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3 The Monetary Mechanism in the Light of Rational Expectations

Olivier Jean Blanchard

This paper uses a structural empirical model to examine the effects of anticipated and unanticipated monetary policy under the assumption of rational expectations. In particular, it characterizes the effects of such a policy on output, the short-term real interest rate, and the stock market.

Existing macroeconometric models provide us with a description of the transmission mechanism, but they assume implicitly that the way agents form their expectations is invariant to policy and, as emphasized by Lucas (1976), this casts serious doubts on the usefulness of their answer. Furthermore, because they do not explicitly specify the role of expectations, their defects cannot be easily remedied; in effect a new model has to be set up and estimated.

The model used here extends the analytical model presented in an earlier paper (Blanchard 1978). It consists of two parts, aggregate demand and aggregate supply. The model of aggregate demand treats expectations explicitly and thus its structure should be approximately invariant to changes in policy. It has been estimated by Blanchard and Wyplosz (1978). The model of aggregate supply is not estimated but postulated; this reflects my belief that there may not be enough information in past data to obtain the exact specification of aggregate supply; the model has characteristics that are both desirable theoretically and in accordance with recent empirical evidence (Barro 1978*b* in particular).

The complete model is used to look at a very simple policy, namely, a decrease in the nominal money stock, starting from steady state. The

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paper is organized as follows: Section 1 presents the model of aggregate demand. Section 2 describes the model of aggregate supply. Section 3 characterizes the steady state and the dynamic behavior of the complete model. Section 4 characterizes the effects of anticipated and unanticipated monetary policy with exogenous prices. The purpose of this section is to give a better understanding of the behavior of aggregate demand, independent of the particular formalization of aggregate supply. Section 5 presents the effects of the same policy with endogenous prices.

1. Aggregate Demand

Aggregate demand is defined as the value of output that equilibrates goods and assets markets given past, current, and anticipated values of the price level.[1] The structure follows the model of Metzler (1951) and emphasizes the interaction between wealth, spending, and output.

In the goods market, wealth determines private spending; private and public spending determine output. Human wealth and stock market wealth in turn are the present discounted values of anticipated labor and capital income; they therefore depend on the sequence of anticipated output.

The model is a quarterly model. Stock and flow variables are in intensive form, divided by physical capital K.[2] They will therefore be constant if the corresponding levels grow at the same rate as capital. (They are denoted by lower-case letters; corresponding upper-case letters will be used to denote their levels when convenient).

The following symbols are used:

${}_t z_{t+1}$	the expectation of z_{t+1}, held at time t
q	the real value of a share which is the title to a unit of physical capital
h	the real (shadow) value of a unit of labor (in efficiency units)
p	the logarithm of the price level
i, r	the short-term nominal and (ex ante) real rates
m	the logarithm of the nominal money stock
b	the real value of government bonds
w	the real value of nonhuman wealth
y	output
yd	disposable income

1. This section summarizes Blanchard and Wyplosz 1978, to which the reader is referred for more detail about definitions of variables, specification, and estimation of the equations.

2. Note that the variables are divided by K, not by L, as is usual in growth models.

π	profit
L	the total labor force (in efficiency units)
c, in	consumption and investment
x	the sum of inventory investment, net exports, and government spending

The model was estimated with data from the period 1953:I to 1976:IV. Means and standard deviations of these variables for that period are given in table 3.1.

Each equation was estimated by two-stage least squares with first-order serial correlation correction. The instruments used for estimation were first tested for statistical exogeneity. Lag structures were left unconstrained. Each equation was tested for partial adjustment versus serial correlation and for subsample stability. The reported estimated coefficients are individually significant at the 90% confidence level.[3]

The equations are as follows:

Goods market

(1) $$c_t = .389\, h_t + (.028\, w_t + .041\, w_{t-1}) + (.250\, yd_t + .117\, yd_{t-1})$$

(2) $$w_t \equiv q_t + b_t$$

(3) $$yd_t = .461 + .33\, y_t$$

(4) $$in_t = -.093 + (.003\, q_t + .025\, q_{t-1} + .019\, q_{t-2} + .021\, q_{t-3}) + (.144\, y_t + .044\, y_{t-1})$$

$$y_t = c_t + in_t + x_t =>$$

(5) $$y_t = .097 + .107\, y_{t-1} + 1.29\, x_t + .502\, h_t + .040\, q_t + .085\, q_{t-1} + .025\, q_{t-2} + .027\, q_{t-3} + .036\, b_t + .053\, b_{t-1}$$

Asset markets

(6) $$m_t - p_t = (.543 - .193\, ln\, K_t) + .590\, (m_{t-1} - p_{t-1}) + .179\, y_t - 1.001\, i_t$$

(7) $$r_t \equiv i_t - 4\, ({}_tp_{t+1} - p_t)$$

3. Two coefficients are not individually significant at the 90% confidence level: current wealth (w_t) in the consumption equation with a t-statistic of 1.46 and current q in the investment equation with a t-statistic of .23.

Table 3.1 **Sample Means and Standard Deviations, 1953:I to 1976:IV**

	Mean	Standard Deviation	1976:IV Value
q	.823	.143	.690
h	1.[a]	—	—
i	3.99%	1.84%	6.11%
r	.91%[b]	—	—
b	.776	.151	.608
$m - p$	−1.073	.230	−1.497
ω	1.589	.189	1.299
y	1.370	.066	1.282
yd	.916	.023	.897
c	.838	.025	.836
in	.202	.021	.168
π	.067	.011	.062
x	.338	.040	.271
K	675.2	188.4	1004.1

NOTES

a. This variable is unobservable. Its mean is normalized to be unity, by the choice of units for labor.

b. This variable, the ex ante real rate, is unobservable. This is the mean ex post real rate defined as the nominal rate minus actual inflation.

(8) $$q_t = \frac{1}{r_t + .075} (4\ ({}_tq_{t+1} - q_t) + 1.04\ \pi_t)$$

(9) $$\pi_t = -.091 + .226\ y_t - .054\ y_{t-1} - .055\ y_{t-2}$$

(10) $$h_t = \frac{1}{r_t + .075} (4\ ({}_th_{t+1} - h_t) + .093\ yd_t)$$

(11) $$yd_t = .461 + .33\ y_t$$

Equations (1)–(3) characterize consumption as a function of wealth —human and nonhuman—and income. Given that wealth is included, disposable income is not a proxy for wealth but indicates the effect of liquidity constraints on current consumption. Nonhuman wealth is defined as the sum of stock market wealth and government bonds. This definition does not, however, imply that the level of government bonds affects consumption: anticipated tax liabilities needed to pay interest on the debt will decrease either q or h (or both), possibly offsetting the effect of b (see Barro 1978*a*). Real money balances are excluded from wealth: outside money is very small compared with the other components.[4] (Equation (1) presents an estimation problem because h, the

4. As noted in Sargent 1976, the presence of outside money in wealth—the direct Pigou effect—leads to nonneutrality of anticipated monetary policy. Removing it from wealth removes therefore this nonneutrality, which is empirically unimportant. (Fischer reaches a similar conclusion; see chap. 7.)

present discounted value of expected labor income, is unobservable. Thus, in order to estimate (1), an assumption must be made about how agents formed their expectations of future labor income during the sample period. Estimation was done assuming static expectations for h.[5] If h was in fact correlated with w and yd, as is likely, the estimated coefficients on w and yd are likely to be biased upwards).

Equation (4) characterizes fixed investment. It depends on the valuation of capital, q. Empirically, investment depends significantly on output which is thus included, although theoretical reasons for its presence are not clear.

Equation (5) characterizes goods market equilibrium and is obtained by replacing equations (1)–(4) in the equilibrium equation. Components of spending other than consumption and fixed investment are unexplained at this stage and will therefore be taken as exogenous in simulations. Equation (5) gives output as a function of the different components of wealth and exogenous spending. The direct effect of the past on current y_t is small: the coefficient on y_{t-1} is .107. The direct short-run multiplier is 1.29: it does not, however, indicate the complete effect of exogenous spending because movements in x_t will usually affect the values of the different components of wealth. The long-run elasticities of y with respect to q and h are of 12% and 41% approximately.

In the assets markets, tradable nonmoney assets such as bonds and shares are assumed perfect substitutes. Equilibrium is thus characterized by equilibrium in the money market and the arbitrage equations between nonmoney assets.

Equation (6) characterizes equilibrium in the money market. This determines the nominal short-term interest rate, given y.[6] The implied elasticities of money demand using 1976:IV values for y and i are .23 and .061, respectively, in the short run, .56 and .148 in the long run. K_t enters equation (6) because, with the less than unitary elasticity with respect to income, the demand for money is not homogenous in K.

Equation (7) defines the ex ante real rate of interest. The presence of 4 comes from the measurement of interest at annual rates, whereas the time unit of the model is the quarter. $({}_tp_{t+1} - p_t)$ is the logarithmic approximation to the expected rate of inflation.

5. Estimation under the assumption of rational expectations is intended.

6. The estimated demand for money depends on two interest rates, the three-month Treasury bill rate and the time deposit rate, j. The equation used here assumes that the time deposit rate follows:

$$j = .5\ (.033) + .5\ (i)$$

.033 is the sample mean of j.

Because of the presence of interest rate ceilings, the behavior of j is more the result of the Fed policy than unconstrained profit maximization by banks. Thus the above relation may be interpreted as a policy rule of the Fed.

Equation (8) is derived from the arbitrage condition between shares and short-term bonds. The expected return on shares—which is the sum of two components, profit income and capital gain (or loss)—must be equal to the expected return on short-term bonds plus a fixed premium β.

$$\text{(8')}\qquad \frac{\pi_t}{q_t} + 4\left(\frac{{}_tq_{t+1} - q_t}{q_t}\right) = r_t + \beta.$$

The arbitrage condition equivalently follows from the statement that q_t is the present discounted value of expected profit:

$$q_t = \sum_{\tau=0}^{\infty} {}_t\pi_{t+\tau}\left(\prod_{i=0}^{\tau}\left(1 + \frac{{}_tr_{t+i} + \beta}{4}\right)^{-1}\right).$$

The only coefficient to be estimated in equation (8') is the premium; it is estimated by the difference between the sample mean return on shares and short-term treasury bills, which is approximately equal to 7.5%. Equation (8) is obtained by replacing β by its numerical value, making a minor adjustment for consistency of the q and π series, multiplying the π series by 1.04, and rearranging the above arbitrage equation (8'). Equation (9) gives profit income as a function of output.

Human wealth is the present discounted value of labor income but is not tradable; it is assumed that the relevant discount rate is the same as for stock market wealth, so that the value of a unit of labor is given by:

$$\text{(10')}\qquad h_t = \sum_{\tau=0}^{\infty} \frac{{}_tYL_{t+\tau}}{\overline{L}_{t+\tau}}\left(\prod_{i=0}^{\tau}\left(1 + \frac{{}_tr_{t+i} + \beta}{4}\right)^{-1}\right),$$

where YL_t denotes labor income and $\overline{L}_t$ denotes the total number of (efficiency) units of labor at time t. In the simulation, agents will be assumed to have rational expectations. If agents have rational expectations, equation (10') implies that h_t follows an "arbitrage-like" equation:[7]

$$\left(\frac{K}{\overline{L}}\right)_t \frac{yl_t}{h_t} + 4\left(\frac{{}_th_{t+1} - h_t}{h_t}\right) = r_t + \beta.$$

The first term is labor income per unit of labor, divided by the shadow value of a unit of labor. The presence of $\left(\frac{K}{\overline{L}}\right)_t$ is due to the fact that yl_t is labor income divided by physical capital: it must therefore be multiplied by capital and divided by labor to give labor income per unit of labor. The second term is the expected "capital gain" or loss.

7. This is derived as follows: Lead (10') once and take conditional expectations as of time t on both sides. Multiply both sides by $(1 + ({}_tr_t+\beta)/4)^{-1}$ and subtract from (10').

The simulations will assume physical capital and the labor force to be growing at the same constant rate, so that $\left(\frac{K}{L}\right)_t$ will be constant and equal to $\left(\frac{\bar{K}}{\bar{L}}\right)$. The value of $\left(\frac{\bar{K}}{\bar{L}}\right)$ depends on the choice of units for labor. They are chosen such that the value of one unit of labor is unity in steady state; this determines $\frac{K}{L} = .093$. Equation (10) is obtained by rearranging the above "arbitrage like" equation. Disposable income, yd_t is used rather than labor income yl_t, because of the poor quality of data on yl_t. Equation (11) gives the relation of disposable income to output.

Therefore in the assets markets, output and nominal money determine the short-term nominal rate, given prices. Given the anticipated rate of inflation, this determines the short-term real rate. Arbitrage equations determine the value of q_t and h_t given the anticipations ${}_tq_{t+1}$ and ${}_th_{t+1}$.

Because the effect of expectations on spending is treated explicitly in this model, through the presence of the different components of wealth, the coefficients of this model should be approximately invariant to policy: they should, abstracting from aggregation problems, depend mainly on coefficients reflecting institutional arrangements, tastes, and technology. Thus the model of aggregate demand, together with a model of aggregate supply can be used to examine the effects of changes in policy.

2. Aggregate Supply

Most economists agree that the behavior of the price level is such that, at least as a first approximation, nominal disturbances have no long-run effect on output. There is also a wide agreement that the short-run real effects of such disturbances, if any, coincide with deviations of the price level from its anticipated value, however defined. There is, however, little knowledge of the precise relation between price level deviations and output. There is little hope of obtaining a precise specification from empirical evidence: it is, for example, very hard to determine the separate effects of the predictions of today's price level made one year and two years ago. (This point is made empirically by Fischer chap. 7.) Thus, an aggregate supply equation can only be estimated by imposing strong specification restrictions, with little guidance by the theory. (An interesting attempt is made by Taylor 1978.)

The model of price level behavior used here is therefore not estimated but postulated; its characteristics and implications are in accordance with the available empirical evidence. Its structure is extremely simple: the price level adjusts toward the price that would equate aggregate supply and aggregate demand. When it differs from this price, production is determined by aggregate demand.[8]

1. If markets were auction markets and there was perfect information about the current state of the world, then, as shown by many authors (Sargent and Wallace 1975, for example), changes in money, both current or anticipated, would have no effect on real variables[9] such as output, the real interest rate, and the values of one unit of physical or human capital. The goods market equilibrium equation (5) and the arbitrage equations (8) and (10) would always be satisfied with y, r, q, h equal to their steady state values denoted $\bar{y}, \bar{r}, \bar{q}, \bar{h}$, respectively. The price level would therefore be such as to maintain portfolio balance. Define for simplicity

$$a(t) \equiv .135 - .048 \ln K_t + .045 \bar{y} - 1.001 \bar{r}. \tag{12}$$

Denote the price level in this case by p^*. It would follow, from equations (6) and (7):

$$({}_tp^*_{t+1} - p^*_t) = a(t) - .250\ (m_t - p^*_t) + .147\ (m_{t-1} - p^*_{t-1}). \tag{13}$$

This equation states that the expected rate of inflation must be such that agents are satisfied with their real money balances. It is, except for the presence of lagged money, similar to the equilibrium condition of the model of Cagan (1956). The behavior of the price level satisfying this condition and rational expectations has been studied by Sargent and Wallace (1973). It is useful to characterize this behavior in two cases, the case of an unanticipated change and the case of an anticipated change in nominal money.

"Unanticipated" and "anticipated" must first be defined. A change is unanticipated if the announcement and implementation of the change are simultaneous. It is anticipated if the announcement precedes the implementation. In both cases, the change is assumed to be known when it is implemented.

If a change in nominal money is unanticipated, and if it is assumed to be permanent, the price level will change at the time of the implementation and in the same proportion as nominal money. If it is anticipated, the price level will start to change at the time of the announcement: if it did not change until the implementation, agents would expect

8. Aggregate demand is assumed to determine sales. Because inventory behavior is unexplained at this stage, it also determines production. Relaxing the equality between production and sales would clearly be desirable.

9. This statement disregards various sources of noneutrality (Tobin, Pigou effects), which are not present in the model of aggregate demand.

a large capital gain or loss on real money balances. The equilibrium path of the price level between the announcement and implementation must be such that agents are satisfied with their real money balances given the expected rate of change of the price level. The important implication, for our purposes, is that the price level will change before the actual change in nominal money if the change is anticipated.

2. The actual price level, p_t, will be assumed to adjust partially toward the "desired" level p^*_t in the following way:

$$p_t = \gamma p^*_t + (1 - \gamma)\, p_{t-1}, \quad \gamma \in [0,1], \tag{14}$$

where p^*_t is given by (13).

Prices would be perfectly flexible and nominal disturbances would have no real effect if $\gamma = 1$; they would be fixed for $\gamma = 0$. What are the characteristics of price level behavior if γ is between 0 and 1? Consider again a permanent change in nominal money.

If it is unanticipated, p^* adjusts immediately to its new equilibrium value and p adjusts gradually over time. After n periods, the proportional difference between them is $(1 - \gamma)^n$. Over time p converges to p^*, and there is no long-run effect of the change of money.

If the change was anticipated, both p^* and p change after the announcement. The longer the period between the announcement and the implementation, the smaller the initial change in p^*, the closer p will be to p^* and the smaller the real effects of a change in money. (This will be shown later.) Thus the longer a change in nominal money has been anticipated, the less real effect it has. If it has been anticipated "forever," it will have no real effect at all.

The only parameter to be chosen is γ. Recent empirical evidence by Barro shows that unanticipated nominal disturbances[10] affect prices over a period of four years. This suggests a value of γ between .1 and .2 approximately.[11] When $\gamma = .2$, the increase in the real money stock is .16 of the initial nominal increase after two years, .02 after four years. When $\gamma = .1$, these numbers are .43 and .18. The value of .2 will be used for most simulations in section 5.

Although equation (14) has desirable properties, it must be slightly changed if the nominal money stock is growing, so that p^* is also growing, say at rate λ. In this case if p followed (14), it would never equal p^*. The natural extension is then:

10. What Barro calls "unanticipated" would in this paper be called "anticipated for less than one year."

11. Another finding of Barro is that the effect of unanticipated money on prices has a hump-shaped lag structure. This cannot be captured adequately by the simple partial adjustment postulated in (14).

(15) $$p_t = \gamma p^*_t + (1 - \gamma)\,(p_{t-1} + \lambda).$$

This formalization implies that changes in the nominal money stock from trend, that is, temporary changes in the rate of growth of money, will have no effect in the long run, or no effect at all if fully anticipated.

Because the policies considered in the following sections will be temporary changes in the rate of growth of money, aggregate supply will be characterized by (13) and (15).

3. Steady State and Dynamics

The system is described by equations (1) to (11) and (13) and (15). I first characterize its steady state, then study its stability under the assumption of rational expectations; finally the exact policy experiment considered in the following sections is described.

The Steady State

The absence of an estimated supply equation does not allow one to determine from the model the steady state values for output and the real interest rate. If the system was approximately in steady state during the sample period, the sample values for the ratio of output to physical capital and the real (ex post) interest rate should be close to the steady state values. Values of 1.377 for $\bar{y}$, and of 1% for $\bar{r}$ are chosen as steady state values. This implies values of .847 for the real value of a unit of physical capital $\bar{q}$, 1.003 for the real value of a unit of labor $\bar{h}$, from the arbitrage equations.[12]

Values of .361 and .776 are chosen for $\bar{x}$ and $\bar{b}$, respectively. (It is clear that a constant value for b implies that government debt is growing at the same rate as capital; this was not true of the sample period.)

The demand for money is not homogenous in capital. Thus a constant ratio of real money to physical capital would lead to an excess supply of real money given the interest rate; equivalently, the ratio of real money to physical capital must decrease to maintain the same interest rate. If a steady state is a state in which the ratios of all real flows and stocks to physical capital are constant, this system has no steady state. For simplicity, this effect is removed by assuming $ln\ K_t$ to be constant in the demand for money equation; this implies that the elasticity of the demand for money is less than one with respect to deviations of output from steady state and one with respect to steady state increase. The value of $ln\ K_t$ will be taken to be 6.911, its 1976:IV value. In this case, the rate of inflation is equal in steady state to the

12. This is close to the mean sample value of q, which is .823. The fact that this sample value is less than one is a well-known puzzle. (The time series for q is taken from von Furstenberg 1977.)

rate of growth of money minus the rate of growth of output. This rate of inflation will be assumed to be equal to 4% at an annual rate. This implies a real money stock of 1.404 for equilibrium in the money market.

The Dynamics

The main conclusion here is that the system, linearized around its steady state, is stable under rational expectations with either exogenous or endogenous prices. "Stability" means that if the exogenous variables follow linear stationary processes, the endogenous variables will also follow linear stationary processes.

Consider first the case where prices are assumed to be exogenous and growing at the steady state rate of inflation. The system is then the aggregate demand system, composed of equations (1)–(11). This system is nonlinear in its two arbitrage equations and must first be linearized around the steady state values of $\bar{q}$, $\bar{h}$, and $\bar{r}$ in order to be solved for rational expectations. It can then be reduced to a system of seven variables. Define

$$z_t \equiv y_{t-1}\ ;\ z1_t \equiv z_{t-1} \text{ and}$$

$$q1_t \equiv q_{t-1}\ ;\ q2_t \equiv q_{t-2}\ ;\ q3_t \equiv q_{t-3}.$$

Then the system can be written as:

$$\text{(16)}\qquad \begin{bmatrix} z_{t+1} \\ z1_{t+1} \\ q1_{t+1} \\ q2_{t+1} \\ q3_{t+1} \\ \cdots \\ {}_t h_{t+1} \\ {}_t q_{t+1} \end{bmatrix} = \underset{(7 \times 7)}{A} \begin{bmatrix} z_t \\ z1_t \\ q1_t \\ q2_t \\ q3_t \\ \cdots \\ h_t \\ q_t \end{bmatrix} + \Omega \xi_t,$$

where ξ_t is a vector of exogenous variables and Ω is a matrix of required dimension.

Although this system resembles a first-order system, it cannot be solved in the usual way. Heuristically, at time t, a variable such as z_{t+1} "depends" on $z_t, z1_t, \ldots$, whereas a variable such as h_t "depends" on ${}_t h_{t+1}$, ${}_t q_{t+1}$.

A more precise statement is that the first five variables are predetermined at time t, whereas the last two, h_t and q_t, are not. Because of the absence of initial conditions for h_t and q_t, there is clearly an infinity of solutions to the system (16).

It may, however, be argued that variables such as h_t and q_t should not depend on the past, except through its effect on the currently predetermined variables, namely, y_{t-1}, y_{t-2}, q_{t-1}, q_{t-2}, and q_{t-3}. If such an argument is accepted, a unique solution satisfies this condition; this is the solution usually chosen in models with rational expectations and is referred to as the "forward" or "forward-looking" solution.

The forward solution to systems such as (16), together with its stability condition have been derived in another paper (Blanchard 1980). The stability condition is that the matrix A must be such that the number of roots inside the unit circle must be equal to the number of predetermined variables, namely five in this case. The roots of A are:

$$\begin{array}{l} -.170 \\ -.059 + .178\,i \\ -.059 - .178\,i \\ .196 + .151\,i \\ .196 - .151\,i \\ 1.0212 \\ 1.0431 \end{array}$$

Thus this system is stable with exogenous prices.

The appendix gives the solution of the system, that is, the current values of the endogenous variables as a function of the past, current, and anticipated future exogenous variables. The five roots inside the unit circle determine heuristically the "weight" of the past in determining the current equilibrium (this is made clear by equations A1 and A2 in the appendix): their small absolute value indicates that the current equilibrium does not depend very much on the past. The inverse of the roots outside the circle determine the "weight" of the anticipated future; the fact that their value is close to unity indicates that the current equilibrium depends largely on these anticipations. These heuristical statements will help in understanding the results of the next two sections.

Consider now the full system of aggregate demand and aggregate supply. It can be reduced to a system of ten variables including the variables above plus p^*_t, $p1^*_t \equiv p^*_{t-1}$, and $p1_t \equiv p_{t-1}$. Both $p1^*_t$ and $p1_t$ are predetermined at time t. The system has the form:

$$(17) \qquad \begin{bmatrix} z_{t+1} \\ z1_{t+1} \\ q1_{t+1} \\ q2_{t+1} \\ q3_{t+1} \\ p1_{t+1} \\ p^*1_{t+1} \\ \cdots \\ {}_tp^*_{t+1} \\ {}_th_{t+1} \\ {}_tq_{t+1} \end{bmatrix} = \underset{(10 \times 10)}{\bar{A}} \begin{bmatrix} z_t \\ z1_t \\ q1_t \\ q2_t \\ q3_t \\ p1_t \\ p^*1_t \\ \cdots \\ p^*_t \\ h_t \\ q_t \end{bmatrix} + \Omega \xi_t.$$

The stability condition is that the system must have seven roots inside the unit circle. This condition is satisfied. The system has the same roots as the aggregate demand system plus three roots which are:

$$.131$$
$$1 - \gamma$$
$$1.117$$

Thus if prices adjust rapidly, that is, if γ is large, all the roots inside the circle are again small and the past is relatively unimportant. If γ is small, prices adjust slowly and the current equilibrium depends more on the past, through prices.

The stability of the system is not just a happy accident. The property that the system has the same number of roots inside the unit circle as predetermined variables is called the "strict saddle point" property. Growth models with many assets have been shown to have this property usually and the present model has a structure similar to these theoretical models.

It is interesting to contrast this stability result with the instability of the MPS model with endogenous prices (the dynamic properties of this model have been studied by Corrado 1976). Except for the treatment of expectations, this model and the MPS have a similar structure. The MPS also emphasizes the role of wealth in spending decisions. Our model, however, assumes rational expectations, whereas the implicit expectations formation mechanism of the MPS is closer to an adaptive expectation mechanism. If we now consider the much simpler Cagan model, we find that it is stable under rational expectations but unstable under adaptive expectations if expectations adapt "too fast." For the same reason, our model is stable and the MPS is unstable.

Although, in principle, the current equilibrium depends on all anticipated future values of the exogenous variables, agents are assumed in the simulations to have a horizon of only (!) 200 quarters. A simulation must therefore specify at any time the anticipations for all future values for all exogenous variables for the following 200 quarters.

The Policy Experiment

The experiment will consist of a decrease in nominal money of 5%, announced n periods in advance. This experiment is shown graphically in figure 3.1. The number of periods, n, between the announcement and implementation, will be taken to be either zero (in which case the policy is unanticipated), five, or fifteen quarters.

Two simplifying assumptions will be made: If the decrease in money is realized through an open market operation, the increase in government bonds may have an effect on spending. It will be assumed that

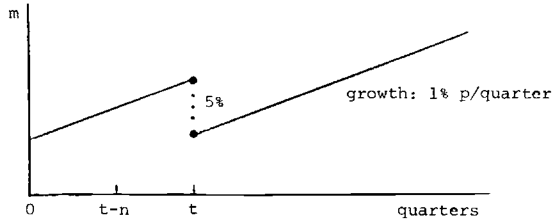


Fig. 3.1 The behavior of nominal money

in this case the increase in wealth in the form of government bonds is exactly offset by the increase in tax liabilities and has no effect on spending. Thus, for simplicity, the real value of bonds (divided by physical capital) and structure of anticipated taxes will remain unchanged in the simulation. Capital will be assumed to grow at a constant steady state rate. Thus, the effects of changes in investment spending on capital accumulation will not be taken into account.

4. Monetary Policy with Exogenous Prices

In this section, prices are assumed to be exogenous and growing at the steady state rate of inflation, 4%. The decrease in nominal money of 5% in one quarter implies here a permanent decrease in real money of 5%.

It is clear that the "steady state" of this section is not a true steady state, for output may be permanently different from its normal level. This section is, however, useful to characterize the dynamics of aggregate demand, independent of the particular formalization of aggregate supply; in particular it shows clearly the interaction between the stock market, output, and the real short-term rate of interest.

The "Steady State"

Given prices, the steady state is characterized by two relations; first, wealth determines output. From equation (5), in steady state (deleting the symbol t):

$$y = .687 + .562\, h + .198\, q.$$

Second, output determines profit and labor income and the real interest rate together with the real money stock; this in turn determines wealth:

$$q = \frac{\pi}{r + .075} = \frac{-.095 + .117\, y}{-.410\,(m - p) - .675 + 179\, y}$$

$$h = \frac{yd}{r + .075} = \frac{.043 + .030\,y}{-.410\,(m - p) - .675 + 179\,y}$$

A lower real money stock leads to both higher interest and lower profit, thus lower wealth and output. A 5% decrease in real money decreases y by 6.2%, q by 20%, h by 10%; the real short-term rate increases by 50%, from 1% to 1.499%.

The Dynamic Effects of an Unanticipated Decrease in Real Money

The results of an unanticipated decrease in real money are reported in table 3.2. The main conclusion is that, in this case, the adjustment is *very fast:* 65% of the adjustment in output takes place in the first quarter; the adjustment is nearly complete in four quarters.

This fast adjustment differs drastically from the effects of a similar change in nominal money in existing models (see again Corrado 1976 for the effects of a similar policy in the MPS with exogenous prices): these models indicate a slow adjustment of the economy to a change in nominal money. There are probably three main reasons for this difference. The first is the assumption about expectations and is probably the most important one. The second comes from the fact that a decrease in the money stock in this and, say, the MPS model may in fact correspond to two different experiments. The fast adjustment is obtained here under the assumptions that the decrease in money is both unanticipated and believed to be permanent. It is possible, for example, that the decrease in money considered in the MPS is of a different nature (implicitly, for the model does not distinguish between anticipated and unanticipated, permanent and temporary). The underlying assumptions may, for example, be that the decrease is initially thought of as temporary by agents and that only over time do agents think of it as being

Table 3.2 **The Effect of an Unanticipated Decrease in the Nominal Money Stock of 5% with Prices Exogenous, Announced and Implemented in the First Quarter.**

Quarters	y	r	π	q	
0	1.377	1.000%	.070	.847	
1	1.319	3.947	.057	.666	Announcement/Implementation
2	1.302	1.691	.056	.674	
3	1.296	1.593	.059	.675	
4	1.291	1.503	.059	.676	
5	1.291	1.498	.059	.676	
6	1.291	1.499	.060	.676	

permanent; this may partially explain the difference between the models.

The third reason is that inventories are taken as exogenous in this model, whereas they are endogenous in the MPS. Intuition (supplemented by the study of the effects of inventory behavior in Blinder and Fischer 1978) suggests that the endogeneity of inventories may lead to a smaller initial response and a slower adjustment process.

Consider now the dynamics of output, wealth and the short-term rate: After the decrease in money, agents anticipate both a higher sequence of interest rates and a lower sequence of profit and labor income. Both effects decrease wealth immediately. The stock market drops by as much as 21%. This in turn decreases spending and output over time, decreasing income and validating the initial anticipations of lower profit and labor income.

Over time the decrease in output reduces the demand for money, leading to a decrease in the interest rate. The decrease in profit is initially large because profit depends both on the level and the rate of change of output. After the first quarter, output decreases but at a slower rate; this affects profit in opposite directions. The combined decrease in the relevant sequence of discount rates and the approximately constant sequence of profits lead to a slight increase in q over time. Initially q decreases by more than its long-run change and after that increases slightly.

Therefore, not only the speed but the qualitative behavior of this model is different from the behavior of existing models; rather than slowly adjusting over time to the higher short-term real rate, the stock market reacts immediately and strongly to the decrease in money.

The Dynamic Effects of a Decrease in Real Money, Announced in Quarter 1 and Implemented in Quarter 6

Table 3.3 presents the behavior of output, the real interest rate, profit, and the stock market.

The announcement is itself contractionary. The stock market drops by 18% in the quarter of the announcement. This is due to anticipations of both higher interest rates and lower profits. This leads to a rapid decrease in output: 52% of the long-run change takes place in the first quarter and the decrease in output between the announcement and the implementation is larger than its long-run change. Over time, between the announcement and the actual implementation, output is decreasing but the real money stock is still constant. Because of the lower transaction demand for money, the short-term rate decreases. Thus the stock market and the short rate move in opposite directions.

As the actual implementation becomes closer in time, the sequence of higher short-term rates also becomes closer, explaining the further

Table 3.3 The Effect of a Decrease in the Nominal Money Stock of 5% with Prices Exogenous, Announced in Quarter 1 and Implemented in the Sixth Quarter.

Quarters	y	r	π	q	
0	1.377	1.000%	.070	.847	
1	1.332	.183	.060	.687	Announcement
2	1.311	−.179	.058	.684	
3	1.303	−.334	.059	.681	
4	1.295	−.474	.059	.678	
5	1.291	−.544	.059	.674	
6	1.287	4.382	.059	.670	Implementation
7	1.290	1.495	.060	.676	
8	1.291	1.497	.060	.676	
9	1.291	1.499	.060	.676	
10	1.291	1.499	.060	.676	

decline of wealth and thus output. These capital losses are expected; note, however, that they are relatively small compared with the initial unexpected drop; they are equal to less than 1% per quarter.

At the time of the implementation, the real money stock decreases, leading to a very large increase in the short-term rate. Because this change was expected, however, little else happens: output and the stock market are already close to their equilibrium values; output even increases slightly after the decrease in real money.

The results of this section have been derived under the assumption of exogenous prices and thus of the possibility that output may be permanently different from its long-run value. This assumption is now relaxed.

5. Monetary Policy with Endogenous Prices

Prices are now endogenous and their behavior is described by equations (13) and (15). The value of γ is .20, unless otherwise indicated: 20% of the desired adjustment of prices takes place during a quarter.

A change in nominal money has no effect in the long run as prices adjust, leaving real money unchanged. Thus only the dynamics of adjustment are of interest.

The Dynamic Effects of an Unanticipated Decrease in Nominal Money

Figure 3.2 gives the behavior of y, q, r, and π in response to an unanticipated decrease in nominal money.

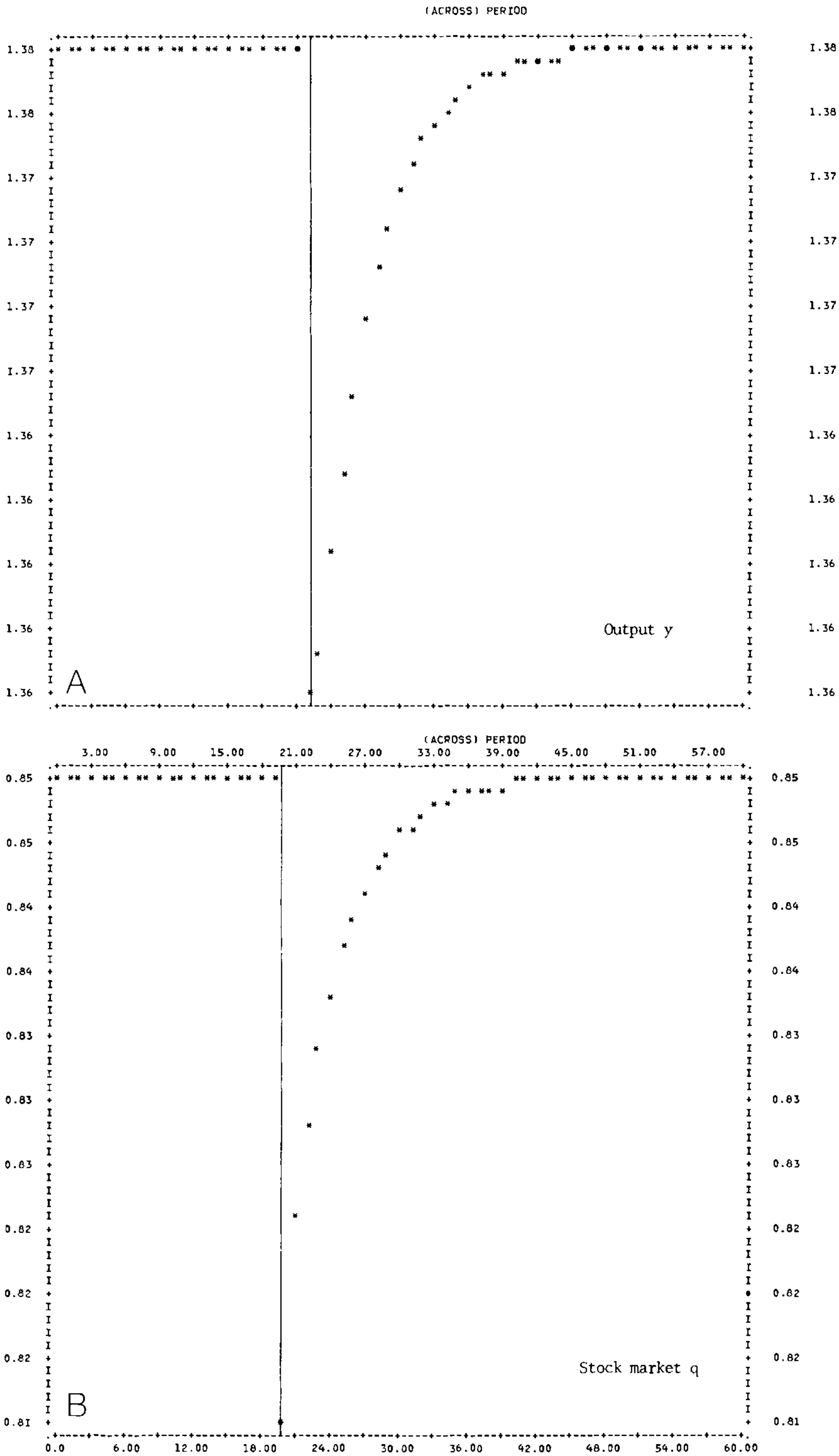
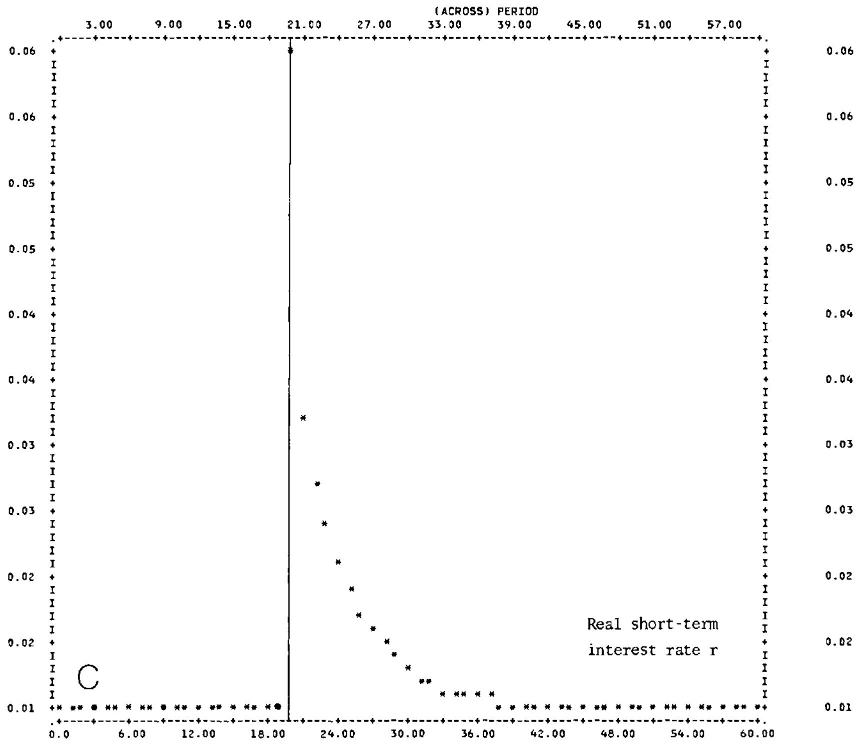
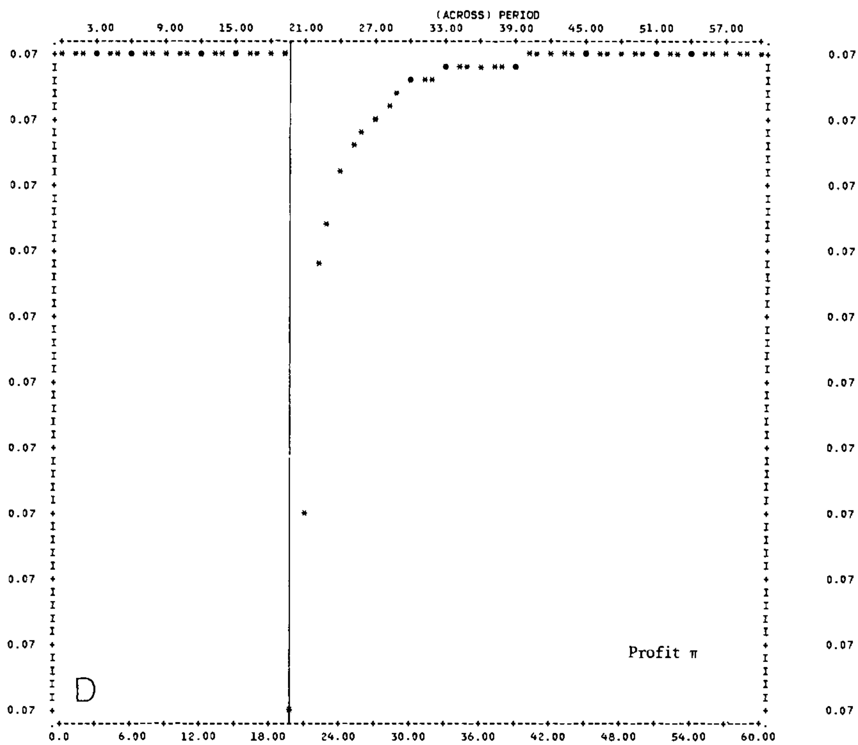


Fig. 3.2A–D The effects of an unanticipated decrease in nominal money


(ACROSS) PERIOD
3.00 9.00 15.00 21.00 27.00 33.00 39.00 45.00 51.00 57.00
0.0 6.00 12.00 18.00 24.00 30.00 36.00 42.00 48.00 54.00 60.00
0.06 0.06 0.05 0.05 0.04 0.04 0.03 0.03 0.02 0.02 0.01
C
Real short-term interest rate r


(ACROSS) PERIOD
3.00 9.00 15.00 21.00 27.00 33.00 39.00 45.00 51.00 57.00
0.0 6.00 12.00 18.00 24.00 30.00 36.00 42.00 48.00 54.00 60.00
0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07
D
Profit π

What is the initial impact of the decrease in money? Again, the combination of lower anticipated profits and higher real rates decreases wealth; the stock market drops but since the economy is expected to return to steady state, profits and interest rates are expected to return to their steady state values; the drop is thus only 5% in the quarter of the policy change compared with 21%, in the exogenous price case. The behavior of y and q in both cases is given in columns 1, 2, 5, and 6 in table 3.4.

The smaller drop in the stock market and in output must be contrasted with the increase of the short-term real rate, which is *larger* than in the exogenous price case: the short-term real rate increases to 6.311% compared with 3.497%. The reason is the presence of the Mundell effect: in addition to the decrease in real money, which increases the nominal rate, there is expected lower inflation, which, given the nominal rate, increases the real rate. This higher short-term real rate, however, is not expected to remain: real rates are expected to be lower in the future than in the exogenous price case. This explains why the decrease in wealth is smaller than in the exogenous price case.

Over time, both the real money stock and the real rate return to their steady state values; wealth increases. There are initially two opposite effects on output: the initial decrease in wealth tends to decrease it; the following increase tends to increase it. The second effect is more powerful for $\gamma = .20$, but, as shown in table 3.4, the first effect dominates initially for $\gamma = .10$: output decreases in the first two quarters before it increases again.

Most of the effect of the policy on real variables has disappeared after 10 quarters: although prices are still 10% away from their steady state value, output is less than 2% away from its steady state value.

The Dynamic Effects of a Decrease in Nominal Money, Announced in Quarter 1 and Implemented in Quarter 6

Figure 3.3 gives the behavior of y, q, r, and π in response to a decrease in money anticipated 5 quarters in advance. The results may be compared with the results of the exogenous price case presented in table 3.3. There are two mechanisms at work: the first one is the one described in the exogenous price case, the second one is the behavior of desired and actual prices. Through the first one, the announcement leads to an anticipated recession and thus a decrease in wealth at the time of the announcement; this implies a rapid decrease in output. There are contradictory effects on the stock market between the announcement and implementation: the higher sequence of anticipated profit tends to increase it but the relevant sequence of discount rates changes over time in a complex way, as can be seen in figure 3.3. In

Table 3.4 **The Effects of an Unanticipated Decrease in Nominal Money in the First Quarter: the first five quarters.**

	1	2	3	4	5	6
Quarter	$\gamma = 0$ (fixed prices)		$\gamma = .10$		$\gamma = .20$	
	y	q	y	q	y	q
0	1.377	.847	1.377	.847	1.377	.847
1	1.319	.666	1.350	.799	1.356	.812
2	1.302	.674	1.348	.809	1.357	.824
3	1.296	.675	1.350	.814	1.360	.830
4	1.291	.676	1.351	.817	1.363	.833
5	1.291	.676	1.354	.821	1.366	.836
6	1.291	.676	1.356	.824	1.368	.839

this case, the net effect is to increase wealth slightly between the first quarter and the sixth.

The implementation again has no noticeable effect, except on the short-term real rate. After that, wealth and output increase slowly back to their steady state value.

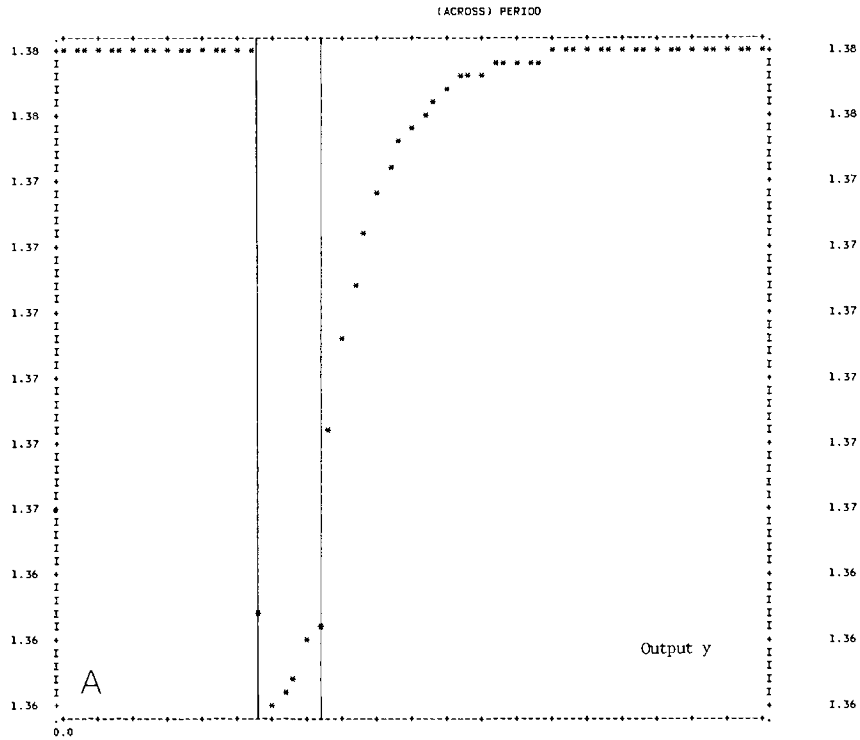
The second mechanism is through prices: after the announcement, the desired price adjusts to its lower level; this leads in turn to an adjustment of the actual price (see above). When nominal money decreases, the actual price has already decreased (compared with its trend) and this leads to a smaller decrease in real money. This reduces the effect of nominal money on output: when unanticipated, the policy led to a maximum decrease in output of 1.5%; when it is anticipated five quarters in advance, the maximum decrease in output is only 1.1%.

The Dynamic Effects of a Decrease in Nominal Money, Announced in Quarter 1 and Implemented in Quarter 16

If a decrease in nominal money is anticipated so long in advance, we would not expect it to have much effect. This is the reason for considering this case. The results are given in figure 3.4.

The effects on y and q are indeed very small. The maximum decrease in output, which takes place at the time of the actual implementation in quarter 16, is of .7%.

The complexity of the different effects of anticipated interest rates and anticipated profit income on the stock market is clearly indicated by the behavior of the stock market between the announcement and the implementation. The rest of the effect is otherwise qualitatively similar to the case of a decrease anticipated five quarters in advance.



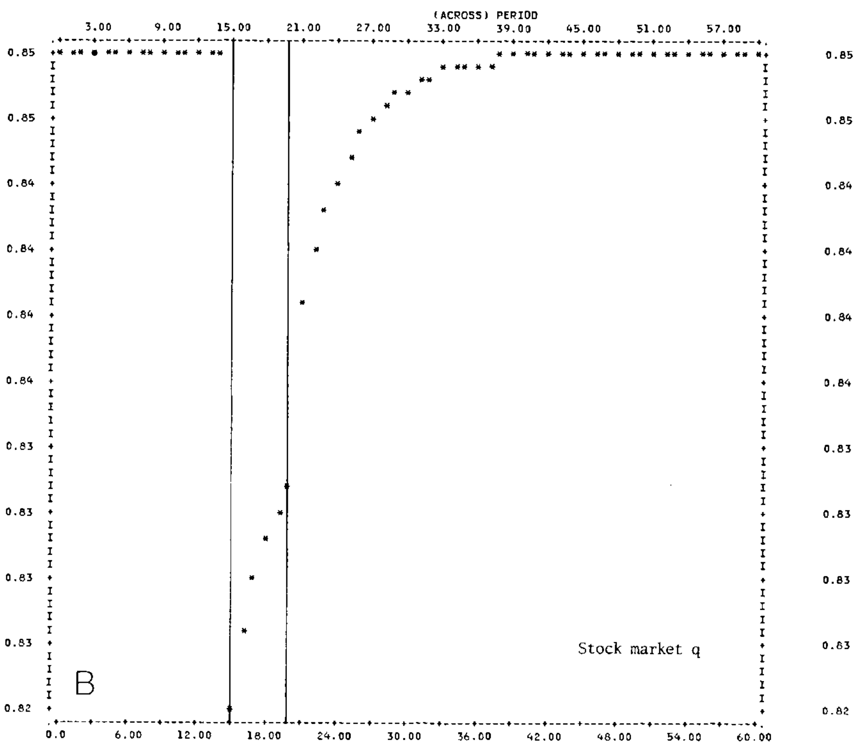
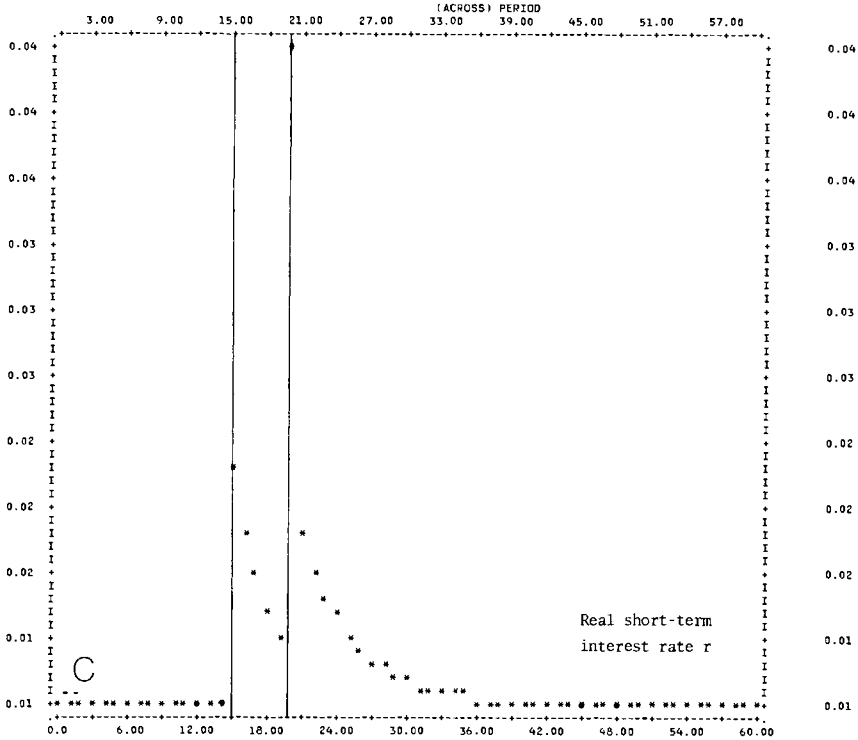
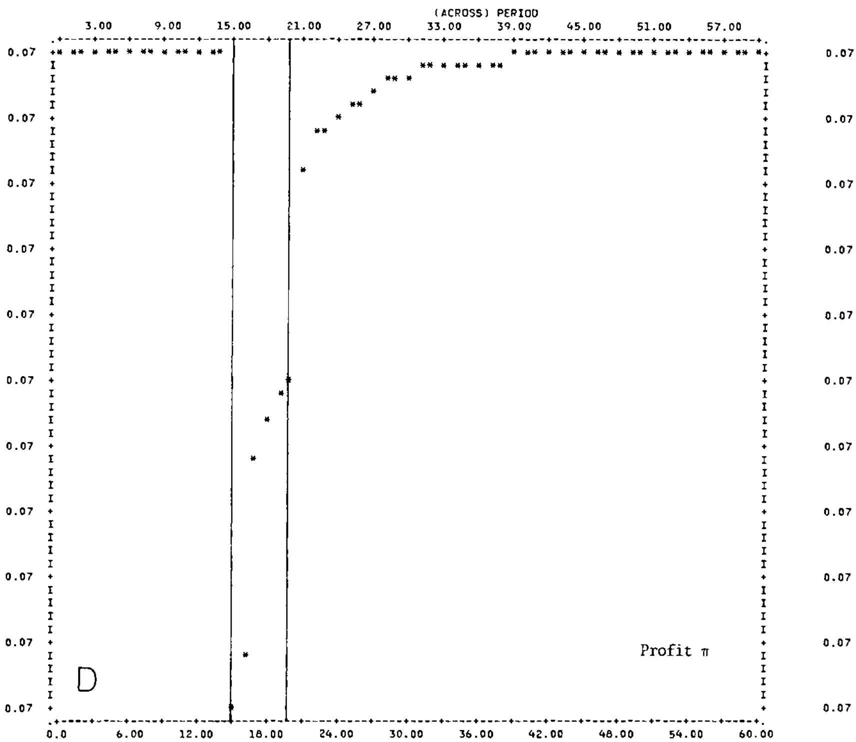


Fig. 3.3A–D The effects of a decrease in money anticipated 5 quarters in advance. (The first vertical line indicates the quarter in which the decrease is announced. The second vertical line indicates the quarter in which it is implemented.)


(ACROSS) PERIOD
Real short-term interest rate r
C


(ACROSS) PERIOD
Profit π
D

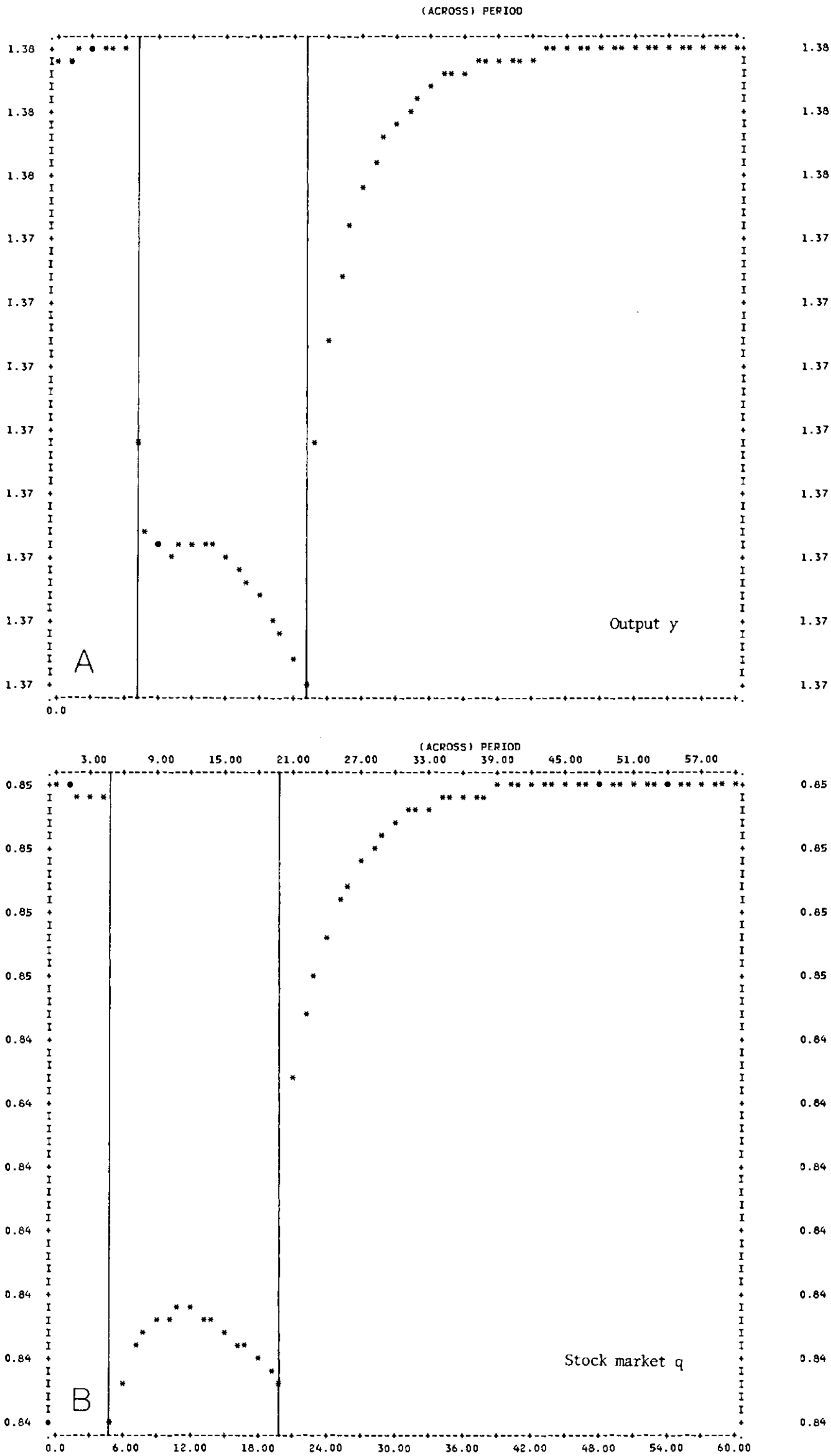
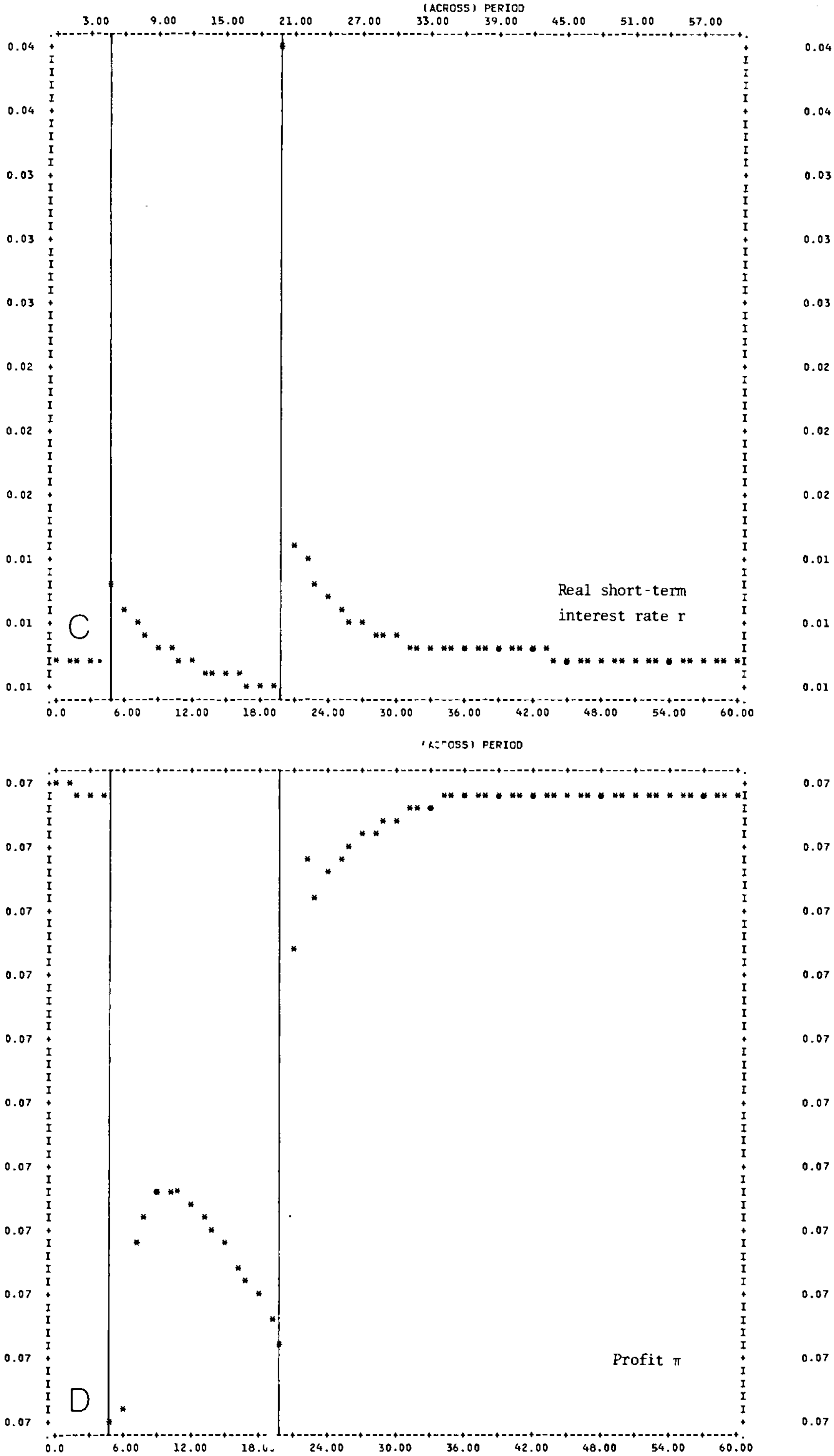


Fig. 3.4A–D The effects of a decrease in money anticipated 15 quarters in advance. (The first vertical line indicates the quarter in which the decrease is announced. The second vertical line indicates the quarter in which it is implemented.)


(ACROSS) PERIOD
C
Real short-term interest rate r
D
Profit π

6. Conclusion

The purpose of the paper was to show that a structural model could be specified, estimated, and used to study the effects of a policy change under the assumption of rational expectations. What is the verdict?

1. Specification and estimation of a model of aggregate demand which should be approximately invariant to policy rules does seem possible. The model used in this paper stresses the role of observable variables, such as the stock market, which contains information about agents' expectations; the result of such a specification is to minimize the number of parameters to estimate in equations with unobservable expectational variables. Given that, estimation does not present particular technical difficulties. A serious problem—not directly related to the assumption of rational expectations—comes, however, from the dubious identification status of some of the estimated equations: few of the potential instruments seem to be statistically exogenous.

It is, in fact, impossible to specify a model involving only observable variables. Because there is no market for human wealth, assumptions about expectations must be made to estimate the effect of human wealth on consumption spending. In the same way, the specification and estimation of inventory investment, which is not explained at this stage, would require the use of unobservable variables such as sales expectations and, thus, an assumption about the formation of these expectations in the sample period. Specification of such relations does not present particular problems and if rational expectations are assumed, the implied cross-equation constraints should help rather than hinder estimation (Wallis 1977 or Sargent 1978).

Even a detailed and reliable model of aggregate demand is of little use without a model of aggregate supply. Although the model of supply used here has both theoretically and empirically desirable properties, it is neither derived from theory nor estimated. The question of whether we can specify and estimate a policy invariant model of aggregate supply is therefore not answered by this paper.

2. Once a model is specified and estimated, the technical problems involved in obtaining policy simulations under the assumption of rational expectations are easily solved. A policy simulation requires the specification for all simulation periods of all current expectations for all future values of all exogenous variables. Although this implies more cumbersome simulations than those in existing models which only require current values of the exogenous variables, this is a logical consequence of the assumption of rational expectations.

The policies considered here are both simple and deterministic but there are no conceptual or technical problems in considering feedback or stochastic rules or both.

3. Although it would be unwise to take the exact quantitative results of the simulations too literally, the following qualitative features of the adjustment process after a change in nominal money are probably fairly robust:

If prices were exogenous, the adjustment of the real variables to their new equilibrium level would be fast, in response to a permanent change in money. With endogenous prices, an unanticipated change in nominal money, assumed to be permanent, has its largest effect on output and the stock market at or shortly after the implementation; there is no slow transmission from short- to long-term rates, to the stock market, and finally to output.

When a policy is anticipated, the announcement itself has a large effect on the stock market and on output; the actual implementation affects the short-term interest rate but has little noticeable effect on the path of output and wealth. Finally, the longer a change in nominal money has been anticipated, the smaller are its effects on real variables.

Appendix

Systems (16) and (17) are of the form:

$$\begin{bmatrix} \mathbf{X}_{t+1} \\ {}_t\mathbf{Y}_{t+1} \end{bmatrix} = \mathbf{A} \begin{bmatrix} \mathbf{X}_t \\ \mathbf{Y}_t \end{bmatrix} + \Omega\, \xi_t,$$

where

$\mathbf{X}$ is a vector of n variables predetermined at t
$\mathbf{Y}$ is a vector of m variables not predetermined at t
ξ is a vector of k exogenous variables
$\mathbf{X} = \mathbf{X}_0$ at time t_0
$\mathbf{A}, \Omega$ are $((n+m) \times (n+m))$ and $((n+m) \times k)$, respectively.

First decompose this system $\mathbf{A}$ and Ω as follows:

$$\begin{bmatrix} \mathbf{X}_{t+1} \\ {}_tY_{t+1} \end{bmatrix} = \begin{bmatrix} \underset{(n\times n)}{\mathbf{A}_{11}} & \underset{(n\times m)}{\mathbf{A}_{12}} \\ \underset{(m\times n)}{\mathbf{A}_{21}} & \underset{(m\times m)}{\mathbf{A}_{22}} \end{bmatrix} \begin{bmatrix} \mathbf{X}_t \\ \mathbf{Y}_t \end{bmatrix} + \begin{bmatrix} \underset{(n\times k)}{\Omega_1} \\ \underset{(m\times k)}{\Omega_2} \end{bmatrix} \xi_t.$$

$\mathbf{A}$ is similar to a diagonal matrix Λ: $\mathbf{A} = \mathbf{B}\Lambda\mathbf{B}^{-1}$
Λ is ordered by increasing absolute value of the characteristic roots
$\mathbf{B}$ and Λ are partitioned as follows:

$$\mathbf{B} = \begin{bmatrix} \underset{(n\times n)}{\mathbf{B}_{11}} & \underset{(n\times m)}{\mathbf{B}_{12}} \\ \underset{(m\times n)}{\mathbf{B}_{21}} & \underset{(m\times m)}{\mathbf{B}_{22}} \end{bmatrix}; \mathbf{B}^{-1} = \begin{bmatrix} \underset{(n\times n)}{\mathbf{C}_{11}} & \underset{(n\times m)}{\mathbf{C}_{12}} \\ \underset{(m\times n)}{\mathbf{C}_{21}} & \underset{(m\times m)}{\mathbf{C}_{22}} \end{bmatrix};$$

$$\mathbf{\Lambda} = \begin{bmatrix} \underset{(n\times n)}{\mathbf{\Lambda}_1} & 0 \\ 0 & \underset{(m\times m)}{\mathbf{\Lambda}_2} \end{bmatrix}.$$

For these systems to be stable, $\mathbf{\Lambda}_1$ must include all the roots inside the unit circle, and $\mathbf{\Lambda}_2$ include all the roots outside.

Then for $t > t_0$ (see Blanchard 1980).

(A1)
$$\mathbf{X}_t = \mathbf{B}_{11}\mathbf{\Lambda}_1\mathbf{B}_{11}^{-1}\mathbf{X}_{t-1} + \Omega_1\xi_{t-1} - \mathbf{A}_{12}\mathbf{C}_{22}^{-1}\sum_{i=0}^{\infty}\mathbf{\Lambda}_2^{-i-1}(\mathbf{C}_{21}\Omega_1 + \mathbf{C}_{22}\Omega_2)_{t-1}\xi_{t-1+i}$$

and

(A2)
$$\mathbf{Y}_t = -\mathbf{C}_{22}^{-1}\mathbf{C}_{21}\mathbf{X}_t - \mathbf{C}_{22}^{-1}\sum_{i=0}^{\infty}\mathbf{\Lambda}_2^{-i-1}(\mathbf{C}_{21}\Omega_1 + \mathbf{C}_{22}\Omega_2)_t\xi_{t+i}.$$

An algorithm giving the values for $\mathbf{X}_t$ and $\mathbf{Y}_t$ given the sequence of actual and anticipated ξ_t's is available upon request.

Comment Bennett T. McCallum

The basic purpose of Blanchard's study is to specify and estimate a macroeconometric model that can be used for valid policy simulations—that is, simulations that are not open to Lucas's (1976) fundamental critique. It seems clear that this would be, if successful, a very useful project. There are a few such models in existence (Barro 1978, Sargent 1976*a*, and Taylor 1979*b*, for example), but Blanchard's aggregate demand sector is specified with considerably more detail than in any of these others.[13] Let us then consider whether his approach seems likely to prove successful.

I shall begin by noting the way in which Blanchard has attempted to build policy-invariance into the model's structure. The main step—

I am indebted to Robert Flood and Peter Garber for helpful discussions and to the National Science Foundation for financial support (SOC 76-81422).

13. Of course the Barro and Sargent models are ones in which the choice among systematic policy feedback rules has no effect on output or unemployment processes. Taylor's, like Blanchard's, leaves more scope for activist stabilization policy.

in conjunction with the adoption of the rational expectations hypothesis —is to make h_t and q_t (the present values of expected future real wage and real profit streams) the principal determinants of consumption and investment demand, respectively. Policy changes should then bring about changes in expected future wage and profit variables and consequently, by way of h_t and q_t, current consumption and investment. While one could quibble over details, this general approach seems reasonably satisfactory in principle,[14] so the issue becomes one of empirical implementation. I shall therefore devote some attention to the model's estimation, which is described in a separate paper by Blanchard and Wyplosz (1978).[15]

In any analysis in which one adopts the rational expectations hypothesis, and accordingly abstains from the use of distributed-lag "proxies" for expectational variables, estimation will necessarily involve some technique that is not entirely "standard" in macroeconomics. In trying to discern how Blanchard has proceeded in this regard, one gradually becomes aware that a significant part of his strategy is to design the model so that unobservable expectational variables appear in very few places. In fact, they appear only in the arbitrage equations, those designated (8) and (10). Furthermore, these equations include a minimal number of parameters—and the values 1.04 in (8) and 0.093 in (10) are simply unit-of-measurement conversion factors that do not need to be obtained by estimation. Thus the *only* parameter estimated in either (8) or (10) is the risk premium, denoted β. The value was estimated as 0.075 in (8) and assumed to be applicable in (10) as well. This strategy for minimizing the number of parameters in equations with expectational variables must be regarded as highly ingenious.

The procedure actually used to estimate β does not, however, strike me as desirable. Blanchard and Wyplosz in effect by writing

$$\beta = \frac{4({}_tq_{t+1} - q_t) + 1.04\pi_t}{q_t} - r_t, \tag{1}$$

14. This statement refers only to the aggregate demand portion of the model. I shall have more to say about aggregate supply below. In addition, it should be mentioned that the current version of the model does not include tax rate variables in several places in which they would be necessary for fiscal policy simulations. Indeed, estimation has probably suffered from these omissions since tax schedules were altered during the sample period. But Blanchard is fully aware of this problem and will no doubt be eliminating it in future versions.

15. I have little to say about the numerical results of the estimation. Two items should, however, be mentioned. First, the estimates of the autoregressive parameters in the structural equations estimated by Fair's (1970) procedure are very high: 0.83 to 0.96. Second, current income variables enter strongly in both the investment and consumption functions, despite their absence from the theoretical model.

where π_t = profit per unit of capital, r_t = *expected* real rate of return on Treasury bills, and ${}_tq_{t+1}$ = the value of "Tobin's q" (as calculated by von Furstenberg 1977) for period $t+1$ expected as of period t. Next they delete the capital gains term $({}_tq_{t+1} - q_t)/q_t$, arguing that its sample average should be small, adopt Nordhaus's (1974) estimate of the mean value of π_t for 1953–73, and compute sample period mean values for q_t and r_t, using for the latter the ex post real rate $i_t - (p_{t+1} - p_t)$ instead of $i_t - ({}_tp_{t+1} - p_t)$. Finally, they substitute these three mean values into expression (1) and use the resulting number as their estimate, β. This use of the ex post real rate and the deletion of the capital gains term are perhaps justifiable, given the rational expectations condition, so β may be statistically consistent. But since the estimation procedure ignores period-to-period interactions among the various terms of (1), it would appear to be unusually inefficient.[16] In addition, it does not permit the calculation of a standard error for β. Thus there is no way of telling, from the Blanchard and Wyplosz paper, whether their estimate is significantly different from zero—or, for that matter, from unity.

The most serious problem with the model's estimation pertains, however, to the consumption function. The source of the problem is that h_t is unobservable in the following specification:

$$c_t = a_1h_t + a_2w_t + a_3w_{t-1} + a_4yd_t + a_5yd_{t-1} + \epsilon_t.$$

How, then, is estimation effected? In fact, the procedure is to choose units of measurement so that the sample mean value of the unobservable h_t must be 1.0, and then simply estimate

$$c_t = a_1 + a_2w_t + a_3w_{t-1} + a_4yd_t + a_5yd_{t-1} + \epsilon_t,$$

using the resulting constant term as an estimate of the slope parameter for h_t. Clearly, this procedure must be inconsistent, because of the omitted variable. And the omission seems particularly inappropriate in the context of a study focusing upon aggregate demand: the consumption function is estimated by a procedure that pretends that its main driving variable is not a variable at all. Blanchard and Wyplosz express the intention of using a more satisfactory procedure in the future, however.

A few words should perhaps be added about identification. I have found rather persuasive the contention of Sims (1979) that the appro-

16. There is, of course, no attempt to exploit or test cross-equation restrictions implied by the rational expectations hypothesis. On this subject, see Wallis 1977.

priate identification criterion for dynamic macroeconometric models is the one developed by Hatanaka (1975), which does *not* assume that distributed-lag lengths and serial correlation properties are known a priori. Also hard to resist is Sims's argument that statistical exogeneity tests should be passed by variables classified as exogenous for purposes of estimation and identification. In fact, Blanchard and Wyplosz carry out such tests for variables used as exogenous instruments (i.e., first-stage regressors) in estimation, a step that should be widely regarded as commendable. But the set of instrumental variables ultimately used is not reassuring. There are six in this set, but two[17] actually fail the exogeneity tests and, of the remaining four, one is the federal profit tax rate while another is the total profit tax rate—which would hardly seem to qualify as distinct variables. Furthermore, the final two in the set are government spending and exports. But in Blanchard's model these apparently enter only in the expenditure equation (5), where they are additive components of the variable x_t. Perhaps one of the two should appear in some additional equation that is not listed explicitly as part of the model.[18] But, if not, these two variables can only count as one for the purpose of identification. Consequently, the system contains only two or perhaps three truly exogenous variables. But the consumption function includes four endogenous variables (counting h_t), even with the current real interest rate excluded, so its identification status should be regarded as dubious.[19] This argument should not be taken as a criticism of Blanchard, whose practice is more conscientious than is usually found in empirical work,[20] but as an indication of the inherent difficulty of reliably identifying structural equations.

My final point concerns the aggregate supply specification in Blanchard's model.[21] At first glance, it appears similar to one that I have used (McCallum 1978), for mine includes a price adjustment equation exactly like Blanchard's (14),

$$p_t - p_{t-1} = \gamma(p^*_t - p_{t-1})$$
$$0 \leq \gamma \leq 1,$$

17. The federal personal tax rate and the actual (realized) required reserve ratio.

18. That there must be some such equations is evident from the list of variables tested as potential instruments, as most of these do not appear at all in Blanchard's equations (1) to (11).

19. The same is true (as Blanchard and Wyplosz point out) for the money demand function.

20. Also commendable is the practice of testing for parameter constancy across sample subperiods.

21. The following comments do not distinguish between the three versions of Blanchard's supply function.

with p^*_t defined as the (log of the) price level that would equate aggregate demand and supply. But my model is one in which monetary policy can affect output only by creating monetary surprises—despite the slow price adjustments that take place with small values of γ—while Blanchard's simulations show output effects without monetary surprises. So the specifications must differ in some important way.

The main difference, it turns out, is that under my specification, aggregate demand is a distinct variable from aggregate supply or output.[22] In most periods the two will differ in value, with inventory holdings fluctuating as a result. In Blanchard's model, by contrast, the same symbol (y_t) denotes both output and quantity demanded, so the two are always equal. They can both differ from their common steady state value, but not from each other.

Now it would seem that, if one is going to construct a model in which price level stickiness leads to discrepancies between aggregate demand and supply in *some* sense, he would want to permit output to differ from quantity demanded. These are, after all, supposed to be determined by different agents (to some extent) and in response to different stimuli. But having said this, I must add that my model, like Blanchard's, has not been justified by any explicit profit-maximizing analysis of inventory-holding producer behavior. Such an analysis has recently been worked out, however, by Blinder and Fischer (1978). Their model features profit-maximizing responses of output and inventory holdings—and therefore prices—to changes in aggregate demand.[23] It would seem that an aggregate supply function based on this sort of analysis would be preferable to the one used by Blanchard. In particular, it should be more likely to be invariant to policy choices than the one used in his simulations.

In summary, then, I have definite reservations about Blanchard's supply specification, his model's identifiability, and some of the estimation procedures. Consequently, it appears that his project has not yet been brought to a successful conclusion. Nevertheless, the model in its present form represents an imaginative and interesting beginning. Studying Blanchard's paper was, for me, a pleasure.

22. With output a distinct variable, another behavioral relation is needed to close the model. In my paper, output is determined by a Lucas-type supply function. Accordingly, even with (14), systematic monetary policy cannot affect output.

23. In the first version of the Blinder-Fischer model, monetary policy has no effects on output. They also present a version in which there are "non-neutralities," but these seem to reflect effects on the "full-employment" output level, rather than the discrepancy between actual and full employment levels. Thus the Blinder-Fischer nonneutralities do not provide theoretical support for activist *stabilization* policy.

Comment Michael Parkin

Blanchard's paper is a useful, compact summary of two other papers (Blanchard 1978, Blanchard and Wyplosz 1978). It sets out the structure, together with numerical parameter estimates, of the aggregate demand side of a macroeconomic model with five markets—goods, money, bonds, equity, and labor. The model is "completed" by adding an ad hoc aggregate supply assumption that the price level gradually adjusts toward its equilibrium level. Simulation experiments are conducted which take account of the policy regime on the expectations of agents, thereby overcoming the Lucas problem. Attention is focused on the stock market and real output responses.

It is possible to get a better feel for how the model hangs together and how it works by looking at Blanchard's earlier paper. The basic structural equations describing the goods market may be summarized as

(1) $$\dot{y} = \sigma(aq - by + g),$$

where $y =$ real output, $q =$ the stock market price of capital, and $g =$ government expenditures, less tax receipts; $\sigma, a, b > 0$. This is a dynamic version of the IS curve of a standard macroeconomic model. The term in parentheses $(aq - by + g)$ is simply the excess of expenditure plans over current receipts. The term aq can be thought of as investment and by as savings, with g representing the net injection of government purchases. Thus equation (1) simply says that output will rise proportionately to the excess of current expenditure plans over current receipts.

Asset equilibrium is summarized by

(2) $$r = cy - h(m - p),$$

where $r =$ the nominal rate of interest, $m =$ the logarithm of the money supply, and $p =$ the logarithm of the price level. This is simply the LM curve. It has no inherent dynamics.

Next there is perfect arbitrage between bonds and equities so that

(3) $$r = \frac{\dot{q}^e}{q} + \frac{\alpha_0 + \alpha_1 y}{q},$$

where the superscript e denotes the expectation of the relevant variable. The second term in this equation $(\alpha_0 + \alpha_1 y)/q$ represents the rate of profit, which is postulated to be an increasing function of output. This simply says that the rate of profit plus the expected rate of capital gain (or loss) on equities must equal the current rate on bonds. Expectations are rational so that

(4) $$\dot{q}^e = \dot{q}.$$

These four equations constitute the aggregate demand system.

The model is completed by adding a fifth equation, namely,

$$\dot{p} = \gamma(p^* - p), \tag{5}$$

where p^* is the equilibrium (logarithm) of the price level.

The model is most simply analyzed if we consider first the case where $\gamma = 0$ and therefore where the price level is stuck at its existing value. In this case the subsystem of equations (1), (2), (3), and (4) determines the level of output, the interest rate, and the stock market value of the capital stock for a given g, m, and p. Figure 3.5 summarizes this model. Equation (1) can be plotted as the IS curve for $\dot{y} = 0$ and equations (2), (3), and (4) used to eliminate the interest rate and $\dot{q}^e$ and plotted for $\dot{q} = 0$. (There are in fact two cases of the $\dot{q} = 0$ locus depending on whether a rise in the profit rate raises or lowers the interest rate in equilibrium. The case we work with is that which the empirical results correspond to.) The only expectational variable in this model is the stock market value of the capital stock. There is no uncertainty explicitly introduced, and therefore we have the deterministic analogue of rational expectations, namely, perfect foresight. All the paths of adjustment of this economy turn out to be perfect foresight paths. However, if we impose the usual terminal conditions to achieve uniqueness, the economy will travel along an arm such as aa′, achieving a steady state at E.

If this economy is disturbed by say a rise in the money stock, then the $\dot{q} = 0$ locus shifts (fig. 3.6) from that marked $M = M_0$ to that marked $M = M_1$. The initial equilibrium was point E and the new equilibrium is B. How the economy moves from E to B depends on the timing of the announcement and the implementation of the change in the money stock. Blanchard analyzes several cases. The most simple and

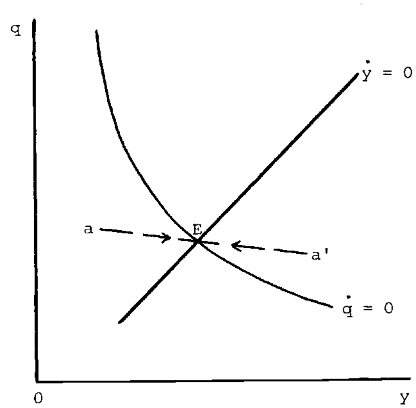


Fig. 3.5 Dynamic adjustment in the basic model

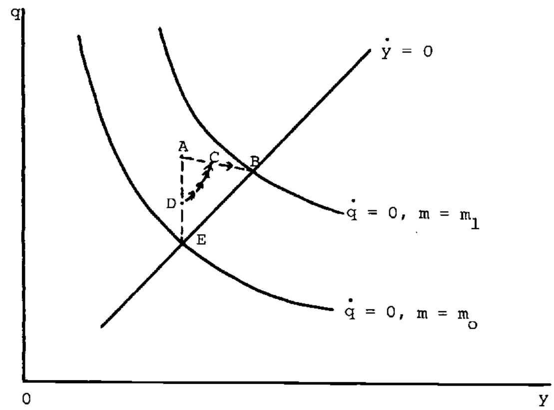


Fig. 3.6 Effects of the change in the money stock

direct is that of a previously unanticipated rise in the money stock. Up to some date, the money stock was at M_0. At the date of shock the money stock is increased to M_1, and it is known that it will be permanently held at M_1 thereafter. At that instant the economy jumps to A and thereafter follows the trajectory marked from A to B. If the rise in the money stock is announced ahead of time, at the moment of announcement the stock market will jump to a position such as D, and in the transition between the announcement and the implementation of the money stock change the economy will follow the trajectory DC. The money stock actually rises to M_1 at point C and thereafter the economy follows the trajectory CB. The further ahead the money supply increase is announced relative to its implementation, the closer will the economy move to traveling along the IS curve. In the limit of an announcement an infinite amount of time ahead of the change the economy would simply gradually track up the IS curve and, at the moment when the money stock was increased, the economy would be at point B.

Blanchard's numerical simulations based on alternative assumptions about the lead time of the anticipation illustrate the differences that arise in the alternative cases. It is clear that the more abrupt a policy change is, the more overshooting we would expect to observe in the stock market, with stock market expectations being regressive once the economy is on the stable arm following the actual change in the policy variable.

In all this discussion the price level has been held constant. It is of some importance to analyze the effects of allowing the price level to change simultaneously with the movements of output in the stock market index. Analytically it is easier to get a feel for what is going on if we examine the special case of $\gamma = \infty$ (equivalent to the $\gamma = 1$ in the discrete time case used in the explicit numerical analysis of Blanchard).

Figure 3.7 illustrates the economy in full equilibrium with output at its equilibrium level y^*. The stock market equilibrium value q^* is determined by the point at which the $\dot{y} = 0$ locus cuts the full employment line. The LM cum arbitrage condition determines the price level, which ensures the the $\dot{q} = 0$ locus is compatible with q^* and y^*. Now let there be an unanticipated change in the money stock. Recall, however, that once the money stock has changed it is understood that it is now at a different level forever. What does this do to the equilibrium displayed in figure 3.7? The answer clearly is nothing. The rise in the money stock would shift the LM arbitrage $\dot{q} = 0$ condition to the northeast. The rise in the price level would, however, bring it back to its original position. There would thus be no dynamics at all to investigate.

In between the extreme cases of no price adjustment and perfect price adjustment, if the price level is permitted to move gradually (and Blanchard allows it to close the equilibrium gap by 1/5 each quarter), then the dynamics become somewhat complicated to deal with analytically. There are, however, some strong and persistent real effects following a monetary shock that occur in the numerical simulations presented.

It is clear that the source of these real effects is the specified aggregate supply assumption. Blanchard's view is that the data are inadequate to discriminate amongst alternative aggregate supply formulations and therefore the ad hoc assumption used is justified. This may turn out to be correct. At the same time it should be noted that the key persistence results arise from ad hoc, and therefore the most unsatisfactory, aspect of Blanchard's model. Were it not for sluggish price adjustment, the model would produce very different price, output, and stock market dynamics. Furthermore, it is interesting to note that the rational ex-

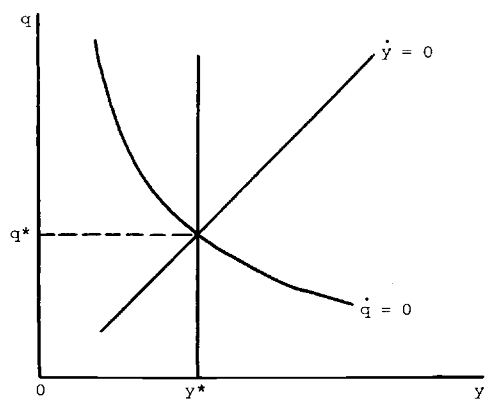


Fig. 3.7 The determination of long-run equilibrium

pectations content of this model bears no relation at all to the standard rational expectations models of price and output determination. The expectations dynamics in Blanchard's analysis concern the stock market price and not the general price level. In fact expectations of the general price level play virtually no role in the analysis at all.

The main virtue of Blanchard's work is in showing how in principle we can develop models that contain rational expectations and yet use those models for policy simulation purposes, taking full account of the effects of the change in the policy regime on the particular expectations formed. Its substantive contribution to the policy debate is limited by virtue of the unsatisfactorily ad hoc and untested assumptions employed on the aggregate supply side. It is in this area that the major research effort is required.

Comment David E. Lindsey*

I was encouraged by Blanchard's paper, particularly by its emphasis upon adjustment of interest rates and stock prices on the basis of rational expectations of the future course of economic variables. While Bennett McCallum noted that expected—as opposed to observed—variables directly enter only in the arbitrage equations, he would not deny that the demand equations include variables which are functions of expected variables. For example, q is a function of expected paths of dividend streams and real discount rates. The profession has been tardy in focusing macroeconomic rational expectations theory on financial markets and can, in fact, go considerably further in this area than this paper does. I shall return to this point later. First, let me clear away some minor underbrush.

The first point has to do with q, which in Blanchard's paper is defined as the real value of a unit of physical capital in the stock market, or the nominal price of stocks divided by the price of goods. His arbitrage equation equalizes the real bond rate plus a premium with the dividend-price ratio plus the expected capital gains in this real stock price, q. But, his empirical estimates use Tobin's q in the consumption and investment functions. Tobin's q is defined as the value of capital in the stock market divided by its replacement cost, or—if a stock is a claim on one unit of capital—the nominal price of stocks divided by the nominal price of capital goods.

*The views expressed herein are entirely mine and do not necessarily represent the opinions of the Board of Governors of the Federal Reserve System.

Unlike the one good economy of Blanchard's theory, in the real world the price of capital goods and the average price of all goods are not identical and do not move together. Thus, Blanchard's q in the real capital gains part of the arbitrage equations represents a concept different from Tobin's q in the estimated demand equations. If the model were to be simulated over the sample period or for policy purposes over an actual post-sample period, this inconsistency would cause the model's forecasts to go astray. As it is, Blanchard's simulations are over hypothetical periods, and it is implicitly assumed that capital prices and all goods prices are identical.

A related problem in my view is that in Blanchard's simulations, which introduce disturbances to the steady state of the economy, the steady state value of Tobin's q is assumed to be .85. This implies that in the steady state, in which capital is growing, firms are continually issuing 85 cents worth of stock to finance \$1 purchases of capital goods, a not very profitable operation. It is a bit hard to accept this description of the steady state, where adjustment costs do not play a role.

On a more important matter, the aggregate supply sector of the model—determining price behavior—is unworthy of the name, since, as McCallum noted, the price level is consistent with any aggregate quantity supplied, which is passively determined by aggregate demand. Given money growth, the path of the price level in this recursive model is determined independently of movements in real income and interest rates, which are then solved for in the demand sector of the model, given expected price levels. While the partial adjustment of prices adds realism to the model, I would have preferred to see it appended to a Lucas-type aggregate supply function—distinguishing between aggregate supply and aggregate demand—so that all the variables could be simultaneously determined. I wonder whether the dynamic properties of the model—involving rapid adjustments of real variables which constitute the paper's main contribution—would not be significantly altered by such an alternative specification.

Another extension of the model that would greatly enhance its realism would be to make the money stock endogenous via a central bank reaction function. Such behavior plays a crucial role in current operations of financial markets. Very short term interest rates and the nominal money stock can be usefully viewed as determined by the interaction of a money demand function and an upward sloping rate setting function of the Federal Reserve, dependent on the observed money stock and other variables, as discussed in Shiller's paper. Thus, as confirmed by Blanchard's statistical causality tests, reserves and high-powered money are in fact endogenous. These variables are adjusted by the Federal Reserve in response to short-run changes in either money demand or the multiplier in order to maintain the desired Federal funds rate (determined by the reaction function).

Market participants essentially forecast the future points of intersection of the money demand and Federal Reserve reaction functions, which imply an expected future path of short-term rates. Then, as is implicit in Blanchard's model, the term structure of rates used in discounting expected stock dividends is determined. Unexpected movements in the stock of money affect market participants' perceptions of future short-term rates and thus affect longer-term rates and stock prices.

There is evidence from studies using weekly data that market participants view the money demand function as being more unstable than the Federal Reserve reaction function. The portion of weekly changes in the money stock that is unexpected gives rise to immediate movements in one-month and longer interest rates in the same direction and immediate movements in stock prices in an opposite direction. That is, when announcements of weekly money stock changes are higher than expected by the market, the market believes that a future increase in the funds rate operating target is then more likely. Hence, all rates tend to move up a bit. Similar estimates of the magnitude of this effect in the 1970s have been found in studies that use different measures of the weekly innovation in the money stock. Each $1 billion innovation in M1 announced at 4:10 P.M. on Thursday is associated, on average, with a 1 to 3 basis point change of the same sign in levels of short and long rates from the close on Thursday to the opening on Friday. This effect is quite significant statistically.

This kind of behavior could be captured in a model like Blanchard's that incorporated the Federal Reserve's reaction function, as well as stochastic effects. Identification problems in the estimation of such a function, however, are severe, as Shiller noted. Incidentally, such problems plague Blanchard's estimated money demand equation, as he is aware.

General Discussion

In responding to comments, Blanchard stated that the main purpose of his paper was to build a structural model that could meet the Lucas challenge, and be used in policy simulations. It became clear very quickly that the data are not powerful enough to distinguish among different aggregate supply specifications. He believed the characteristics of the aggregate supply specification he had chosen were reasonable.

Blanchard said it was difficult to find variables that are exogenous with respect to aggregate demand. He thought that the lack of instruments might be a problem mainly for the demand for money function. He added that he did not think the fact that the steady state value of q in his model was less than one was of great significance, since the level might well be improperly measured.

Robert Hall commented that the conference was not really about rational expectations at all, but rather about market clearing. The Blanchard paper accepts rational expectations and uses it in a clear way but is something of a throwback in not specifying the basis for predetermined prices. He did not see why prices should be predetermined and thought that contract theory did not justify any such assumption. Setting price and letting the buyer determine quantity is not rational. He felt that we are neglecting a key link by merely assuming sticky wages and prices.

Edmund Phelps responded that the Calvo and Phelps paper (1977) tries to explain rigid wages—in Phelps's view, with some success.

Alan Blinder noted that there were nonneutralities of money other than those arising from sticky prices. For instance, real interest rate effects on investment would allow monetary changes to affect output. He felt that the Blanchard paper was missing inventories and their effects on production. He also remarked that the government budget constraint is violated in the paper.

Robert Gordon agreed that there was no good theory of rigid prices. He believed that the required theory would build on the heterogeneity of goods and factors, as well as markets. For instance, there is no time to conduct a separate auction for every item in a supermarket; similarly it is optimal to keep prices of airline seats fixed in the short run. He was not himself sure that labor markets deserved the central role they had been given.

Robert Solow felt there was a tendency to believe there must be a single reason for wage and price inflexibility, whereas there are in fact probably ten or eleven. He added that he saw nothing bad in Blanchard's strategy of elaborating on the demand side of his model and assuming a slow adjustment process on the supply side.

In summing up, Blanchard remarked that the aggregate demand side of a model had to be specified, whatever was done about aggregate supply. He had tried to incorporate inventories, but so far without much empirical success.

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