6 An Aggregate Demand–Aggregate Supply Analysis of Japanese Monetary Policy, 1973–1990

Kenneth D. West

This paper studies the sources of the business cycle in Japan, 1973–90, focusing on the role played by money supply shocks. A secondary aim is to get a feel for whether the effects of Japanese monetary policy are roughly similar to those that would result if the Bank of Japan were operating under a simple, stylized rule or objective function.

For my analysis, I use a simple open economy aggregate demand–aggregate supply model, estimated on monthly data, January 1973 to August 1990. The six variables in the model are output, price, money supply, oil prices, foreign (U.S.) output, and the real yen/dollar exchange rate. The reduced form of the model is an unrestricted vector autoregression, and identification of the underlying linear simultaneous equations system is achieved in part with covariance restrictions of the sort first suggested by Blanchard and Watson (1986).

The model yields a decomposition of movements in the variables in the system into five underlying shocks: demand, cost, money supply, oil, and a residual foreign shock. It is found that movements in output are mainly attributable to demand and foreign shocks, movements in foreign output and the real exchange rate to foreign shocks; movements in prices are not driven overwhelmingly by any one kind of shock. For no variable apart from growth in the money supply itself are monetary shocks a particularly important source of variability, a conclusion also reached in some studies of the U.S. economy cited below. But unlike such studies, which typically find a major role for

Kenneth D. West is professor of economics at the University of Wisconsin and a faculty research fellow of the National Bureau of Economic Research.

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monetary policy in the recession of 1982 and perhaps elsewhere, I find that money supply shocks in Japan do not appear to play an especially prominent role in any of the cyclical turning points that have occurred in the sample.

These findings are obviously consistent with Friedman's (1985, 27) monetarist view that the Bank of Japan has aimed above all for "highly stable and highly dependable" money growth, putting relatively light weight on the state of the economy when determining monetary policy. The findings are also consistent with what I call the "textbook view" that the monetary authority should set the money supply rule by maximizing an objective function that aims at stabilizing output and prices (and, perhaps, other variables such as the exchange rate or the money supply itself as well); Bryant (1990) and, implicitly, Hamada and Hayashi (1985) attribute a sophisticated version of this view to the Bank of Japan. The bank's operating instruments (M_2, in the present paper) will then be set as a time-invariant function of all the variables that influence the path of price and output (e.g., Chow 1983, chap. 12). A relatively small overall role of monetary shocks (where shocks are surprises in monetary policy, i.e., deviations of the money supply from the level specified in the rule), with no special prominence for such shocks at cyclical turning points, seems consistent with this textbook view.

I do not attempt to distinguish beween these interpretations by formally inverting my estimated money growth rule to obtain the weights on money, output, and price stability in a policy objective function. This is mainly because some reduced-form evidence suggests that no simple story will stand very close scrutiny: both U.S. and Japanese output growth help predict money supply growth, a fact inconsistent with an extreme monetarist view that the money supply in Japan is set in total disregard to the state of the economy (not a view that Friedman or anyone else has advocated, as far as I know). On the other hand, money growth is not predicted by inflation, oil price inflation, or changes in the real exchange rate; these three variables all help predict output and inflation and thus should influence the path of the money supply as well, if indeed the textbook view is correct.

Instead, I see how well a simple monetarist view characterizes the effects (if not the intentions) of monetary policy by simulating the behavior of the economy during 1973–90, under a counterfactual policy of constant expected money growth, keeping all shocks fixed at their estimated values. To my surprise, the behavior of output growth and inflation is practically unchanged. (This is not because any and all anticipated monetary policy has vanishingly small real effects, as shown by a simulation under a policy of adjusting the money supply in response to movements in nominal GNP.) While the simulations cast no direct light on the *intentions* of the Bank of Japan's monetary policy, it does raise the possibility that the *effects* of the activist component of its policy—if any—were small. I leave open the question as to whether in fact there is a gap between intentions and effects and, if so, why.

Before turning to the analysis, several comments on the approach might be

useful to prevent misinterpretation. First, I do not calculate standard errors on the variance decompositions. Related work (West 1992) suggests that these will be quite large. So it is probably not wise to put too much weight on any single point estimate.

Second, I limit myself to inferences mechanically drawn from the estimates of my model. I assume that the Bank of Japan can perfectly control the value of M_2, up to a zero mean and serially uncorrelated shock; I abstract from problems that the bank no doubt faces with data availability, uncertainty about the values of key parameters, serial correlation in shocks, and so on. I do so not because I doubt the importance of such problems in practice, but because I do not believe that my simplified approach biases my results in an obvious way. Nonetheless, in light of the papers for this volume by Okina, Ueda, and Yoshikawa, as well as Hutchison (1986), it obviously would be useful to consider extensions of the model in which the bank's operating instrument is interest rates.

Third, the model used is essentially a textbook open economy model, with unrestricted lags put on the right-hand side of all equations to capture dynamics. Many of the features of the Japanese economy that from one or another point of view might require special treatment—the system of wage payments, the high savings rates, and so forth—are, I believe, comfortably subsumed in the standard model. See Taylor (1989), for example. Other features, such as the credit and interest rate controls that apparently have been operative, especially in the early part of the sample (Fukui 1986; Ito 1989; Kosai and Ogino 1984, chap. 6), perhaps are not as easily subsumed. But the standard model still tells a "story . . . consistent with the data," to use Blanchard's (1989, 1146) conclusion for a similar model applied to U.S. data. I interpret this as suggesting that it is reasonable in a first effort such as this to abstract from such special features, while acknowledging that much might be learned by modeling such features explicitly.

Finally, as is well known, the model is not derived from optimization; in addition here, as in, for example, Blanchard (1989) but not Taylor (1989), expectations are not explicitly modeled but instead are absorbed in distributed lags on past variables. It should be noted first of all that the fact that expectations are not explicitly modeled leads to inefficient but not inconsistent estimates of parameters, impulse response functions, or variance decompositions if, as in Taylor (1989), the "true" structural model is simply a rational expectations version of the aggregate demand–aggregate supply model. The advantage of the present approach is that it does not require detailed specification of the variables being forecast. For example, in the aggregate supply curve, is it just next month's price, as in a monthly version of Lucas (1973), or a weighted sum of the next twelve months of prices, as in a monthly version of Taylor (1989)? On the other hand, the simulations under alternative money supply rules potentially fall prey to the Lucas critique. I discuss this briefly in the relevant section of the paper.

More generally, some readers will be skeptical about estimates of an aggregate demand–aggregate supply model, with or without rational expectations. I hope that such readers will still find in this paper two results that will be useful to keep in mind in future, and perhaps more highly structured, work. I state these now, since in the body of the paper I will assume the validity of the model in interpreting the empirical results.

The first result is that at conventional significance levels the broad measure of money used here (M_2) Granger causes the real variables in the model. Eichenbaum and Singleton (1986) and Christiano and Ljungqvist (1988), among others, suggest that such a finding is inconsistent with a strict real business cycle theory. A small amount of experimentation suggests that, in possible contrast to U.S. data (e.g., Eichenbaum and Singleton 1986), this finding is robust to the method used to detrend the data.[1]

Second, while the technique used to orthogonalize shocks relies on the assumed model for its validity, one can to a limited extent think of it in terms of the atheoretical approach exemplified by Sims (1980). In this context, the procedure can be interpreted as putting oil price shocks first, the residual foreign shock last, with demand, cost, and money supply shocks in between (and no simple Sims-style statement of the order of these three shocks is possible). The fact that oil price shocks nonetheless play a small role and foreign shocks a big role in output fluctuations suggests that the results for these two shocks may be robust to alternative procedures for orthogonalizing the disturbances.

Section 6.1 describes the model, section 6.2 the data, section 6.3 the estimates, section 6.4 the sensitivity of the results to minor changes in specification, and section 6.5 the behavior of the economy under hypothetical alternative money supply rules. An appendix available on request contains some additional results omitted from the body of the paper to save space.

6.1 The Model

The variables in the model, all of which are in logs, are:

y_t = output (industrial production)
p_t = price level (WPI)
m_t = money supply (M_2 + CD)
o_t = oil prices (WPI for petroleum and coal)
y^*_t = foreign output (U.S. industrial production)
a_t = real exchange rate (yen/dollar)

1. On the other hand, the finding is not robust to the measure of money used. High-powered money does not Granger cause any of the three sets of real variables just listed. I believe that, in contrast to the argument Eichenbaum and Singleton (1986) and Christiano and Ljungqvist (1988), the argument in Plosser (1990) would suggest that the overall pattern of Granger causality is therefore consistent with a real business cycle view.

Let $x_t \equiv (y_t, p_t, m_t, o_t, y^*_t, a_t)'$ be the (6×1) vector of endogenous variables, with $v_t \equiv (v_{yt}, v_{pt}, v_{mt}, v_{ot}, v_{y^*t}, v_{at})'$ the corresponding vector of reduced-form innovations (one-step-ahead prediction errors), $v_t = x_t - {}_{t-1}x_t$.

Six linear simultaneous equations determine the six endogenous variables in x_t. On the right-hand side of all six are n lags of each of the six endogenous variables. Together with a constant term, this set of lags is denoted by the $(6n + 1) \times 1$ vector $z_{t-1} \equiv (1, x_{t-1}', \ldots, x_{t-n}')'$. The structural equations are

$$(1) \qquad y_t = \alpha_1(m_t - p_t) + \alpha_2 a_t + \alpha_3 y^*_t + \Gamma_y' z_{t-1} + u_{dt};$$

$$(2) \qquad p_t = \beta_1 y_t + \beta_2 o_t + \Gamma_p' z_{t-1} + u_{ct};$$

$$(3) \qquad m_t = \gamma_1 v_{yt} + \gamma_2 v_{pt} + \gamma_3 v_{at} + \Gamma_m' z_{t-1} + u_{mt};$$

$$(4) \qquad o_t = \Gamma_o' z_{t-1} + u_{ot};$$

$$(5) \qquad y^*_t = \delta_1 v_{yt} + \delta_2 v_{pt} + \delta_3 v_{mt} + \delta_4 v_{ot} + \Gamma_{y^*}' z_{t-1} + u_{y^*t};$$

$$(6) \qquad a_t = \phi_1 v_{yt} + \phi_2 v_{pt} + \phi_3 v_{mt} + \phi_4 v_{ot} + \phi_5 v_{y^*t} + \Gamma_a' z_{t-1} + u_{at}$$

The u's are mutually and serially uncorrelated disturbances, the Γ's are $(6n + 1) \times 1$ vectors of parameters.

Equation (1) is an aggregate demand curve, u_{dt} a demand shock. The demand curve may be obtained by combining IS and LM curves, substituting out for the nominal interest rate. The dependence of a standard IS curve on the real rate rather than the nominal rate is implicitly allowed, since $\Gamma_y' z_{t-1}$ will absorb any term in expected inflation.

The term in real balances $(m_t - p_t)$ in (1) comes from the LM curve, and $\alpha_1 > 0$. The terms in the real exchange rate a_t and foreign output y^*_t come from the IS curve. These terms capture the effect that a_t and y^*_t have on the trade balance. If a J-curve is operative, so that depreciation (increase in a_t) has a perverse negative effect on the trade balance in the short run, $\alpha_2 < 0$, otherwise $\alpha_2 \geq 0$. In any case, $\alpha_3 > 0$, since increases in foreign output affect exports, and thus the trade balance and aggregate demand, positively.

Equation (2) is an aggregate supply curve, u_{ct} a cost (supply) shock. Both β_1 and β_2 are positive: quantity supplied depends positively on output and negatively on oil prices. Terms in expected prices or output are absorbed in $\Gamma_p' z_{t-1}$.

Equation (3) is the money supply rule. I assume that, at the beginning of month t, the monetary authority chooses an expected value for the period t money supply, ${}_{t-1}m_t$. The difference between m_t and ${}_{t-1}m_t$ (the variable v_{mt}) might or might not depend on intramonth attempts by the Bank of Japan to influence the path of nonmonetary variables. Output and price, and perhaps the real exchange rate, are present to allow for the possibility of such intramonth attempts to target these variables (Bryant 1990). A second reason that output and price are present is that the measure of money used in the empirical work is a broad one whose period t value cannot be perfectly controlled at time ($t - 1$), but instead will depend on surprises in money demand (velocity), even if the bank makes no such intramonth attempts. A second reason that the real exchange rate is present is that its value might affect intramonth decisions about whether or not to sterilize exchange rate operations, and thus affect the value of the money supply.

The monetary rule of course might also depend in part on interest rates. Equation (3) allows for this implicitly: use the LM curve to write the nominal interest rate in terms of money, output, and prices, and possibly lagged values of these and other variables, and then substitute out for the interest rate in the monetary rule.[2] The resulting disturbance will then depend in part on velocity shocks and thus be correlated with the aggregate demand shock u_{dt}. The estimation procedure described below will, however, yield a shock to the money supply that is uncorrelated with demand shocks by construction. This is interpreted as the component of money supply shocks uncorrelated with velocity shocks. Under this interpretation, the estimation procedure is attributing entirely to demand shocks a component shared by both demand and money shocks.

In related literature (Blanchard and Watson 1986), the money supply rule is written in terms of levels rather than surprises (e.g., $\gamma_1 y_t$ rather than $\gamma_1 v_{yt}$). In the present setup, the specifications are observationally equivalent: estimates of the parameters in (1)–(6), and the implied variance decompositions, impulse response functions, and so on, are the same whether levels or surprises are used. I write (3) as a function of surprises in accord with my interpretation of monetary policy as a rule for setting ${}_{t-1}m_t$; in simulations below on the hypothetical effects of alternative rules over the sample period, I take both the γ_i's and the v_t's as structural and invariant to the policy rule.

Equation (4) says that the period t oil price is a predetermined variable, which in the present setup means that its innovation is contemporaneously uncorrelated with the other innovations in the model. Shapiro and Watson (1988) argue that this is reasonable because movements in oil prices are dominated by a few sharp swings. Note that the oil price being predetermined is perfectly consistent with it being Granger caused by other variables.

Equations (5) and (6) are vacuous identities, simply stating that the period t surprise in each of these variables can be written as a linear combination of other surprises, plus a term orthogonal to these surprises. The idea is that foreign output, while not modeled explicitly, is determined by a set of equations similar to those determining Japanese output. Since demand, cost, money, and oil shocks plausibly are correlated across countries, the period t surprise in foreign output will be correlated with all these shocks, as well as with any shocks to the exchange rate. The estimation procedure will attribute

2. If the interest rate targeted by the Bank of Japan is different from that in the LM curve (e.g., call rate versus gensaki), one must also use an equation relating the two rates to eliminate interest rates from the system. The only reason I have not explicitly used interest rates is to avoid increasing the dimensionality of an already complicated system of equations.

this common element of foreign and Japanese demand shocks, for example, to u_{dt} and similarly for other shocks. The residual u_{y^*t} is thus the idiosyncratic component on foreign cycles after any common components have been absorbed by u_{dt}, u_{ct}, u_{mt}, and u_{ot}.

Similarly, the exchange rate is often thought to be set by forward-looking behavior of the sort generally presumed to determine asset prices, so, like other asset prices, its surprise will depend on the surprises of all the fundamental variables in the model (e.g., Dornbusch 1976; West 1987). The residual component u_{at} may thus be interpreted as reflecting speculative forces or variations in risk premiums uncorrelated with the fundamentals variables.

Once again, an observationally equivalent model would result if the surprises in (5) and (6) were replaced by levels. The potential effects of alternative policies for setting ${}_{t-1}m_t$, however, will be different in the two specifications. As written above, the reduced form equations for y^*_t and a_t will not change with a change in the rule for setting ${}_{t-1}m_t$, while those equations would change if levels were on the right-hand side. Since tests on the reduced form suggest that these two variables are exogenous in the Granger sense from the remaining variables (see below), in practice it probably would not make much difference which specification is used; I use surprises rather than levels in accord with my a priori view that it is implausible that the sorts of changes in the rule for setting ${}_{t-1}m_t$ contemplated below will much affect the coefficients in the reduced-form stochastic process for foreign output and the real exchange rate.

In equations (5) and (6), putting foreign output y^*_t before the real exchange rate a_t is arbitrary; the variance decompositions reported below simply report a contribution from "foreign terms" that is the sum of contributions of u_{y^*t} and u_{at}.

To solve the model, tentatively replace the surprises in (3)–(6) with levels (e.g., replace v_{yt} in [3] with y_t). Write (1)–(6) in matrix form as

$$B_0 x_t = k + B_1 x_{t-1} + \ldots + B_n x_{t-n} + u_t, \tag{7}$$

where B_i are 6×6 matrices, k is a 6×1 vector of coefficients on constant terms, and $(u_{dt}, u_{ct}, u_{mt}, u_{ot}, u_{y^*t}, u_{at})'$ is a 6×1 vector of mutually and serially uncorrelated disturbances. Premultiplying both sides of (1)–(6) by B_o^{-1} yields a vector autoregressive reduced form,

$$\begin{aligned} x_t &= B_0^{-1}k + B_0^{-1}B_1 x_{t-1} + \ldots + B_0^{-1}B_n x_{t-n} + B_0^{-1}u_t \\ &\equiv c + \Pi_1 x_{t-1} + \ldots + \Pi_n x_{t-n} + v_t, \end{aligned} \tag{8}$$

where $v_t \equiv (v_{yt}, v_{pt}, v_{mt}, v_{Ot}, v_{y^*t}, v_{at})' = B_0^{-1}u_t$ is the 6×1 vector of reduced-form innovations. Even though surprises rather than levels appear in equations (3)–(6), one can similarly deduce that the reduced form of (1)–(6) follows an n'th-order vector autoregression, with a similar mapping from reduced form to structural disturbances; I omit the algebra for simplicity.

Given B_0 and Π_i, variance decompositions and impulse response functions can be calculated in the usual way. Π_i may be obtained by OLS. B_0 may then be obtained from the variance-covariance matrix of v_t as follows. This matrix has twenty-one distinct elements. These must determine twenty-three parameters: six variances, one for each of the elements of u_t, and the seventeen coefficients on contemporaneous variables or surprises in equations (1)–(6). Without additional information, the system is not identified. Given the wealth of studies on the determinants of the Japanese trade balance, which have produced some consensus estimates of relevant elasticities, it seems likely to be uncontroversial to impose values for α_2 and α_3, the instantaneous elasticities of aggregate demand with respect to the real exchange rate and foreign output, and so I used these studies to impose such values. This leaves twenty-one parameters to be determined from the twenty-one elements of the variance-covariance matrix of v_t.

The structure of the system is such that the information in these twenty-one elements can be exploited by standard instrumental variables techniques. The residual from estimating the oil equation (4) $u_{ot} \equiv v_{ot}$ can be used to instrument the aggregate demand equation, to obtain $\hat{\alpha}_1$. The aggregate demand and oil residuals u_{dt} and u_{ot} can then be used as instruments in the price equation; u_{dt}, u_{ct}, and u_{ot} can then be used as instruments in the money supply equation; u_{dt}, u_{ct}, u_{ot}, and u_{mt} can then be used as instruments in the foreign output equation; and the entire set of structural disturbances can be used in the real exchange rate equation.

6.2 Data

The data are monthly, January 1973 to August 1990, for a total of 212 observations, with pre-1973 data used for initial lags. The ending point of the sample was determined by data availability. The starting point was determined, first, by the evident fact that the Japanese economy has behaved quite differently post-1973 than pre-1973 and, second, by the presumption that monetary policy was rather different in the era of fixed exchange rates than in the era of floating exchange rates. The exact date January 1973 was chosen in accord with Hamada and Hayashi (1985, 109), who concluded that January 1973 is the likeliest date for a one-time shift in monetary policy in the early 1970s. Results of estimates with two other subsamples, January 1976 to August 1990 and January 1973 to March 1990, are very similar, as noted below.

Data for both the United States and Japan through mid-1988 were obtained from the OECD's *Main Economic Indicators* (MEI) as supplied on PC diskettes by VAR Econometrics, and updated by published sources as indicated below. The MEI indices of Japanese industrial production, seasonally adjusted, and the WPI for mining and manufacturing, all 1980 = 100, were converted to 1985 = 100, and together with seasonally adjusted data on monthly averages of M_2 + CD were then linked with post-1988 data published in various issues of the Bank of Japan's *Economic Statistics Monthly.* (The MEI series is labeled "M1 + Quasimoney," but comparison with the figures in *Economic Statistics Monthly* indicates that the data are for M_2 + CD. The only seasonally adjusted data for M_2 + CD in *Economic Statistics Monthly* were for growth rates rather than levels, so I constructed a post-1988 level series using as an initial condition the last available MEI figure.) The MEI series on the end-of-month yen/dollar exchange rate was updated with data kindly supplied by Kunio Okina.

These measures of price level and money stock were chosen following Bryant (1990), who suggests that the WPI is the most appropriate single monthly price index, and Ito (1989, 1990) and Suzuki (1985), who suggest that M_2 + CD is the most appropriate single measure of the money stock from the point of view of monetary targeting.

The MEI indices of U.S. industrial production, seasonally adjusted, and the WPI, both 1980 = 100, were converted to 1987 = 100 and 1982 = 100, respectively, and then linked with post-1988 data published in the *Survey of Current Business* and the Federal Reserve Bank of St. Louis's *National Economic Trends.* All data were converted to logs, with the real exchange rate defined as log(yen/dollar) + log(U.S. WPI) − log(Japanese WPI).

Figure 6.1 has plots of the growth rates (log differences) and log levels of the data, with contraction phases of the reference cycle as defined by the Economic Planning Agency noted by shaded areas. Table 6.1 has some basic statistics. The negative first autocorrelation of output growth and the somewhat choppy pattern of autocorrelations for money growth and inflation in oil prices (rows 1, 3, and 4) are unusual features of the data (at least to one used to working with U.S. data); the jerky behavior that leads to these patterns can be seen in the graphs for these variables in figure 6.1.

6.3 Empirical Estimates

6.3.1 Preliminaries

The empirical work began with tests for unit roots. Standard univariate-augmented Dickey-Fuller tests suggested that one difference sufficed to induce stationarity in each of the variables; a version of the Johansen (1988) test for cointegration, extended to include trend as well as constant terms, found, according to p-values kindly supplied by James H. Stock, no evidence of cointegration. Details on these tests are available upon request. I thus simply differenced all variables before proceeding with the empirical work. For example, y_t is the growth rate of output. I nonetheless generally refer to y_t as simply "output," except where this might cause confusion. Results from specifications estimated in levels rather than differences were quite similar, as noted below.

Using the differenced data, I estimated three different VARs, with six,

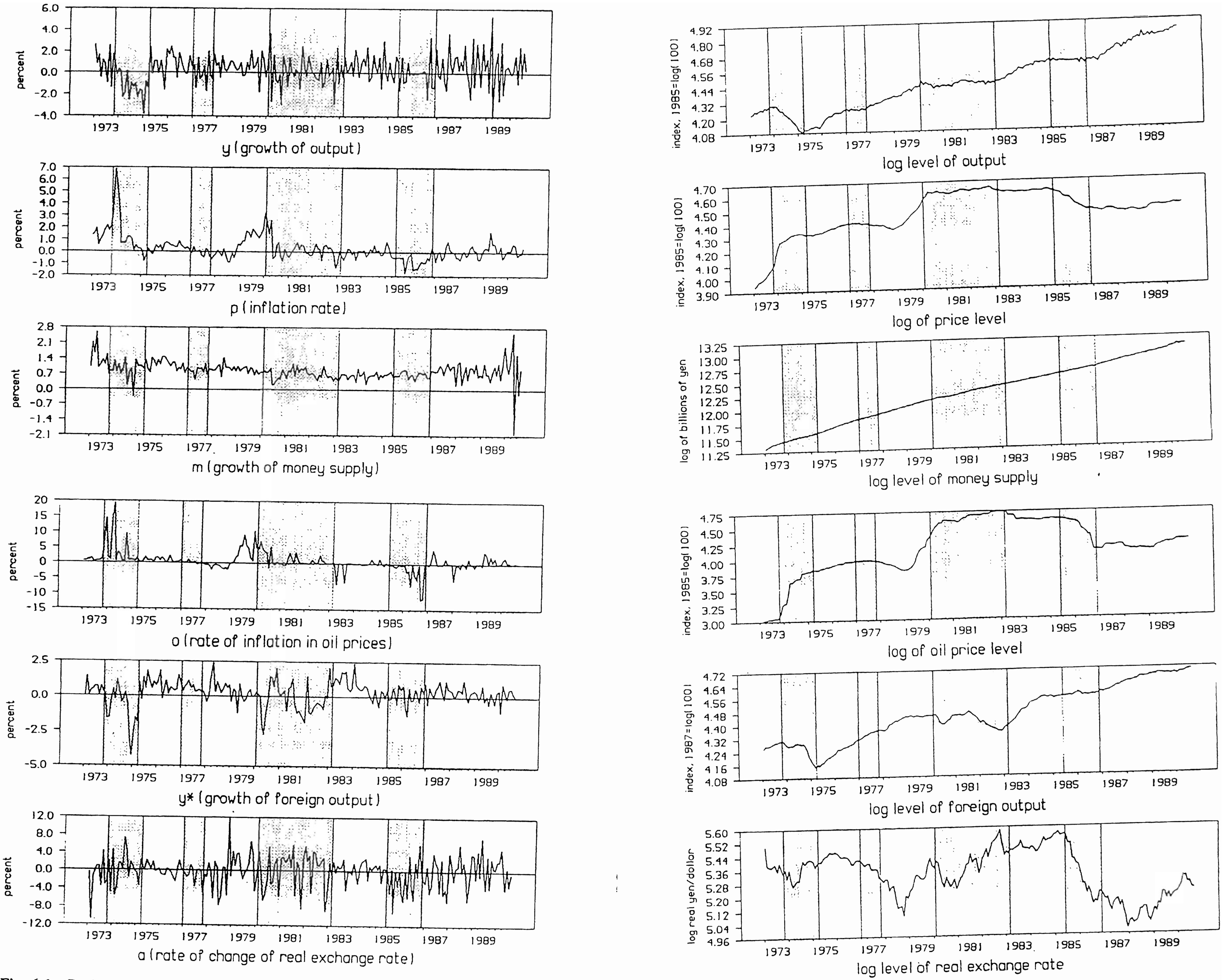

Fig. 6.1 Basic data

Table 6.1 **Basic Statistics**

	Mean	Standard Deviation	Autocorrelations 1	2	3	4	5
(1) y	0.304	1.444	−0.271	0.186	0.262	−.068	0.131
(2) p	0.274	1.000	0.780	0.596	0.491	0.458	0.423
(3) m	0.845	0.410	−0.008	0.294	0.219	0.148	0.110
(4) o	0.599	3.090	0.496	0.298	0.417	0.396	0.239
(5) y^*	0.211	0.897	0.510	0.353	0.262	0.157	0.087
(6) a	−0.130	3.367	−0.026	0.009	0.068	0.004	0.007

Note: The statistics are based on 212 monthly observations from January 1973 to August 1990. Variables: y = rate of growth of output (index of industrial production, mining, and manufacturing, seasonally adjusted, 1985 = 100); p = rate of inflation (WPI); m = growth rate of M_2 + CD, seasonally adjusted; o = rate of inflation in oil prices (WPI for petroleum and coal); y^* = rate of growth of U.S. output (index of industrial production, seasonally adjusted, 1987 = 100); a = percentage change in real exchange rate (yen/dollar).

twelve, and twenty-four lags of each right-hand-side variable, plus a constant term. All regressions began in January 1973, with the twenty-four-lag regression, for example, reaching back to January 1971 for lags to put on the right-hand side. Likelihood ratio tests using the degrees of freedom adjustment suggested by Sims (1980) rejected the null of six lags in favor of the alternative of twelve ($\chi^2(216)$ = 274.2, p-value = .003), but did not reject the null of twelve lags in favor of the alternative of twenty-four ($\chi^2(432)$ = 311.4, p-value = 1.00). In addition, both Q-statistics (reported below) and the individual autocorrelations of the residuals suggested that a lag length of twelve sufficed to reduce the residuals in each equation to white noise. I thus set the lag length to twelve.

6.3.2 Reduced Form

The model suggests that, except in special cases, anything that Granger causes money, oil prices, foreign output, and the real exchange rate ought to Granger cause output and prices as well (though of course there may be such Granger causality to output and prices even in the absence of Granger causality to the right-hand-side endogenous variables in equations [1] and [2]). Table 6.2, panel A, presents F-statistics suggesting that this is essentially the case: at conventional significance levels, at least one of money, oil prices, and foreign output is Granger caused by each of the six variables (rows 3–5), and, indeed, all six variables Granger cause output (row 1), and all but foreign output Granger cause prices (row 2). The standard errors for sums of distributed lags reported in table 6.2, panel B, yield compatible implications for when movements in one variable help predict movements in another.

Note that money Granger causes both output and prices (table 6.2, panel A, rows 1 and 2, column 3), suggesting the possibility that monetary policy may be used to influence the path of these two variables. If the monetary authority

Table 6.2 **Reduced Form**

A. Granger Causality Tests

To	From (1) y	(2) p	(3) m	(4) o	(5) y^*	(6) a	(7) y, p, m, o	(8) y^*, a
(1) y	7.202 [0.000]	3.318 [0.000]	2.723 [0.002]	2.352 [0.009]	3.569 [0.000]	2.345 [0.009]	4.206 [0.000]	2.648 [0.000]
(2) p	1.131 [0.340]	5.280 [0.000]	1.926 [0.036]	2.027 [0.026]	0.784 [0.666]	4.019 [0.000]	9.936 [0.000]	2.172 [0.003]
(3) m	2.055 [0.024]	0.766 [0.685]	4.221 [0.000]	0.797 [0.653]	0.973 [0.477]	0.624 [0.819]	2.495 [0.000]	0.651 [0.889]
(4) o	2.022 [0.026]	5.334 [0.000]	1.792 [0.055]	3.236 [0.000]	1.558 [0.111]	1.786 [0.056]	5.856 [0.000]	1.801 [0.019]
(5) y^*	0.981 [0.470]	1.704 [0.072]	0.725 [0.725]	1.530 [0.120]	2.596 [0.004]	1.844 [0.047]	1.468 [0.044]	3.049 [0.000]
(6) a	0.792 [0.658]	1.144 [0.330]	0.430 [0.949]	0.679 [0.769]	0.489 [0.918]	1.126 [0.344]	0.729 [0.896]	0.808 [0.722]

(7) H_A: m_t does not Granger cause y_t, $m_t - p_t$, $o_t - p_t$, y^*_t, a_t ~ $\chi^2(60)$ = 92.490 [0.004]
(8) H_B: m_t does not Granger cause y_t, $m_t - p_t$, $o_t - p_t$, ~ $\chi^2(36)$ = 80.504 [0.000]

B. Summary Statistics

Left-hand-side Variable	Right-hand-side Variables: Sums of Lag Coefficients (1) y	(2) p	(3) m	(4) o	(5) y^*	(6) a	Summary Statistics (7) Standard Error	(8) $\bar{R}^2$	(9) Q (42)
(1) y	−0.695 (0.348)	−1.477 (0.433)	1.216 (0.420)	0.416 (0.154)	1.173 (0.311)	0.176 (0.104)	1.033	.49	33.98 [0.81]
(2) p	0.218 (0.183)	0.836 (0.228)	0.658 (0.221)	−0.085 (0.081)	−0.114 (0.163)	0.087 (0.055)	0.543	.71	23.66 [0.99]
(3) m	−0.297 (0.121)	−0.109 (0.150)	0.709 (0.146)	0.032 (0.054)	0.200 (0.108)	0.018 (0.036)	0.359	.23	20.08 [1.00]
(4) o	0.378 (0.660)	4.179 (0.822)	−1.369 (0.797)	−0.697 (0.293)	−0.540 (0.590)	0.589 (0.197)	1.960	.60	34.01 [0.81]
(5) y^*	−0.029 (0.238)	0.240 (0.296)	−0.177 (0.288)	−0.143 (0.106)	0.437 (0.213)	0.006 (0.071)	0.707	.38	29.29 [0.93]
(6) a	0.573 (1.194)	0.946 (1.487)	−0.469 (1.442)	−0.412 (0.529)	−0.547 (1.066)	0.297 (0.357)	3.545	−.11	25.49 [0.98]

Notes: Panel A: The F-statistics in rows 1–6 test the null that the coefficients are zero for all lags of the variables in a given column, when the variable in a given row is on the left-hand side. p-values are given in brackets. The degrees of freedom for the tests in the first six columns are 12,139, in column 7 are 48,139, and in column 8 are 24,139. Panel B: In columns 1–6 asymptotic standard errors are in parentheses. Column 7 presents the standard error of the regression. In column 9 the p-value for the Q-statistic is in brackets.

is following a program of targeting or stabilizing output and/or prices, in general it should adjust the money supply in response to whatever variables influence the path of those two variables (see, e.g., Chow 1983, chapter 12). In light of the results in rows 1 and 2, this means in response to all the variables in the system. In a stationary world (one in which the objective function of the monetary authority and parameters of the model are unchanging), this would lead to money being Granger caused by all the variables in the system.

It appears, however, that money is Granger caused only by itself and output (row 3, columns 1 and 3). Tests on sums of distributed lag coefficients reported in table 6.2, panel B, find some predictive power in foreign output as well. But overall there is no reduced-form evidence that the money supply responds to prices, oil prices, or the real exchange rate.

One possible reason for the lack of Granger causality is that, while there is indeed a stable feedback rule consistent with targeting of output and prices, the sample is too small to accurately reflect this fact, a distinct possibility given that I am using a profligately parameterized model. But while it would not be wise to interpret the lack of Granger causality as sharp evidence against the simple textbook model of output and price targeting, it seems equally foolish to expect the estimates of this model to yield sharp implications about what the price and output targets of the Bank of Japan are, even if one's priors are that such targets are central to the bank's decision making (e.g., Bryant 1990).

Also, the fact that both output and foreign output help predict the money supply suggests that the bank does have its eyes on the economy when it determines the money supply. That this money growth is not exogenous has been argued by many, including in particular Hutchison (1986), who uses Granger causality tests such as those applied here. Once again, it would be foolish to expect the estimates of this model to yield a clear statement that the bank follows a money-targeting rule, even if one's priors are that this is essentially the case.

One final note on the reduced form: the evidence that money Granger causes real variables is quite strong. Consider rewriting the system so that money is the only nominal variable, with $m_t - p_t$ (real balances) and $o_t - p_t$ (real oil prices) joining y_t, y_t^*, and a_t as real variables. As reported in rows 7 and 8 of table 6.2, panel A, the null that money does not Granger cause any of these variables is strongly rejected, as is the null that money does not Granger cause the set of domestic variables y_t, $m_t - p_t$, and $o_t - p_t$.

6.3.3 Structural Equations

Table 6.3, panel A, has estimates of equations (1)–(6). The coefficients on y_t^* and a_t in the aggregate demand equation were imposed rather than estimated: Noland (1989) estimated a long-run elasticity of Japanese exports with respect to foreign output of about 1.4. Since exports are about 10 to 15% of GNP, and the short-run effect is presumably less than the long-run, this sug-

Table 6.3 **Structural Estimates**

A. Parameter Estimates[a]

(1) $y_t = \underset{(.591)}{0.512}(m_t - p_t) - 0.03a_t + .20y_t^* + \hat{\Gamma}_y' z_{t-1} + \hat{u}_{dt}$

(2) $p_t = \underset{(.047)}{0.255}y_t + \underset{(.023)}{0.094}o_t + \hat{\Gamma}_p' z_{t-1} + \hat{u}_{ct}$

(3) $m_t = \underset{(.035)}{-0.038}v_{yt} - \underset{(.112)}{0.057}v_{pt} - \underset{(.051)}{0.017}v_{ot} + \hat{\Gamma}_m' z_{t-1} + \hat{u}_{mt}$

(4) $o_t = \hat{\Gamma}_o' z_{t-1} + \hat{u}_{ot}$

(5) $y_t^* = \underset{(.060)}{0.065}v_{yt} - \underset{(.119)}{0.167}v_{pt} - \underset{(.169)}{0.096}v_{mt} + \underset{(.032)}{0.002}v_{ot} + \hat{\Gamma}_{y^*}' z_{t-1} + \hat{u}_{y^*t}$

(6) $a_t = \underset{(.301)}{0.268}v_{yt} + \underset{(.590)}{2.412}v_{pt} + \underset{(.838)}{1.859}v_{mt} - \underset{(.160)}{0.344}v_{ot} - \underset{(.428)}{0.021}v_{y^*t} + \hat{\Gamma}_a' z_{t-1} + \hat{u}_{at}$

B. Summary Statistics

Equation	Right-hand-side variables: Sums of Lag Coefficients						Summary Statistics		
	y	p	m	o	y^*	a	Standard Error	$\bar{R}^2$	Q(42)
(1)	−0.408	−1.524	1.723	0.372	1.109	0.189	1.144	.36	27.64
	(0.491)	(0.481)	(0.729)	(0.184)	(0.391)	(0.122)			[0.96]
(2)	0.615	0.821	0.476	−0.032	−0.363	−0.013	0.531	.72	28.56
	(0.195)	(0.250)	(0.225)	(0.090)	(0.169)	(0.056)			[0.94]

Notes: Asymptotic standard errors in parentheses. The coefficients in equation (1) in panel A without standard errors were imposed rather than estimated. See notes to table 6.2 for additional description.

[a] $\hat{\sigma}_d = 1.144$; $\hat{\sigma}_c = 0.531$; $\hat{\sigma}_m = 0.372$; $\hat{\sigma}_o = 1.960$; $\hat{\sigma}_{y^*} = 0.706$; $\hat{\sigma}_a = 3.484$.

gests an upper bound of about 0.2 for the short-run elasticity of aggregate demand with respect to foreign output. Krugman and Obstfeld (1988, 454) report that Artus and Knight (1984) found that the six-month elasticity of the Japanese current account with respect to the real exchange rate was about −0.25, and Noland (1989) found a one-quarter elasticity of about −1 (the negative signs being consistent with a J-curve), again suggesting an aggregate demand elasticity about 10 to 15% of those figures: hence the −0.03. Some alternative imposed values for these short-run elasticities led to very similar results, as noted below.

The remaining parameters in table 6.3 were estimated by instrumental variables, as described above. The three freely estimated parameters in the aggregate demand and aggregate supply equations are all correctly signed. I do not know of estimates for Japanese data to which the estimates can be directly compared, but comparison with U.S. studies suggests that they are plausible.

Although the estimate of the instantaneous elasticity of aggregate demand with respect to real balances is fairly imprecise, the 0.512 value is bracketed by estimates from quarterly U.S. data. On the one hand, the 0.15 quarterly figure for the MPS model for the United States (Blanchard 1989, 1150) is somewhat lower. On the other hand, if one combines the Japanese money demand estimates in Hamada and Hayashi (1985, table 4.5; income elasticity ≈ 0.2 to 0.5, interest elasticity ≈ -0.01 to -0.02) with the range of interest elasticities of the IS curve found in U.S. studies (≈ -0.1 to -0.2; e.g., Friedman 1977), the implied value of the elasticity is about 2–5, somewhat higher than the estimated value of 0.512.

The estimated price elasticity of supply of about 4 ($4 \approx 1/0.255$) is bracketed by the quarterly U.S. estimates of 0.81 (Blanchard and Watson (1986, 132)) and 10–12 (Blanchard 1989, 1152). The 0.094 figure on oil prices is consistent with the monthly estimate in Blanchard (1987, 68) that a 1% increase in crude materials prices causes a 0.02% increase in consumer prices.

The three negative signs on the variables in the money supply equation are consistent with the possibility that the intramonth response of the Bank of Japan to shocks is one of "leaning against the wind"; on the other hand, the signs could as well simply reflect factors beyond the control of the authority, such as intramonth shocks to the money multiplier. In any case, none of the three estimates is significantly different from zero, so, in the absence of any a priori theoretical bounds on plausible values, it is probably not advisable to read much into the signs or magnitudes of the estimates.

As noted above, theory does not restrict the signs or values of the coefficients on the foreign output and real exchange rate equations.

Table 6.3, panel B, has estimates of sums of distributed lag coefficients in the aggregate demand and supply equations. (The sums for the other equations are exactly as presented in table 6.2, panel B.) Coefficients on contemporaneous right-hand-side variables (e.g., m_t in [1]) are included in these sums. By and large, the significance of the sums of these distributed lag coefficients is consistent with the Granger causality tests reported above.

The long-run response of a given left-hand-side variable to a permanent increase in a given right-hand-side variable can be inferred from the estimates in the table. The long-run elasticity of aggregate demand with respect to money is about 1.2 ($\approx 1.723/1.408$), with respect to prices about -1.1 ($\approx -1.524/1.408$), which is probably consistent with a long-run elasticity of aggregate demand with respect to real balances of about 1, a point estimate suggested by Hamada and Hayashi (1985, 101). The long-run elasticity of aggregate demand with respect to the real exchange rate is about 0.13 ($\approx 0.189/1.408$), comparable to the figures of about 0.15 and 0.05 implied by Artus and Knight (1984, cited in Krugman and Obstfeld 1988, 484) and Noland (1989, 177). The elasticity with respect to foreign output is about 0.8 ($\approx 1.109/1.408$), somewhat higher than the 0.14 figure implied by Noland (1989). (The stated figures for Artus and Knight and Noland were obtained by

multiplying their reported elasticities by 0.10, approximately the share of imports or exports in Japanese GNP.)

The long-run price elasticity of supply is about 0.13 ($\approx [1 - 0.821]/[1 + 0.615 - 0.255]$).

Figure 6.2 plots impulse response functions (dynamic multipliers), that is, one-to-sixty-month response of the levels of output, prices, and money to demand, cost, money, and oil shocks. (The responses to u_{y^*t} and u_{at} are not given, since the breakdown of the residual foreign shock into these two components is arbitrary; plots of responses of oil prices, U.S. output, and the real

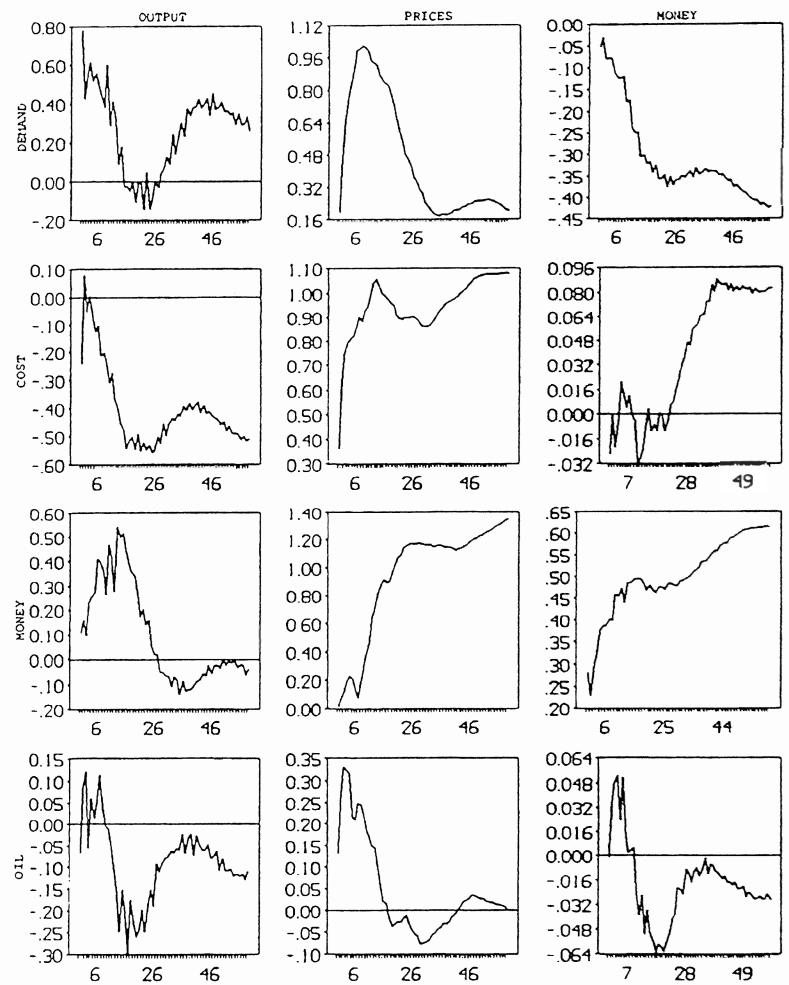

Fig. 6.2 Impulse response functions

exchange rate are omitted to save space.) While the responses are rather choppy, probably because of the negative first-order serial correlations of y_t and the choppy patterns of autocorrelations of m_t (see table 6.1), the overall patterns were as expected: demand shocks increase output and prices; cost shocks increase prices and decrease output; money shocks increase prices and output, with the long-run effect on output very close to zero. Demand shocks decrease the money supply, suggesting countercyclical stabilization; cost shocks cause fluctuations in the money stock for the first six months, but ultimately the stock increases, suggesting accommodation, at least in the long run.

Table 6.4 has variance decompositions for both growth rates and levels. Fluctuations in the growth of output are dominated by aggregate demand disturbances, and in the level of output by the foreign shock, at least at horizons of a year or more. While others have emphasized the role of the foreign sector in output fluctuations (e.g., Horiye, Naniwa, and Ishihara 1987), the estimated figure for levels strikes me as a little high. In any case, it is not clear to me why foreign shocks are much more important for fluctuations of levels than of growth rates.

Table 6.4 indicates that supply disturbances (u_c and u_o) account for about 20–25% of output fluctuations in both growth and levels. The figures for growth rates are quite close to those in West (1992), which used a different model and technique for identifying sources of fluctuations over a slightly shorter sample period. They are also comparable to the U.S. results in levels for Blanchard and Watson (1986) (though not those in Blanchard 1989, Gali 1990, or Shapiro and Watson 1988, all of which constrain supply disturbances to dominate output fluctuations in the long run). Money supply shocks do not contribute much to the variance of the level or growth of output (about 10%), again as in the U.S. studies just cited. It is useful to recall here and in the remainder of the discussion of variance decompositions that if the Bank of Japan is targeting interest rates, there will be a common component to demand and money supply shocks, and the estimation procedure will attribute this component entirely to demand shocks. Finally, oil price shocks do not appear to have been very important for output fluctuations.

Movements in inflation and prices are roughly equally attributable to supply, demand, and money factors (table 6.4); the U.S. studies cited above tend to find demand factors more important. The contribution of money supply shocks begins quite small and increases gradually over time, as one might expect in a sticky price model.

Most of the variance of the growth and level of the money supply is due to money supply shocks (table 6.4); U.S. studies tend to find figures that are slightly smaller (Blanchard and Watson 1986; Gali 1990). Fluctuations in oil prices are not dominated by any single shock, at least at long horizons (recall that the 100% figure for one month holds by construction). Fluctuations in U.S. output and the real exchange rate are dominated by foreign shocks. The

Table 6.4 Variance Decompositions

	Growth Rates					Log Levels				
Months	u_d	u_c	u_m	u_o	$u_{y^*} + u_e$	u_d	u_c	u_m	u_o	$u_{y^*} + u_e$
					Output					
1	87.2	8.1	1.6	0.6	2.4	87.2	8.1	1.6	0.6	2.4
2	74.4	15.9	1.4	2.8	5.5	80.3	6.3	3.6	1.2	8.6
3	71.3	16.5	1.7	2.8	7.7	73.5	4.4	3.1	1.8	17.2
6	64.8	15.6	3.1	6.4	10.0	54.4	2.2	6.4	0.9	36.1
12	60.9	13.4	7.2	5.9	12.6	34.5	4.3	12.3	0.6	48.4
24	57.3	11.9	11.8	7.6	11.5	15.7	15.2	12.8	2.8	53.6
60	57.8	11.3	11.9	8.0	11.0	14.6	23.2	6.4	2.0	53.8
					Prices					
1	20.6	69.4	0.4	9.0	0.6	20.6	69.4	0.4	9.0	0.6
2	27.4	54.8	0.7	9.6	7.5	27.1	59.5	0.7	10.0	2.7
3	32.4	50.4	1.1	9.2	6.9	32.2	53.8	1.0	9.8	3.1
6	33.0	43.6	2.5	10.0	10.9	40.2	44.7	2.3	6.6	6.3
12	29.3	37.6	10.0	8.9	14.2	40.2	37.6	3.2	3.3	15.6
24	27.3	31.9	17.7	8.4	14.8	27.0	33.3	19.3	1.3	19.0
60	27.6	31.0	17.5	8.3	15.6	11.6	35.2	40.6	0.5	12.1
					Money					
1	3.1	0.8	94.1	0.0	2.1	3.1	0.8	94.1	0.0	2.1
2	3.3	1.4	89.9	1.3	4.1	2.6	0.5	94.8	0.8	1.4
3	5.5	1.7	87.5	1.4	3.9	4.2	0.5	92.9	1.4	1.1
6	5.9	2.4	81.6	2.7	7.4	5.2	0.2	91.2	1.4	2.0
12	10.8	2.9	73.2	4.4	8.7	9.8	0.2	86.3	0.6	3.1
24	14.1	3.2	67.3	4.9	10.5	23.5	0.1	72.8	0.7	2.9
60	15.8	3.6	64.5	5.3	10.7	27.2	0.9	66.8	0.3	4.9
					Oil Prices					
1	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
2	2.4	0.3	1.8	93.8	1.6	1.1	0.2	0.9	97.1	0.8
3	10.1	4.2	2.2	79.9	3.5	7.5	2.4	2.1	85.6	2.3
6	13.7	20.5	1.9	54.3	9.6	19.2	19.7	1.8	51.6	7.7
12	14.7	17.1	6.8	43.6	17.8	28.3	23.9	2.6	20.4	24.8
24	14.0	16.0	12.6	39.9	17.4	25.2	25.1	9.2	8.3	32.2
60	14.9	15.7	12.8	38.8	17.7	14.7	27.3	24.8	4.5	28.7
					U.S. Output					
1	0.2	1.7	0.2	0.2	97.8	0.2	1.7	0.2	0.2	97.8
2	2.3	2.0	0.4	0.4	95.0	1.4	2.2	0.4	0.4	95.7
3	2.4	1.9	1.8	0.3	93.6	1.1	2.2	0.2	0.4	96.1
6	2.8	2.2	2.3	3.5	89.2	0.9	2.9	0.2	2.5	93.5
12	5.8	3.7	4.3	4.0	82.3	1.2	1.9	1.5	3.7	91.7
24	10.7	9.3	4.6	4.4	71.0	4.0	7.4	2.1	4.6	82.0
60	11.9	9.1	7.9	4.5	66.6	2.5	8.4	8.6	4.0	76.7
					Real Exchange Rate					
1	4.3	7.3	4.6	0.7	83.1	4.3	7.3	4.6	0.7	83.1
2	4.7	7.4	4.7	0.8	82.5	3.2	8.8	5.6	0.5	81.9

(*continued*)

Table 6.4 (continued)

	Growth Rates					Log Levels				
Months	u_d	u_c	u_m	u_o	$u_{y^*} + u_e$	u_d	u_c	u_m	u_o	$u_{y^*} + u_e$
3	4.8	7.7	5.1	0.8	81.6	3.2	7.9	7.2	0.5	81.3
6	4.8	8.9	4.7	0.9	80.7	2.5	3.9	7.7	0.7	85.2
12	5.2	10.5	7.7	1.9	74.7	2.5	5.0	7.0	2.3	83.1
24	7.3	10.7	10.5	2.1	69.5	5.3	5.3	5.1	2.8	81.6
60	9.3	10.5	10.8	2.4	67.1	6.2	4.5	4.5	3.2	81.6

Notes: Standard errors are not available. Computation is described in text.

result for output is as in West (1992), but not for the exchange rate, whose movements West found to be dominated by cost shocks.

Money supply shocks, then, do not account for a large share of the variance in any of the variables in the model, except the money supply itself. It is nonetheless possible that such shocks are important at cyclical turning points: Gali (1990, tables 4, 5), for example, finds that money supply shocks account for less than 15% of the variance of U.S. output at business cycle horizons, but attributes to such shocks the leading role in the 1981–82 recession. Table 6.5 however, suggests that this is not the case for Japan.

Table 6.5 computes causes of peak to trough changes in the (log) levels of output and prices.[3] To read the table, consider row 1. The peak (November 1973) to trough (March 1975) fall of the index of industrial was 19.32% in this contraction (column 1). The estimates of the model indicate that as of November 1973 the index was predicted to be only 11.71% lower in March 1975 (column 2), implying that the index fell 7.62% more than predicted (column 3). Of this forecast error, 45% (i.e., about −3.43 of the −7.62 that appears in column 3) is accounted for by demand shocks, 23% by cost shocks, 15% by money shocks, 5% by oil shocks, and 12% by foreign shocks. In columns 4–8, negative signs mean that the indicated shock was of the opposite sign of the forecast error in column 3.

One contraction involved such a small (in absolute value) forecast error for output (row 2, column 3) that the estimates in columns 4–8 are very sensitive to small changes in the estimate of column 3. The estimates in rows 1, 3, and 4 are not as sensitive, and the figures in column 6 in these rows indicate that money supply shocks have not played a dominant role in movements in output over any of the contractions in the sample (and, more generally, contractions

3. Since the growth rate rather than the level of output appears to be a coincident indicator in Japan, there might be a choice of subperiods that would be more revealing about the effects of monetary shocks on the level of output, but I know of no source for cyclical phases in the level of output in Japan.

Table 6.5 Percentage Changes during Contractions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Components of (3) (%)				
	Actual	Forecast	(1) − (2)	Demand	Cost	Money	Oil	Foreign
			Level of Output					
(1) 1973:11–1975:3	−19.32	−11.71	−7.62	45	23	15	5	12
(2) 1977:1–1977:10	0.60	1.79	−1.19	328	−24	42	−7	−240
(3) 1980:2–1983:2	1.89	8.82	−6.93	−11	5	−2	9	99
(4) 1985:6–1986:11	−1.43	7.84	−9.27	27	12	22	0	39
			Price Level					
(5) 1973:11–1975:3	24.96	24.71	0.25	−547	1236	−624	−169	204
(6) 1977:1–1977:10	−0.12	5.99	−6.11	98	15	4	−6	−12
(7) 1980:2–1983:2	6.81	1.19	5.62	49	−21	59	−22	35
(8) 1985:6–1986:11	−13.95	−1.19	−12.76	52	−26	15	−3	62

Notes: The dates given are the peak and trough of the four contractions in the sample. Column 1 gives the actual percentage change in the variable during that contraction. Column 2 gives the percentage change over that row's contraction as forecast at the peak using parameters estimated over the whole sample. Column 3 gives the difference between columns 1 and 2. Columns 4 to 8 decompose column 3 into the five uncorrelated shocks in the model, expressed as a percenttage of column 3; a minus sign means that the shocks had a sign opposite to the entry in column 3. The numbers in columns 4 to 8 may not add to 100, due to rounding.

are not attributable to a single type of shock).[4] Row 7 does indicate that money supply shocks had a substantial impact on the unexpected component of the change in the price level in the contraction of February 1980 to March 1982. (I ignore row 5, again because the figure in column 3 for that row is so small that small changes in it lead to large changes in the estimates in columns 4–8.)

I conclude, then, that money supply shocks have not played a dominant role in output fluctuations, either over the sample as a whole or over any of the contractions that have occurred in the sample; they have been somewhat more prominent in accounting for price and inflation fluctuations.

6.4 Sensitivity of Results

In this section, I briefly summarize the results of a set of experiments undertaken to see whether the results are sensitive to minor changes in specification. The experiments are listed in panel A of table 6.6. Specification A is the one used in previous tables and is repeated here solely to facilitate comparison. Specifications B and C impose different values for the short-run elasticities of aggregate demand with respect to foreign output and the real exchange rate (see equation [1]). Specification D imposes a random walk on the real ex-

4. The relatively small contribution of oil shocks in row 1 is puzzling.

Table 6.6 Effects of Alternative Specifications

A. Alternative Specifications[a]

	Sample Period	α_2, α_3	Levels, Trend	Other
A	1973:1–1990:8	−.03, .20	no, no	
B	1973:1–1990:8	−.20, .20	no, no	
C	1973:1–1990:8	−.03, .05	no, no	
D	1973:1–1990:8	−.03, .20	no, no	Real exchange rate is random walk
E	1976:1–1990:8	−.03, .20	no, no	
F	1973:1–1990:3	−.03, .20	no, no	
G	1973:1–1990:8	−.03, .20	no, no	High-powered money instead of M_2
H	1973:1–1990:8	−.03, .20	yes, yes	
I	1973:1–1990:8	−.03, .20	yes, no	

B. Granger Causality[b]

	(1)	(2)	(3)	(4)	(5)
	Causality at .05 (.10) Level to			p-value for	
	y_t	p_t	m_t	H_A	H_B
A–D	y, p, m, o, y^*, a	p, m, o, a	y, m	0.004	0.000
E	y, m, o, y^*	$(y), a$	$(y), m$	0.012	0.000
F	y, p, m, o, y^*, a	p, m, o, a	y, m	0.003	0.000
G	y, p, o, y^*, a	$p, (m), a$	$m, (o), y^*$	0.145	0.218
H	y, p, m, o, y^*, a	$p, (o), a$	$(y), m$	0.001	0.000
I	$y, p, (m), o, y^*, a$	$p, (m), a$	$(y), m$	0.013	0.001

C. Variance Decompositions of Levels at Twenty-Four Month Horizon[c]

	y_t			p_t			m_t		
	$u_d+u_s+u_w$	u_e+u_o	u_m	$u_d+u_s+u_w$	u_e+u_o	u_m	$u_d+u_s+u_w$	u_e+u_o	u_m
A	69	18	13	46	35	19	26	1	73
B	66	22	12	60	20	20	23	1	75
C	69	18	13	46	35	20	27	1	72
D	70	17	12	45	35	20	28	1	72
E	69	16	16	55	36	8	35	4	62
F	67	17	16	49	34	17	33	1	66
G	69	27	4	65	33	2	53	10	37
H	56	37	7	51	39	10	41	16	42
I	66	29	5	55	44	2	40	32	28

[a]The results for specification A, which is the one used in previous tables, are repeated for convenience of comparison. Specifications B and C impose different values of the parameters α_2 and α_3, which are defined in equation (1). Specification D sets to zero all the coefficients in the reduced-form equation for a_t. Specifications E and F try different sample periods. Specification G substitutes high-powered money for M_2. In specifications A–G all variables are in differences; in specifications H and I all variables are in levels, with a trend term in all equations in specification H.

[b]In the first three columns, each variable that Granger causes the indicated variable at the .10 but not .05 level is given in parentheses; the other listed variables Granger cause at the .05 or lower level. The last two columns report the results of the hypothesis tests and are defined in rows (7) and (8) of table 6.2.

[c]Totals may not add to 100, due to rounding.

change rate a_t, a result consistent with the reduced-form evidence presented above.[5] Specifications E and F try different sample periods. January 1976 to August 1990 was studied because Hamada and Hayashi (1985) and Suzuki (1985) suggest that the Bank of Japan changed its policy in response to the first oil shock; January 1973 to March 1990 was studied to eliminate possible effects of the huge fluctuation in money growth from April 1990 to May 1990 (see figure 6.1). Specification G substitutes high-powered money for M_2. Specification H assumes trend stationarity of all variables, and estimates with a trend term and twelve lags of the levels of all variables in all equations. Specification I assumes difference stationarity of all variables, allowing for the possibility of cointegration. In this specification, all equations had thirteen lags of all variables; the hypothesis tests were performed on the first twelve lags, so that an asymptotic normal distribution could be used in the hypothesis tests in panel B (see Sims, Stock, and Watson 1990).

Some Granger causality tests are summarized in panel B; results for specifications A–D are of course identical. With the exception of specification G, when high-powered money was used instead of M_2, money Granger causes real variables (panel B, columns 1, 4, and 5). (In contrast to U.S. data, then, this causality result holds for various techniques for inducing stationarity [Stock and Watson 1989].) The variance decompositions in panel C indicate that money supply shocks nonetheless do not seem to account for much of the movement in output, although they do account for most of the movement in the money supply.

I conclude that my basic result, that money seems to Granger cause real variables but nonetheless does not account for much of the movement in output, is unlikely to be very sensitive to minor changes in imposed parameters, sample period, or technique to induce differencing. On the other hand, the causality result is sensitive to the measure of the money stock. As noted above, however, Ito (1989, 1990) and Suzuki (1985) suggest that M_2 is a better measure of the money stock from the point of view of monetary targeting.

6.5 Effects of Alternative Money Supply Rules

A number of authors have suggested that the Bank of Japan uses its operating instruments with its eyes focused on "final" (as distinct from intermediate) targets. The targets that have been proposed, at least for the post-OPEC-I era, include "control of inflation" above all, along with "avoidance of pronounced cyclical swings in output and aggregate demand" and targeting of the real exchange rate and balance of payments (Bryant 1990, 32); "price stability and

5. The model was estimated by the instrumental variables technique described above; since a_t is not exactly orthogonal to past data in the sample, slightly different estimates would be obtained if I had used a different method of extracting parameter estimates from the variance-covariance matrix of the reduced-form residuals.

the maintenance of an adequate level of demand" (Hamada and Hayashi 1985, 83); "price stability" and "a high and stable exchange rate" (Fukui 1986, 110).

Bryant (1990, 33–34), Hamada and Hayashi (1985, 116), and Ito (1989) seem to doubt that the bank places much weight on deviations of any given monetary aggregate from its targeted value. On the other hand, Fukui (1986, 110–11) and Suzuki (1985, 9) seem to view the money supply as an intermediate target that gets considerable weight. And Friedman (1985, 27) lauds the bank for a "fairly consistent" policy of keeping money growth "relatively steady" (i.e., relative to the United States and Great Britain).

What does the money supply rule estimated above reveal about such descriptions? The reduced-form and structural evidence presented so far is strongly suggestive of neither a simple story of money supply targeting nor the simple textbook one of straightforward targeting of output and prices (perhaps with secondary weight placed on the money supply). I therefore doubt the wisdom of attempting to invert the estimated rule, to deduce an underlying objective function that maps one-to-one into the seventy-three parameters of the rule. Instead, to maintain a focus on simple and easy-to-understand objective functions, I simulate the behavior of the economy over the sample period under the apparently counterfactual assumption of a simple objective function.

This objective function is consistent with constant expected money growth. I assume that the monetary authority can perfectly control ${}_{t-1}m_t$ but not m_t. For simplicity, I abstract from the Lucas critique. I take as given the set of shocks and assume that the estimates of the parameters of equations (1)–(6) are invariant to such a change in regime. (In footnote 7, I briefly speculate on the possible biases from this simplification.) The coefficients in the reduced-form equations for y_t, p_t, and, of course, m_t will change; those for o_t, y^*_t, and a_t will not. The simulated time series process for all six variables of course is different from the actual.

The objective function corresponding to constant expected money growth aims to minimize the variance of money growth, since under this set of assumptions it is easy to see that minimizing the variance of m_t means setting ${}_{t-1}m_t$ to a constant. This constant was set to the estimated sample mean of money growth.

Table 6.7 has the sample means and standard deviations for the growth of nominal output and for each of the six endogenous variables from the actual (columns 1 and 4) and simulated (columns 2 and 5) data, as well as correlations between the actual and simulated data (column 7); columns 3, 6, and 8 will be described in a moment. As may be seen in columns 1 and 2, the simulated and actual data have nearly identical means. Perhaps surprisingly, they also have very similar standard deviations (columns 4 and 5)[6] and, with the predictable exception of the money supply, are very highly correlated (column 7). Moreover, the actual and simulated data are so close that it is difficult to tell one from the other when they are plotted. See figure 6.3, in which the actual data are represented by the solid line, the simulated by a dashed line; when the software that generated the graph decided that the simulated and actual were too close to be distinguished by eye (as happens especially for output growth), it plotted only a dashed line.

6. The standard deviation of the money supply (.291) differs from the value of $\hat{\sigma}_m$ given in table 6.3 (0.372) only because the latter was calculated using a degrees of freedom adjustment.

Table 6.7 **Effects of Alternative Money Supply Rules**

	Means			Standard Deviations			Correlation with Actual	
	(1) Rule a	(2) Rule b	(3) Rule c	(4) Rule a	(5) Rule b	(6) Rule c	(7) Rule b	(8) Rule c
(1) y	0.304	0.305	0.298	1.444	1.372	1.558	0.964	0.776
(2) p	0.274	0.279	0.273	1.000	0.962	1.105	0.919	0.713
(3) m	0.845	0.845	0.842	0.410	0.291	0.569	0.710	0.197
(4) o	0.599	0.596	0.594	3.090	3.108	3.590	0.940	0.764
(5) y^*	0.211	0.210	0.211	0.897	0.939	1.038	0.969	0.841
(6) a	−0.130	−0.136	−0.132	3.367	3.461	3.822	0.979	0.877
(7) $y + p$	0.578	0.584	0.571	1.787	1.716	1.922	0.957	0.774

Notes: Money supply rule a is the one actually estimated. Rule b sets expected money growth to a constant. Rule c sets expected money growth according to ${}_{t-1}m_t = \mu_1 + \lambda({}_{t-1}y_t + {}_{t-1}p_t - \mu_2)$, where $\mu_1 = 0.845$, $\mu_2 = 0.578$, and $\lambda = -0.25$. The figures in columns 1 and 4 are simply the sample moments from the data. The figures reported in the remaining columns are computed from a simulation under the indicated rule.

According to the estimated model, then, whether or not the Bank of Japan was concerned above all else with stability of money growth, its policies had effects on the economy quite similar to those that would have occurred had the bank followed a rule of constant expected money growth. To interpret this tentative conclusion, let us begin by considering the possibility that the effects of anticipated monetary policy are so small that a wide range of money supply rules will lead to qualitatively similar behavior of output and prices.

Consider, then, performing the same counterfactual simulation with a different alternative policy, similar in spirit though very different in detail to one proposed by McCallum (1988) for U.S. monetary policy. Let expected money growth be determined by

$${}_{t-1}m_t = \mu_1 + \lambda(y_t + p_t - \mu_2),$$

where μ_1 and μ_2 are constants, μ_2 is a target rate for the growth of nominal output, and λ is a negative parameter. I set μ_1 to the sample mean of money growth, μ_2 to the sample mean of nominal output growth, and $\lambda = -0.25$ (a value that McCallum [1988] found worked well for the United States in his more sophisticated feedback rule).

Columns 3, 6, and 8 have the resulting sample means, standard deviations,

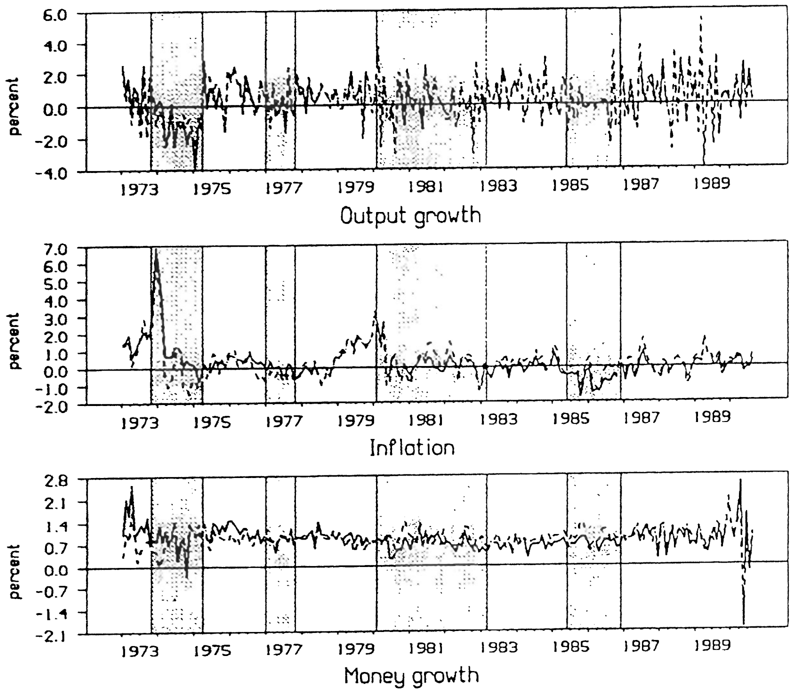

Fig. 6.3 Effects of constant money growth rule
Note: The actual data are represented by a solid line; the simulated data are represented by a dashed line. When the actual and simulated data are too close to distinguish (as happens especially for output growth), a dashed line represents both.

and correlations with the actual data. As may be seen, the means are, once again, largely unchanged, but now the standard deviations are slightly and the correlations greatly different, not only for money growth but for output, inflation, and nominal output growth as well. Anticipated monetary policy, then, does have effects sufficiently large that the estimates suggest that at least one alternative policy would have led to very different behavior.[7]

7. Even if rational expectations had been modeled explicitly, as in, for example, Taylor (1989), my aggregate demand–aggregate supply model might well still suggest that a hypothetical switch to a constant money growth rule would little change output and price behavior. The expectations that are relevant are of future prices and output. That the path of these variables is essentially unchanged under the new rule, when expectational effects are ignored, indicates that rational forecasts of these variables are similarly unchanged—that is, if we were to write the forecasts as distributed lags on the variables in the model, the coefficients in these distributed lags would not change much. This suggests (to me, at least) that a rational expectations version of the model may also have an equilibrium in which the distributed lag coefficients are not much different. This means that the coefficients on lagged variables in equations (1)–(6) will change little, which is exactly the assumption required to validate the exercise above.
Such an argument does not apply to the second money supply rule, which for well-known reasons might, in a rational expectations environment, lead to dramatic additional changes in the reduced form beyond those allowed in the simulation.

Now, nothing in table 6.7 calls for the conclusion that the Bank of Japan must have been concentrating solely on stable money growth. Indeed, a simple continuity argument indicates that similar results would obtain if the hypothetical objective function were one of stable money growth together with, say, stable prices and output, provided the weight on money growth was sufficiently large. And it is possible in principle that an objective function that places little or no weight on stability of money growth but measures output and inflation stability in a complicated and sophisticated fashion would lead to a monetary rule whose simulated effects are as similar to those of the actual rule as are those of the constant expected money growth rule.

I thus do not interpret the results in table 6.7 and the previous section as arguing strongly for Friedman's (1985) view that, even if the Bank of Japan has not followed monetarist doctrine to the letter, it has followed the doctrine in spirit. I interpret these results as raising the intriguing possibility that, insofar as the bank was pursuing activist stabilization policy, such policy had little overall effect on the economy. An interesting question for future research is why this seems to be the case.

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