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This paper contains preliminary findings from research work still in progress and should not be quoted without prior approval of the author.

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I would like to thank Dominique Demougin for his assistance. Any remaining errors are my own.

I. INTRODUCTION

There is a widely held belief that the effects of monetary or fiscal policies on an economy tend to be distributed over a lengthy period of time after the full implementation of the policy. Different policies are said to have different effects and are also said to have their impacts at different intervals after their implementation. In addition, one frequently hears discussion as to what policy should be implemented today to avert some forecasted economic event; the implication here is that if action is not undertaken soon, the lagged impact of the policy may take place too late to achieve the desired effect. However, as yet there are few general equilibrium models which have the implication that government policies can have lagged effects on aggregate variables. The model presented in this paper is an attempt to show how this gap might be filled.

Andersen and Carlson (1970), using the Federal Reserve Bank of St. Louis model, estimated that changes in the money supply have effects on aggregate output which last up to three quarters. They also estimated that the effects of such a shock on the price level would be more prolonged. That these lags exist is also suggested by the work of Sims (1980), who uses vector autoregressive techniques. In fact, Sims' estimates of these lags appears to be longer than the estimates by Andersen and Carlson. The equations used by Barro (1978) show that a positive (unanticipated) money shock causes an expansion of aggregate production over approximately three years. The same shock however, has an impact on the price level which lasts for up to six years.

One of the few equilibrium models where policy has lagged effects is that of Lucas (1972). In this paper changes in the money supply, introduced through a specific type of fiscal policy, are not perceived correctly when agents face a signal extraction problem. As a result, changes in the money supply can potentially cause certain inflation-output correlations. Therefore, in Lucas's model it is seen that informational difficulties result in agents being unable to perceive the full nature of the environment and consequently the policies' effects are felt in a subsequent period. In this model, however, the full impact of a change in the money supply is felt one period after its implementation. Hence the model does not produce a delayed response which persists for many periods.

In the model used in this paper changes in the money supply, introduced through an increase in government consumption, can produce changes in the price level and consumption allocations an arbitrary number of periods after the implementation of the policy. This is a counterexample to the economy studied by Lucas and Stokey (1984). They state that

> "In a model in which information is common, a monetary change is irrelevant history as soon as it has occurred, and it affects real resource allocations only insofar as it conveys information about the future."

In the model of this paper endowment shocks also have a delayed impact on the price level as well as consumption allocations. In addition, it is shown that tax-transfer schemes, of a specific type can have an impact on the economy for many periods after those agents who were directly affected by the policy have left the economy.

The remainder of this paper is organized as follows. In Section II the physical environment of the model is described. The model is one in which agents have identical, arbitrarily-long planning horizons. These agents have an endowment of the consumption good in the first period of their life and can hold fiat currency, which would enable them to consume in future periods. It is shown that the equilibrium price level takes an interesting form. In Section III the dynamics of the model are explored. Section IV contains a discussion of the implications of these results.

II. THE MODEL

In this economy time is discrete and is indexed by t=1,2,... . At each date (t) there are born H identical agents, who will be referred to as members of generation (t). Each agent lives for N periods where $2 < N < \infty$. An individual born in period (t) is endowed with y_t units of the consumption good in period (t) and receives no other such endowment in any subsequent period. To preclude certain risk-sharing agreements, it is assumed that the value of (y_t) is realized prior to or simultaneously with the appearance of generation (t). Each agent who is a member of generation (t) seeks to maximize the expected value of the discounted finite sum of utilities

$$E_t\{\sum_{i=1}^{N} \beta^{i-1} \ln(C_i^{t+i-1})\} \qquad \beta > 0 .$$[1]

Here C_i^{t+i-1} refers to period (t+i-1) consumption of an agent who is of age (i). Here an agent who is born in period t will be said to be of age 1 in period (t).

In period (t) there exist M_{t-1} units of fiat currency which were brought forward from the previous period by agents. P_t is defined to be the price of fiat currency in units of goods. The remainder of this paper will deal with equilibria in which fiat currency is valued.

An agent who is a member of generation (t) may wish to purchase m_1^t units of fiat currency in period (t), at the price (P_t). Similarly, in period t+i $(1 \leq i \leq N-2)$ this agent will bring forth m_i^{t+i-1} units of currency from the previous period. The agent will choose to hold m_{i+1}^{t+i} units of the currency at the end of this period. In addition the government can levy a lump-sum tax of τ_t units on the endowments of agents who are members of generation (t). In each period (t) the government can also augment the total supply of currency by the amount $(M_t - M_{t-1})$ through, say, an increase in government consumption.

At date t=1 there are H(N-1) agents whose behaviour has yet to be described. There are H agents who live for n periods for n=1,2,...N-1. An agent who lives only n more periods, including period t=1, maximizes the utility function

$$\sum_{i=1}^{n} \beta^{i-1} U(C_{N-n+i}^{i})$$

where C_{N-n+i}^{i} denotes period (i) consumption of an agent who, at time (t=1), lives for only (n) more periods. At time t=1 an agent who lives from period 1 until period n, where $1 \leq n \leq N-1$, currently holds m_{N-n}^{0} units of currency. It is assumed that $m_{N-n}^{0} > 0$ for all such n, which is an initial condition for the economy. The market clearing condition for this economy is

$$H \sum_{i=1}^{N-1} m_i^t = M_t ,$$

for t=1,2,3,... . Since all members of a generation are identical, it will simplify the analyses, with no consequent loss of generality, if it is assumed that H=1. However, at any date (t) the population will still be heterogeneous because of the existence of agents who are of different ages, and who likely hold different portfolios.

An agent who is a member of generation (t) (t=1,2,...) then solves the following problems

$$\max E_t \{ \sum_{i=1}^{N} \beta^i \ln(C_i^{t+i-1}) \}$$

subject to the constraints

$$C_1^t = (y_t - \tau_t) - P_t \cdot m_1^t \qquad (1)$$

$$C_i^{t+i-1} = P_{t+1} \cdot (m_{i-1}^{t+1-2} - m_i^{t+i-1}) \qquad i = 2,3... N-1 \qquad (2)$$

$$C_N^{t+N-1} = P_t + N - 1 \cdot (m_{N-1}^{t+N-2}) \qquad (3)$$

This problem must be solved recursively to find the optimal money holdings in each successive period. In period (t+N-2) an agent who is a member of generation (t) will choose m_{N-1}^{t+N-2} in such a way as to solve the first order condition

$$\left[\frac{P_{t+N-2}}{P_{t+N-2} (m_{N-2}^{t+N-3} - m_{N-1}^{t+N-2})} \right] = \left[\frac{\beta}{m_{N-1}^{t+N-2}} \right]$$

and so

$$m_{N-1}^{t+N-2} = \left(\frac{\beta}{1+\beta}\right) m_{N-2}^{t+N-3} .$$

This then implies

$$C_{N-1}^{t+N-2} = \left(\frac{1}{1+\beta}\right) P_{t+N-2}\, m_{N-2}^{t+N-3}$$

Recursive substitution into the first order condition resulting from solving the optimization problem at time (t+N-2) yields

$$m_{N-2}^{t+N-3} = \left[\frac{\beta+\beta^2}{1+\beta+\beta^2}\right] \left(m_{N-3}^{t+N-4}\right)$$

and

$$C_{N-2}^{t+N-3} = \left[\frac{1}{1+\beta+\beta^2}\right] P_{t+N-3} \left(m_{N-3}^{t+N-4}\right).$$

In general it can be shown that the optimal decision rules take the form

$$m_{N-i}^{t+N-i-1} = \left[\frac{\sum_{j=0}^{i-1} \beta^{j+1}}{\sum_{j=0}^{i} \beta^{i}}\right] \left(m_{N-i-1}^{t+N-i-2}\right), \qquad i=1,2,...N-2 \qquad (4)$$

$$C_{N-i}^{t+N-i-1} = \left[\frac{1}{\sum_{j=0}^{i} \beta^{i}}\right] P_{t+N-i-1} \cdot \left(m_{N-i-1}^{t+N-i-2}\right) \qquad i=1,2,...N-2 \qquad (5)$$

Lastly, solving the optimization problem which the agent faces in the first period of his life yields

$$P_t\, m_1^t = \left[\frac{\sum_{j=1}^{N-1} \beta^{j}}{\sum_{j=1}^{N} \beta^{j-1}}\right] (y_t - \tau_t) \qquad (6)$$

and

$$C_1^t = \left[\frac{1}{\sum_{j=1}^{N} \beta^{j-1}} \right] (y_t - \tau_t) \qquad (7)$$

Note that the optimal consumption and money-holdings in equations (1)-(4) are void of any expectations operator. An unfortunate consequence of this is that equilibrium holdings of currency are not functions of expected rates of return.

Equilibrium in the market for capital dictates that

$$\sum_{i=1}^{N-1} m_i^t = M_t .$$

Through the use of equations (1) and (3), this can be rewritten as

$$\left[\frac{\sum_{j=1}^{N-1} \beta^j}{\sum_{j=1}^{N} \beta^{j-1}} \right] (y_t - \tau_t) + P_t \sum_{i=1}^{N-2} \left[\frac{\sum_{j=0}^{N-i-2} \beta^{j+1}}{\sum_{j=0}^{N-i-1} \beta^j} \right] (m_i^{t-1}) = P_t \cdot M_t$$

The equilibrium price of money is then

$$P_t = \left\{ M_t - \sum_{i=1}^{N-2} \left[\frac{\sum_{j=0}^{N-i-2} \beta^{j+1}}{\sum_{j=0}^{N-i-1} \beta^j} \right] (m_i^{t-1}) \right\}^{-1} \left\{ \left[\frac{\sum_{j=1}^{N-1} \beta^j}{\sum_{j=1}^{N} \beta^{j-1}} \right] (y_t - \tau_t) \right\} \qquad (8)$$

Equation (8) is a reduced form function which shows how the price level depends upon the state of the economy. In particular, the determinants of the price level include the endowment (y_t), the money supply (M_t), and the existing money holdings of all agents (m_i^{t-1}, i=1,2,...N-1) which were determined in the previous period. This is a novel feature and will be important in the sequel. These existing money holdings are determined by the constraints which agents faced in previous periods. Hence the price level is indirectly affected by such things as endowment or money supply shocks which occurred in previous periods. For example, consider the pathological case in which all currency was held by agents of age two. Then the price of currency is determined as

$$P_t = \left\{ M_t - \left[\frac{\sum_{j=0}^{N-3} \beta^{j+1}}{\sum_{j=0}^{N-2} \beta^{j}} \right] (m_1^{t-1}) \right\}^{-1} \left\{ \left[\frac{\sum_{j=1}^{N-1} \beta^{j}}{\sum_{j=1}^{N} \beta^{j-1}} \right] y_t \right\} .$$

And in the other polar case where all currency is held by agents of age N the price level is

$$P_t = \left\{ M_t - \left(\frac{\beta}{1+\beta}\right)(m_{N-1}^{t-1}) \right\}^{-1} \left\{ \left[\frac{\sum_{j=1}^{N-1} \beta^{j}}{\sum_{j=1}^{N} \beta^{j-1}} \right] \right\} y_t .$$

It will be shown that the inflation rate in any period will also depend upon decisions made in previous periods. This is a novel feature when compared with existing general equilibrium models which have a role for money. In the infinitely-lived representative agent model, or the two period-lived overlapping generations model there is either an absence of heterogeneity, or a trivial heterogeneity of the population. As a result, the above described features are absent from these models.

III. DYNAMICS

Although equation (8) is illustrative of the novel features of this model, it is analytically cumbersome. Therefore it will be illuminating to consider a few examples of experiments which are conducted with the model. First however, it is important to note that equation (8) is a function of variables which are known at time (t). This is beneficial because this will permit the analysis of the total effect on the economy of a single specific shock--without complicating the analysis with further disturbances.

Figure 1 shows the impact on the inflation rate of a tax on endowments which raises government consumption. The economy is assumed to be in its steady state prior to period 1.[2] In period 1 there is a lump-sum tax levied on agents who are in the first period of their life, which is equivalent to half their endowment. Agents are assumed to live for five periods. As the diagram illustrates, the inflation rate can be affected in a prolonged manner by such an event. The rate of inflation exhibits oscillations which are dampened as the economy approaches the steady state. Clearly the effects of the policy on the inflation rate last long after the agents who were directly affected by the policy have left the economy. In addition, the cycles which the inflation rate exhibits in Figure 1 have a frequency of 4 periods. That is, time periods 1, 2 and 3 etc. are the same stage at the cycle as periods 5, 6, and 7 etc., respectively.

Figure 1 also shows the impact on the inflation rate of a one-period shock to the endowments. That is if the economy was in its steady state with $y_t = 10$ for $t \leq 0$, $y_1 = 5$, $y_t = 10$ for $t \geq 2$, the inflation rate would react as illustrated. Again notice that the agents who were the source of such a shock leave the economy in period 5, but the inflation rate still deviates from its steady state level (of zero) in period 14!.

Though the government could increase its consumption by raising taxes, presumably it could do so also by means of an inflation tax as well. Figure 2 shows the path of the price level when the government doubles the outstanding supply of fiat currency in order to increase its own consumption. In this case agents have a planning horizon of ten periods. In period (0) the economy is in its steady state, and the supply of currency is doubled in period 1. The price level increased dramatically in the period in which the extra amount of currency is introduced. Agents who enter this economy in period t = 1 then face a lower price of currency in terms of goods. Hence they purchase more (nominal) currency than they otherwise would have purchased. These agents benefit from the increase in the amount of currency. As they sell off their currency holdings over their lifetime the price level rises. The big jump in the price level in period 10 is a result of the agents, who are members of generation t = 1, selling off their rather large remaining currency holdings. At time t = 10 the economy begins to repeat a cycle similar to that which began at t = 1. As can be seen, the price level follows a cyclical path which converges to the new steady state. The length of the cycle is 9 periods. Again it should be noted that the price level still fluctuates long after the agents, who were present when the money supply increased, have left the economy. In fact, the economy still displays 4% inflation 18 periods after the initial disturbance.

In Figures 1 and 2 the frequency of the cycles is directly related to the length of the planning horizon of the agents in the economy. The length of the cycles in these examples is equal to the length of the agent's planning horizon minus one. Hence, if the above experiments were conducted for the economy in which agents live for two periods, a similar pattern for the price level (or inflation rate) would emerge as for the same experiment conducted on an economy whose agents had an infinite planning horizon. Therefore, there may be very interesting reasons for considering economies which are alternatives to the two period-lived overlapping generations model, and the infinitely-lived representative agent construct.

It may be enlightening to consider augmenting the agents budget constraints, equations (1) - (3), to include the possibility of proportional monetary transfers. If agents can receive such transfers the budget constraints can be rewritten as

$$c_1^t = (y_t - \tau_t) - P_t m_1^t$$
$$c_i^{t+i-1} = P_{t+i} (\gamma_i^{t+i-1} \cdot m_{i-1}^{t+i-2} - m_i^{t+i-1}), \ i = 2,3...N-1$$
$$c_N^{t+N-1} = P_{t+N-1} \cdot m_{N-1}^{t+N-2} \cdot \gamma_N^{t+N-1}$$

Here $(\gamma_i^t - 1)$ represents the proportionate increase (decrease if negative) in currency holdings in period t for an agent who is in the i^{th} period of his life. In this case the optimal currency holdings are determined by equation (6) together with the following

$$m_{N-i}^{t+N-i-1} = \frac{\sum_{j=0}^{i-1} \beta^j}{\sum_{j=0}^{i} \beta^j} (\gamma_{N-i}^{t+N-i-1} \, m_{N-i-1}^{t+N-i-2}) \ , \ i = 1,2...N-2$$

In this case if every agent who held currency at the beginning of a period had their currency holdings doubled through an identical equi-proportional transfer, the sole effect would be that the price level would double and the economy would not exhibit other after affects.

It may be of some interest to consider making the (ad hoc) assumption that agents cannot insure themselves against the impact of fiscal policy which is introduced in this manner. This will permit the analysis of the impact of different policies on the price level. Figure 1 illustrates the impact on the inflation rate of a lump-sum tax whose proceeds are given to agents in the final period of their life in the form of a proportioned monetary transfer. This is because the effect on the price level is the same if the government consumes the goods or the agents in the final period of their life get them instead. Figure 3 illustrates the impact on the inflation rate of the same tax with the proceeds given to agents in the second period of their life. Figures (1) and (3) clearly display quite different paths for the inflation rate for quite similar policies. Similarly, it can be shown that increases in the money supply which are introduced in different manners, can have quite different impacts on the inflation rate.

IV. DISCUSSION

The model constructed in this paper has been used to show that certain fiscal policies can have an impact on the price level and consumption allocations over a protracted period of time. The overlapping generations construct, or the heterogeneity of the population serves as a propogation mechanism whereby policies can have a prolonged effect on the price level.

An unfortunate consequence of the specification of the utility function was that the optimal currency holdings did not depend upon the distribution of expected rates of return. Incorporating this feature into the economy would make the analysis somewhat more complicated. However, it seems that such an alteration would not abrogate the main point of this analysis: namely, that temporary shocks can have persistent effects upon an economy.

In this model agents transfer wealth from one period to the next by holding fiat currency. It would be straightforward to add another group of agents to the model who would be forced to borrow against their endowments, which are received at the end of their planning horizons. These agents could be termed borrowers and the securities these agents issue could be termed inside money. The existing agents (lenders) would then hold both inside and outside (fiat) currency. The price level could then exhibit prolonged fluctuations to changes in both the quantity of outside and inside money. Changes in the amount of inside money could be introduced by a change in the number of borrowers, or a change in their endowments. Therefore, the price level could potentially exhibit a prolonged response to shocks which are not attributable to changes in policy.

Although the existing model of this paper shows how one disturbance can influence the price level over several periods, the model does not produce similar behaviour for other real aggregates such as output. This is merely because output was assumed to be exogenous in order to simplify the model. It is therefore interesting to consider the results of this paper in a broader context. Consider augmenting the model of this paper by introducing a non-trivial labour supply decision for agents, so that it is an N-period version of Lucas (1972). In addition agents observe the price level but not the portfolio holdings of others. In this case it is conceivable that a one-period increase in the money supply, or a one-period tax-transfer scheme, could alter the inflation rate over several periods. This could change agents' intertemporal marginal rates of substitution and alter the amount of output produced in the economy. Since the policy has already been seen to have effects on the price level over many periods, such a policy could also cause the level of output to fluctuate over many periods as well. This could result in output changing over many periods in reaction to a one-period change in a policy variable. Furthermore, the lagged effects on real variables can be produced without having to resort to such things as learning or incomplete information.

If an agent's endowment were instead the output resulting from a labour-leisure choice problem combined with a production function, a change in the endowment may be interpreted as a change in the marginal productivity of that agent. This shock could then potentially have an impact on the price level (Figure 1). This in turn could cause changes in the amount of output other agents would wish to produce. Therefore, changes in the marginal product of an agent could conceivably cause changes in the amount of output produced by all agents over several periods after the initial shock.

Whereas Kydland and Prescott (1982) showed that the time-to-build technology served as a propogation mechanism, this paper implies that the natural heterogeneity of the economy could perform a similar task.

The preceeding analysis also sheds some light on the difficulties involved in considering an individual's optimization problem when agents have arbitrarily long planning horizons. In a two period-lived overlapping generations model, or in an infinitely-lived representative agent model, knowledge of the growth rate of the money supply from one period to the next is generally sufficient for the determination of the inflation rate over this period. This is not the case in the model of this paper. If agents are to forecast the rate of inflation accurately they must know not only the rate of growth of the currency supply and how currency is being introduced into the economy, but agents must also know <u>the existing portfolios of agents of all ages in the economy</u>. Accurate forecasting then entails that an agent must acquire information on the behaviour of other agents as well as the policymaker. This problem would be compounded if agents did not have the same planning horizon. This stands in contrast to the analysis of Lucas and Stokey (1984) where the <u>only</u> impact of a given increase in the money supply was as a <u>signal</u> concerning the future state of the economy. In their model given change in the supply of currency which carried no information concerning the future of the economy would then have no affect upon real allocations. In the framework of the present paper, however, changes in the supply of currency, which are subsequently known by everyone, have prolonged effects upon the price level as well as on individual allocations.

Lastly, it has become a popular pastime among some to ask whether movements in the price level can be attributed to "speculative or price-level bubbles". Flood and Garber (1980) define such bubbles as instances in which the price is "driven by arbitrary, self-fulfilling elements of expectations". Since such expectations are not observable, one is left to examine whether the variability of prices can be attributed to "real factors". Consider an observer of the economy whose behaviour is displayed in, say, Figure 1. The observer would see a rather variable price level from period (2) onward, <u>without any contemporaneous fluctuations in aggregate output</u>. An observer might then be tempted to conclude that real factors, or changes in the supply of currency could not be responsible for the variability in prices, and that therefore it must be a very peculiar expectations mechanism which is the driving force behind these cycles. Of course, such a view is seriously flawed and results from not considering the impact of distributional forces on prices.

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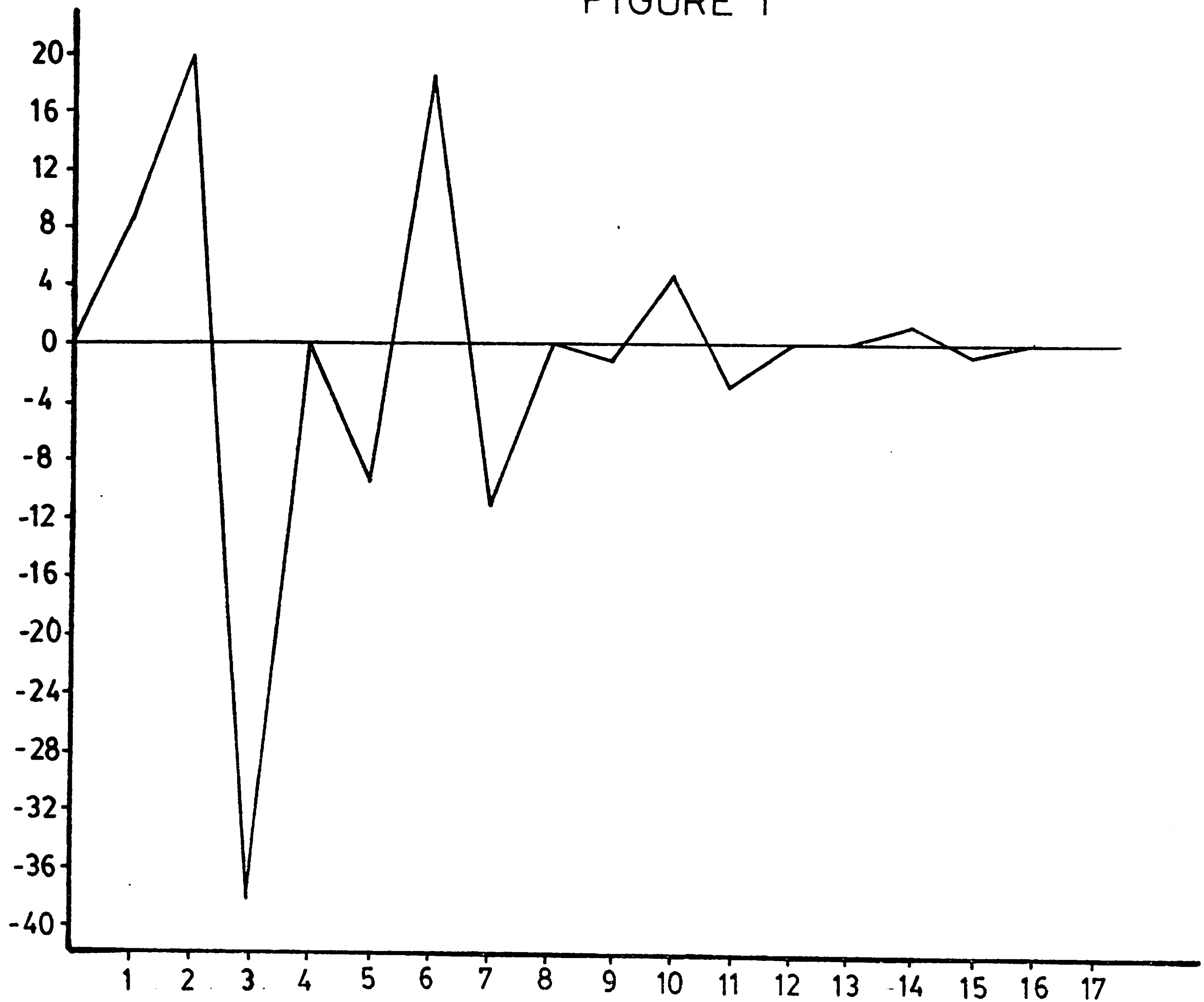
FOOTNOTES

[1]It would appear that some generality is lost with this particular specification of the utility function. However, the advantage of this specification is that it leads to tractable decision rules. The results of this paper are intended to be illustrative. It should be clear that similar results could be obtained from a more general model.

[2]This will permit the analysis of the effect the change in the money supply along will have upon the economy. That is, the effects shown in Figure 1 are <u>not</u> in any way attributable to previous distributional effects or to other disturbances.

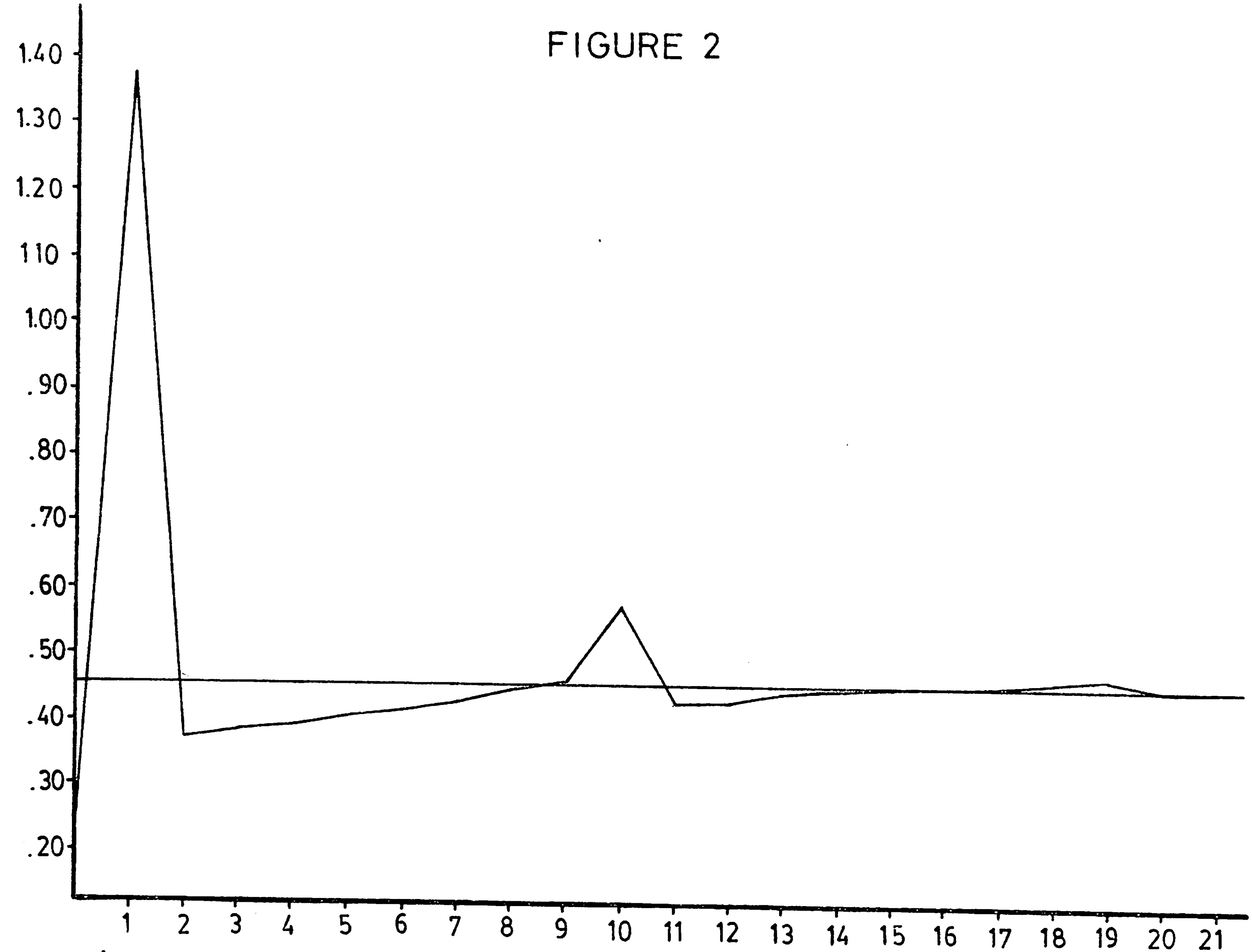
FIGURE 1



$(y_t - \tau_t) = 10.0$ for $t \neq 1$, $(y_1 - \tau_1) = 5.0$

$M_t = 10.0$, $\beta = .95$, $N = 5$

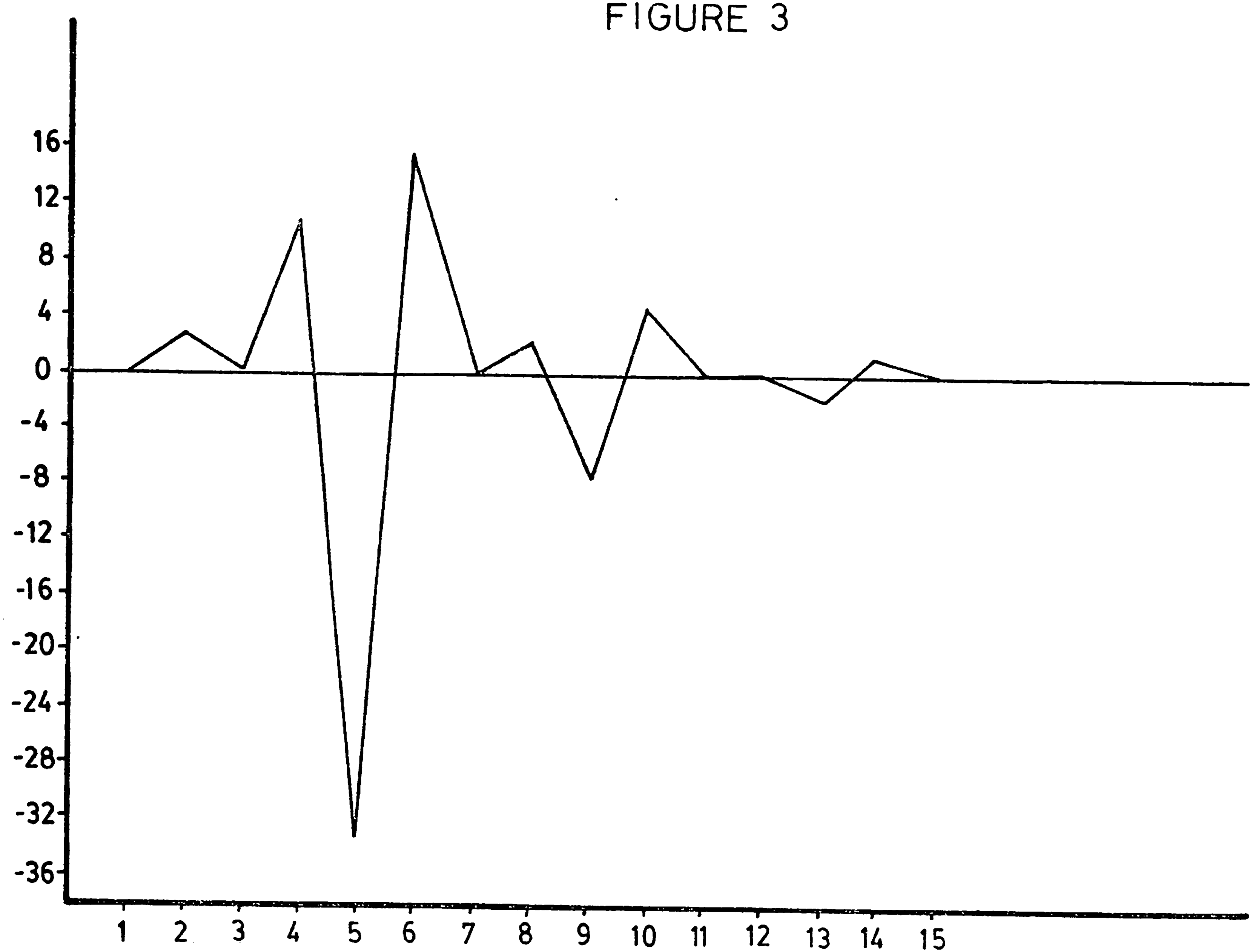
FIGURE 2



$(y_t - T_t) = 10.0$ for all t, $\beta = .95$, $N = 10$

$M_0 = 10.0$, $M_t = 20$ for $t \geqq 1$

FIGURE 3



$(y_t - T_t) = 10.0$, for $t \neq 1$, $(y_1 - T_1) = 5.0$, $M_t = 10.0$, $\beta = .95$, $N = 5$,
$\gamma_2^1 = 2.3621$, $\gamma_j^i = 0$ for all other i,j

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