A LONG-WAVE THEORY OF REAL INTEREST RATE BEHAVIOR

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I. INTRODUCTION*

Businessmen, bankers, private citizens, and government officials share deep concerns over the high values of interest rates in today's economy. Of particular concern has been real interest rate, the rate of interest adjusted for inflation. Although nominal interest rates have followed a generally declining trend over the past year, this decline has generally lagged declining inflation and has failed to keep pace with the drop in inflation.

Many believe that the current values of real interest rates represent the most serious challenge to continued economic recovery. A recent Business Week article began by stating, "It is the most crucial question facing the world economy" (Business Week, September 26, 1983). High real interest rates present a double threat to a sustained recovery. The high cost of funds for domestic borrowers suppresses capital investment and investment in consumer durables and housing. Moreover, high real

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* The author is indebted to Alan K. Graham, research director of the System Dynamics National Project, for his efforts in developing the ideas presented in this paper. Any remaining errors are the sole responsibility of the author.

interest rates in the United States make dollar-denominated financial assets attractive on international markets. This contributes to a high value of the dollar, thereby depressing demand for U.S. goods in foreign countries.

Administration officials blame bankers for keeping nominal interest rates high while inflation has subsided. Bankers are accused of reticence in reducing rates to maintain high profit margins and to cover weak foreign loans. In response, members of the banking community are quick to point to the large government deficits as the primary cause of high interest rates. On the whole, the business community and the public at large commonly see high real interest rates as the result of unprecedented government deficits. This view holds that large volumes of government borrowing, created by deficits and tight monetary policy, compete with private borrowing to drive up nominal interest rates.

This paper challenges the commonly held view that today's high real interest rates are due primarily to government deficits and tight monetary policy. The central thesis developed below is that rising real interest rates come from the disinflationary forces caused by the downturn of the economic long wave. When the economy entered long-wave downturns in the 1870s and 1880s and in the 1920s and 1930s, real interest rates reached unprecedented high levels. Large government deficits did not characterize these historical periods. In fact, increased government spending in the 1930s actually lowered real interest rates by interrupting the deflationary

spiral that was driving up real rates. The effects of monetary policy on real rates also need to be reexamined. Making monetary policy more accommodative to credit needs will have relatively little impact on real rates if rising real rates are not fundamentally caused by tight credit.

This paper is the first of two on the problem of high real interest rates. It focuses on developing a theoretical framework for understanding the role played by real interest rates in the long wave. The second part of the study will focus on the effects of government deficits and alternative monetary policies. The primary purpose of this study is to show that the downturn of the long wave can cause rising real interest rates even with no government deficit or change in monetary policy.

The analysis below was developed from research on the System Dynamics National Model (SDNM)(see Forrester et al. 1976). This model represents a novel approach to understanding longer-term macroeconomic patterns of behavior based on detailed representation of micro-level decision making. The model generates several patterns of economic behavior internally, including the business cycle, the economic long wave, and persistent inflation. Of particular interest here is the theory of the economic long wave. Research on the SDNM suggests that real interest rates play an important role in determining the length and severity of the long wave.

II. RECENT HISTORY OF REAL INTEREST RATES

Real interest rates were low from the early 1960s to the mid-1970s (figure 1). There are many different ways to compute real interest rates, based on different nominal rates and different indices of inflation. Since present theory concerns the effect of real interest rates on demand for productive assets, real rates will be computed whenever possible based upon rates of inflation in investment price indexes. Figure 1 computes real interest rates based on market yields for ninety-day treasury bills and the three-month rate of change in prices for nonresidential fixed investment. During several intervals in the 1970s, particularly the mid-1970s, inflation in consumer prices exceeded nominal interest rates, giving negative real rates. This pattern of low real interest rates contributed strongly to the capital spending and household investment in housing and consumer durables over the past twenty years.

Beginning in the mid-1970s, real rates began to rise. The data in figure 1 put the minimum in real rates in 1974. Alternative calculations of real interest, based on alternative nominal rates or alternative price indexes, result in minima between 1973 and 1976. The modest upward trend in real rates in the latter part of the 1970s terminated in an abrupt increase in the later part of 1980, with continued high real rates since then. Inflation has declined dramatically during the past two years; yet, nominal rates have declined much less. From a peak value of 11.5% in the second quarter of 1981, inflation in capital price fell to -4.2% in the

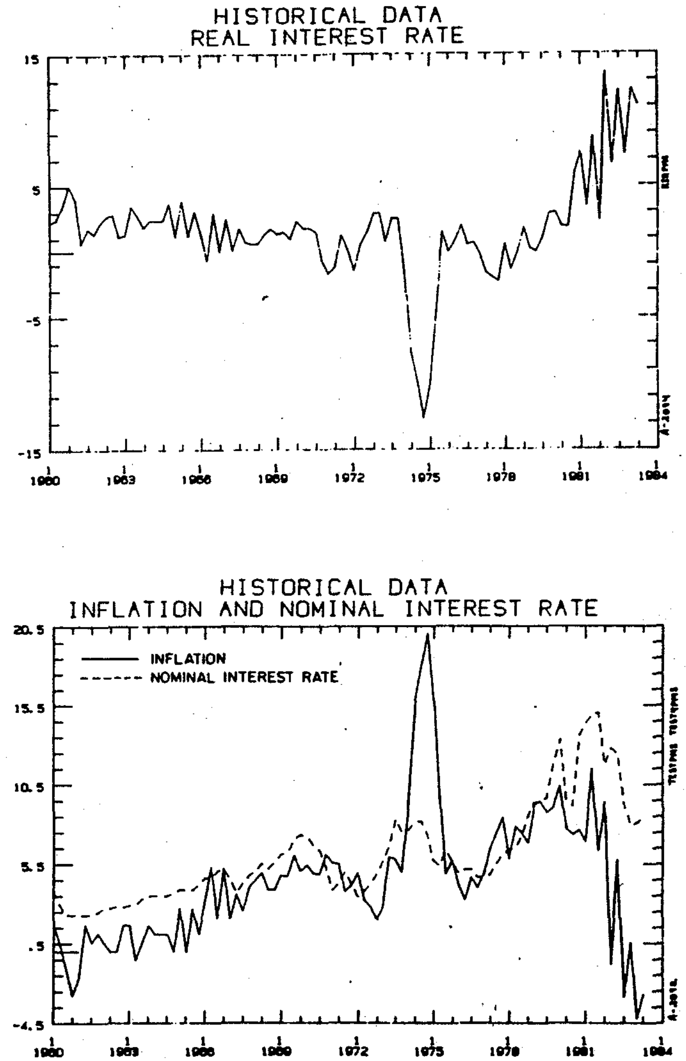

Figure 1

first quarter of 1983. Nominal interest rates fell about 7% during the same period and remain at or slightly above their values at the beginning of 1983.

This same pattern of rising inflation and falling real interest rates, followed by falling inflation and rising real interest rates, is generated by the SDNM. Figure 2 shows a computer simulation of the model, which is part of a much longer-term simulation, shown in figure 3.* Over this longer span of time, real interest rates move up and down over an approximate fifty-year period. This is the economic long wave as simulated by the SDNM. The patterns of behavior shown in figure 2 arise near the long-wave peak in real GNP (indicated by the arrow), when the falling real rates characteristic of the expansion phase reverse.

Both the model simulation and the historical data suggest that real interest rates have begun to rise because inflation has fallen more quickly than nominal interest rates. As long as inflation was increasing, real

* The computer simulation shown in figures 2 and 3, as well as those in the remainder of the paper, include a variety of simplifications in order to focus attention on the long-wave dynamics. In particular, these particular simulations omit longer-term technological and population growth, as well as short-term business-cycle fluctuations and still shorter-term random fluctuations. In the full SDNM the business cycle and economic long wave appear as cyclic modes superimposed on longer-term growth.

rates fell. Disinflation has brought rising real rates historically and in the model simulation.*

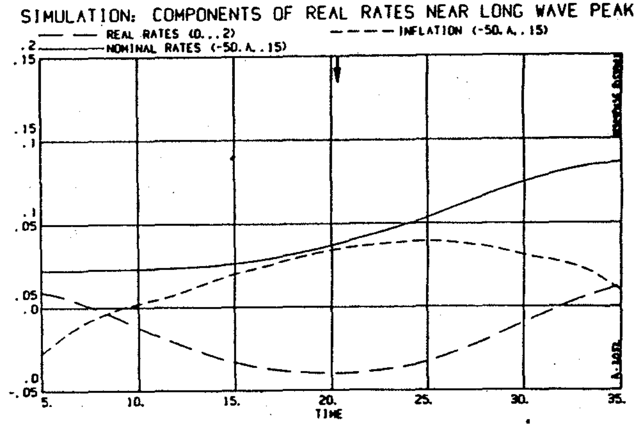

Figure 2

III. THE ROLE OF REAL INTEREST RATES IN THE ECONOMIC LONG WAVE

A computer model capable of reproducing historical patterns of behavior is useful as a guide to economic policy only if the mechanisms causing behavior in the model are realistic. If the computer model reproduces history only because historical data fed into the model cause that outcome, the model tells us nothing that the data themselves do not convey. The computer simulations shown in figures 2 and 3 are quite different from

* The primary difference between the model simulation and historical behavior are the sharp spike in inflation (and real rates) due to the oil price hike in the mid-'70s and the abrupt increase in real interest rates in 1980-1981. The present model purposely omits such external shocks and changes in monetary policy such as occurred in the last three to four years to focus on the long-wave dynamics.

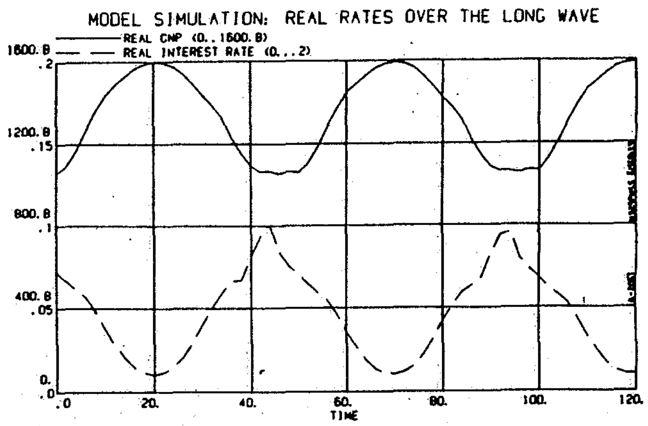

Figure 3

this, however. The patterns of simulated behavior arise completely from internal interactions with the model. No historical data of any sort have been fed into the computer model. The model generates a fifty-year cycle due to mechanisms represented in the model. The model shows a pattern of falling real interest rates during the expansion of this cycle and rising real rates during a contraction due to these interactions. These mechanisms constitute a theory of the causes of the economic long wave and the movement of real interest rates over the long wave.

Overview of Long-Wave Mechanisms. Research on the SDNM suggests that there are multiple mechanisms in an advanced economy that are capable of generating longer-term economic cycles. These mechanisms apparently merge to create the long wave observed historically.* Central to the mechanisms

* A thorough survey of historical evidence for the long wave lies beyond the present scope. Such evidence is available in the general studies of Freeman et al. (1982), Van Duijn (1983), and Senge (1982) as well as the specific studies of long-wave behavior in labor markets (Rothwell and Zegveld 1979), technological innovation (Mensch 1979, Freeman et al. 1981), and political values (Namenwirth 1972, Weber 1981).

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Table 1

SUMMARY OF REINFORCING MECHANISMS CAUSING LONG WAVE

- "Self-ordering" in capital sector
- Interaction of inflation with demand for "productive" assets (capital plant and equipment, housing, durables)
- Interaction of income, wealth, and consumption demand

underlying the long wave is a set of reinforcing mechanisms summarized in table 1.

During an expansion of the economic long wave, the reinforcing mechanisms in table 1 fuel rising capital demand, rising demand for consumer goods, and rising inflation. However, these reinforcing pressures also result in imbalances that limit expansion. For example, over the very long term, technological progress allows the substitution of capital for labor in the production of goods and services. During a long-wave expansion, reinforcing demands for capital and the limited potential work force cause capital intensity to grow at a more rapid pace than the rate of long-term technological progress can support. For example, from 1948 to 1977, capital stock in U.S. manufacturing grew approximately 470%, equivalent to a compound 6.0% per year growth. During the same time, employment in manufacturing grew about 26%, equivalent to a compound growth rate of 0.8%. This corresponds to a 5.2% annual growth in the capital/labor ratio, almost three times the long-term (1850 to the present) average of about 1.8% growth.

Falling real interest rates offset the imbalances that develop during a long-wave expansion. By lowering the real cost of capital investment, they allow the continued substitution of capital for labor. Declining real interest rates likewise lower the real cost of consumer durables and housing, thereby further boosting demand for the capital tp produce durables and housing. However, falling real rates only mask the imbalances developed during a long-wave expansion; they do not eliminate them. Eventually, the imbalances become evident through signs such as falling return on investment (which peaked in the U.S. around 1966), declining capacity utilization (0.91 in 1966, 0.69 in 1982), and rising ratio of private debt to GNP (which approximately tripled between 1945 and 1980).

During a long-wave downturn, the reinforcing pressures that accelerated growth during an expansion accelerate decline. Eventually the imbalances analogous to those that ended the expansion terminate the contraction. High unemployment and labor mobility provide large pools of readily available low-cost labor, low debt levels creating renewed borrowing capacity. And, low capital intensity (combined with technological obsolescence of much of the capital) creates opportunities for new capital formation (especially, capital embodying new innovations). However, rising real interest rates during a long-wave contraction can offset emerging conditions for a new expansion phase. Just as low real rates prolong expansion, high real rates can prolong the contraction phase of the long wave.

<u>Key Reinforcing Feedback Loops</u>. One set of reinforcing mechanisms arises from the "self-ordering" character of capital production in an advanced economy. In an advanced economy, capital manufacturers order capital from one another. This means that the aggregate capital-producing sector of the economy supplies itself. The inner feedback loop in figure 4 illustrates the reinforcing demands for capital created by self-ordering. For example, consider the consequences of an increase in demand for capital. The higher demand for capital boosts desired production, which in turn means that the producers of that capital (manufacturers of equipment and the construction industry) need more capital themselves to meet the demand. This increased demand for capital in the capital sector reinforces the overall demand for capital.

REINFORCING LOOPS INVOLVING CAPITAL "SELF-ORDERING" AND CAPITAL INTENSITY

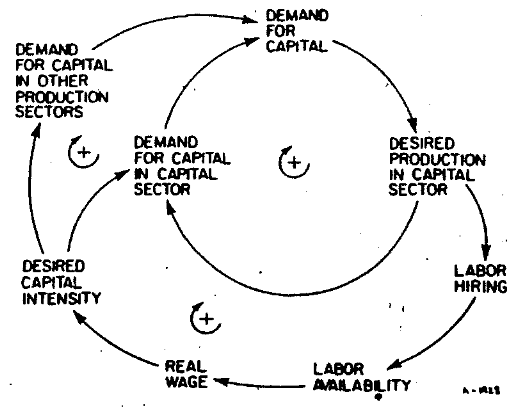

Figure 4

Earlier research based on the SDNM showed that self-ordering pressures such as those described above are sufficient to account for long-wave behavior (for example, see Graham and Senge 1980 and Sterman 1983). More recent research reveals additional mechanisms of comparable significance. One such mechanism is shown in the outer loops in figure 4. The outer loops in figure 4 show how reinforcing pressures for increasing capital intensity and rising real wage can develop. These loops become particularly strong once an expansion has continued for ten to twenty years and labor markets begin to tighten. As labor availability falls, real wages are bid up, and pressures for increased intensity of capital production throughout the economy rise. The result is further demand for capital, leading to further demand for workers to produce the capital, reinforcing the rising real wage and desired capital intensity. This outer feedback loop tends to be a dominant cause of capital growth from the mid-1960s until the mid-1970s, a period during which there was little increase in employment in the manufacturing sector while real wages and capital stock grew rapidly.

A second set of feedback loops relate pressures to increase capital intensity to inflation and falling real interest rate. Virtually all economic and econometric models of investment behavior incorporate the real cost of funds to finance investment (Jorgenson 1963, Bischoff 1971, Ando et al. 1974). When inflation rises relative to the nominal cost of funds, the incentive to invest increases. The value of the asset to be purchased appreciates relative to the debt instrument used for its purchase. The

effect of inflation to encourage capital expenditure creates the reinforcing feedback loops shown in figure 5. When real interest rates fall, desired capital intensity increases, boosting demand for capital throughout the economy and inflation in capital price, and reinforcing the fall in real interest.

The strength of the reinforcing loops in figure 5 depend on the extent to which nominal interest rates also adjust to changes in inflation. If, for example, nominal rates immediately passed through any change in inflation, the net effect of inflation on real rates would be zero. This turns out not to be the case in either the model or the economy, as shown in Section IV.

REINFORCING LOOPS INVOLVING CAPITAL DEMAND AND INFLATION

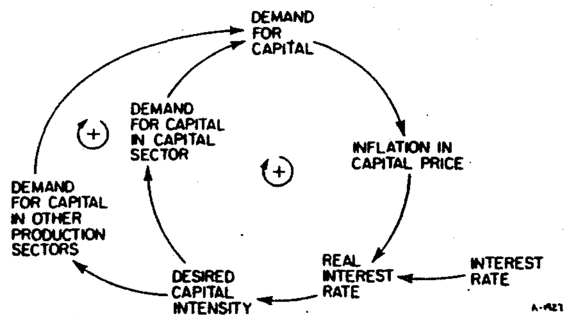

Figure 5

Real interest rates have a similar effect on demand for assets held by consumers, particularly housing and consumer durables (figure 6). The value of the asset appreciates with inflation, while the cost of repaying the debt does not. Thus, inflation depresses the real cost of consumer assets and boosts consumer demand. Much of this speculative housing activity of the 1970s was fueled by expectations of rapid increases in housing costs. High inflation and low real interest rate can also diminish desired stocks of savings, since a dollar-denominated financial asset, such as a savings deposit, fails to appreciate in value as real assets do. As desired savings falls, demand for consumer goods rises still further, since consumers are willing to spend a larger fraction of their current income.

REINFORCING LOOPS INVOLVING CONSUMER DEMAND FOR ASSETS AND INFLATION

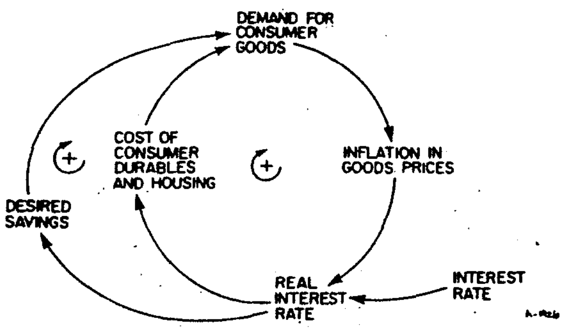

Figure 6

This further reinforces inflation and falling real interest rates. Thus, demand for physical assets by consumers, desired savings, and real interest rate are linked in reinforcing feedback loops analogous to those involving real interest rate and demand for capital by producers. The strength of the feedback loops shown in figure 6 depend once again on the extent to which nominal interest rates also adjust to changes in inflation.

Lastly, rises in consumer demand and capital demand are reinforced through the accumulated income and wealth of households. The feedback relationships shown in figure 7 are well known in economic theories of consumer demand. But, like many of the other relationships described

REINFORCING LOOPS INVOLVING CONSUMER DEMAND, INCOME AND WEALTH

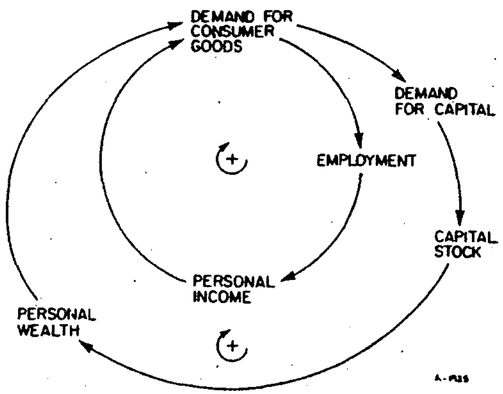

Figure 7

above, their potential role in creating longer-term economic fluctuations is not widely recognized.

Behavior of Real Interest Rate Over the Long Wave. The feedback relationships in figures 4, 5, and 6 suggest a similar role for real wages and real interest rates in generating the long wave. Falling real interest rates and rising real wages contribute to the relative attractiveness of physical assets. Real interest rates reflect the real cost of the asset by comparing the rate at which the asset appreciates to the cost of borrowing to finance the asset's purchase. Falling real interest rates boost demands for assets such as capital, housing, and consumer durables. Similarly, rising wages relative to the price of capital encourage producers to substitute capital for labor. Rising wages relative to the price of consumer goods increase work-force participation and consumer demand.

During a long-wave expansion, rising real wages and falling real interest rate prolong the expansion by offsetting imbalances that would otherwise curtail the expansion. Figure 8 illustrates this behavior in a computer simulation of real wages, real interest rate, and the marginal productivity of capital over a long wave. (The behavior shown in figure 8 is taken from the same computer simulation presented in figures 2 and 3.) Marginal productivity of capital is a theoretical measure of the contribution to production of an additional unit of capital.*

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* Calculation on the basis of a modified Cobb-Douglas production function.

When the marginal productivity of capital is high, adding capital has a large impact on production. Figure 8 shows that marginal productivity of capital peaks early in the long-wave expansion (fifteen to twenty years before the peak in real GNP) and then declines throughout the later part of the long-wave expansion.*

The causes of the behavior in marginal productivity of capital can be seen in the behavior of employment and capital stock over the long wave (figure 9). Starting from the trough when unemployment is high, employment expands more rapidly than capital during the first fifteen years of the expansion phase. The resulting high labor intensity of production makes additional capital highly productive, as reflected in the rising marginal productivity of capital. During the later phase of the expansion, employment growth slows as labor becomes less available, while capital growth continues. Marginal productivity of capital during the later phase of the long wave declines because increasing capital intensity of production renders still further increases in capital less productive.

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* Because the long-wave simulations presented in this study are generated with no long-term secular trends in technology, marginal productivity of capital and real wages oscillate around constant values in the simulation. When exogenous technological growth is included in the model, the long wave in both variables appears superimposed on a growth trend, as occurs historically.

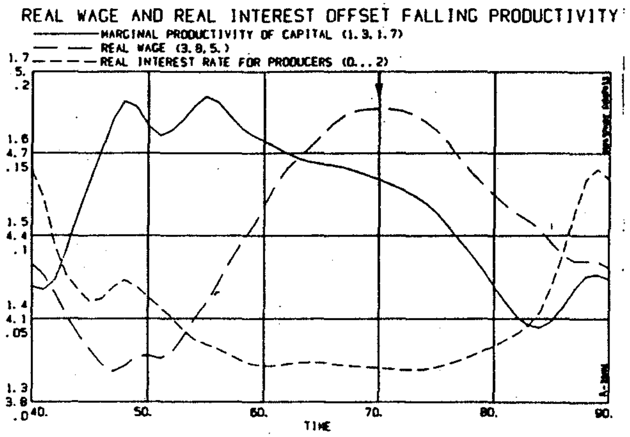

Figure 8

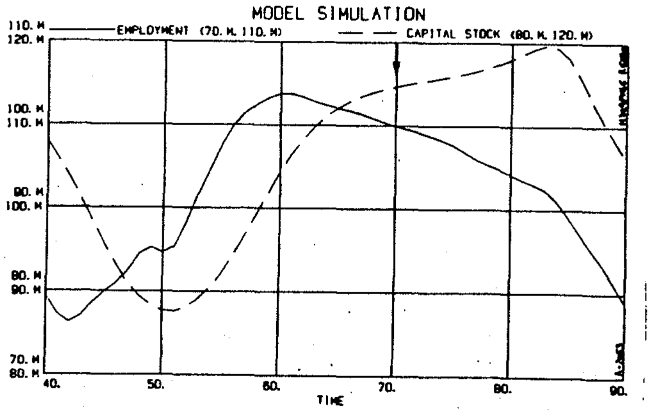

Figure 9

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This same pattern of capital and employment growth is evident in the postwar data for the U.S. Figure 10 shows that employment in U.S. manufacturing and capital grew together from 1947 to 1969 (although capital grew more rapidly). From 1969 to 1983, employment growth was negative, while capital stock approximately doubled. This same pattern of vigorous employment growth until the late 1960s, followed by flat or negative employment growth in the 1970s has occurred in all of the European economies in the postwar period (see Rothwell and Zegfeld 1979).

Real wages and real interest rates similarly compensate for imbalances that develop in the household over a long wave. To understand these imbalances, one must recognize that households make allocation decisions

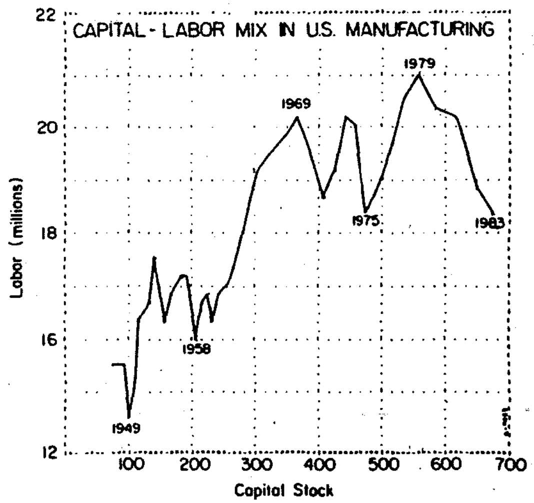

Figure 10

analogous to producers' decisions regarding capital- and labor-intensity of production. Households must balance desire for goods with desire for "household time." Although additional consumer goods are always attractive (have positive marginal utility), a family must continually balance its desire for goods with demands for child rearing, leisure, and direct production of goods and services at home. Figure 11 shows that marginal utility of goods is high at the end of a long-wave downturn, since consumption has been depressed for several years. As an expansion phase unfolds, the stock of goods increases and household time decreases, as more people are drawn into the paid work force. This results in a gradual decline in marginal utility of consumer goods--that is, the relative attractiveness of additional consumer goods compared to additional household time declines.*

Falling marginal utility of goods is offset by falling real interest rate and rising real wage. The former represents lower cost of goods; the latter represents the increasing "cost" of household time, that is, the cost of foregoing paid employment. Falling real interest rate and rising real wage keep consumer demand and work-force participation rising despite the decreasing marginal utility of additional consumer goods (and the increasing marginal utility of household time).

* The determinants of consumption demand in the SDNM include a variety of pressures in addition to marginal utility: for example, wealth, desired wealth, disposable income, liquidity, availability, real interest rate, and real wages.

Thus, falling real interest rates and rising real wages prolong a long-wave expansion in consumer demand and work-force participation, just as they prolong the expansion in capital demand. Moreover, as shown in figures 4 to 6, the pressures driving real rates down and real wages up are reinforcing. As falling real rates drive asset demands upwards, inflation rises and real rates are pushed down further. At the same time, as higher real wages boost desires to substitute capital for labor, demand for labor to produce the capital increases and real wages are pushed up further.

Historical evidence. Although the above theory deals with fluctuations around a fixed (i.e., nongrowing) equilibrium, it has clear implications for behavior in the presence of population and technology growth. The theory predicts that the ratios of capital to labor and consumer goods to

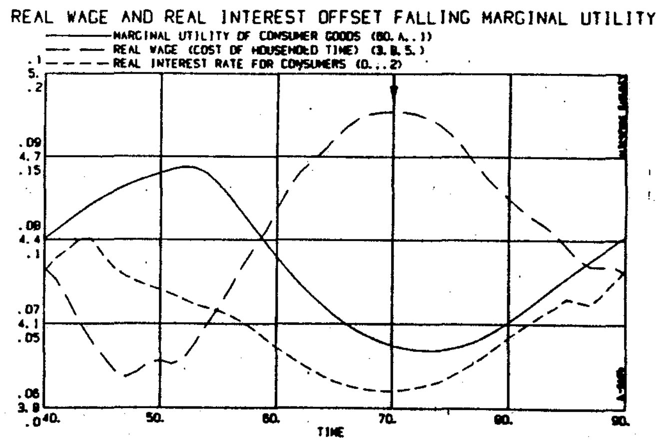

Figure 11

household time increase more rapidly than normal during a long-wave expansion and that these increases are offset by 1) especially rapid increases in real wages and 2) low real interest rates. Conversely, during a long-wave downturn, capital intensity and goods should increase more slowly than normal, while real wages should grow more slowly and real interest rates should be high. An initial survey of evidence corroborates these patterns for the U.S.

From 1948 through 1977, the ratios of capital to labor and goods to household time have increased much more rapidly than their long-term growth rates (table 2).* During this period real wages rose at an annual rate of 2.3%, as compared with the long-term average of 1.3%. Real interest rates have been highly variable, as is typical (highly erratic from 1948 to 1952, then fairly stable and rising slightly on average until the early 1960s, then declining until the mid-1970s, then sharply increasing in the early 1980s). However, the average real interest rate from 1948 through 1977 was -0.2%. since then, real rates have averaged 4.6%. By contrast, real rates have averaged around 2% since 1900.

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* Capital and employment figures based on data in figure 10 (see Graham and Senge 1980). Stock of consumer goods based on aggregate data for consumer expenditures, accumulated by perpetual inventory method, assuming different service lives for different components of expenditure stream: 50 years for housing, 20 years for long-lived durables, and negligible lifetimes for services and nondurables. Real interest rate data based on data in figure 1. Real wages based on Bureau of Labor Department statistics for total nonfarm work force.

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HISTORICAL DATA

	CAPITAL/LABOR IN MFG. (1972$/PERSON)	GOODS/FULL-TIME HOUSEHOLDERS (1972$/PERSON)	REAL WAGE (1977=100)
1948	5.760	18.000	50.6
1977	26.000	94.600	100
GROWTH	351%	426%	98%
ANNUAL GROWTH	5.2%	5.7%	2.3%
LONG-TERM AVERAGE	1.8%	2%	1.3%

A-2021

Table 2

Longer-term data provide further corroboration of the long-wave theory of real interest rates and real wages. Table 3 shows average rates of growth in real wages and average real interest rates for long-wave downturns and upturns from 1870 to the present.* The table shows that periods of long-wave downturns are characterized by lower than average rates of growth in real wages and higher than average levels of real interest rates. By contrast, growth in real wages is high and real interest rates are low during upturns in the long wave. For example, real

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* The dating scheme used in table 3 corresponds roughly to that of van Duijn (1983) and most other long-wave scholars. The only significant discrepancy concerns the dating of the upturn begun at the end of the 19th century. The initial date for this upturn shown in table 3 seems more appropriate for the American experience than the date (1884) chosen by van Duijn for both Europe and the U.S. The data for real wages in table 3 are derived from estimates of nominal wage rates from the Bureau of the Census's Historical Statistics and consumer price indices. Real interest rates are based on long-term nominal rates reported by Homer (1963) corrected for inflation using wholesale price index data from the Historical Statistics.

wages rose more than twice as rapidly for 1894 to 1923 than from 1870 to 1894; growth during the 1973-1983 period approximately matched that from 1870 to 1894. Similarly, real interest rates averaged 9.2% during the downturn period 1870-1894, but only 3.5% during the ensuing thirty-year upturn phase. From 1923 to 1932, real interest rates once again were extremely high, averaging 8.4%. Beginning in 1933, real rates came down sharply, as the rapid deflation of '30 to '32 gave way to renewed inflation, with prices moving generally upwards during the remainder of the

HISTORICAL DATA:
RATE OF GROWTH IN REAL WAGES

Period		Annual Growth Rate
1870-1894	(DOWNTURN)	0.9%
1894-1923	(UPTURN)	1.9%
1923-1938	(DOWNTURN)	1.0%
1938-1977	(UPTURN)	2.2%
1977-1982		-0.9%

A-2033

HISTORICAL DATA: REAL INTEREST RATE

Period		Average Real Interest Rate
1870-1894	(DOWNTURN)	9.2%
1894-1923	(UPTURN)	3.5%
1923-1938	(DOWNTURN)	4.6%
(1923-1932		8.4%)
1938-1977	(UPTURN)	-.1%
(1948-1977		-0.2%)
1977-1982	(DOWNTURN)	2.9%

A-2032

Table 3

1930s. On the average, real rates in the postwar period have again been low by long-term historical standards, consistent with the pattern for a long-wave upturn.

IV. THE BEHAVIOR OF NOMINAL INTEREST RATES OVER THE LONG WAVE

Central to the above theory are reinforcing pressures involving inflation in the price of consumer durables and housing and in capital goods, real interest rates, and the demand for these productive assets. Implicit in the argument have been assumptions regarding the behavior of nominal interest rates. In particular, it is assumed that nominal interest rates do not adjust immediately to changes in the rate of inflation. If they did, real interest rates would remain near constant, and the effects of the reinforcing feedback loops described above would be minimal.

The primary determinant of nominal interest rates in the System Dynamics National Model is the availability of bank reserves. When there is a shortage of reserves relative to those required to cover bank liabilities, interest rates rise. They continue to rise until the shortage is eliminated. Conversely, when there is a surplus of bank reserves, interest rates fall until the surplus is eliminated. By basing interest rate change on the relative availability of reserves, the model coincides with most descriptive accounts of interest rate setting. Irving Fisher (1930) states

> that there is a relationship between bank reserves and the rate of bank discount is perhaps self-evident. Every banker and businessman is familiar with it (Fisher 1930, p. 444).

Fisher goes on to cite several studies that have shown reserve availability to correlate closely with changes in nominal interest rates. The specific formulation for nominal interest rates in the SDNM has been analyzed and tested against statistical data by Hines (1983). This study shows the formulation to provide a very good fit for post-World War II movements in nominal interest rates.

The key dynamic characteristic of the formulation for nominal interest rates in the SDNM is that interest rates tend to continue to adjust until reserve imbalances are eliminated. This has important ramifications for the behavior of real interest rates over the long wave. Figure 12 shows the behavior of availability of bank reserves and nominal interest rates over the long wave in the simulation presented earlier. The figure shows that nominal interest rates continue to expand until the credit shortage (negative "availability of reserves") characteristic of the expansion and peak phases of the long wave has been exhausted. Conversely, nominal rates continue to fall until the credit surplus characteristic of the contraction and trough phases is eliminated.*

Prices similarly integrate imbalances of supply and demand. For example, figure 13 shows the behavior of the price of consumer goods over a

* Nominal interest rates are constrained in the model not to fall below 2%. Consequently, rates plateau at this lower level even though a credit surplus still exists after about year 55 in the figure.

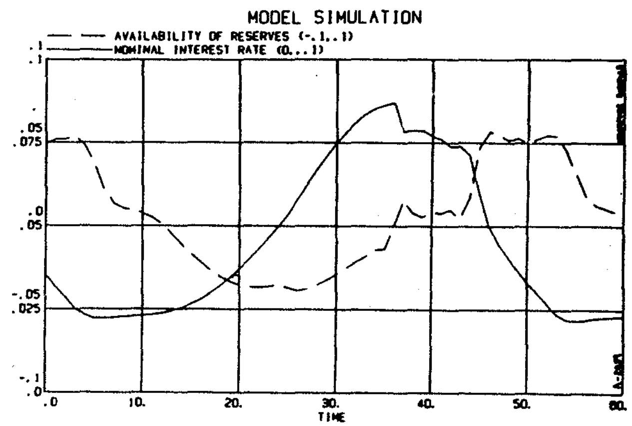

Figure 12

long wave compared to the degree of excess demand or supply for goods. (Capital prices move relatively closely in phase with goods prices over the long wave). Price keeps rising until excess demand for goods is eliminated (i.e., equals zero) and falls until excess supply is eliminated.* On the other hand, inflation, the rate of change in prices, is highest midway up the price curve. As a measure of rate of change, inflation naturally leads the price level.

* Note that price continues to rise for about five years after year 32 (when the excess demand has been eliminated) because of continued inflationary expectations in the wage- and price-setting processes in the model.

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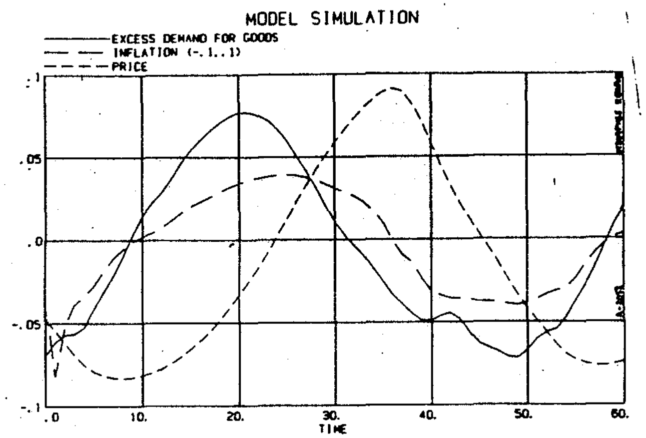

Figure 13

The different character of inflation and nominal interest rate behavior over the long wave is important for understanding why real interest rate falls during the upturn and rises during the downturn. Table 4 summarizes this character. Because nominal interest rate "integrates" credit imbalances, it keeps rising until the credit shortage characteristic of an expansion is eliminated. On the other hand, inflation peaks when the goods shortage characteristic of an expansion is at its highest. This implies that inflation would peak well before nominal interest rate, provided that credit shortages and goods shortages are more or less in

REAL INTEREST RATE =	NOMINAL INTEREST RATE -	INFLATION
DURING UPTURN:	KEEPS RISING UNTIL CREDIT SHORTAGE ELIMINATED	PEAKS WHEN GOODS SHORTAGE PEAKS
DURING DOWNTURN:	KEEPS FALLING UNTIL CREDIT SURPLUS ELIMINATED	TROUGH WHEN GOODS SURPLUS PEAKS

A-2020

Table 4

phase over the long wave. This is in fact the case, as illustrated in figure 14. This simulation shows that during most of the time when there is an excess demand for consumer goods, there is also a shortage of available credit (negative availability of reserves.) Alternatively put, over the long wave, the price of money (nominal interest rate) and the price of goods and capital move closely together. Both are driven up during an expansion period by rising demands for goods and capital and by rising credit demands; both continue to rise past the peak in real GNP, and both fall once a contraction is well under way. On the other hand, inflation peaks considerably before prices. As shown in figure 15, this means that real interest rate begins to rise well before the peak in nominal rates, approximately when inflation begins to fall (generally near the peak in real GNP).

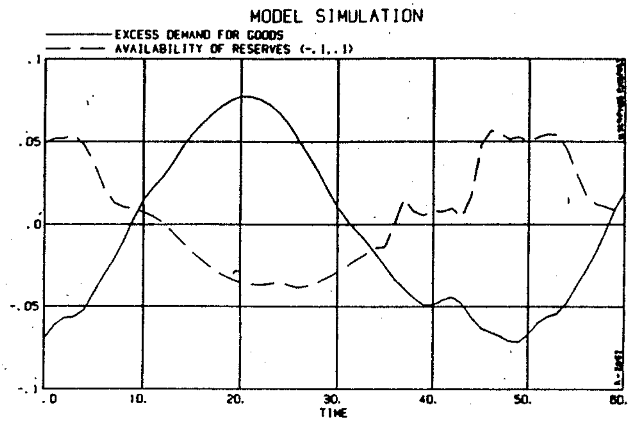

Figure 14

Figure 15 shows that real interest rates rise during the long-wave contraction because inflation begins to fall sooner than nominal interest rates. In the simulation, there is a lag of approximately ten years between the peak in inflation and the peak in nominal interest rates. During this time, real interest rates begin to increase. (Moreover, real interest rates continue to increase after the peak in nominal rates, due to the more rapid decline in inflation than in nominal rates. The primary cause of the relatively slow decline in nominal rates after the peak is a sharp reduction in savings brought about by falling real incomes.) Is a lag of this magnitude realistic, especially in light of the beliefs of some economists, notably those of the "rational expectations" school, that inflation rates are quickly passed through into nominal interest rates?

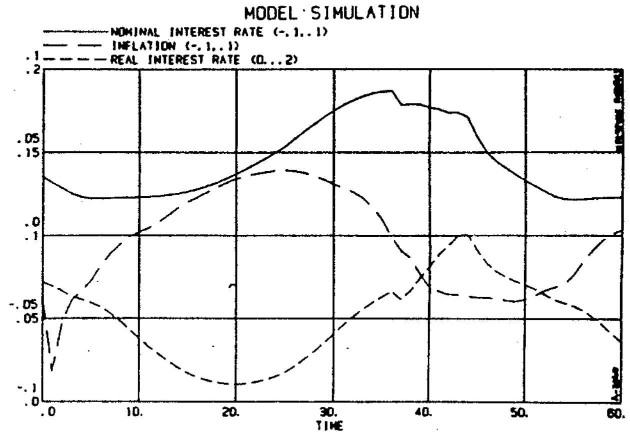

Figure 15

Table 5 shows years in which inflation and nominal interest rate hit peaks and troughs over the economic long wave. The table indicates lags of nominal interest rate behind inflation at the peak that vary from 3 to 9 years. Lags at the trough vary from 15 to 22 years. However, this evidence needs to be viewed cautiously, particularly in light of the highly erratic behavior of inflation rates. Note, in particular, that peak rates of inflation for the first two long waves cited are coincident with wartime periods of rapid price increase. The data for wholesale prices and nominal interest rates upon which these estimates are based appear as figures 16 and 17. Both long-term time series exhibit approximate fifty-year cycles, with peaks and troughs roughly in phase. This implies that nominal rates would tend to lag inflation, but the length of the lag cannot be estimated reliably from simply inspecting the data.

PEAKS AND TROUGHS OF INFLATION
AND NOMINAL INTEREST RATES
OVER THE LONG WAVE

PEAKS		TROUGHS	
INFLATION (WHOLESALE PRICE INDEX)	NOMINAL INTEREST RATE	INFLATION (WHOLESALE PRICE INDEX)	NOMINAL INTEREST RATE
1864 (31.1%)	1873 (6.6%)	1878 (-16.5%)	1900 (3%)
1917 (27.2%)	1920 (5.25%)	1931 (-18.7%)	1946 (2.4%)
1974 (15.9%)	1981 (15%)		

A-2019

Table 5

An alternative approach to estimating the lag between inflation and nominal interest rates is through statistical analysis, such as the distributed lag analysis used by Irving Fisher in his classic treatise <u>The Theory of Interest</u>. Fisher starts by testing the "theoretical" view that real interest rates should remain relatively stable while nominal interest rates fluctuate with the rate of inflation. Analyzing multiple long-term series for nominal rates and inflation, Fisher found that standard deviations for real rates were typically about ten times greater than those for nominal rates. The relative stability of nominal rates implies that changes in inflation are not passed through quickly into nominal rates. Fisher concluded that variations in rates of inflation were eventually reflected in nominal interest rates, but only after a substantial period of time:

> When the effects of price changes upon interest rates are <u>distributed</u> over several years, we have found remarkably high coefficients of correlation, thus indicating that interest rates follow price changes closely in degree, though rather distantly in time. (Fisher 1930, p. 451)

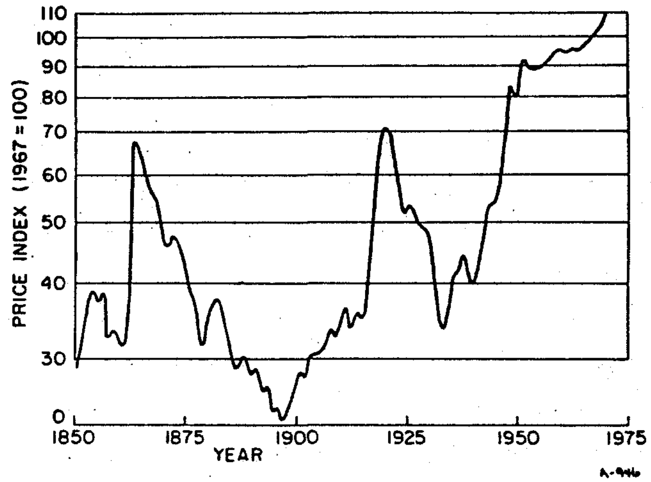

Figure 16

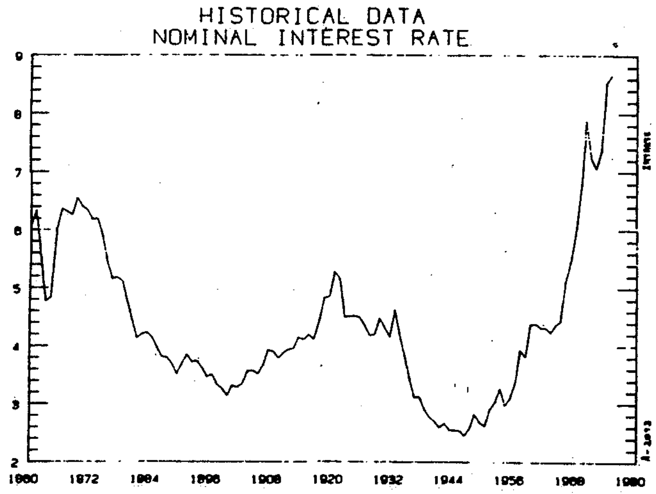

Figure 17

In particular, Fisher found mean lags for English data that varied from 6.7 to 9.8 years for different historical periods. For the United States, mean lags varied from 2.5 to 10 years. Finally, Fisher showed that the level of prices and the level of nominal interest rates correlate much more closely, as they do in the SDNM. He found an average lag of nominal interest rates behind price of only one year.

Repeating this thorough statistical analysis for post-World War II data would provide a further test of the long-wave theory of real interest rates. Behavior from 1970 onwards in figure 1 are very suggestive of similar results, insofar as inflation peaks in 1974, when nominal rates are approximately one-half the value they subsequently reached in 1981.

V. SENSITIVITY OF REAL INTEREST RATE BEHAVIOR IN THE SDNM

The movement of real interest rate over the long wave generated by the SDNM is highly insensitive to assumptions regarding the rapidity of change of prices and nominal interest rate. For example, given that interest rate rises in the model as a result of inflation peaking ahead of nominal rate, would model behavior change if prices changed more slowly and interest rates changed more quickly? This question is consistent with the view held by many, apparently including members of the Administration, that real interest rates are high because bankers are adjusting nominal rates more slowly than producers are adjusting prices. Figure 18 shows the result of

repeating the base-run simulation with much faster interest rate adjustments and much slower price adjustments.*

Figure 18 should be compared with figure 3. In both simulations, real interest rates move approximately out of phase relative to real GNP. The range of variation of both real interest rate and real GNP over the simulated long waves is almost identical. There <u>is</u> a slight shift in the timing of real interest rates, as illustrated by the peak in real interest rate at year 42 slightly in advance of the trough in real GNP. But there

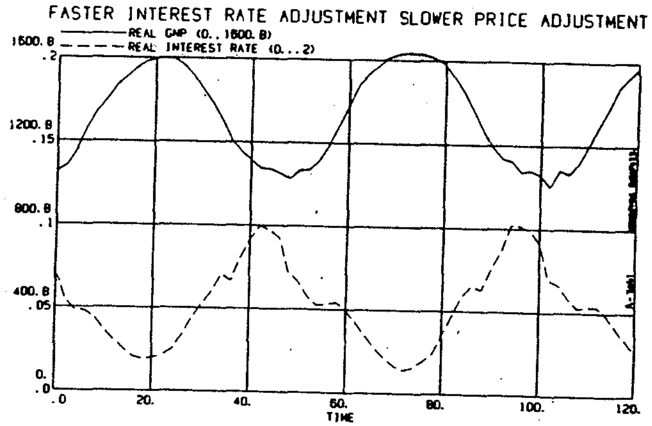

Figure 18

* The simulation in figure 18 is generated by increasing the rapidity of long-term interest rate adjustment by a factor of 5 (from 2 to .4 years) in slowing the rate of long-term (i.e., list) price change by a factor of 5 also (from .8 years to 4 years).

is no significant change that results from the substantial changes in assumed rapidity of price and interest rate response.

Similar questions regarding model sensitivity can be asked in connection with the assumed monetary policy in the base run. Monetary policy is basically accommodative in the base run (figure 19). During most of the expansion period in real GNP, the reserve base is expanded because of the perceived growth in real output. In the model, bonds are purchased from the public to increase the reserve base to accommodate anticipated continued growth. Starting about midway in the expansion phase for real GNP, credit shortages develop, driving up nominal interest rates and causing further monetary intervention. The rate of bond purchase due to credit shortage persists for more than ten years after the peak in real

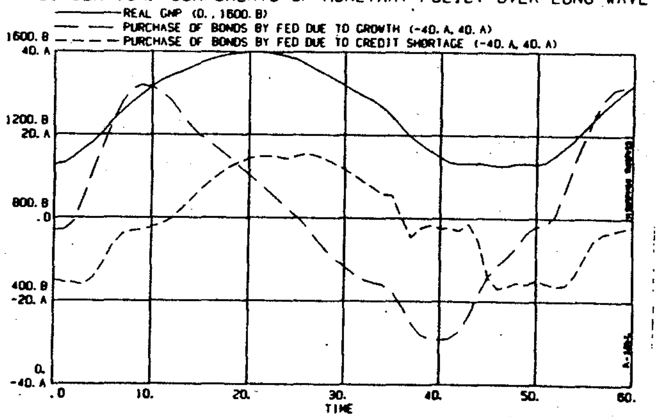

Figure 19

GNP, as the Federal Reserve attempts to ease credit shortages during the peak and early downturn. Eventually, approximately midway in the contraction of real GNP, credit surpluses begin to appear, causing pressure for the monetary authority to sell bonds to the public to reduce the reserve base in order to moderate the decline in nominal interest rates.

Figure 20 shows the effects of increasing the responsiveness of monetary policy to credit availability. In this simulation, the monetary authority purchases or sells bonds at twice the rate as in the base run for any given level of credit shortage or surplus. The "new" monetary policy is more "accommodative" in injecting additional reserves into the system when there is a shortage, but more aggressive in removing excess reserves when there is a surplus.

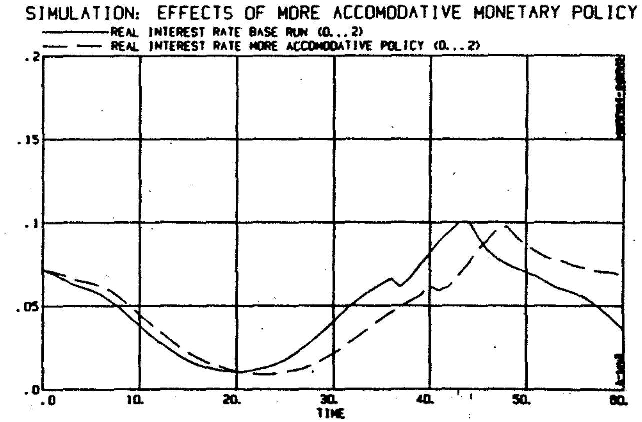

Figure 20

By making more reserves available during the later part of the long-wave expansion, the new monetary policy in figure 20 prolongs the expansion period and slows the rise in real interest rates during the early part of the contraction phase. However, this only serves to lengthen the contraction phase, resulting in a peak in real interest rates in year 48 rather than year 43. Real interest rates still rise throughout the long-wave downturn with the revised monetary policy. (With the revised policy, real GNP peaks at year 23 and hits a trough at year 48.) Moreover, real rates eventually reach about the same peak value as in the base case. Similar experiments with a wide range of assumptions regarding the responsiveness of monetary policy to both growth and credit availability indicate that such monetary policies have some effect on the period and overall amplitude of the long wave, but no impact whatsoever on the relative timing of real interest rates.

In all sensitivity experiments conducted to date, real interest rates fall during the expansion of the long wave and rise during the contraction. The causes for the movement in real interest rate lie in the positive feedback loops discussed in section III combined with the structures that cause nominal interest rates to lag inflation discussed in the preceding section. These basic mechanisms in the SDNM are unaltered by changing the assumed rapidity of response of price or nominal interest rate, or by changing the responsiveness of monetary policy.

VI. CONCLUSIONS

The purpose of this paper has been to develop a theoretical framework for understanding the role of real interest rates in generating the economic long wave. The paper has endeavored to show that a plausible set of mechanisms exist to cause rising real rates during a long-wave downturn, even in the absence of government deficits and changes in monetary policy.

Real interest rates tend to rise as the inflationary pressures of a long-wave expansion give way to deflationary pressures of a long-wave contraction. Rising real interest rates reduce demand for capital, consumer durables, and housing, thereby reinforcing the deflationary forces and the increasing real interest rates. A central structural assumption imbedded in this theory concerns the relative sluggishness with which nominal interest rates adjust to changes in the rate of inflation. In the SDNM, nominal interest rates continue to rise until the credit shortages characteristic of the end of a long-wave expansion are eliminated. Prices tend to move in parallel with nominal interest rates, rising until the excess demand of an expansion phase is eliminated. By contrast, inflation, the rate of change in price, begins to decline considerably before the peak in nominal interest rates. This behavior was shown to be consistent with a variety of historical observations and with Fisher's statistical analysis of the effects of inflation on nominal interest rates prior to 1930. Further statistical analysis for the post-World War II era is needed.

An interesting feature of the theory developed above is the parallel roles of real interest rates and real wages. Both variables tend to prolong long wave expansions and contractions by masking imbalances. Both variables play key roles in reinforcing processes that influence desired capital intensity in the production sectors and the desired mix of consumer goods versus household time in the household sector. The two variables tend to move inversely over the long wave, real interest rates rising more rapidly than normal during expansion periods and real interest rates being low during expansion periods.

The chief implication of this paper is to call into question the dominant view that today's high real interest rates are due to government deficits and tight monetary policy. Neither deficits (government spending is always equal to tax revenues) nor changes in monetary policy are present in any of the simulations of the SDNM upon which the above theory was based. However, the above analysis does not prove that deficits or tight monetary policy are unimportant. It only proves that they are not necessary to generate recent rises in real rates, if one accepts the hypothesis of the economic long wave.

The next major research step is to expand the analysis to include rising government deficits and changes in monetary policy. The System Dynamics National Model should be a powerful tool for conducting this analysis, due to its ability to generate the economic long wave endogenously, as well as to represent monetary and fiscal policies in

considerably more dynamic detail than most alternative macroeconometric models.

REFERENCES

Ando, A. K., F. Modigliani, R. Rasche, and S. Turnovsky, "On the Role of Expectations of Price and Technological Change in an Investment Function," International Economic Review vol. 15 (1974), pp. 384-414.

Bischoff, C. W., "Business Investment in the 1970s: A Comparison of Models," Brookings Papers on Economic Activity, 1:1971, pp. 13-53.

Coen, R. M., "Investment Behavior, the Measurement of Depreciation and Tax Policy," American Economic Review vol. 65 (1075), pp. 59-74.

Fisher, I. N., The Theory of Investment, original edition 1930, reprinted by Augustus M. Kelley (NY) 1965.

Forrester, J. W., N. J. Mass, and C. J. Ryan, "The System Dynamics National Model: Understanding Socio-Economic Behavior and Policy Alternatives," Technological Forecasting and Social Change vol. 9 (1976), pp. 51-68.

Freeman, C., "Technical Innovation and Long Waves in World Economic Development," Futures vol. 13 (1981).

Freeman, C., J. Clark, and L. Soete, Unemployment and Technical Innovation, Westport, Conn.: Greenwood Press, 1982.

Graham, A. K. and P. M. Senge, "A Long-Wave Hypothesis of Innovation," Technological Forecasting and Social Change vol. 17 (1980), pp. 283-311.

Hines, J. H., "System Dynamics National Model Interest Rate Formulation: Theory and Estimation," Sloan School Working Paper, Sloan School of Management, M.I.T., Cambridge, Mass., 1983.

Homer, S., A History of Interest Rates, New Brunswick, N.J.: Rutgers University Press, 1963.

Jorgenson, P. N., "Capital Theory and Investment Behavior," American Economic Review vol. 53 (1963), pp. 247-259.

Mensch, G., Stalemate in Technology, Cambridge, Mass., Ballinger, 1979.

Namenwirth, Z., "The Wheels of Time and the Interdependency of Value Change," Journal of Interdisciplinary History vol. 3 (1973), pp. 649-683.

Rothwell, R. and W. Zegveld, Technical Change and Unemployment, New York: St. Martin's Press, 1979.

Senge, P. M., "The Economic Long Wave: A Survey of Evidence," System Dynamics Group Working Paper D-3262-1, Sloan School of Management, M.I.T., Cambridge, Mass., 1982.

Sterman, J. D., "A Simple Model of the Economic Long Wave," Sloan School Working Paper WP-1422-83, Sloan School of Management, M.I.T., Cambridge, Mass., 1983.

Van Duijn, J. J., The Long Wave in Economic Life, London: George Allen & Unwin, 1983.

Wasson, R. C. et al., "Alternative Estimates of Fixed Business Capital in the U.S., 1925-1968," Survey of Current Business vol. 50 (1970), pp. 18-36.

Weber, P., "Society and Economy in the Western World System," Social Forces, 1981, pp. 1130-1148.