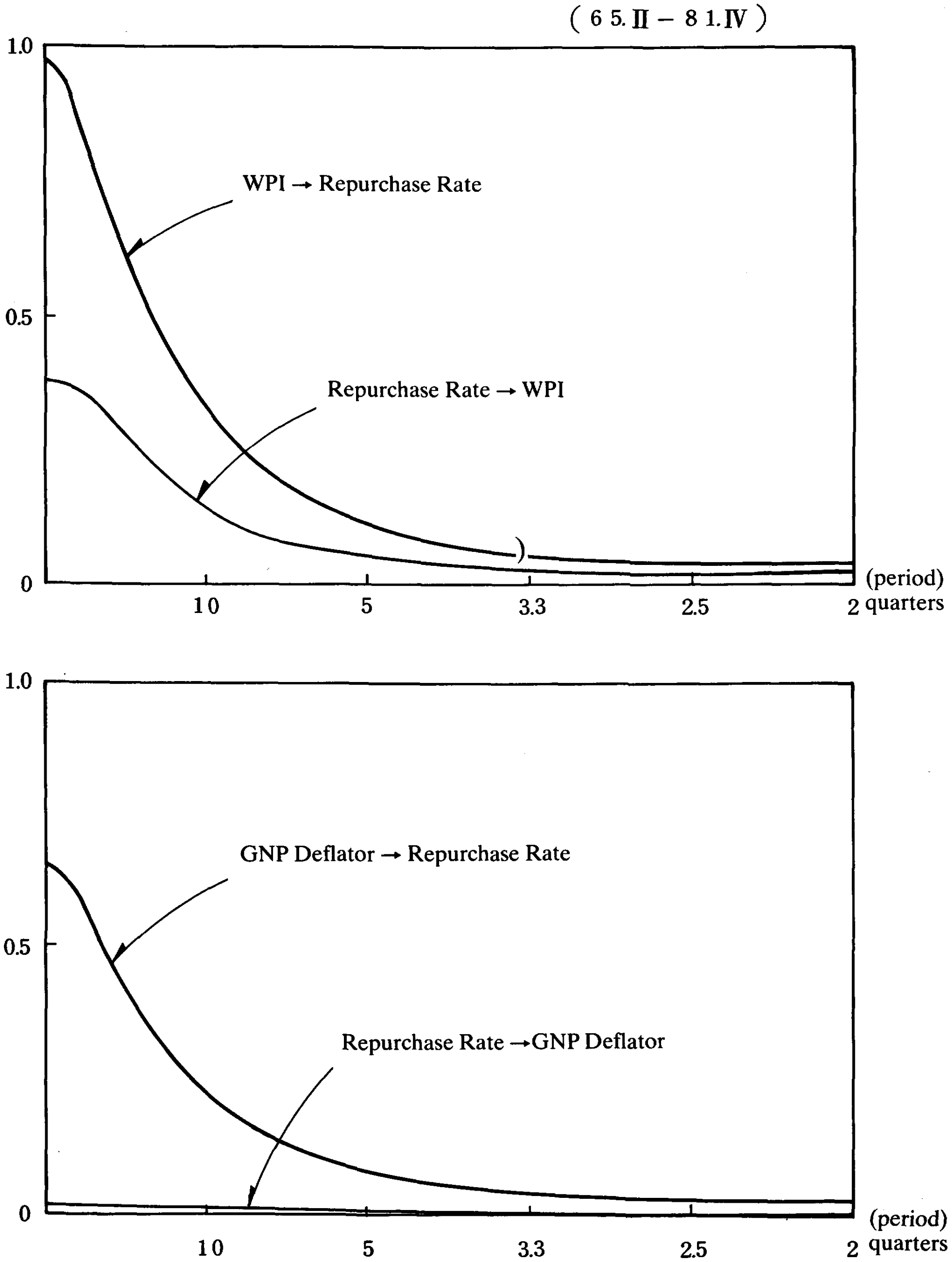
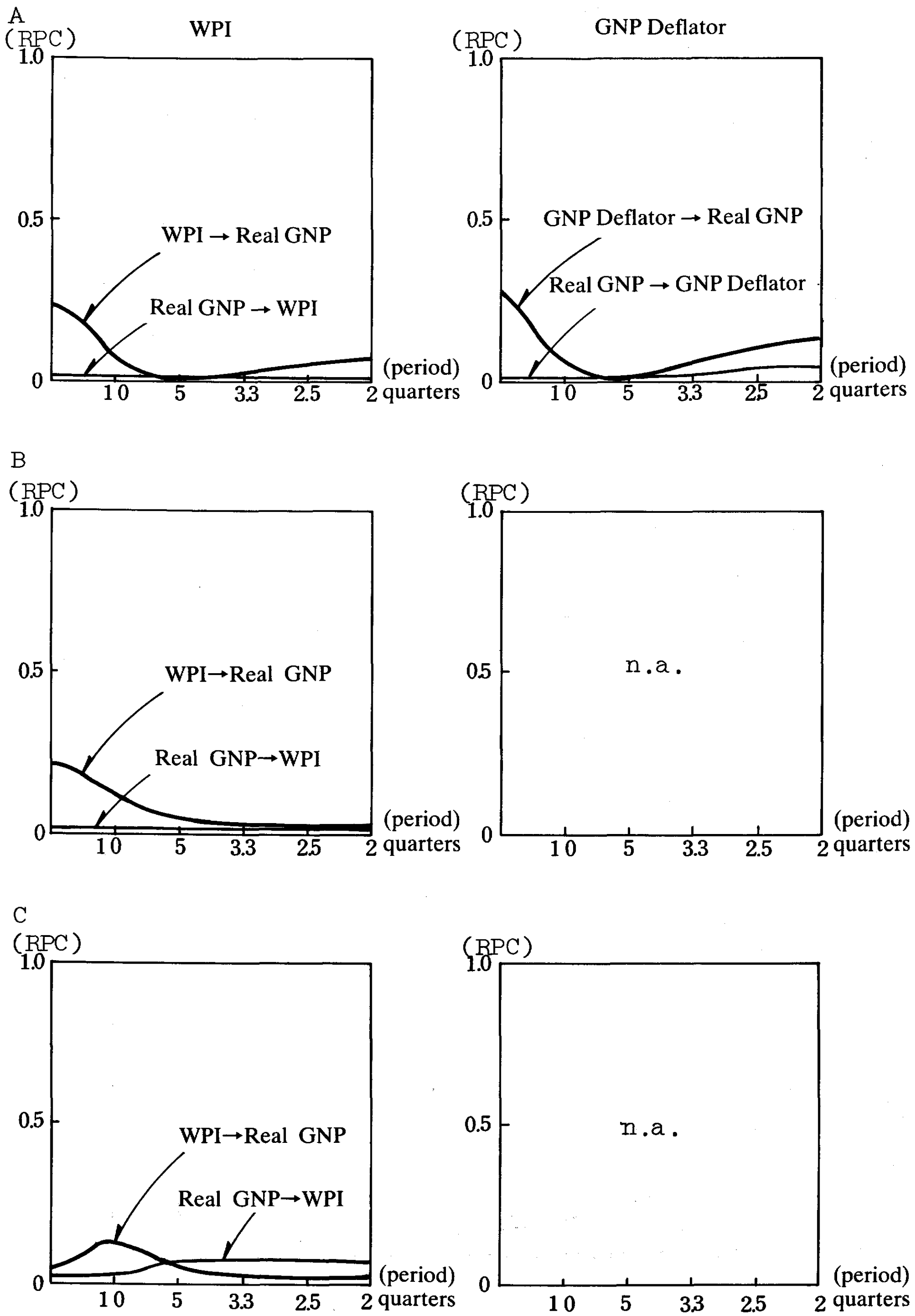


Chart 8

Real Income and Prices



(nominal) adjustment in the short term money markets, we may investigate the causality between policy influenced interest rates and the money supply. Chart 9 shows the relevant RPCs. For both M_1 and M_2 +CD in both periods B and C, causality from policy interest rates to money supply can be seen. The causality is unindirectional and very strong in period C. Implementation of monetary policy in Japan became explicitly money-supply oriented in the last half of the 1970s, and period C, which almost exactly coincides with this change, clearly demonstrates the relatively strong causality from policy influenced interest rates to money.

Chart 10 compares the influences of the call rate and the monetary base on M_2 +CD. The period of observation is 1963/II to 1981/IV. The results shows relatively strong causality from the call rate to M_2 +CD ; in contrast, causality between M_2 + CD and the monetary base runs from the former to the latter. This supports the usual contention that monetary control in Japan is effected not by changes in the base, but rather by adjustment of policy influenced interest rates. This demonstrates, contrary to the contention of theory, that acutal movements of the base are the result of movements of income, and not exogenous stimuli.

G. Broad Money Versus Narrow Money

Let us now consider the differences between use of M_1 and M_2 +CD in light of the various causality relationships discussed above. Chart 1 shows that both M_1 and M_2 +CD display about the same movements, and that in general M_1 movements were somewhat more volatile. However, as seen in Table 1, the causality relations between the two types of money and other variables were quite similar. But looking more closely after the first oil crisis, we see that M_2 +CD was a bit better related to other economic variables than M_1.

H. Structural Change in Relations Among Variables

There were, however, some differences between the relationships of variables before the first oil crisis (period B) and after it (period C). The important differences were:

(1) The relationship of M_2 +CD and GNP showed a feedback relation in period B, but was closer to unidirectional from M_2 +CD to GNP for period C.

(2) The relationship between money supply and policy influenced interest rates such as the call and bill rates exhibited feedback in the earlier period, but a clear unidirectional causality from the interest rates to money in the later period.

(3) The relationship between nominal market interest rates (Nippon Telephone and Telegraph bond rates) and income exhibited feedback in period B, but much stronger causality from nominal interest rates to income in period C.

Chart 9

Money Supply and Call/Bill Rate Average

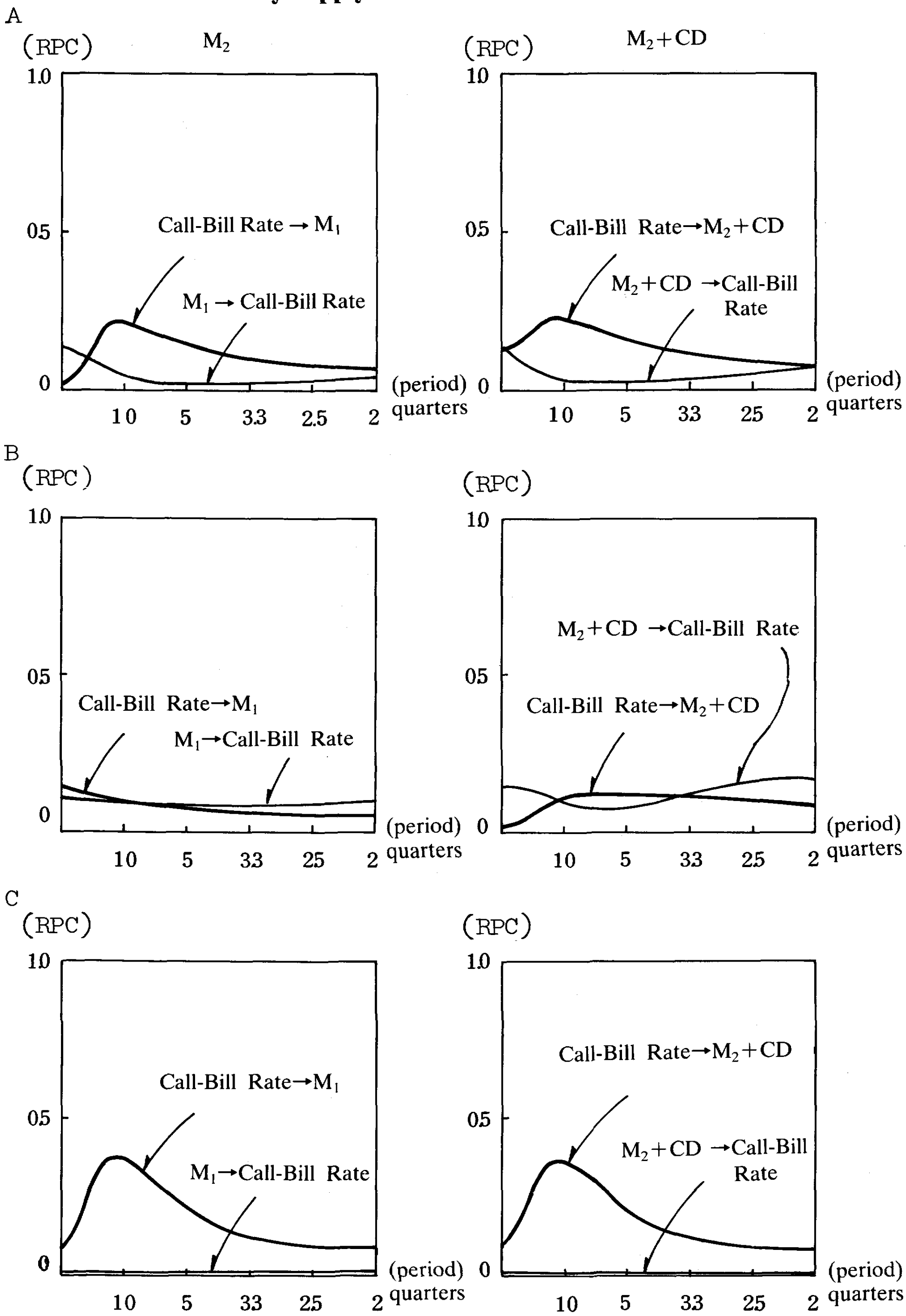
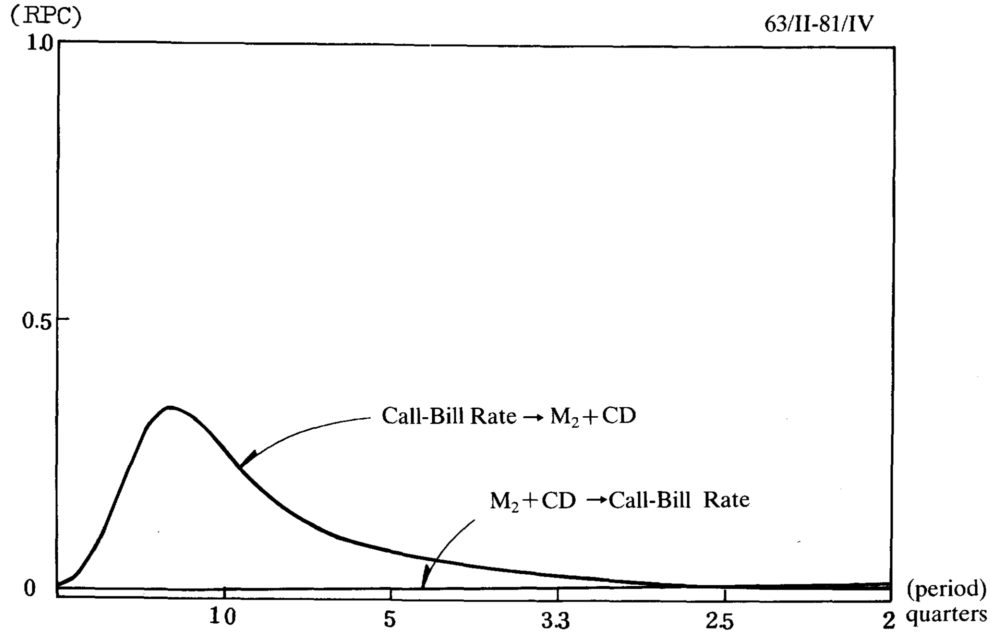
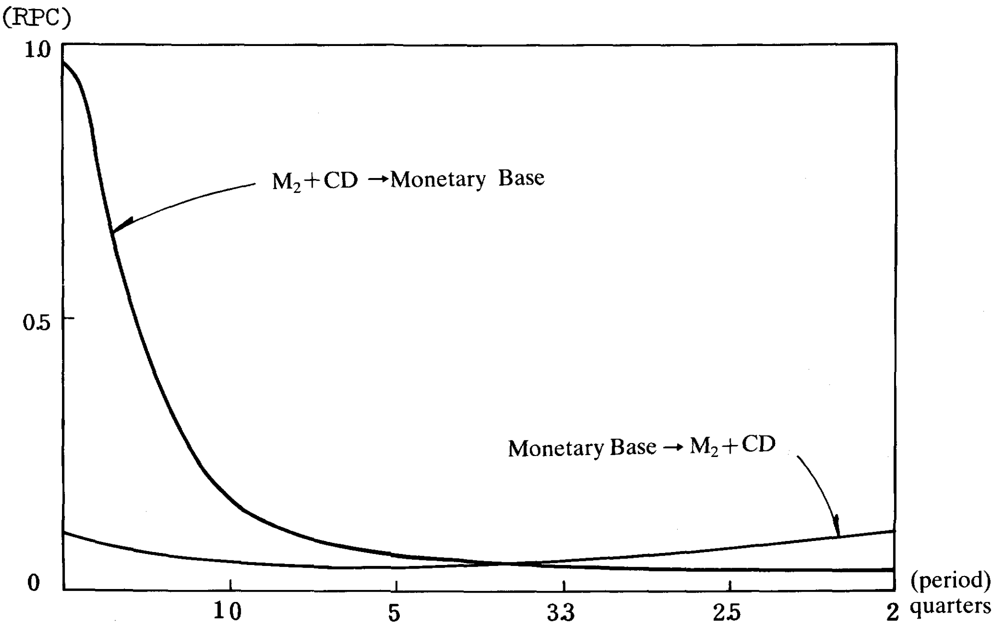


Chart 10

The Monetary Base, the Call / Bill Rate Average and M_2+CD





Judging from these observed differences (even while remembering that the different lengths of observation period B and C reduce the value of comparison), we conclude that a structural change in the relationships between monetary variables and other economic variables occured at about the time of the first oil crisis.

IV. Causality Among Money, Interest, Income, and Prices — Multivariate Model Causality —

The main purpose of this section is to examine the causal relations between real interest rates,[10] which are not directly observable, and the final target variables of monetary policy. Once this is done, we can examine whether the unobservable real interest rate or the observable money supply is a better intermediate target for monetary policy. We shall also analyze the usefulness of nominal interest rates and compare their usefulness to those of money supply and the real interest rate.

The methodolgy for this section is basically the same as above, except that this section will use multivariate models, which consider all relationships simultaneously,[11] instead of bivariate models.

A. Variables, Periods, and Methods

Determining the ultimate targets of monetary policy is an important topic, but here we will limit ourselves to prices, which all agree is a concern of monetary policy, and real GNP, to represent real activity. Based on the results of the previous section, we shall use the GNP deflator for the price indicator.

For intermediate targets, we will use perfect forecasts of real rates,[12] money supply (M_2 +CD), and nominal interest rates. These are the most important indicators of monetary policy stance in Japan, and M_2 +CD is chosen on the basis of its better performance in the causality analysis carried out above. Chart 11 shows the movements of GNP, the GNP deflator, real interest rates, and the money supply.

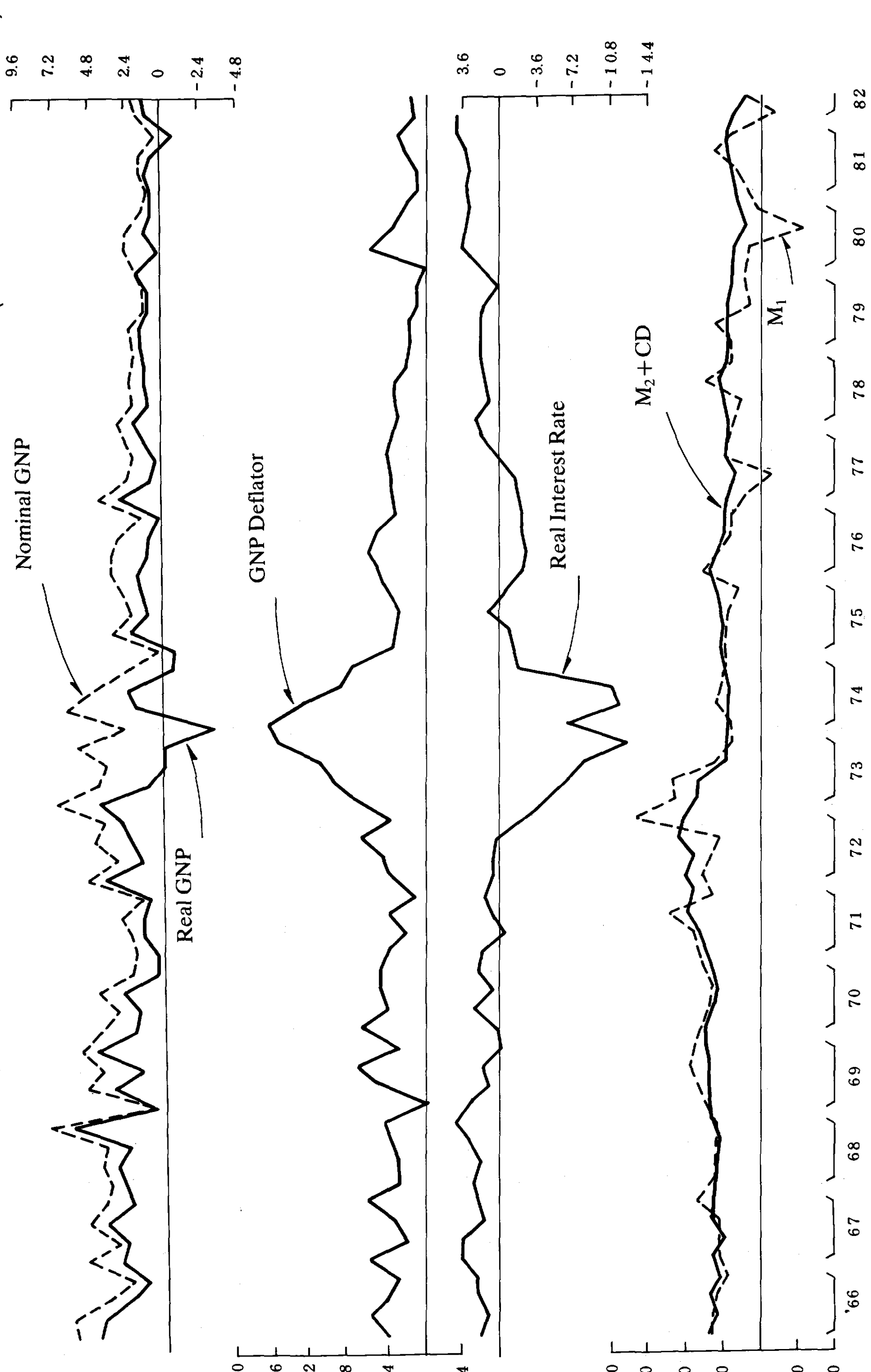
The previous section suggested that the first oil crisis was a turning point in the

10. For specification of real interest rates, see Appendix.

11. The RPCs calculated from bivariate relations show nothing more than the relative importance of the variables versus each other. For example, if A influences B, and C also influences B, we cannot determine the relative importance of A and C on B from the bivariate methods. But a trivariate time series model can investigate the causality among all variables, and can also, through expressing the interrelationships and A, B, and C, determine the relative importance of A and C in influencing B.

12. See Appendix for details of derivation of real rates.

Chart 11 **GNP, The GNP Deflator, Real Interest Rates, and Money**



relationships among economic variables. In this section too, it would be best to separate the sample period, but estimation of a multivariate model requires a rather large amount of data. Thus, it is not reasonable to carry out estimations on short samples. Hence, this section will not assume a structural change, and will use the entire avaiable sample period (1965/II to 1982II).

The first stage is to estimate a four variable model, using prices, real GNP, real interest rates, and money, and compare the contribution of each series' noise to the other series. This allows us to see the influence of intermediate targets of money supply and real interest rates on the final targets of prices and real GNP. We will also be able to re-examine the relation between prices and real GNP, which was also investigated above.

One criterion on which to choose the intermediate target of monetry policy is of course closeness of causal relationship with final targets. But in addition, the target should be isolated from significant influence from other variables; that is the intermediate target should be exogenous. This can be determined to an extent by the degree to which a variable's RPC shows it to be determined by its own noise.[13]

The second stage of investigation will add the nominal interest rate to the list of intermediate targets. The sequence of analysis is first to examine the effects of the three intermediate targets on the GNP deflator, and then to do the same for real income. Finally, we will examine a five varible model, using prices, real interest rates, nominal interest rates, real GNP and money supply, in order to give an overall analysis.

B. Estimation Results

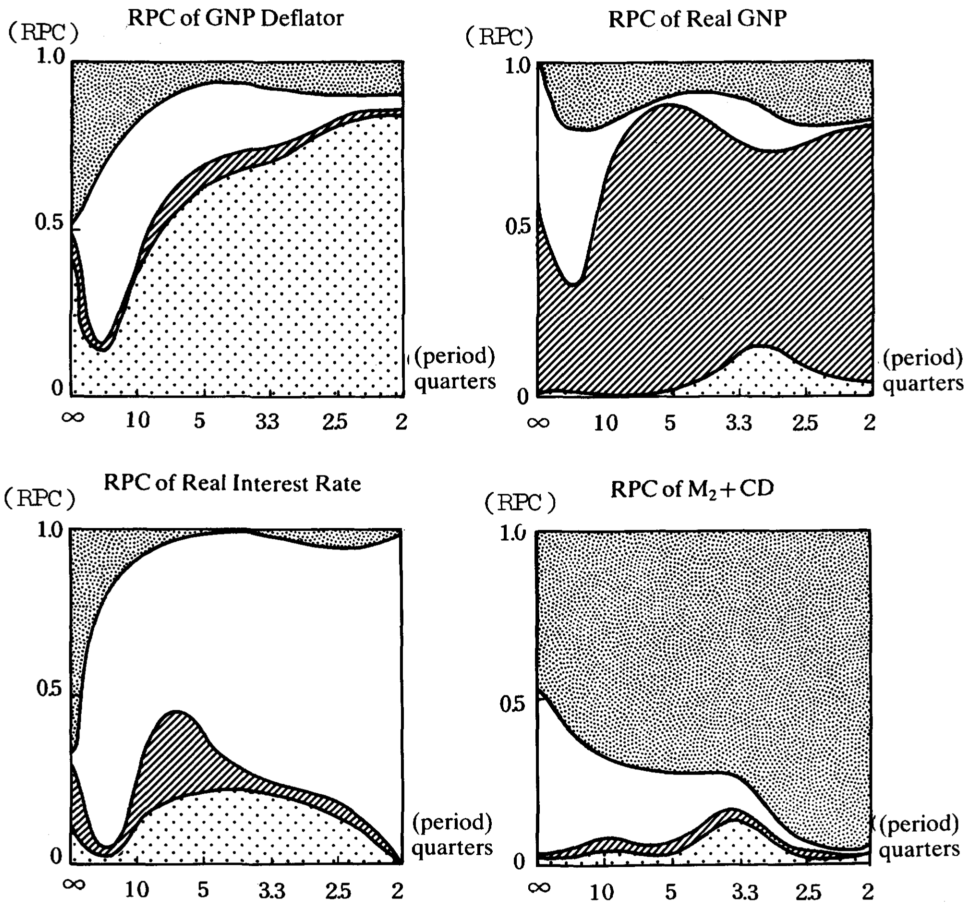
1) Model with GNP Deflator, Real GNP, Real Interest Rates and Money Supply

Chart 12 shows the RPCs of the four variable time series model (AR model) based on the varaibles listed above. The RPC of the GNP deflator (upper left) shows that the explanatory power of the deflator's own noise is large, but also that the contributions of the real interest rate and M_2 +CD are relatively large. The contributions of the interest rate and money are about the same. The contribution of real GNP during the sample period was small, and so no causality from GNP to prices can be proven for this period. On the other hand, the RPC for real income (in the upper right) shows a large contribution of its own noice. This can be interpreted as corresponding to autonomous expenditure. The contribution of the GNP deflator was small, and this, combined with the small contribution of GNP to the RPC of prices,

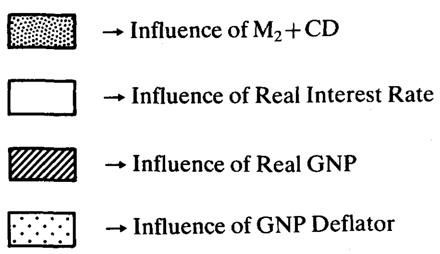
13. When the variables used in the estimate of a multivariate model include all the variables under consideration, then a variable which is determined almost entirely by its own noise may be regarded as exogenous.

Chart 12

RPCs of Four Variable Model*
(GNP Deflator, Real GNP, Real Interest Rate, M_2+CD)



* Based on the AIC (Akaike's Information Criterion), third degree was used.



indicates that no causality relation exists between prices and real income, just an analysis in the previous section showed. Some contributions to real income by both M_2 +CD and real interest rates are visible. Real interest rates have particularly large contributions at the long periodicities. Hence, real interest rates do seem to influence real income.

Let us next consider the RPCs of the real interest rate and the moey supply. The RPC for the real interest rate shows nontrivial contributions by prices, real GNP, M_2 +CD ; feedback realtions between these and the real rate can be seen. The RPC for M_2 +CD shows substantial exogeneity for it. But considering this along with the influence of M_2 +CD on the real interest rate seen in the latter's RPC, there seems to be a feedback relation between money and the real interest rate.

2) Model with GNP Deflator, Real Interest Rates, Nominal Interst Rates, and Money

Chart 13 gives the RPCs for an AR time series model using the four variables listed in the heading. Here, all the variables contirbute to the RPC of the GNP deflator, and the contribution of own-noise to the deflator is very low -- below 50%. All three intermediate targets (real rates, nominal rates, and money) contribute about the same amounts. The interrelations of the intermediate targets are about the same here, with M_2 +CD and the GNP deflator contributing somewhat to the real interest rate, and with M_2 +CD and the real rate contributing substantially to the nominal interest rate. The exogeneity of the money supply is extremely high.

3) Model with Real GNP, Real Interest Rates, Nominal Rates, and Money

Let us consider a model with real GNP as the final target. The RPCs for this model are given in Chart 14. The RPC for real GNP shows most of the power in own-noise, but some contribution by M_2 +CD. At long periodicities, the real interest rate contributes a great deal. In contrast, nominal interest rates contributes a great deal. In contrast, nominal interest rates contribute almost nothing. Looking at the intermediate targets, we see M_2 +CD contributing a bit to the real rate, but the nominal rate contributing nothing. The nominal rate's RPC shows a rather large contribution by the real rate, and some contribution by M_2 +CD as well. The RPC for M_2 +CD shows that it is the most exogenous of the variables considered.

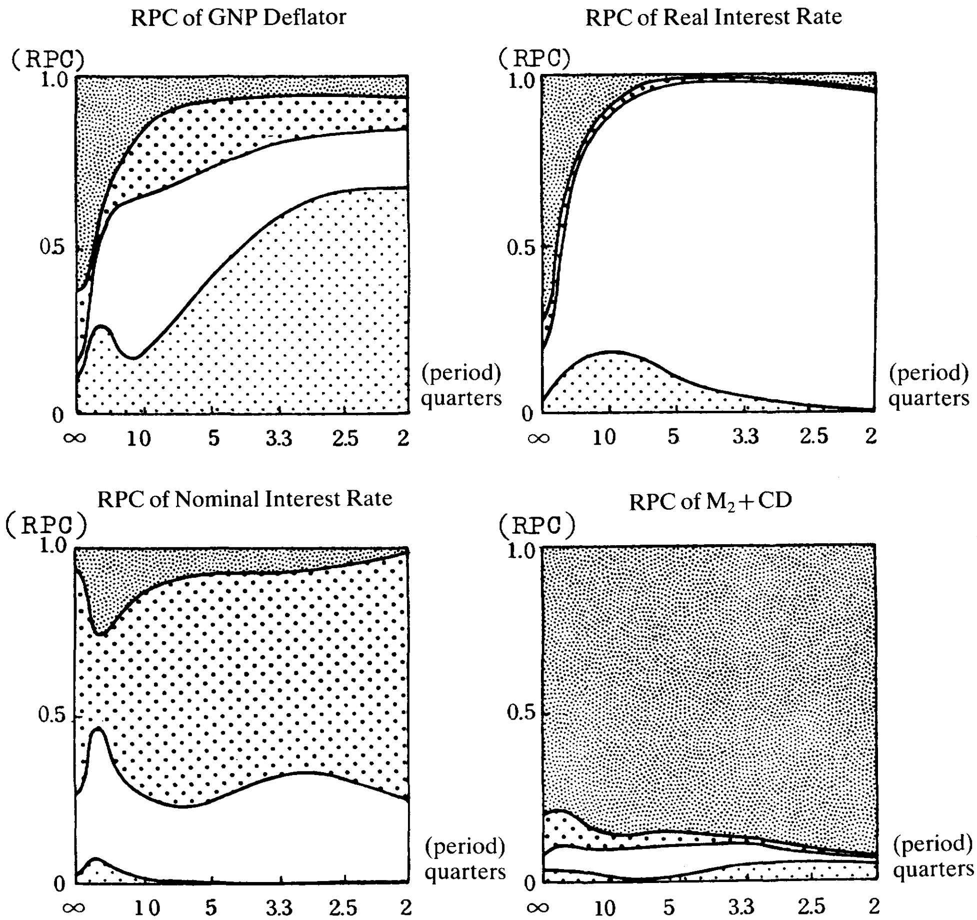
4) Model with Real GNP, Prices, Real Interest Rates, Nominal Interest Rates, and Money

This five variable model simultaneously considers all the relationships discussed above. Most relationships seen previously reoccur, but the changes in proportional contributions are interesting, change. This model also gives an overall viewpoint by summarizing the results. The RPCs from this model are given in Chart 15. The major points are as follows:

1) The GNP deflator is influenced by M_2 +CD, nominal rates, and real rates, but the only feedback relation is with real rates.

Chart 13

RPCs of Four Variable Model*
(GNP Deflator, Nominal Interest Rate, Real Interest Rate, M_2+CD)



* Based on the AIC (Akaike's Information Criterion), second degree was used.

→ Influence of M_2+CD

→ Influence of Nominal Interest Rate

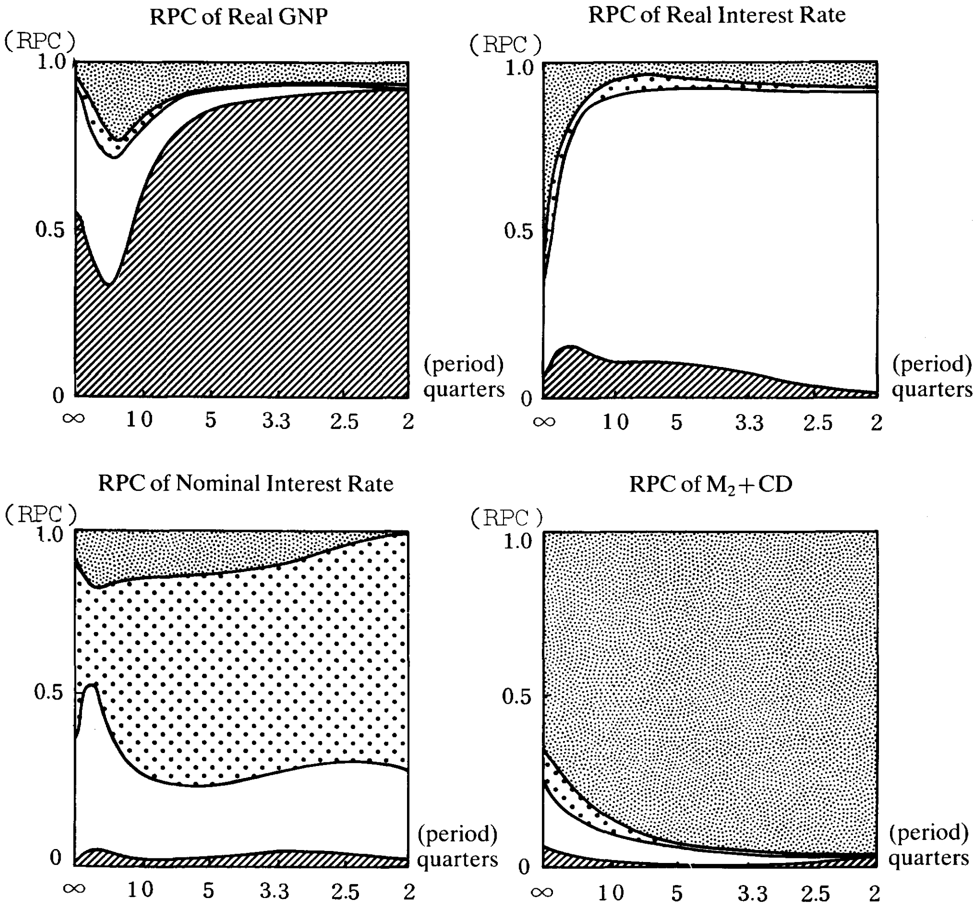
→ Influence of Real Interest Rate

→ Influence of GNP Deflator

Chart 14

RPCs of Four Variable Model*
(Real GNP, Nominal Interest Rate, Real Interest Rate, M_2+CD)

65/II-82/I



* Based on the AIC (Akaike's Information Criterion), second degree was used.

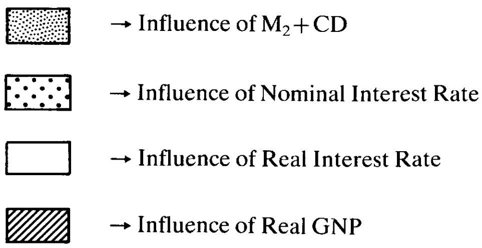
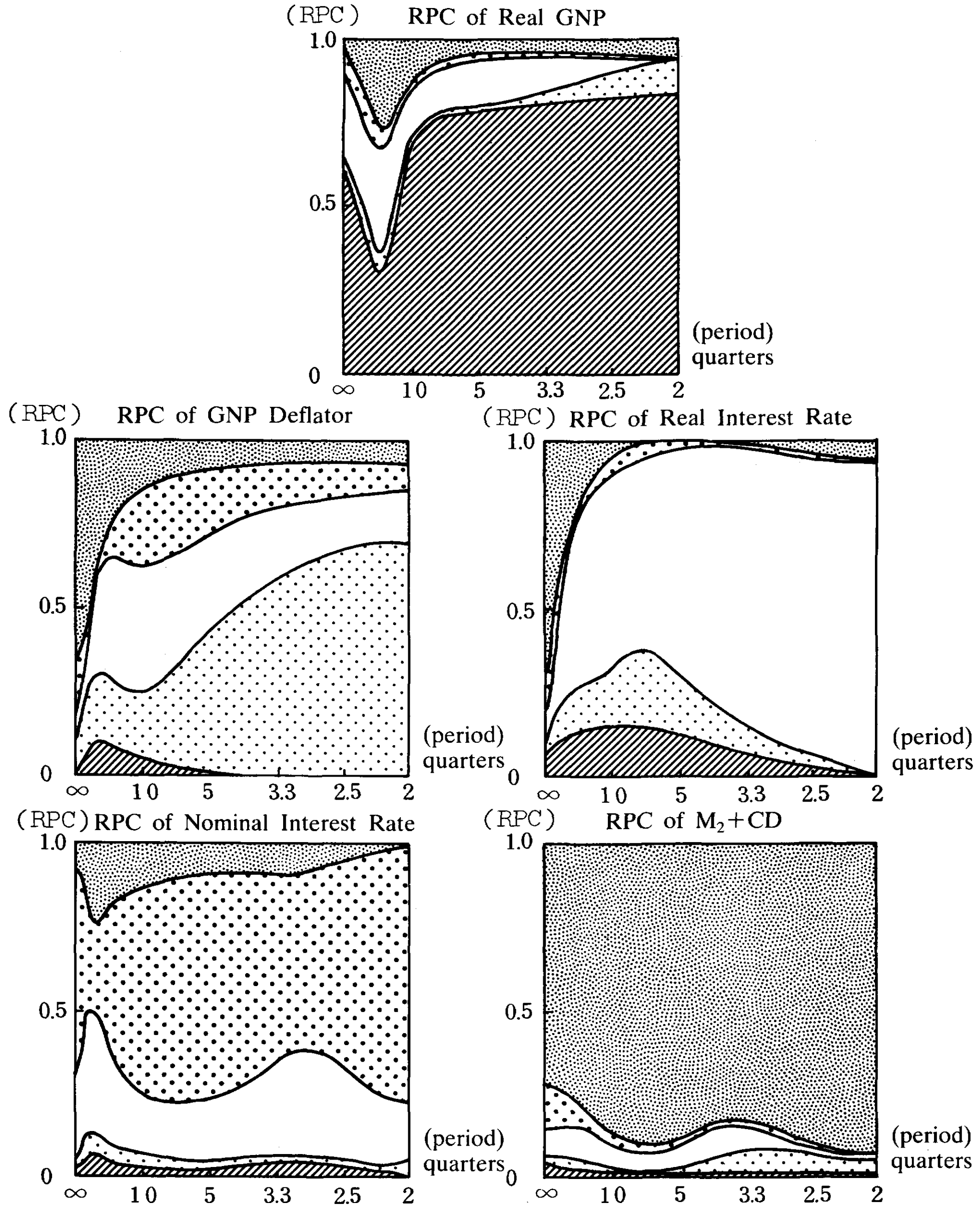


Chart 15

RPCs of Five Variable Model*
Real GNP, Nominal Interest Rate, Real Interest Rate, M_2+CD , and GNP Deflator



* Based on the AIC (Akaike's Information Criterion), second degree was used.

→ Influence of M_2+CD

→ Influence of GNP Deflator

→ Influence of Nominal Interest Rate

→ Influence of Real GNP

→ Influence of Real Interest Rate

2) Most movements of GNP are due to its own noise, but the contribution of real interest rates cannot be ignored. Indeed,there is a feedback relation between real rates and GNP, so the causality between them is not unidirectional.
3) No clear relationship between the GNP deflator and real GNP exists.
4) The real interest rate is influenced by M_2 +CD, the GNP deflator, and real GNP.
5) Both M_2 +CD and the real interest rate influence the nominal rate strongly.
6) The most exogenous of the variables considered here is M_2 +CD.

Judging on the basis of the findings here, comparison of the three intermediate targets (real interest rate, nominal rate, and money) shows that, from the viewpoint of both relation with final targets and exogeneity, the nominal rate is the worst candidate. The money supply surpasses the real interest rate on the basis of exogeneity. Both money and the real rate are about equally closely related to prices, but the real rate seems to be more closely related to real GNP.

V. Conclusion

The resluts of the analysis of the bivariate RPC procedures used in this paper may be summarized as follows:
1) Money supply has continuously exhibited a strong effect on nominal income. Some influence of nominal income on money was present before the first oil crisis, but this was probably only due to constraint of individual asset portfolios to hold deposits. No clear conclusion on the function of interest rates in the transmission mechanism from money to income is possible.
2) Clear causality exists from money supply to the GNP deflator.
3) No clear relation exists between real income and price movements, particularly in recent years. This can be interpreted to mean that the Phillips curve in Japan is of the form envisioned by the natural rate hypothes is (i.e. vertical).
4) Money supply control in Japan works through policy influenced interest rates.
5) A clear Fisher relation exists in Japan.
6) M_2+CD is more closely related to other economic variables that M_1, at least recently. This indicates the reasonability of emphasizing M_2 +CD and the intermediate target for monetary policy.
7) Analysis of differences of relationships of financial variables and other economic variables across subperiods of the sample indicates that structural changes occurred at the time of the first oil crisis.

The results of RPC analysis of causality in the multivariate model using money, real interest rates, nominal rates, income, and prices are follows:
8) The influence of real interest rates and money supply on prices, the final target which monetary authorities hold most important, are about the same.
9) The influence of real interest rates on real GNP is stronger than that of money.

10) Money supply is the most exogenous of the intermediate targets.
11) Nominal interest rates are inferior to both real rates and money supply as an intermediate target.

Appendix: Specification of Real Interest Rates

There are three main problems in specifying real interest rates: (1) which interest rate to use, (2) how to derive inflationary expectations, and (3) which price index to use for the inflation rate. The following discusses how these problems were approached in this paper.

Which Interest Rate?

When analyzing interest rates, it is necessary to specify clearly the maturity of the interest rate being used. The term structure of interest rates is determined by arbitrage between short and long rates, and this is particularly important when studying long rates. (See Kuroda and Ōkubo [7] and [8], and Kuroda [9].) In what follows we simplify by considering the short rate to be that on a one period bond. For the short rate, this paper has used the relatively free repurchase rate (a three month rate).

Inflationary Expectations

In a probabilistic world, with the nominal interest rate on a one period bond at time t denoted as i_t, the *ex ante* real rate on the bond as ρ_t, and expected inflation as π_t^e, the following relationship, as seen in Fisher [28], holds:

$$i_t = \rho_t + \pi_t^e \tag{1}$$

The *ex post* real rate for time period t (denoted ρ_t^{exp}) is equal to the inflation between time t and time t+1 (π_{t+1}) subtracted from the nominal rate at time t, that is:

$$\rho_t^{exp} = i_t - \pi_{t+1} \tag{2}$$

From equations (1) and (2) we derive

$$\rho_t^{exp} = \rho_t - (\pi_{t+1} - \pi_t^e) \tag{3}$$

that is, the difference of the *ex ante* and the *ex post* real rates equals the error in forecasting inflation.[14] Since both ρ^{exp} and π_{t+1} are observable, finding π_t^e by some

14. The return on a one period bond at time t, when the bond price is denoted by v, is

$$i_t = (v_{t+1} - v_t)/v_t$$

Here, v_{t+1} is considered probabilistically give, but it is sufficient to think of a discount bond. With the price level denoted by p, the inflation rate is defined as method allows us to estimate the *ex ante* real interest rate ρ_t. People at time t base their inflationary expectations for time t+1 on all information available at time t, and hence know something about the difference between the inflation rate at time t, that is π_t, and the inflation rate at time t+1, that is π_{t+1}. We let the error in inflationary expectations be proportional to the actual difference of inflation rates, and hence get

$$\pi^e_t - \pi_t = \alpha (\pi_{t+1} - \pi_t)$$

where α is between 0 and 1. Estimation of coefficient α is a critical matter in deriving inflationary expectations. There are several concrete methods of deriving inflationary expectations. (1) quantifying the results of actual survey research, (2) using a distributed lag model to generate weights for a weighted average of past inflation to represent expected inflation, and (3) using the results of a time series forecasting model to generate expected inflation. Of these, both (2) and (3) are adaptive expectations models which choose values of parameter α between 0 and 1. This paper, however, has assumed $\alpha = 1$; that is, we have assumed perfect foresight. The suitability of this assumption is subject to debate, but the above methods are also ways of approximating this with the best fit. This fact, combined with the ease of using perfect foresight, make it the most convenient method.

Which Price Index?

The three indexes most often used for measuring inflation are the consumer price index (CPI), the wholesale price index (WPI), and the GNP deflator. Here we have used the CPI, with the inflation rate measured as the change in CPI versus the same quarter of the previous year.

$$\pi_t = (p_t - p_{t-1}) / p_{t-1}$$

so that there is a one period discrepancy in the dating of inflation and the interest rate. Hence, when using the two variables together, we must use the actual inflation rate x_{t+1}, since this is the time span over which the interest rate in question applies.

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