THE BUSINESS CYCLE AND MONEY

An Analysis of the Inventory Investment Hypothesis

James H. Hines, Jr.
Sloan School of Management
Massachusetts Institute of Technology
Cambridge, massachusetts 02139

Abstract

Among the most stable phase relationships between economic variables is that between money, the change in money, and general economic activity. Both the change in money and money itself lead production over the business cycle. This relationship, buttressed with results of the Granger/Sims test for causality, has been used to support the notion that money causes real activity. This notion, in turn, is used to argue both that monetary policy causes the business cycle and that monetary policy can ameliorate the business cycle.

This paper examines a hypothesis for the phase relationships which assumes that money does not cause real activity, but, rather, real activity causes money. According to the hypothesis inventory investment, which leads business activity, induces corporate borrowing, which in turn causes a money expansion with a lead similar to that observed. This has been a working hypothesis for the phasing in money of the System Dynamics National Model Project. It is concluded that the hypothesis, by itself, is insufficient to account for the observed timing relationships. However, the inventory investment hypothesis combined with additional hypotheses such as a mechanism for household portfolio adjustment, can account for the phasing. These results do not depend upon a causal flow from money to real activity. As a consequence, business cycle phase relationships should not be taken to imply money causes the business cycle nor that monetary policy can influence the business cycle.

This paper has benefited from the comments and suggestions, some expressed with considerable vigor, of Bob Eberlein, Mark Paich, George Richardson, Peter Senge, and John Sterman.

Questions of Timing and Policy. Arthur Burns and Wesley Mitchel developed the first list of leading, coincident and lagging indicators in 1937 (Moore 1978). Interest in the phase relationships between economic time series has continued ever since. In summing up the work conducted over the past two generations, Robert Lucas states:

> Though there is absolutely no theoretical reason to anticipate it, one is led by the facts to conclude that, with respect to the qualtitative behavior of comovements among series, business cycles are all alike. (Lucas [1977] 1981, 218)

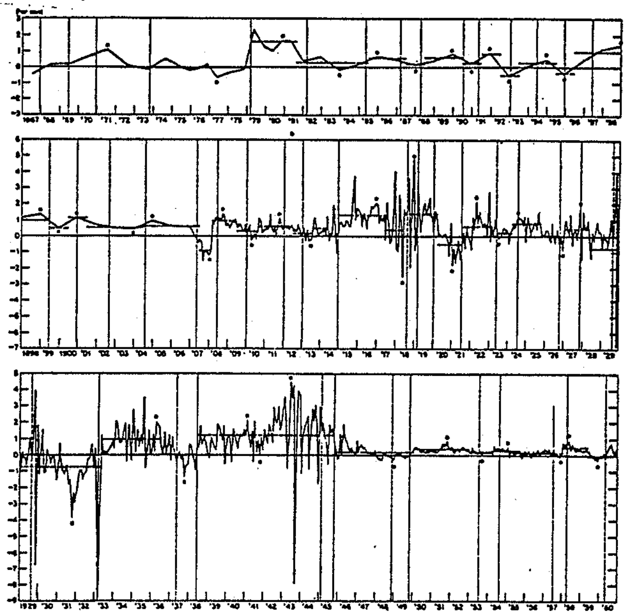
Lucas intends his observation to hold across time and across all countries with decentralized market economies.

Perhaps no relationship between economic time series has been as thoroughly noted as that between money and real activity. The data indicate that movements in both the change in money (M1 or M2) and the stock of money lead movements in general economic activity (M.Friedman February, 1963; Batten and Hager 1982; Lucas 1977). Figure 1 presents the relationship between the change in money and the NBER reference cycles from 1867 to 1960. Figure 2 presents the relationship between various money series and the NBER reference cycles from 1956 to March, 1983. The Change in money (M1) has led the NBER reference cycles at the peak by an average of 21 months and at the trough by 7 months; while the money supply in constant dollars (M1) has lead by an average of about 12 months at the peak and 8 months at the trough (BCD, 1977). Leads for M2 differ slightly.

BCD (1977) gives scores between 0 and 100 to time series based upon the reliability of the phase or timing relationship. A series which always shows a given timing relationship (lead, lag, or coincident) would recieve a score of 100. A series which has no consistant phase relationship would recieve a score of zero. Change in M1 gets an overal timing score of 64; M1 itself receives a timing score of 86 and is included as one of the

Figure 1: change in Money & the Business Cycle 1567- 1960

MONTH-TO-MONTH RATE OF CHANGE IN U.S. MONEY STOCK, 1867–1960

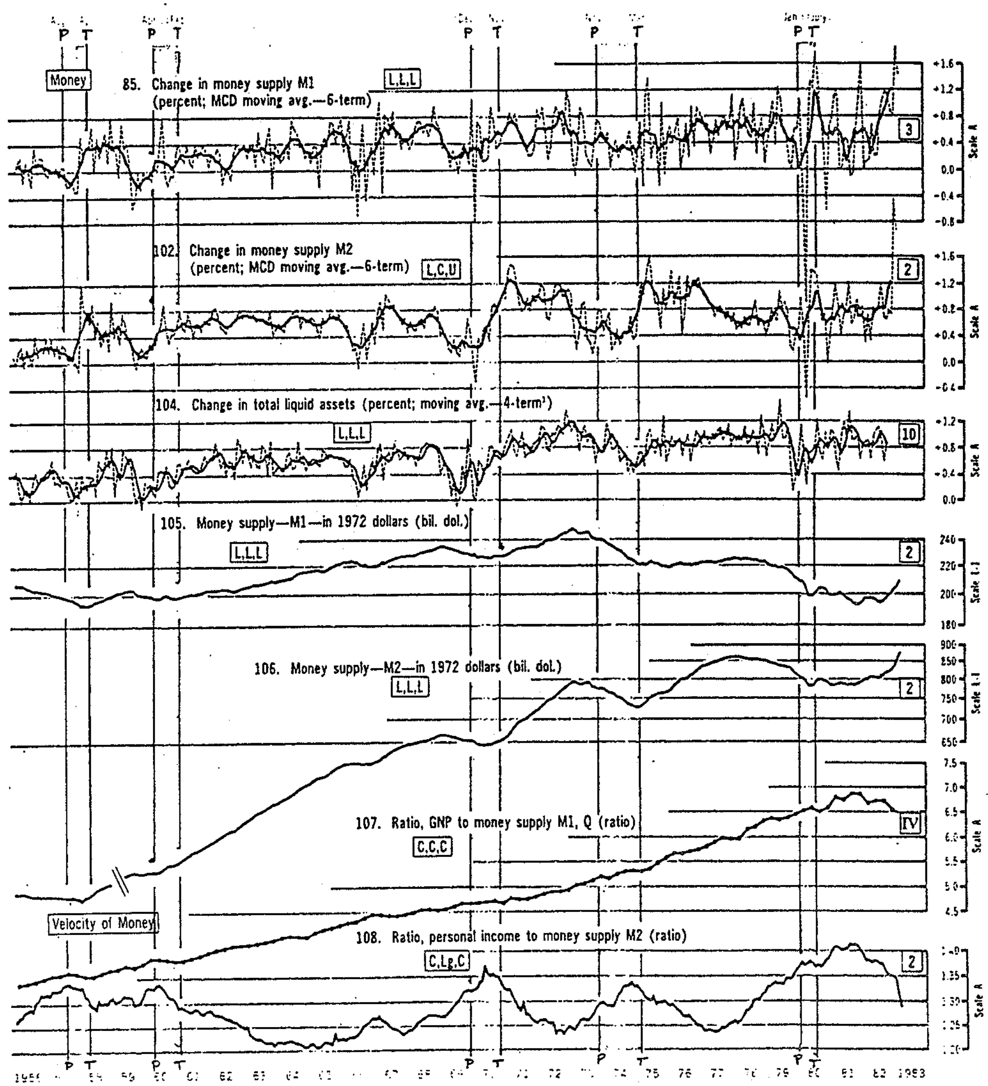


NOTE: Solid vertical lines represent reference cycle troughs; broken lines, peaks. Dots represent peaks and troughs of specific cycles. The horizontal broken lines represent high and low steps in the rate of change.
SOURCE: In the annual or semiannual segment, 1867–1907, the change in natural logarithm from one date to the next in the data underlying Chart 1 was divided by the number of months intervening, and the quotient plotted at the middle of the month halfway between. In the monthly segment, 1907–60, the month-to-month change in natural logarithm was plotted in the middle of the second month. Reference dates are from the National Bureau (see Table 1).

(from Friedman and Schwartz 1963, 194)

Figure 2: Financial Variables 1956-1983

Money and Credit



This is a weighted 4-term moving average (with weights 1,2,2,1) placed on the terminal month of the span.
Current data for these series are shown on page 71.

BCD MARCH 1983

NOTE: P - Peak T- Trough

twelve leading indicators. The mean score, for the 111 cyclical indicators, is 76 with a standard deviation of 18.

While, the relationship between money and business activity has long been observed, the relationship between credit and business conditions has also recently been studied. Benjamin Friedman concludes that:

> The relationship between credit and nonfinancial economic activity exhibits stability that is comparable to that of the relationship between money and economic activity. (Benjamin Friedman 1982)

Friedman goes on to note that

> The econmic behavior underlying the stability of the credit-to-income relationship remains a major puzzle -- though, on reflection, no more so than the stablity of the money-to-income relationship. (Benjamin Friedman 1982)

The puzzle of why the data reveal these consistencies is of importance as a theoretical question. The existence of stable timing patterns suggests the existence of stable causal mechanisms (Lucas 1977). Beyond this, it is often suggested that the stable lead of money with respect to real activity is evidence for a causal link from money to real activity (M.Friedman 1963, M.Friedman 1969, Cagan 1965, Cagin in Entine 1965, Meigs 1968). While the easy association of timing and causality has been vigorously contested (Tobin 1970, Frisch 1933), more sophistocated econometric techniques designed to test causal direction from time series data have more recently been employed. These suggest that money does cause GNP (Sims 1972).

The step from causation to policy is a small one. Current public debate over the role of the Fed with respect to the current economic difficulties reveals nothing if not the existance of a sizable group of people who believe that monetary policy can influence real activity with a lag shorter than or equal to the phase lag observed in the data. For example, a major news magazine states that "in the fall of 1979 ... Volker abruptly

changed the focus of the Federal Reserve's policy ... to slow the growth of money and credit ... This sent the economy into recession". The article attributes to subsequent Fed actions in the summer of 1982 "the present recovery" including a slight drop in unemployment, a rise in retail sales, an expected profit in the auto industry, and a one week jump of 46.63 in the Dow Jones industrials. (Time, vol. 121 no.17, April 25, 1983, pp.96-97).

In spite of the great hopes (and fears) that people place in the Fed, we do not yet have a comprehensive, let alone consensus, understanding of the impact of monetary variables on non-financial economic activity (Lucas 1977, B. Friedman 1982). There is a need to understand the underlying causes of the observed lead of financial variables with respect to aggregate economic activity. We need to be able to explain why the data do what they do.

An explanation will help provide answers to the monetary questions of current public concern: Does monetary policy cause the business cycle? Is monetary policy a high-leverage means of controlling the business cycle?

<u>Paper Purpose</u>. The purpose of this paper is to examine one hypothesis for the phase relationships between the stock of money, the change in money, and production. The hypothesis, briefly stated, is that inventory investment is financed through borrowing which causes a money expansion with the observed phase relationship relative to the business cycle.

Prior to the present study, this was the working hypothesis of the System Dynamics National Model Project. It accorded well with results suggesting that the observed lead in financial variables with respect to real variables was not a result of causal flow from money to real economic activity (Senge and Paich 1980). The results reported in this paper suggest that the inventory investment hypothesis alone is insufficient to account for the the phase relationships. However, an elaborated version of the hypothesis is presented which can account for the phase relationships. The augmented hypothesis is also in accord with earlier results that the business cycle arises independently of financial variables.

Jay Forrester has expressed the inventory hypothesis succinctly.

> Peaks in the growth of money have occured shortly before busniess-cycle peaks in production ... Business-cycle fluctuation is generated within the private-business part of the economy. As inventories rise, investment in inventories is supported by borrowing money, which increases the money supply. Inventories rise most rapidly shortly before the peaks of production and produce the observed changes in the money supply. (Forrester 1982, 32-33)

This suggestion has much to recommend it. Consider what causes a change in money in our economy. The monetary authority may increase the reserves of banks by buying government bonds from private holders. This act will increase the money supply immediately as long as the monetary authority does not buy the bonds from banks. But, in the scheme of money creation this immediate effect will prove to be rather small. What accounts for the lion's portion of a money supply increase is the money-multiplier. The money multiplier, of course, operates through a process involving the borrowing (and redepositing) of free reserves. The question of money creation, therefore, is the question of borrowing.[2]

Schumpeter in a similar context noted

> Any satisfactory analysis of causes must start with what induces that credit expansion, as every satisfactory analysis of effects must start by investigating what is done with the increased monetary resources. (Schumpeter 1935, 14).

What are the causes of the credit expansion? In the macro-economy the household sector is a net holder of financial assets, while the production sector is a net holder of financial liabilities. This suggests that a consideration of corporate borrowing over the business cycle might be of value in looking for the source of net pressures for credit in the financial

system. There are several reasons businesses might borrow. Perhaps the most basic is simply to meet meet cash expenses: Businesses borrow when their cash flows are negative and repay their obligations when cash flows are positive.

It has been argued (N. Forrester 1982, Mass 1975, Low 1980) that the business cycle has much to do with inventory investment and less to do with investment in capital plant and equipment. This suggests that business cycle phase relationships between money and real activity may result from negative cash flows associated with inventory investment.

Financial Activity and Real Activity. Philip Cagan would suggest that by assuming the business cycle to be little influenced by money or other financial variables, one enters

> a debate continuing for centuries [which] pits the classical writers, who view money as an independent source of economic disturbance, against the critics of this view, who say money is a passive adapter to business conditions with little independent influence. (Cagan, 1965, p.xiv)

The current paper, while questioning the adequacy of the current system dynamics working hypothesis, nonetheless joins prior work in taking the side of the "critics". However, the causal arena in which we intend to take sides is not as wide as might first appear.

First, let us distinquish between two or three types of cycles. Friedman and Schwartz (1963) divide business cycles into mild cycles (eg. 1958-61) and severe cycles (eg. 1927-1933). They conclude that the case is strong for a monetary cause of major downturns, and less strong for a monetary cause of minor downturns. Cagan (1965) comes to much the same conlusion. Forrester (1983), for his part, believes that money is not a prime cause of the "business cycle" which he associates with mild downturns, but believes that monetary policy or the behavior of financial variables may help to aggravate or alleviate major downturns (personal communication 1983).

If the influence of money on real activity were absent in only one circumstance, it appears there is some agreement that that circumstance would be mild-downturns or, in Forrester's terms, the business cycle proper. As a consequence, the current effort focusses on the mild and more frequent downturns which recur with a period of two to seven years. I associate these cycles with what Forrester and Volker (1978) call business cycles and what Schumpeter (1935) merely notes as a cycle of roughly forty months.

It is important, nonetheless to be clear about the mechanisms we are considering and those we are not. In brief, the assumption implicit in the inventory-investment hypothesis is that the demand for credit primarily determines the money supply. When businesses demand funds to meet negative cash flows, that demand puts "pressure" on the financial system. The pressure is relieved by a process involving the simultaneous creation of money and credit.

It is beyond the scope of the current effort to consider the several (Cagan 1965) mechanisms by which money is made available. However, making the assumption that money is made available as needed is assuming no more than what is assumed in most econometric studies of the demand for money. These studies generally assume that money is endogenous (ie. a dependent variable); the justification offered is that the Fed has often appeared to be reacting to interest rates (Judd and Scadding, 1982).

A Model of Real Activity. In "Understanding Business Cycles", Lucas presented a model in words rather that in mathematical symbols. He later wrote:

> Isn't it remarkable how simple it all becomes in plain English? Yet how deceptive this simplicity is: The description of inventory behavior ... is as coherent as the description of accelerator effects, yet the latter is a verbal transcrition of a fully worked-out model while the former is only conjecture. (Lucas, 1981, p.15)

Much of the argument to be carried out below could have been

developed in "plain English" without reference to a mathematical model. By presenting the analysis in the context of a mathematical model, I hope not to sacrifice simplicity, but only to avoid deception.

The initial hypothesis explored here is an attempt to account for the phase relationship between real activity and money over the business cycle. The hypothesis assumes that real activity causes money through inventory investment and that money does not have an effect on real activity. This suggests that an appropriate starting point would be an inventory model of the business cycle in which financial variables do not effect real variables.

The model of the real sector to be presented here is very similar to both Metzler's model (1941) and several models (or parts of models) in the system dynamics literature (N. Forrester 1982, Mass 1975, Mass and Senge 1974, Lyneis 1980). The primary mechanism responsible for oscillations in these models is the interaction between workforce and inventory.

The model is formulated in continuous time. The basic model equations appear in figure 3. A graphical representation of the model appears in figure 4 using standard system dynamics symbols for stocks and flows (Richardson and Pugh 1981). A complete computer model, written in DYNAMO, is documented in appendix 3.

Figure 3: A Model of Real Economic Activity

(1) $\dot{I} = PR-SR$	Inventory (goods)
(2) $PR = W*PROD$	Production rate (goods/year)
(3) $SR = CGD*EAS$	Shipment rate (goods/year)
(4) $EAS = f(DSI/CGD)$	Effect of availability on shipments (dimensionless)
(5) $DSI = I/NIC$	Desired shipments from inventory (goods/year)
(6) $\dot{W} = (DW-W)/TAW$	Workforce (people)
(7) $DW = DP/PROD$	Desired workforce (people)
(8) $DP = IC+CGD$	Desired production (goods/year)
(9) $IC = (DI-I)/TCI$	Inventory correction (goods/year)
(10) $DI = CGD*NIC$	Desired inventory (goods)
(11) $\dot{HSAV} = TWR-HEXP$	Household savings (dollars)
(12) $TWR = W*WPP$	Total wage receipts (dollars/year)
(13) $HEXP = SR*P$	Household expenditures (dollars/year)
(14) $CGD = (TWR-CS)/P$	Consumer goods demand (goods/year)
(15) $CS = (DHSAV-HSAV)/TAS$	Correction to savings (dollars/year)
(16) $DHSAV = DWC*TWR$	Desired household savings (dollars)

Constants:

PROD	Productivity (goods/person)
NIC	Normal Inventory Coverage (years)
TAW	Time to Adjust Workforce (years)
TCI	Time to Correct Inventory (years)
P	Price (dollars)
TAS	Time to Adjust Savings (years)
DWC	Desired Wage Coverage (years)

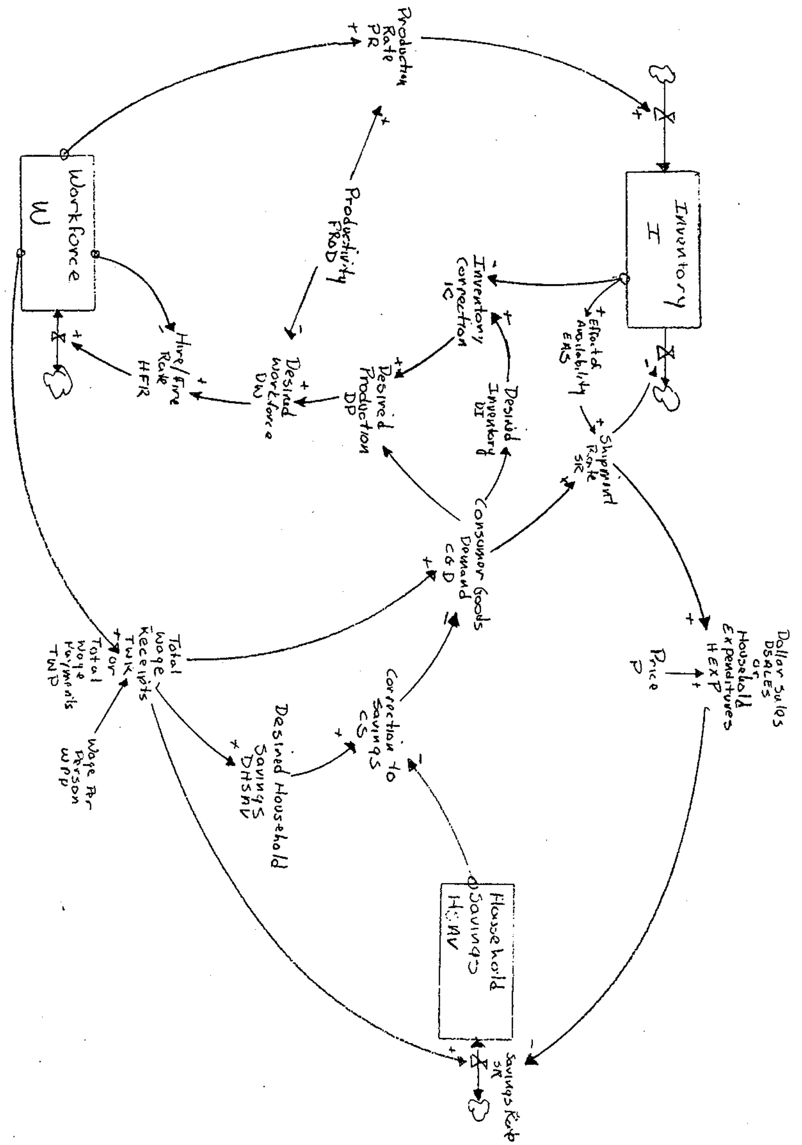


Figure 4: A Model of Real Economic Activity

Since there are three state variables in figure 3 (denoted by rectangles in figure 4), this set of 16 equations could be reduced to three first order differential equations or a single third order equation. The coefficients, which would have appeared in either of these more compact forms, have been disaggregated in order to clarify the behavioral assumptions underlying the model.

The rate of change in inventories is the difference between the production rate which increases inventory and the shipment rate which depletes inventory. The production rate is calculated as the number of workers multiplied by the average productivity per worker. Average productivity is assumed constant in this simple model. The shipment rate is a function of demand from consumers and the availability of goods. If goods are unavailable (ie. if inventories are low) shipments will be below consumer demand. If there is an excess of inventories, shipments may be slightly higher than consumer demand as sellers induce their customers to buy a bit more than they would have otherwise wanted.

The effect of availability on shipments is a nonlinear function of "desired shipments from inventories" and consumer goods demand. The shape of the function is presented in figure 5.

The independent variable (DSI/CGD) in the function defining the effect of availability on shipments (EAS) is a measure of the relationship between what retailers would like to ship or what their distribution network is designed to handle and what consumers are demanding. The actual shipment rate is a compromise between the two. When consumers demand too much, the distribution system is not adequate to ship everything that is demanded and consumers do not receive all they want when they want it.

A bit of algebraic manipulation gives another familiar way of looking at DSI/CGD:

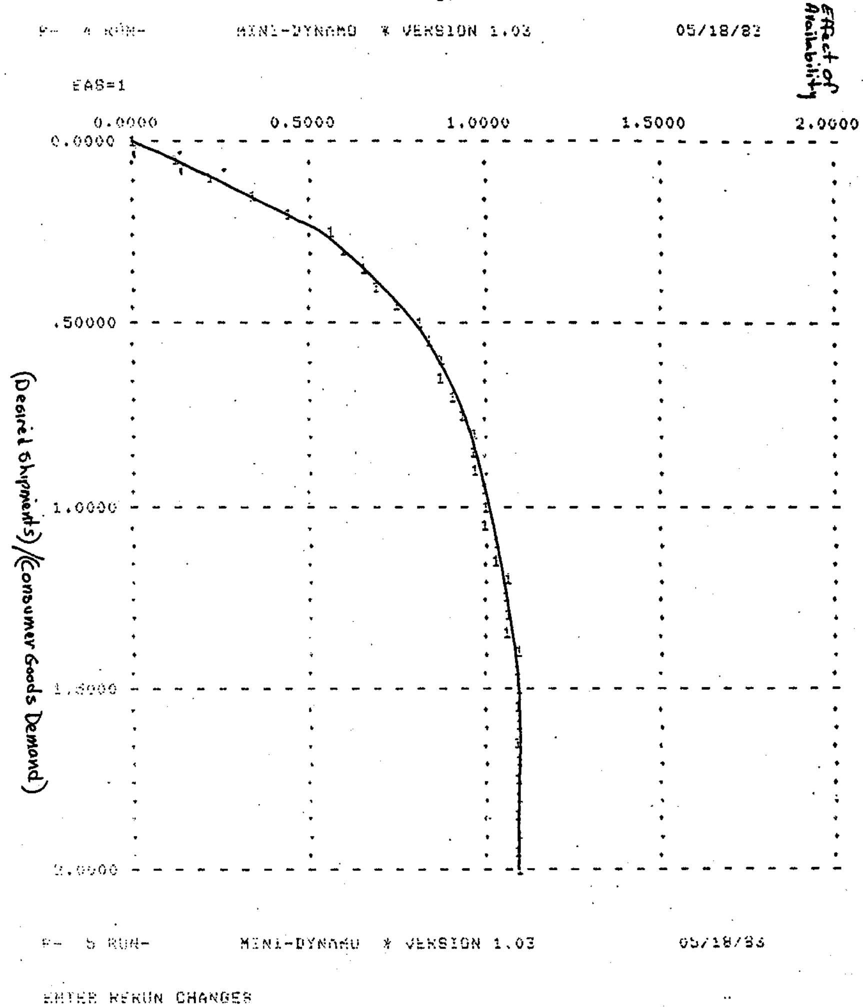


Figure 5: Effect of Availability on Shipments

$$(DSI/CGD) = (I/NIC)/CGD = I/(NIC*CGD)$$
$$= \text{Inventory / Desired Inventory} \quad \text{(i)}$$

the effect of availability on shipments may be interpretted as a stockout effect (Homer 1978).[3] The rate of change of the workforce is determined by a stock adjustment process. The actual workforce will adjust exponentially to the desired workforce with a time constant of TAW. Desired workforce (DW) is the number of people required to produce at the desired production rate (DP).

Desired production (DP) is composed of two terms: consumer goods demand and inventory correction. The former represents the production required to meet demand, while the latter represents the production rate necessary to exponentially adjust inventories to desired levels. The desired level of inventory (DI) is merely a normal coverage of consumer goods demand. In the context of equation (i) immediately above, this normal coverage may be interpretted as determining the level of inventory necessary to maintain a normal or desired stockout rate. In the current formulation, the normal or desired stockout rate is assumed to be zero. That is, when inventory equals desired inventory, consumer goods demand is met in its entirety. While a zero stock out rate is, no doubt, too low; it simplifies putting the system into equilibrium and changes no substantive results.

The rate of change of the stock of savings is the difference between total wage receipts and household expenditures. Total wage receipts is calculated as the average wage per person (WPP) multiplied by the number of people employed (W). Household expenditures are the dollar value of the goods shipped.
In addition to the actual level of savings, households have a desired level of savings which they form on the basis of their income. The flip-side of desired savings is, of course, desired expenditures or consumer goods demand (CGD).

Both Friedman (1957) and Modigliani and Bromberg (1952) saw the

consumption problem as one of allocating consumption through time. In general, this means that individuals will save while income is high and disave when income is low. In conformity with this, consumers in the model developed here wish to save some of their income for periods during their working years when they are, in fact, not working (or are working less); they also wish to save income from their working years for their retirement years.

Desired household savings (DHSAV) increases with income. On the one hand this results from the simple observation that it is easier to save when one is making more money, than it is when one is making less. Beyond this, however, savings are designed to yield a certain standard of living during non-working periods. This desired standard of living from savings is a function of the current standard of living: People who are used to the good life, will try to save in order to continue the good life when they are no longer working. They will, in fact, desire to save more than those who have not become accustomed to as good a life. The current attainable standard of living is proportional to income. Consequently, as income increases, desired savings must also increase.

Desired savings has been modeled as a constant number of years worth of income. The use of a constant here may be as reasonable as any other assumption. A slightly more complicated justification may be found in appendix 2.

The household attempts to adjust its actual savings stock to its desired savings stock. It does this by saving a portion of income which is designed to bring household savings (HSAV) up to desired over an adjustment time (TAS). The amount set aside is called "correction for savings" (CS).

The household is free to spend income (TWR) in excess of the correction for savings (CS). Indeed the very point of determining what to "set aside" is to know what may be spent. Consequently, consumer goods demand is formulated as the difference, adjusted for price, of total wage receipts TWR and and the correction for savings (CS).

This way of looking at the household's expenditure decision is a bit different from that of Friedman (1957). Friedman suggests that households set a consumption target based on "permanent" income. Some have equated consumption with expenditures. In this case the savings rate will fluctuate depending upon the relationship between current income and "permanent income", and expenditures will be smooth. On the other hand, in the model presented here, consumers set a savings target, and actual expenditures will fluctuate with income and the savings correction. The dynamic implications of this difference are considered in appendix 1.

Of course, Friedman, himself, did make a distinction between consumption and expenditure. He allowed that expenditures might fluctuate with current income, while "consumption" (e.g. use of, rather than expenditure on, durable goods) might not (Friedman 1957, p.28). Hence, Friedman thought that expenditures might fluctuate with income. Particularly in the current context, it is important to model expenditures, rather than consumption. The current formulation provides a simple, behaviorally plausible expenditure function.

It is interesting that the formulation suggested here may be manipulated as follows:

```
CGD = TWR/P - CS/P
    = TWR/P - (DWC*TWR - SAV)/(TAS*P)
    = (TWR/P)*((TAS-DWC)/TAS) + (1/TAS)*(SAV/P)
    = (Real Income)*C + A*(Real Wealth)
```


The last form of this equation is identical to the consumption function which Dornbusch and Fischer derive for the life-cycle hypothesis (Dornbusch and Fischer 1978, p. 147,152). The coefficients which they estimate imply a value for TAS of 25.64 years and a value of DWC of 6.67 years. These values are used in the model and seem reasonable: Since the average worker is employed for forty years or more and, since, this is the relevant period over which the worker must accumulate his savings, the average time to adjust savings twenty-five years is not as long as it might otherwise sound. As to the figure for coverage, assume the average worker retires at sixty-five with 6.67 times his average income in savings. He will have an average of about 16 years remaining to live (National Center for Health Statistics, 1982, table 5-3). If he has invested his savings at 5% (cf. Ibbotson and Sinquefield 1977, p.10), he will be able to recieve about sixty per cent of his average pre-retirement income until he dies. This seems to be a reasonable result. (Relevant formulae are in appendix 2).

Comparison with Similar Models. The first difference between this model and Metzler's (1942) model is that Metzler's was a discrete time model, while the above is a continuous time model. Beyond that, the delay between desired production and output is explicitly attributable, in the model developed here, to the movement of people into and out of the workforce through hiring, firing, and quits.

One structural difference is the more sophistocated expenditure function. Whereas Metzler in effect assumed a fixed average propensity to consume, the present model has an average propensity to consume which varies with the relationship between actual savings and desired savings. The propensity to consume in a stationary unstressed equilibrium (ie. an equilibrium in which actual quantities are equal to desired quantities) is one. Figure 6 presents a plot of the average propensity to consume after the model has been disturbed from equilibrium by a sudden,

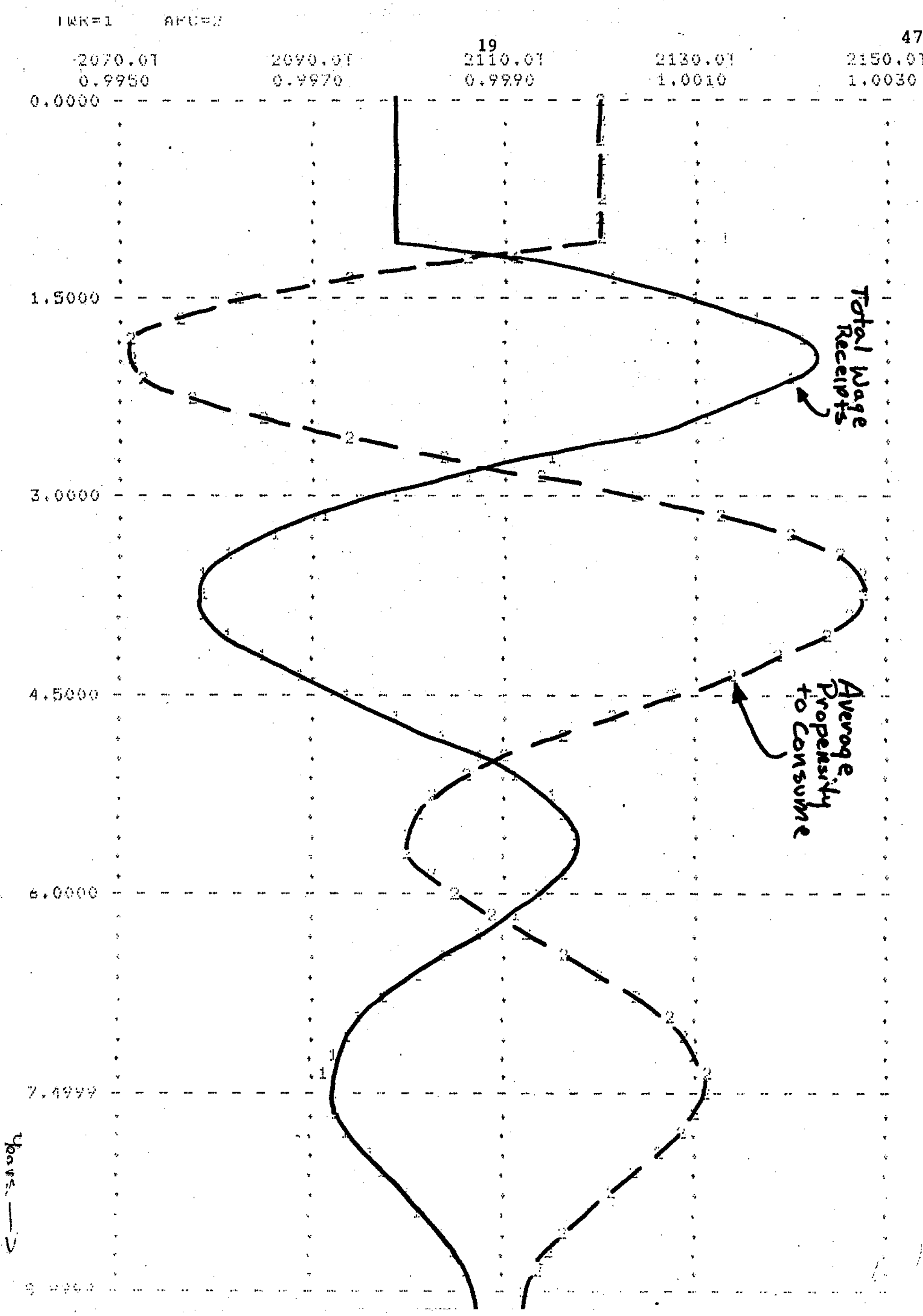


Figure 6: Average Propensity to Consume vs. Income

two per cent reduction of inventory. The average propensity to consume falls as income rises (Cf. Dornbush and Fischer 1978, 144).

Finally, this model explicity recognizes the impact of low inventories: slowed deliveries or stock outs. Metzler did not represent this effect. Incorporating this effect increases the stability of the system (see appendix 1).

The major difference between the model considered here and past workforce-inventory models in system dynamics (N.Forrester 1982, Mass 1975) is the consumer expenditure function described above. In keeping with a common interpretation of Freidman, Forrester and Mass both modeled (desired) consumer expenditures as proportional to an exponential average of income. While, there is some "smoothing" of expenditures in the formulation in the model developed here, this smoothing includes an immediate, substantial, though partial, expenditure response to variations in income. The difference has some importance to stability. As discussed more fully in appendix 1, consumer demand in this model, in contrast to Forrester's and Mass' models, is destablizing to the business cycle.

This discussion has focussed on differences. Obvously, there is much that is the same. It is most important to note that this model, like Metzler's and other system dynamics models, is a model where physical processes are key. Any dynamics that are generated within the real economy are the result of the real economy; financial variables have no impact on real processes. Financial variables will be introduced below. However, movements in financial variables will always be caused in this paper by movements in the real economy, never the reverse.

<u>Timing</u>. The length of the business cycle is variable. Nonetheless evidence from the National Bureau of Economic Research indicates the "business cycle [has] an average length of

4 RUN- JAMES H. HINES, JR. 21 05/06/83

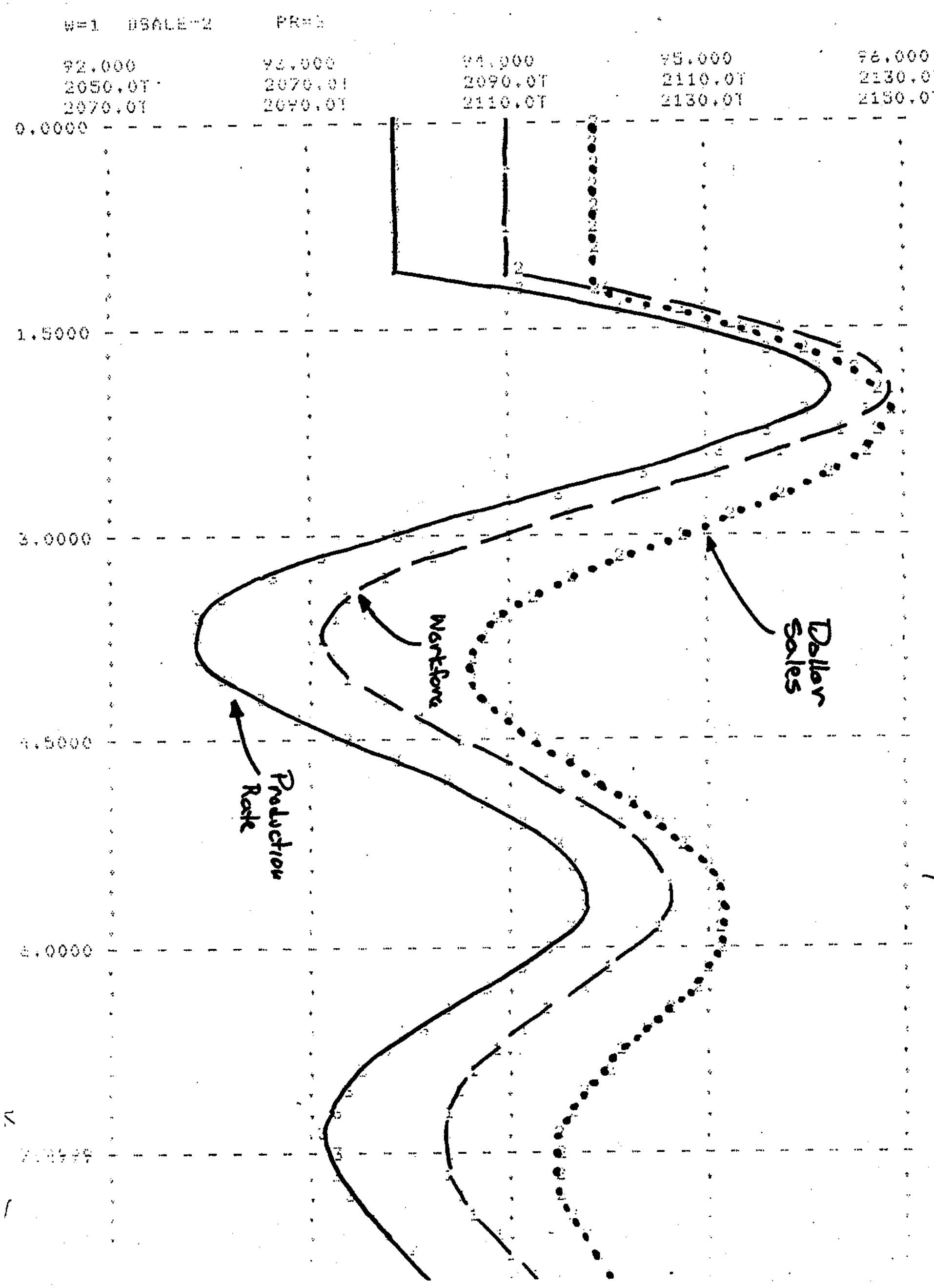


Figure 7: Base Run, Model Response to 2% Reduction of Inventory

5 RUN- JAMES H. HINES, JR. 22 05/06/83

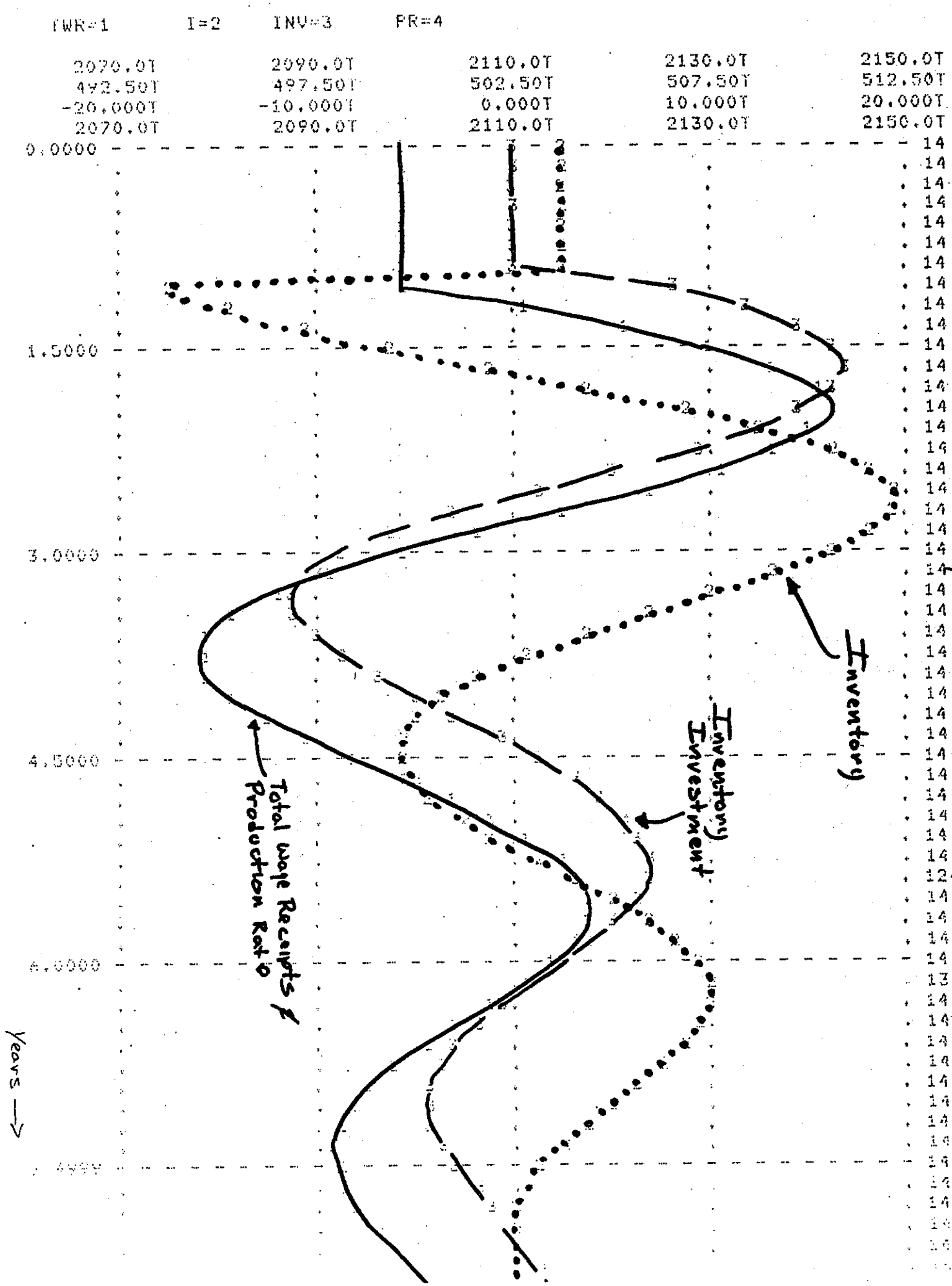


Figure 8: Base Run; Model Response to 2% Inventory Reduction

Figure 9
Timing Relationsips of Economic and Modeled Variables

BCD Indicators			Model Variables	
No.	Name	Average lag* and standard deviation (months)	Name	Lag* (months)
41	Employees on nonagricultural payrolls	.5 (2.4)	Workforce	0
49	Value of Goods Output (1972 $)	0 (1.4)	Production	0
51	Personal income less transfer payments (1972 $)	.2 (1.7)	Total wage receipts	0
59	Sales of retail stores (1972 $)	-.4 (2.2)	Dollar Sales	.1
30	Change in inventories (1972 $)	-4.9 (5.8)	Change in inventories	-3.75
70	Mfg. and trade inventories (1972 $)	4.8 (2.7)	Inventory	7.5

* Lags are measured relative to production (value of goods output, 1972 dollars). A negative lag is a lead.

(Source: Handbood of Cyclical Indicators, 1977)

about three years from peak to peak" (Sargent 1979, 215). The damped period of the model is also three years.[4]

Figures 7 and 8 presents plots of several variables generated by the model. The model was perturbed from equilibrium at the end of year 1 by an instantaneous "evaporation" of two per cent of the inventory in the economy. Figure 9 presents a comparison between the timing of these variables and corresponding variables in the economy. The performance of the model seems rather good.

The Inventory Argument and Variations. The hypothesis we wish to investigate is that business borrowing may be a cause of money supply expansion and that expansion arising in this manner will result in the observed timing relationships between money and production: Change in money leads money leads production.

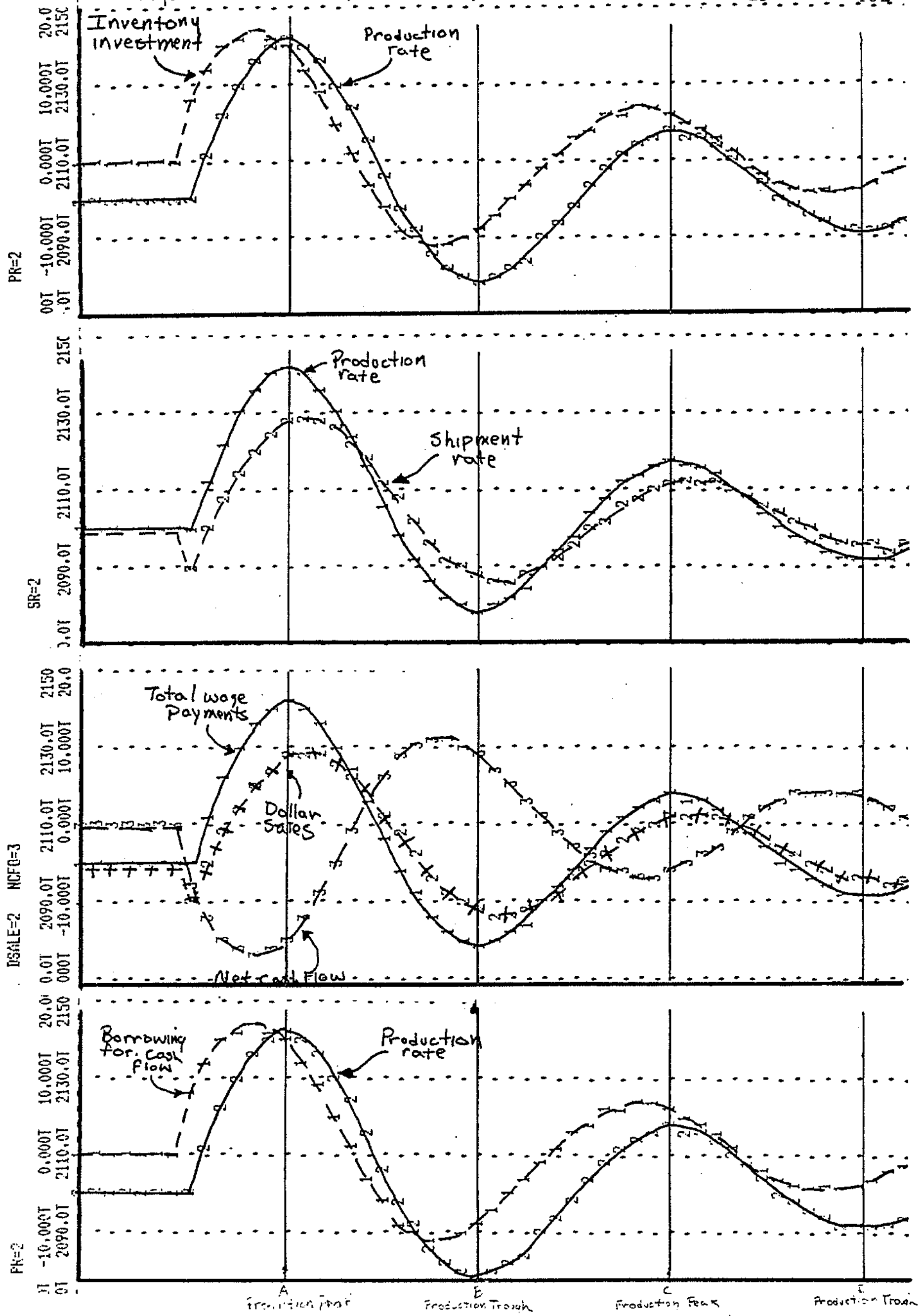
Most basically, businesses borrow when their cash flows are negative and repay when their cash flows are positive. A working hypothesis in the System Dynamics National Model Project has been that business borrowing is related to the need to finance inventory expansion. It is possible now to develop more rigorously the relationship between inventories and cash flows.

Consider the set of curves in figure 10. These curves represent the behavior of several model variables when the model is disturbed from equilibrium by an instantaneous, one-time two per cent "evaporation" of inventory.

The two curves in the first panel represent the production rate on the one hand and inventory investment (ie. change in inventories) on the other. As in the real economy, inventory investment leads production.

Inventory investment is the difference between the production rate and the shipment rate. Consequently, the relationship between inventory investment and production has implications for

Figure 10: Inventory Investment, Production, & Cash Flow



the relationship between production and shipments. In particular, in order for inventory investment to lead production, the shipment rate must lag the production rate. The computer plot in the second panel of figure 10 shows the shipment rate lagging the production rate.

In order to see the necessary connection between the first two panels of figure 10, note that the production rate reaches a peak and is consequently not changing at time A. The shipment rate, however, is still increasing in year three. This means that the difference between production and shipments, inventory investments, must be declining; that is, inventory investment must peak before time A.

Production and shipments have implications for expenses and hrevenues. It seems reasonable to suppose that in the real economy cash production costs and, in particular, wage payments will be approximately in phase with production. And cash revenues will be approximately in phase with shipments. The third panel presents corresponding model variables. (Total wage payments of the production sector are identically equal to the the total wage receipts of the household sector in figure 3). Both cash revenues and cash wage payments might in reality be displaced slightly to the right, if consumers buy on time and if producers pay wages only after they have been earned.

The difference between cash revenues (dollar sales) and production expenses (total wage payments) is net cash flow which is plotted in the third panel of figure 10. To get a sense of the timing relationships, note that at time A total wage payments peak and, consequently, are momentarily unchanging. Dollar sales, on the other hand, are still rising. This means that net cash flow must be rising; hence, the trough in net cash flow must occur before point A.

If businesses borrow when cash flows are negative and repay when cash flows are negative, business borrowing for cash flow will be a "flipped-over" version of net cash flows; that is, borrowing for cash flow purposes will be 180 degrees out of phase with cash flows themselves. The final panel in figure 10 plots the borrowing rate implied by the pattern of net cash flow plotted in the preceeding panel. As may be seen, borrowing for cash flow leads the production rate. According to the System Dynamics working hypothesis, this borrowing may be interpretted as an increase in the money supply. Maintaining this interpretation, we can reinterpret borrowing as the rate of change of money. In figure 11 this reinterpretation has been carried out and the money stock, which now integrates a rate of change which is equal to the net borrowing rate, is shown as well. While the change in money leads, the money stock lags production.

An integration lags its derivative by ninety degrees. Since borrowing (change in money) leads production by less than ninety degrees, the stock of money must lag production in this model. The too-small lead in borrowing is likel to be a characteristic of the economy as well as of this model. To see this more precisely, consider an idealized case where both cash outflow (wages) and cash inflow (revenues) are sine waves. In this case, borrowing for net cash flow will be the difference of two sines and may be written:

$$\text{Borrowing} = \text{Wages} - \text{Revenues}$$
$$= A*SIN(wt) - B*SIN(wt-g)$$
$$= K*SIN(wt + h)$$

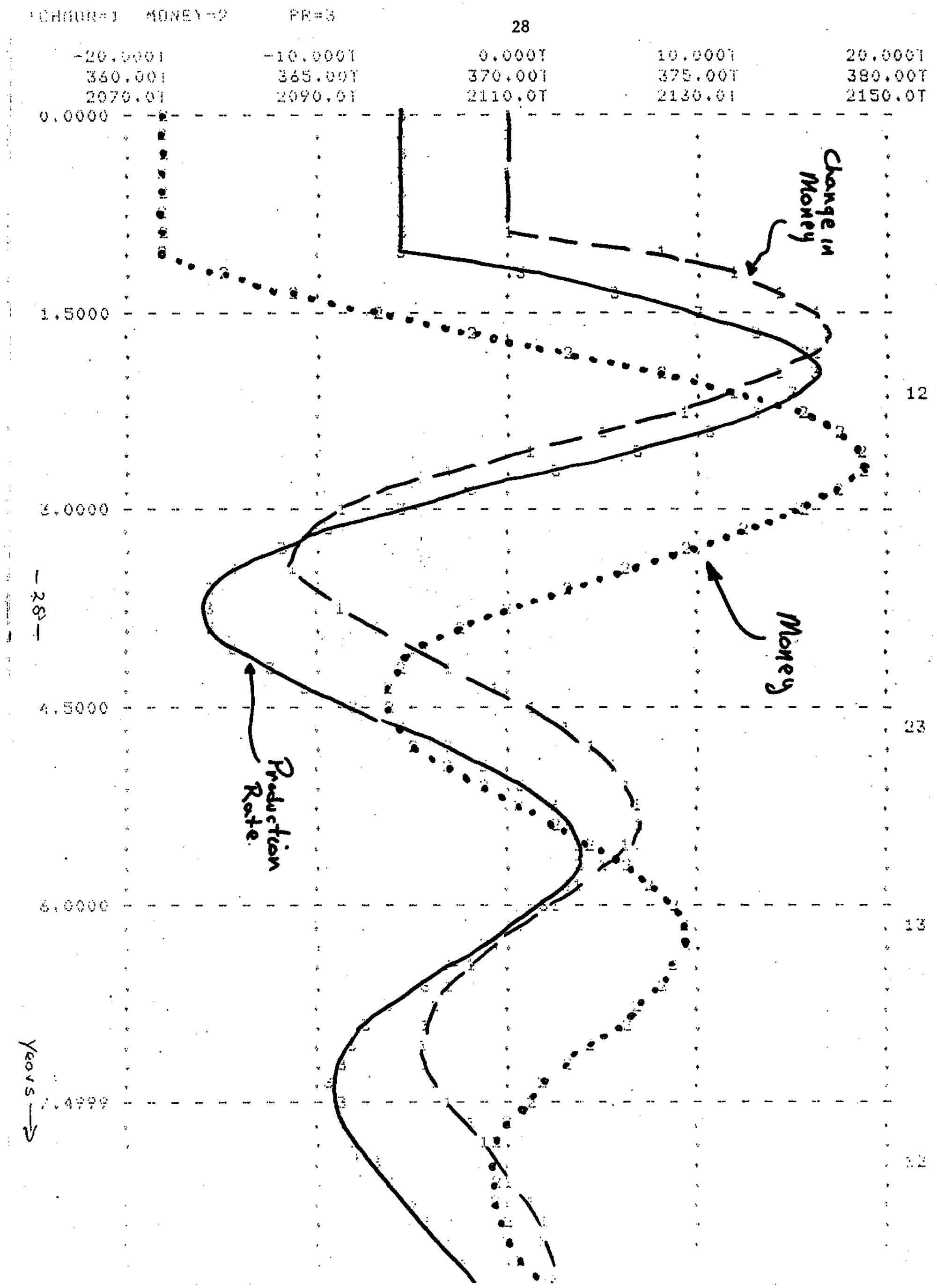


Figure 11: Timing of Money, change in Money, and Production Under the Inventory-Investment Hypothesis

Where w is the frequency of the business cycle

A is the amplitude of wages

B is the amplitude of revenues

g is the phase lag of revenues behind wages

K is the amplitude of borrowing and may be written:

$$K=SQR(A^2 - 2ABCOS(g) + B^2)$$

h is the lead of borrowing in front of production which may be written:

$$ARCTAN(B*SIN(g)/(A-B*COS(g)))$$

Restricting our attention to revenue lags between zero and 180 degrees, it should be clear from the above equation that the lead of borrowing with respect to production will depend upon both the phase lag of revenues and the relative amplitude of wages relative to revenues. Figure 12 shows the lead of borrowing with respect to production for several combinations of relative amplitudes and revenue lags.

Note that leads greater than ninety degrees occur only when the amplitude of revenues is greater than the amplitude of wages. Since, wages are income to the household and sales are household expenditures, these large leads occur when consumer expenditures vary more than consumer income. In the model considered here, it is not possible for the amplitude of consumer expenditures to exceed consumer income since the consumption function, based on reasonable decision rules, will immediately pass through to expenditures only a fraction (seventy five per cent) of a change in income. While it is not impossible that the variability in aggregate consumer expenditures would exceeed the variability of aggregate income, it is not easy to construct a situation in which this would occur. It would seem that allowing consumers

Figure 12: Lead of Change in Money Over Production Rate (degrees)

	(Amplitude of Wages)/(Amplitude of Sales)				
	0	.5	1	1.5	2
Sales lag					
.018°	179°	179°	89.97°	.036°	.018°
18°	162°	146°	81.0°	29.4°	16.4°
36°	144°	118°	72.0°	40.4°	26.3°
54°	126°	96.2°	63.0°	41.6°	29.8°
72°	108°	78.6°	54.0°	38.6°	29.4°
90°	90.0°	63.4°	45.0°	33.4°	26.6°
108°	72.0°	49.6°	36.0°	27.7°	22.4°
126°	54.0°	36.6°	27.0°	21.2°	17.4°
144°	36.0°	24.2°	18.0°	14.3°	11.8°
162°	18.0°	12.0°	9.00°	7.19°	5.98°
180°	0.00°	0.00°	0.00°	0.00°	0.00°

to borrow in order to spend more than their incomes might produce a case in which consumers as an aggregate desire to spend more than they earned. I have looked at consumer-debt-adjustment processes both in the context of the present model and in the context of models containing endogenous price movements and of models containing limits on total workforce participation. None of these have been capable of generating a run in which consumer expenditures exceeed income under reasonable choices for parameters.

Restricting our attention to the three right-most columns of figure 12, where the amplitude of wages is greater than the amplitude of sales, it may be seen that the maximum phase lead of borrowing ahead of production is ninety degrees.[5] As mentioned, an integration follows its derivative with a lag of ninety degrees (as long as the derivative is symmetric). It is clearly impossible in this model, and unlikely in the economy, for the stock of borrowing-generated money to lead production. At best, it will coincide with money. Hence, the inventory-borrowing argument appears unable to account for the fact that the stock of money leads business activity.

<u>New Directions</u>. We have assumed above that borrowing would be translated into money creation, or, more specifically, net pressures on the financial system. It is, however, important to remember that in a closed model one sector's (or person's) cash outlfow is another's inflow. Hence, in the simple two sector view of the world taken here, the negative cash flow of the production sector will be balanced by a positive cash flow of the household sector. In fact, the two are identical in magnitude, but opposite in sign. The wage expenses (cash outflow) of the production sector are the wage revenues (cash inflows) of the household sector. The dollar sales (cash inflow) of the production sector are the household expenditures (cash outflow) of the household sector. To make this precise, the production sector net cash flow is defined as

(17) NCFO = DSALE - TWP Net cash flow (dollars/year)

(18) TWP = TWR Total wage payments

(19) DSALE = HEXP Dollar sales

Compare these equations with equation (11) in figure 3. Clearly, the one is the additive inverse of the other.

This means that when the production sector borrows, the household saves in just the same amount. The household could save by investing in (ie. lending to) the production sector. If this is the case there will be no net pressure on the financial system. There will be no need to create money, as illustrated in figure 13.

The important point here is that what the household does with its cash flow is crucial in understanding the timing of net pressures in the financial system. While this points up a fundamental flaw in the corporate cash flow argument, it also provides a means of resuscitating the underlying argument that the lead of money with respect to production need not result from money causing production. While inventory investment by itself cannot account for the observed phase relationship, it may be possible that an elaborated theory, consistent with the assumptions and focussing on the interaction between the borrowing demand of producers and investment demand of consumers, will be able to account for the timing relationships.

There are a number of factors effecting household investment demand which, in combination with the above inventory argument, might yield the observed timing relationships between money and production. I will focus on aggregate default risk and return. These are, of course, central considerations in portfolio decisions. Further, the default risk/return factor can be considered through relatively minor changes to the model developed thus far, and, hence, the discussion can proceed at a

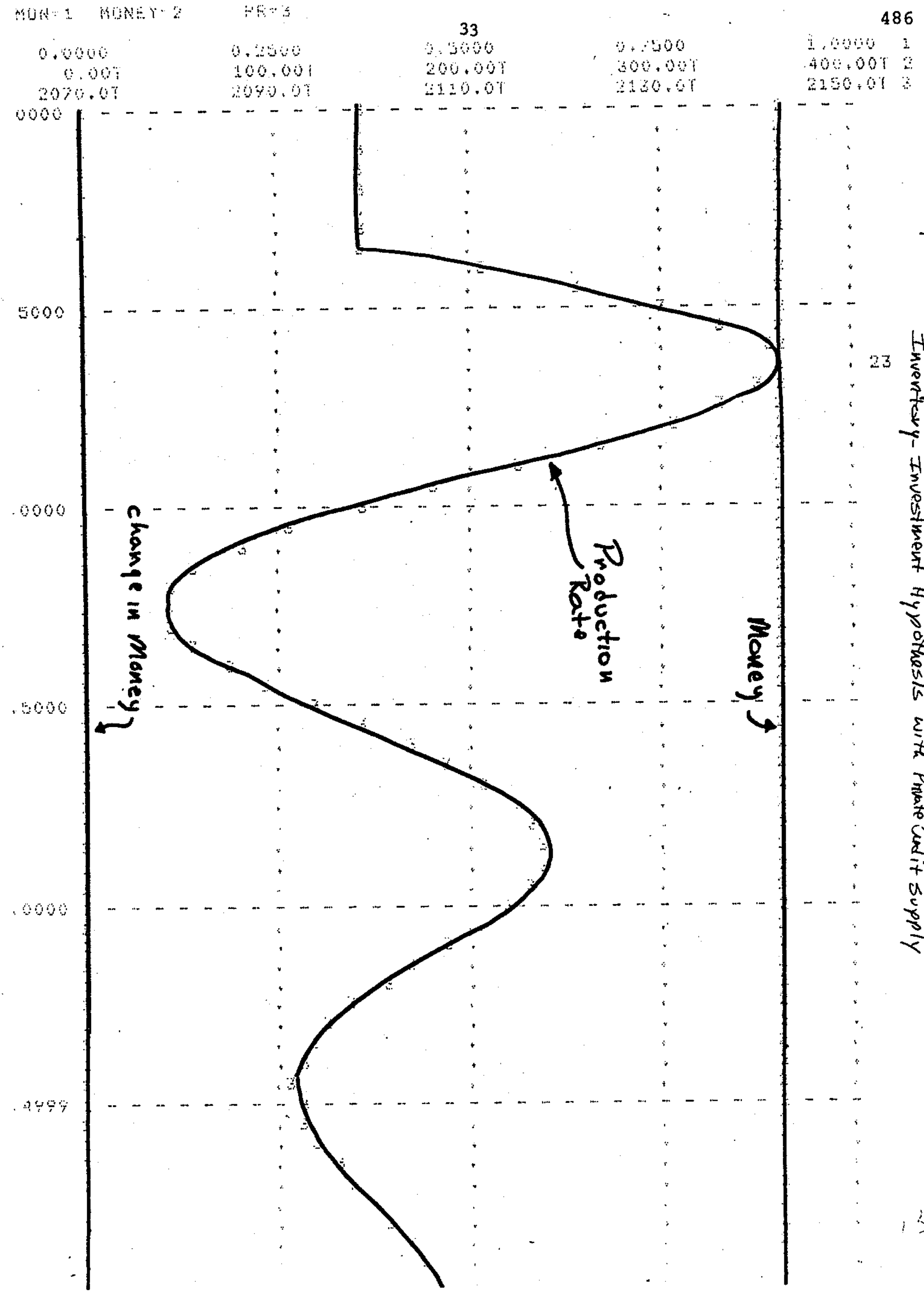


Figure 13: Money, change in Money, and Production Under Inventory-Investment Hypothesis with Private Credit Supply

faster pace. The following development is intended to be illustrative rather than definitive.

There may, of course, be other influences effecting the demand for money balances which are not treated in what follows. Perhaps the prime candidate here is transactions demand (Judd and Scadding 1982), although some might argue that the importance of the transactions function of money has been exagerated (Wilmouth 1982). I have considered the effect of transactions demand for financial assets on the part of businesses. By itself, this mechanism can generate at best a 90 degree phase lead of money change and a zero lead of money stock with respect to production. The mechanism is not sufficient to account for the observed timing relationships of money and production. However, transactions demand for money or other financial assets may be an additional influence in the economy determining the aggregate timing of financial variables.

Risk, expected return and household money holdings. The situation considered immediately above and illustrated by figure 13 was one in which consumers invested their entire cash flow in the production sector. While the household could save by investing in the production sector, it does not have to. The household is, after all, making portfolio decisions and it could choose to hold its assets as money.[6] In this case, as the stream of cash comes from the production sector to the household, a portion may be funnelled off. That portion, held as cash, will not be available to satisfy the producer's demand for credit. The excess demand for credit will appear as pressures in the financial system which may be met through the creation of money.

It is necessary to consider factors which the household might consider in managing its portfolio. It is reasonable to suppose that expected return will be one force determining portfolio composition. The aggregate return on assets is, of course, correlated with movements in production. Indeed, abstracting from price movements, aggregate production is aggregate return.

Hence as expected aggregate production declines, expected aggregate return will decline as well. In this case, any descrepancy in expected return between holding money and holding other financial assets will also decline with the economy. This should make money relatively more attractive than it was and people might reasonable choose to hold more of it. It may also be reasonable to suppose that as expected return declines people will expect to become poorer. As people become poorer they may become more risk averse (Merton 1982). If an economic downturn is associated with the populace becomming poorer and if poorer people are more risk averse, the household will want to put more of its financial assets into safe assets, such as money, as times begin looking grim. In line with these arguments, Cagan (1964) suggests that during depressons household holdings of currency may increase; we may suppose that during mild recesions the household may wish to channal more of its cash flow into its money balances.

It is important to identify information sources for the formation of perceptions of the likely course of the economy. Investors certainly may use the leading indicators mentioned in the introduction to this paper as a source of information about the economy. After all, the original purpose of the leading indicators was to provide just this information (Moore 1978). Today, of course, the indicators get much play in both the print and broadcast news services. The indirect influence of the leading indicators may also be substantial since much secondary information, such as the quoted opinions of business economists, may be based in part on a consideration of these leading indicators. There are other ways in which the household could gain a sense of the direction of the economy, such as the rate of change of income, either on a personal level through direct experience or on an aggregate level though the publications of news organizations or of government agencies.

It is probably less important in the present context to list all the possible sources of information about where the economy is

likely to head, than it is to recognize that people use this kind of information. People can and do predict where the economy is likely to be a short time in the future: Consumer sentiment, itself, is a leading indicator (BCD 1977).

For the purposes of this illustration, it is convenient to allow investors to use a leading indicator that has already been considered: Inventory investment. Results would not differ radically if we modelled many leading indicators and allowed investors to form an average or an index of them.

In brief, we assume the household uses inventory investment to gain a sense of where the economy is heading; this information is assumed to effect expected return and risk preferences. As expected returns and the desire for risk go down, cash holdings go up. Consider what would be the case if the household used actual inventory investment as the basis of its decision to add to or decrease cash holdings. When inventory investment was high, the consumer, believing most confidently that the economy was improving, would be decreasing his cash holdings at the fastest rate. He would be removing assets from his money balance and attempting to give them to the production secor. His demand for investment would, in fact, exceed his positive cash in flow. This means that his demand for investment would exceed the producer's demand for credit. There would be net pressure in the financial system. The monetary authority could relieve this pressure by destroying money.

Under these circumstances, the destruction of money occurs at its greatest rate at the peak of inventory investment. This gives exactly the reverse timing of the simple inventory-investment argument according to which money is created at its fastest rate at the peak of borrowing demand, that is, at the peak of inventory investment. Under the new assumptions, creation of money would be 180 degrees out of phase with borrowing demand. This means that it would be precisely in phase with producer's net cash flow of figure 10. Clearly, this means there is a very substantial lead in the rate of change of money (ie. cash flow).

The lead is so great that not only does the peak in money change lead the peak in production, but the trouph in money change leads the peak in production as well. This lead is too great. Friedman and Schwartz' data (1963 p. 197) suggests that a trough in money change follows within a month or two a peak in production, it does not preceed it.

This too-substantial lead occurs because we have neglected two considerations thus far in the analysis. First, no one is aware of the rate of inventory investment as it is occuring. The data must be gathered, and while results may gradually become clear even before the publication of the final tabulations, there will still be a delay between actual inventory investment and the perception of that investment. Further, even if the household were able to know inventory investment at the time of the investment, there is still likely to be a delay: While consumers may watch the leading indicators, it takes a while for them to decide that what they see is actually a harbinger of economic conditions to come. Economic data is noisy, consumers will not want to respond to every gust of the windy economic indicators. Investors will wish to smooth their information; they will want time to see whether the promise of the indicators is finding evidence in a general economic expansion. This "delay for deliberation" may be even more significant than the delay associated with gathering and deseminating the raw information about inventory investment.

The following equations are consistant with the above discussion. The equations present the household increasing its money balance when it percieve the economy will improve and decreasing its money balance when it percieves the economy faltering.

(20)	$\dot{\text{HMON}}$ = MCHM*EECP*HMON	Household money (dollars)
(21)	EECP = g(DINV)	Effect of economic conditions on portfolio (dimensionless)
(22)	DINV = SMOOTH(INV,TCINV)	Deliberated inventory investment ($/yr)

( )	INV = $\dot{\text{I}}$	Inventory Investment ($/yr.)
(23)	$\dot{\text{MONEY}}$ = NBOR - HDINV	Money supply (dollars)
(24)	HDINV = $\dot{\text{HSAV}}$ - $\dot{\text{HMON}}$	Household desired invesment (dollars/year)

constants:

MCHM	Maximum change in household money (dollars/year)
TCINV	Time to consider inventory investment (years)

SMOOTH is the exponential smoothing function.

This formulation, while adequate for the present illustration, would, no doubt, require revision in an extended treatment of the problem of household portfolio selection.

Equation twenty suggests that the rate of change of the household's money balance is a function of the household's perception of where the economy is heading. The equation suggests that an investor, believing the economy will worsen (on the basis of leading indicators), will increase his money balance, and, conversely, when the investor believes the economy is improving he will decrease his money balance.

As written, the equation contains feedback from the money balance itself, but not from the rest of the portfolio. In a more formal treatment, the rate of increase in money balances might decrease as other investments become low. While, this causes no problems in the current model, since the fluctuations of the mild business cycle are, by definition, mild; the building of confidence in the impact of household portfolio decisons will eventually require testing a formulation under extreme conditions. Further, an explicit representation of return to investments as well as risk is important if one wishes to assume that the household is reacting to or in anticipation of these factors. Finally, it may be that the control of money balances might better be represented as a stock adjustment process.

As discussed above, equation 21 suggests that a sense of impending economic conditions may be gleaned from a smoothed version of inventory investment. Here, EECP is in general a nonlinear function of inventory investment. In the following simulations, I have assumed a linear function:

EECP = -C*(DINV/II)

Where C and II (initial inventory) are constants.

The process by which consumers deliberate upon the significance of the leading indicators has been represented by a first order information delay (equation 22). It might be argued that a third order information delay would better represent the formation of perceptions in regard to an economic indicator. As it turns out, using a third order delay, rather than the first order delay above, makes almost no difference. I have chosen to stay with the simpler formulation.

The forces shaping the change in money have been made explicit in equation 23. Net pressure in the financial system is the difference between producer's demand for credit (NBOR) and the household's desire for investment (HDINV). The household's desire for investment (in the private sector) is determined by two other decisions which have already been considered: the household savings rate and the adjustment of the households money balance. This follows from the fact that in this model household savings must equal the sum of investments and household money.

The form of the equations above should not obscure the fact that the change in the money supply will be the same as the change in the household's money balance. These equations give the equivalence of two views of pressures for money creation: (1) Pressure for money creation results from credit needs of business which are not met by the household; or (2) pressure for money creation results from the desire of the household to hold money. It seems that the the first way of looking at the matter

represents the true structural relationship in the model, the second is a kind of reduced form representation. In any case, the equations explicitly represent the relationship between credit demands and money.

The result of adding the above equations to the model may be seen in figure 14 which plots the response of variables of the altered model to the familiar 2% inventory evaporation. The timing is very close to desired as figure 15 shows.

Figure 15

Leads and Lags in Money and Change in Money

BCD Economic Time Series	Lag Peak	Lag Trough	Lag All Turns	Model Variable	Lag
Change in M1	-19.7 (5.5)	-6.7 (5.5)	-13.2 (8.9)	Change in Money	-19
M1 (1972 $)	-10.5 (6.8)	-7.5 (4.2)	-9.0 (6.0)	Money	-7

(Note: A negative lag is a lead. Standard deviations appear in parentheses)

It must be stressed that in this model money is entirely passive; it excerts no influence on the rate of production. Causality flows from production to money. Nonetheless, money leads production.

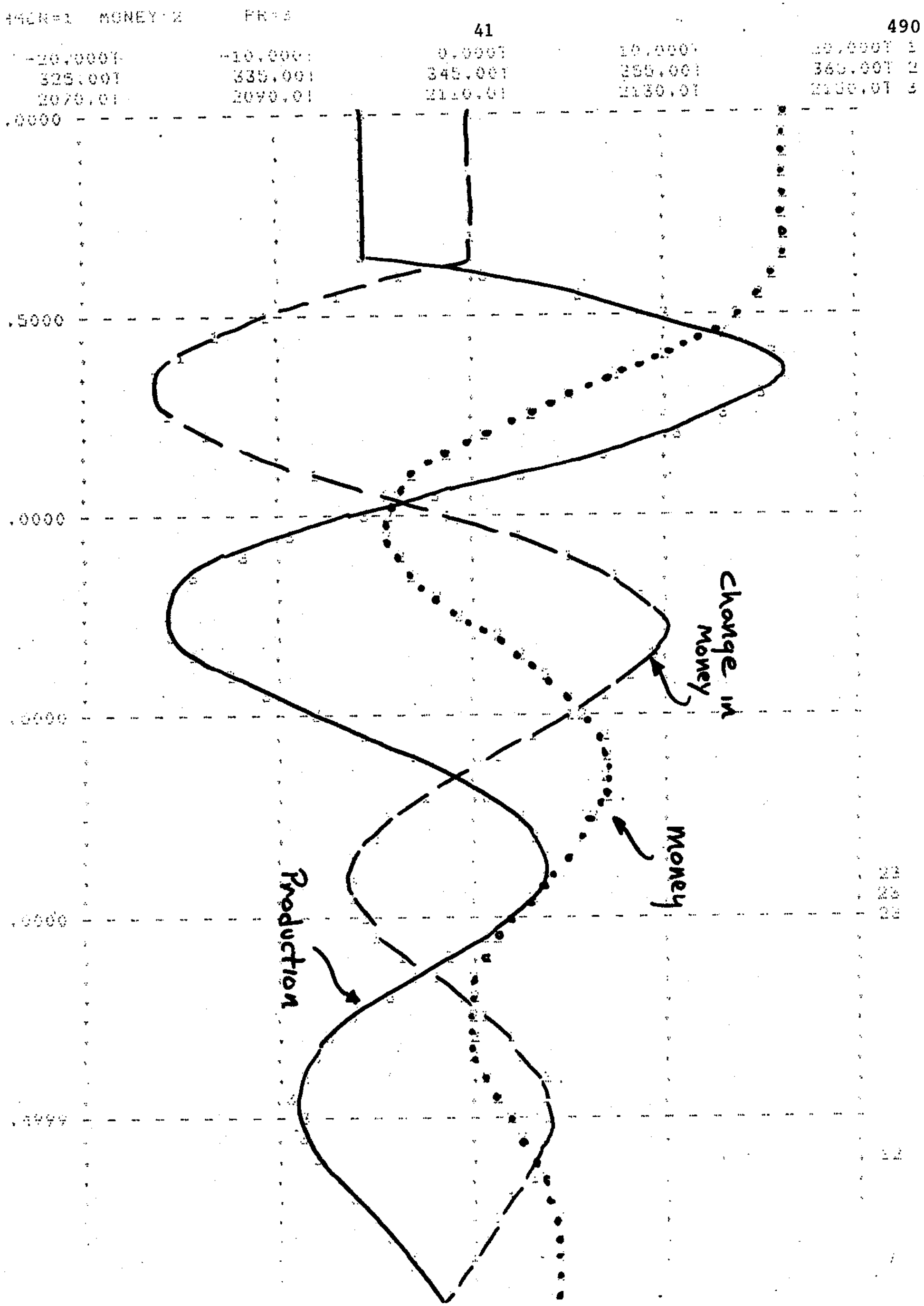


Figure 14: Money, change in Money, and Production Inventory Investment with Household Portfolio Adjustment

This model is not the first to demonstrate that causality cannot be deduced from the lead of one time series with respect to another. In "Money and Income: Post Hoc Ergo Proper Hoc?" (1970) James Tobin constructed a model which, like this one, generated leads of money over production even though causation flowed from production to money. In 1972, however, Sims suggested an econometric test for causality based upon work done by Granger several years earlier. In his paper Sims stated

> The method of identifying causal direction employed here does rest on a sophisticated version of the post hoc ergo propter hoc principle. However, the method is not easily fooled. Simple linear structures with reversed causality like the one put forth by Tobin cannot be constructed to give apparent money-to-GNP causality. (Sims 1972, 543)

Sims concluded that the data were consistent with unidirectional causation from money to GNP. Since 1972 an "enormous number" of empirical studies, stimulated in part by Sims' paper, have used similar proceedures to (attempt to) deduce causality from time series data (Newbold 1982). Nonetheless, others, includings Sims (1983) himself, have argued that Granger causality might be misleading.

It may be of interest to see how the Granger/Sims test for causality performs on this model for two reasons. First, while the model produces output which "looks" as if it contains the proper timing relationships, it is desirable to submit it to statistical tests. Sims 1972 test showed causality running from money to real activity. A similar result here would indicate that the model output is, indeed, behaviorally similar to the real world. Further, of course, a result here showing causality flowing from money to production, while confirming one's visual impression, would raise some doubts about the usefulness of the Sim's test for identifying the direction of causal flow.

The following proceedures were used. Desired wage coverage was reduced from 6.667 to 4.5 years in order to make the system less damped. This change allows the model to generate long series of cyclic data without great amounts of attenuation and without the need for a noise input, a consideration of which is beyond this paper. This change has the additional impact of shortening the period of oscillation. However, the relative timing of money with respect to production is largely unaffected. Two hundred quarters of data were generated. The first seventy quarters were discarded to eliminate any direct impact of the initial disturbance which occurs in the fourth quarter. This leaves thirty-one years of data (the last quarter was not used); Sims (1972) used twenty two years of data in his original study.

Sim's proceedure is a "statistical test for unidirectional causality". It consists of running a variable Y on future and past values of a variable X. If causation runs unidirectionally from X to Y, the coefficients on future values of X will be insignificantly different from zero. Sims used four leading values and eight lagged values of the independent variable; I have done the same. Results are presented in figure 16 where, following Sims, an F-test has been used to test whether coefficients on future values of the independent variable are significantly (at .01 level) different from zero.

Figure 16 -- Granger/Sims' Test for Causality

Regression	OLS F Statistic	Significantly different from zero? (.01 Level)
Production on money (Tests whether money causes production)	.58	No
Money on production (Tests whether production causes money)	229	Yes

To quote Sims:

> These results allow firm rejection of the hypothesis that

> money is purely passive, responding to GNP [ie. production] without influencing it. They are consistent with the hypothesis that GNP is purely passive, reponding to M[oney]...but not influencing M[oney]. (Sims 1972,

This conclusion which Sims reached looking at his test applied to data from the real world, is the same conclusion reached by applying his test to the model output. This supports the visual impression the model produces the proper sorts of leads.

While this result lends credence to the simulation model and points to the potential usefulness of comparing statistical tests performed upon a model with those performed upon real data, this result does not engender confidence in the usefulness of the Granger/Sim's test for detecting the direction of causal flow between time series. The test's conclusion about the direction of causal flow are entirely false. Causality is entirely from production to money, money has not one iota of influence on production in this model.

It is important to note that the conditions under which the Granger/Sims test has been evaluated are quite favorable. There are more observations than are usually available for this sort of thing. There were no shifts in parameters during the period covered by the data. There is no measurement error. And there is no stochasticity. All these possible ways in which causal relationship may be obscured have been removed. What is left is specification error. The Granger/Sims test fails because the bivariate model upon which it is based does not mirror the simulation model. Since there is no promise that the bivariate model will be an any better mirror of the more complex and less linear real world, the usefulness of the Granger/Sims test for understanding causal relationships in the economy is open to serious question.

It should be noted that the Durbin-Watson statistic is quite low. Although there is no stochasticity here, the low Durbin-Watson might suggest an autocorrelated disturbance to a naive investigator. This in turn suggests the use of generalized least squares. Results are given in figure 17. This might be interpretted as a slight improvement: We may now firmly reject unidirectional causality in both directions instead of only in the wrong direction. Of course, it happens that there is unidirectional causality from production to money in the simulation model.

Figure 17--Granger-Sims' with GLS

Regression	Cochrane-Orcutt F	Statistically different from zero? (at .01 level)
Production on money (Tests whether money causes producton)	19.43	Yes
Money on production (Tests whether production causes money)	433	Yes

Summary. Both the change in mony and the stock of money lead production over the business cycle. This paper has considered one hypothesis of these phase relationships. According to the hypothesis, inventory investment causes business borrowing which causes an increase in the money supply with a lead relative to the rate of production. It was concluded that this hypothesis could not account for the timing relationships between money and production. Inventory-investment inspired borrowing, considered alone, causes a lead in the change of money but a lag in money itself with regard to production.

The chief problem with the inventory investment argument is that it does not take account of the supply of credit. The inventory investment hypothesis combined with a mechanism for adjusting the household's portfolio does have the potential of accounting for the observed phase relationships.

A model of the inventory-investment-cum-household-portfolio argument was developed in which the household adjusted its portfolio based upon expectations about the future course of the economy. The model generated the observed phase relationships. In addition, the Granger/Sim's test for causality, applied to simulation model output, yielded results which were qualitatively similar to results of the test when applied to real data. This similarity in results enhanced the credibility of the argument, while calling into question the usefulness of the Granger/Sim's test for detecting causal direction.

The augmented hypothesis maintained the assumptions that real activity causes financial activity and that credit demand and supply determines money. However, an essential similarity between the credit demand and supply viewpoint and a money demand viewpoint was discovered.

Further Steps. It is important not to lose sight of ultimate goals. What we seek is an explanation for the stable timing relationships observed between money, credit, and economic activity. We wish to know whether money causes and whether monetary policy is a high-leverage means of controlling the business cycle.

This paper has shown that it is not necessarily the case that money causes the business cycle despite the intuitive appeal of post hoc propter hoc arguments and despite results of the Granger/Sim's test for causality.

It is necessary to go beyond this conclusion. It is necessary to explore the mechanisms by which money might influence business activity. It may be that those mechanisms are weak or operate on a time scale different from the business cycle. It may be that the story told here gets at the essential reasons for the observed stability of the phase relationships. But we cannot know this until we have taken explicit account of the influences of financial variables on real activity.

The next step is to connect the current understanding, as embodied in the simulation model, with causal mechanisms by which financial variables may influence real variables. The work presented in this paper provides a foundation for that task.

APPENDICES AVAILABLE ON REQUEST

REFERENCES

BCD (Business Conditions Digest). 1977. Handbook of Cyclical Indicators. Bureau of Economic Analysis.

Business Conditions Digest. 1983. 23 (March).

Bryant, R. 1983. "Money and Monetary Policy." The Brookings Review 1 (Spring):6-12.

Cagan, P. 1965. Determinants and Effects of Changes in the Stock of Money 1875-1960. New York: National Bureau of Economic Research.

_____. 1965. "Current Issues in the Theory of Monetary Policy", in Patterns of market Behavior: Essays in Honor of Philip Taft, edited by M. J. Brennan, 135-154. Providence: Brown University Press. (Also in Monetary Economics: Readings, edited by A.E. Entine, 293-312). Belmont, Ca: Wadsworth Publishing Company, Inc., 1968).

Dallas, D., and R. W. Hager. 1982. "Short-Run Money Growth Fluctuations and Real Economic Activity: Some Implications for Monetary Targeting."Federal REserve Bank of St. Louis Review 64 (May):15-20.

Dornbusch, R., and S. Fischer. 1978. Macroeconomics. New York: Mcgraw-Hill, Inc.

Forrester, J. W. 1961. Industrial Dynamics. Cambridge, Ma: MIT Press.

Forrester, J. W. 1982. "Mechanisms of Price Transmission." Address invited by Statistics Canada. Canadian Government Series on Prices and Inflation. Ottawa.

Forrester, N. B. 1982. A Dynamic Synthesis of Basic Macroeconomic Theory: Implications for Stablilization Policy Analysis. Ph.D. diss., System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Ma.

Friedman, B. 1982. "Money, Credit and Nonfinancial Economic Activity: An Empirical Study of Five Countres." National Bureau of Economic Research, Working Paper no. 1033. Cambridge.

Friedman, M. 1956 "The Quantity Theory of Money: A Restatement." in Studies in the Quantity Theory of Money, edited by M. Friedman. Chicago: University of Chicago Press. (Also in The Optimum Quantity of Money and Other Essays, edited by M. Friedman, 51-67. Chicago: Aldine Publishing Company, 1969).

_____. 1964. "The Monetary Studies of the National Bureau." The National Bureau Enters its 45th Year, 44th Annual Report of the National Bureau of Economic Research, 7-25. (Also in The Optimum Quantity of Money and Other Essays, edited by M. Friedman, 261-284. Chicago: Aldine Publishing Company, 1969).

_____. 1970. "Comment on Tobin." The Quarterly Journal of Economics, 84 (May): 318-327.

Friedman, M., and A. Schwartz. 1963. "Money and Business Cycles." Review of Ecnomics and Statistics 45 (1 part2:supplement): 261-184. (Also in The Optimum Quantity of Money and Other Essays, edited by M. Friedman,189-235. Chicago: Aldine Publishing Company, 1969).

Frisch, R. 1933. Economic Essays in Honor of Gustaz Cassel. London: George Allen and Unwn, Ltd. (Also in Readings in Business Cycles, selected by R.A. Gordon and L. R. Klein, 155-185. Homewood, Il: Richard D. Irwin, Inc., 1965).

Goldfeld, S., and M. Stephen. 1976. "The Case of the Missing Money." Brookings Papers on Economic Activity. No. 3: 683-730.

Graham, A. K. 1977. Principles on the Relationship Between Structure and Behavior of Dynamic Systems. Ph.D. diss., Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Ma.

Haberler, G. 1956. "Monetary and Real Factors Affecting Ecnomic Stability: A Critique of Certain Tendencies in Modern Economic Theory." Banca Nazionale del Lavoro Quarterly Review 9 (September). (Also in Readings in Business Cycles, selected by R.A. Gordon and L. R. Klein, 130-149. Homewood, Il: Richard D. Irwin, Inc., 1965).

Hayek, F. 1939. "Price Expectations, Monetary Disturbances and Malinvestments." In Profits, Interest and Investment. London: George Routledge and Sons, Ltd. (Also in Readings in Business Cycle Theory, selected by G. Haberler et al, 350-365. Philadelphia: The Blakiston Company, 1944).

Hicks, J. R. 1949. "Mr. Harrod's Dynamic Thory." Econometrica 16 (May). (Also in Readings in Business Cycle Theory, selected by G. Haberler et al, 350-365. Philadelphia: The Blakiston Company, 1944).

Homer, J. 1978. "The Effect of Inventory Adequacy on Shipments: A Probabilistic Approach." System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology. Photocopy.

Ibbotson, R. G., and R. A. Singuefield. 1977. Stocks, Bonds, Bills, and Inflation. Chicago: Financial Analysts Research Foundation.

Judd, J. and Scadding, S. 1982. "The Search for a Stable Money

Demand Function: A Survey of the Post-1973 Literature." Journal of Economic Literature. 20 (September): 993-1023.

Low, G. 1980. "The Multiplier-Accelerator Model of Business Cycles Interpreted from a System Dynamics Perspective." Tims Studies in Management Science 14: 107-124. North-Holland Publishing Company.

Lucas, R. 1977. "Understanding Business Cycles". Stabilization of the Domestic Economy and International Economy, Volume 5 of Carnegie-Rochester Series on Publisc Policy, edited by K. Brunner and A. H. Metler, 7-29. Amsterdam: North-Holland publishing Company. (Also in Studies in Business Cycle Theory, by R. Lucas, 215-239. Cambridge: MIT Press, 1981.)

_____. 1981. Studies in Business Cycle Theory. Cambridge: MIT Press.

Mankiw, N. 1982. "Hall's Consumption Hypothesis and Durable Goods." Journal of Monetary Economics 10 (November): 417-425.

Mass, N. J. 1975. Economic Cycles: An Analysis of Underlying Causes. Cambridge, Ma: Wright-Allen Press, Inc.

Meigs, J. 1968. "Money in Business Fluctuations." in Monetary Economics: Readings, edited by A. E. Entine, 324-334. Belmont, Ca: Wadsworth Publishing Company, Inc.

Merton, R. 1981. Lecture in Finance Theory, Course 15.415, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Ma.

Metzler, L. 1941. The review of Economic Statistics 22 (August). (Also in Readings in Business Cycles, selected by R.A. Gordon and L. R. Klein, 130-149. Homewood, Il: Richard D. Irwin, Inc., 1965).

Moore G. 1978. "The Forty-Second Anniversary of the Leading Indicators." The National Bureau of Economic Research Reporter Winter (Also in Business Cycles, Inflation, and Forecasting. National Bureau of Economic Research Studies in Business Cycles no. 24. Cambridge: Ballinger Publishing Company, 1980.)

National Center for Health Statistics: Vital Statistics of the United States, 1978, Vol.II, Part A. DHHS Pub. No. (PHS) 83-1101. Public Health Service, Washington. U.S. Government Printing Office, 1982.

Newbold, P. 1982. "Causality Testing in Economics." In Time Series Analysis: Theory and Practice, edited by O.D. Anderson, 701-716. North Holland Publishing Company.

Ott, M. 1982. "Money, Credit and Velocity." Federal Reserve Bank of St. Louis Review 64 (May):21-34.

Richardson, G. P., and A. L. Pugh III. 1981. Introduction to

System Dynamics with DYNAMO. Cambridge, Ma: The MIT Press.

Senge, P. and M. Paich. 1980. "Causal Versus Correlational Approaches to Monetary Policy." System Dynamics Group, sloan School of Management, Massachusetts Institute of Technology. Memo: D-3224.

Sims, C. 1972. "Money, Income and Causality." American Economic Review (May):540-552.

Sims, C. 1983. "Is There a Monetary Business Cycle?" American Economic Review 73 (May):228-233.

Tobin, J. 1970. "Money and Income: Post Hoc Ergo Propter Hoc?" The Quarterly Journal of Economics 84 (May):301-317.

Wilmeth, H. D. 1982. "The Path to Economic Recovery." Paper presented at Annual Meeting of the Society of Actuaries, Washington, D. C.