A SYSTEM DYNAMICS REPRESENTATION
OF MONETARY AND FISCAL POLICY THEORY
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A SYSTEM DYNAMICS REPRESENTATION
OF MONETARY AND FISCAL POLICY THEORY

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ABSTRACT

A critical review of current economic theory through
the conceptualization technique of System Dynamics reveals
omissions of error in the controversy over fiscal or
monetary policy in economic management. A comprehensive
model written in DYNAMO includes the authors' assumptions as
well as several formerly disconnected theories such as
unemployment, wage/price spiral, multiplier-accelerator,
conservation of money, inflation, and liquidity. Its
purpose is to demonstrate the utility of the System Dynamics
methodology in the representational task and to provide a
credible first step towards future completion of a validated
model.

No attempt is made here to complete the analysis
through simulation, validation or policy experimentation.
Thus, no justification of these features of the technique is
implied.

Thesis Supervisor: Alexander L. Pugh, III
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This Thesis is dedicated to Susan and Daisy.

We would like to add our thanks to those who helped make this work possible.

To Jack Pugh for his guidance.
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1 INTRODUCTION

Any individual's organization of his knowledge of a topic is a model, no matter how unsophisticated, informal, subjective, inaccurate, or incomprehensible (to others) this organization may be. The process of learning may be viewed as the testing, updating, revision, enlargement, restructuring, rebuilding, or replacement of a model. In recent times, the professional literature in many fields has reflected an increasing use of explicit, formal models to overcome the limitations of mental models and verbal models, and to facilitate the communication of ideas. Models are usually framed from common building blocks with which the user is familiar and from which he can identify the trade-offs between accuracy and usefulness. For this reason the modeller is wise to choose a modelling technique that satisfies the requirements of the model.

In general, an ideal set of modelling techniques would be (1) simple, requiring little mathematical sophistication or other technical formalism for implementation or understanding; (2) robust, allowing representation of a variety of complex behavior modes, relationships, and outputs; (3) capable of incorporating imprecise perceptions and probabilistic effects; (4) telegraphic, that is, would provide a mechanism for concise (perhaps visual, e.g., graphs) approximations of complex parts of a model; and
would be suitable for construction of a model for a variety of purposes which were (5) modular: easy to change; (6) extensible: susceptible to major additions; and (7) easy to explore, evaluate, and test.

We feel that the current models implicit in the mental representations, teaching, and professional communication of knowledge bear evaluation in light of these criteria, and comparison against alternatives. We believe that the System Dynamics modelling methodology embodies many of the aspects mentioned and deserves far more wide-spread consideration as such an alternative than it currently receives. The work reported herein is an attempt to demonstrate the utility of System Dynamics as a representational tool through its application to the design of a simulation model of U.S. economy, focused on the issues of the relationship of government monetary and fiscal policy to national income, inflation, and unemployment.
1.1 The Monetary vs. Fiscal Policy Controversy

A central issue in economic theory today is the effect of monetary vs. fiscal policy on national income. The ongoing and, as yet, unresolved debate on this issue has absorbed the time, energies and publication efforts of some of the leading names in economics and has divided many of them into two prominent schools of economic thought. The 'monetarist' movement, led by Milton Friedman and frequently represented by Karl Brunner and Allan Meltzer, contends that changes in the money supply are the dominant influences on trends in aggregate demand, inflation, and output. Spokesmen for the 'post- (or neo-) Keynesian' or 'fiscalist' position include Franco Modigliani, James Tobin, and Paul Samuelson. This group holds that government fiscal policy, as reflected in taxation and deficit spending, is a much more influential determinant of changes in the key economic variables. Chapter 2 of this work provides an elaboration of some of the details of the dispute; however Anderson (1973) conveys some of its flavor in a concise statement:
According to Samuelson, money has an important influence only when it is created to finance Government expenditures. Monetarists contend that Government expenditures increase aggregate demand permanently only if they are continually financed by creating money.

The nature and magnitude of the differences between the two positions is of major significance not only to economics students and theoreticians, but to legislators and government policy makers as well. The practical significance of an acceptable resolution of the dispute cannot be over-estimated. The U.S. economy has experienced periods of serious inflation, unemployment, and recession while the legal powers and economic control mechanisms existed which would allow government to put into effect either school's prescribed solution rapidly. Yet almost forty years have passed (since the publication of Keynes' General Theory) without significant general agreement on the basic issues among professional economists.

One part of the problem is the lack of conclusive empirical evidence from economic history (or, at least, unsettled disagreement on the conclusiveness of observed data) in support of either position. However, some economists feel that a more fundamental difficulty is the lack of agreement on a common theoretical framework within which, presumably, debate might continue to rage on the values of significant parameters. Tobin notes (1972):
If the monetarists and the neo-Keynesians could agree as to which values of which parameters in which behavior relations imply which policy conclusions, then they could concentrate on the evidence regarding the values of those parameters.

Our review of the economics literature indicates an even more basic barrier to resolution of the controversy. Most models presented as individual contributions towards an accepted theory are so under-specified or incomplete that they justify limited conclusions or do not adequately consider some of the key, well-known sub-issues of the debate. The most common prose description of a theory usually omits even rough approximations of parameter values necessary for an independent derivation of results. Witness Brunner and Meltzer (1972) on a Friedman example:

One difficulty in interpreting some of Friedman's statements arises because he tells us very little about timing and speed of adjustment or the length of run to which his models apply.

Simple mathematical formulations with explicit parameter values, such as those found in Smith (1970), are often insufficient to handle common criticisms involving, for instance, dynamic non-linear effects. At the other end of the spectrum, fully specified, robust theories are occasionally purported to be embodied in major works such as
the PRB-MIT and Wharton Models. Such models are too large, detailed, and mathematically sophisticated to be effective tools for communication and experimentation in the theoretical realm.

In our view, the results of much of the currently popular econometric activity can be interpreted as short-cuts to the justification of theoretical formulations. By 'fitting' a regression line to the observed values of variables selected in a hypothetical relationship, precise parameter values are derived and completeness is said to be justified by the quality of the 'fit' and analysis of the residuals. If the selected variables 'explain' the endogenous variable sufficiently, then no other variable should be important. Our doubts about this methodology involve such unresolved questions as the usefulness of data points observed in a complex and 'noisy' real world, the accuracy of the measurements of such data, and the validity of necessary assumptions about distributions and measurement data. In addition, the inability of regression analysis to indicate variable dependency vs. independency has serious ramifications on the cause and effect conclusions necessary for truly informative theory. Aside from all this, good fit alone without plausible explanation of the mechanisms embodied in the equation so fitted is not acceptable theory justification, even for many dedicated econometricians.
Evidence of this is seen in the wide-spread controversy over 'reduced-form vs. structural form' sparked by the Anderson-Jordan study (1968).

In summary, we see a clear need for a scheme that represents and communicates fiscal and monetary theory, that requires sufficient specification to justify conclusions, that is sufficiently robust to allow incorporation of all relevant issues, and which at the same time is simple, concise and illuminating. We see the System Dynamics methodology as a technique possessing these requirement. Why it has been ignored by the economic community despite its years of existence and variety of published applications is puzzling.
1.2 System Dynamics

System Dynamics is a methodology for systems analysis developed more than fifteen years ago by Jay W. Forrester. It is described in detail in two of his books (1968) (1969). In addition, a brief definition of the mechanics can be found in Pugh (1973).

As a process, System Dynamics involves (1) analysis, guided by a philosophy of variable characterizations and key inter-relationships; (2) derivation of a representation of conceptualizations, as depicted in DYNAMO flow diagrams; (3) implementation as a set of equations written in a programming language called DYNAMO (Pugh, 1973); and (4) computer simulation by the DYNAMO compiler.

As a technique for modelling of complex systems, System Dynamics offers many advantages. It is simple to learn and use. Little mathematical sophistication is required for the formulation or comprehension of the equations. No analytic solution is required to determine model behavior. Rather, this output is derived via computer simulation and is usually represented by graphs of chosen variable values over time. The technique is extremely powerful. It allows consideration of complex non-linear, dynamic and multiple-loop feedback effects. Cause and effect are explicitly differentiable. It is suitable for all but the
most detailed levels of model disaggregation. DYNAMO equations represent differential equations, including those which do not possess known analytical (let alone un-aided mental) solutions.

System Dynamics models are easy to modularize and manipulate (extend, revise, reduce) at the DYNAMO flow diagram and equation levels. As a result, the development of a complex model is frequently hierarchical: a rough highly-aggregated model is implemented, tested via simulation, then extended until desired behavior is captured.

It is important to note that System Dynamics postulates certain constraints on real world behavior which guide the approach to factor identification and conceptualization. The differentiation of stocks and flows and restrictions on their inter-relationships, the primacy of feedback mechanisms, the conservation of material flows, and continuity of stock adjustments are all axioms in the System Dynamics view of the real world. As we will attempt to illustrate, the framework comprising these tenets can be extremely helpful in understanding complex system phenomena and perceptions of structure.
1.3 Purpose

The purpose of our work is twofold: (1) to justify the efficacy of the System Dynamics philosophy and methods in the representation of complex systems, particularly economic systems; and (2) to provide insight into theoretical monetary and fiscal policy issues via our analysis and the resultant model derived. Note that we do not attempt to demonstrate the most significant aspects of System Dynamics: its use in investigating system behavior and exploring policy alternatives. These are considered beyond the scope of this work. The insight we hope to provide is that derived from generating a simple and graphic formulation of complex dynamic effects and inter-relationships. With regard to the second goal, we recognize that our model represents necessarily subjective judgments on proper factor aggregation, mechanism identification, and synthesis of individual theoretical viewpoints. Thus we readily acknowledge the possibility of other equally justifiable formulations. Our intention is to provide a credible first step (the first, to our knowledge, at the level of detail presented) at a System Dynamics representation of the issues addressed which is useful as starting point for further analysis.

Our most important goal is to provide sufficient
justification to motivate more extensive consideration of System Dynamics as an economic systems analysis tool. We have found it extremely useful in understanding and comparing prevailing models, identifying their inconsistencies and limitations, and integrating our resultant derivations of key components of the overall system. We attempt to provide descriptions, not only of our model, but of the approaches which were particularly significant in its development as evidence for our views.
2 PROBLEM, APPROACH AND PROCESS

2.1 Basic Monetary and Fiscal Policy Issues

Although the monetary vs. fiscal policy debate involves issues of macro-economic theory, interpretations of historical data and research methodology, the conflict appears to focus primarily on the proper policy for economic stabilization. Monetarists believe that the best course of government action for optimum levels of GNP, prices and unemployment is a small, constant growth of the money supply via open market sales of government securities by the Federal Reserve Banks. This is said to provide a framework for steady growth without perturbations whose results are uncertain. Neo-Keynesians assert that stability requires autonomous government intervention in the normal aggregate demand or national income mechanisms via government expenditures or taxation policy. They claim a multiplier effect of such actions on aggregate levels which provides sufficient stimulus or restraint, as indicated.

Justifications for the two views involve opposition on several aspects of the structure and behavior of our economic system. It is interesting to note that some of the major variances involve concepts for which System Dynamics modelling is well-suited.
A key monetarist tenet is that the conservation of money in the system has important consequences that Keynesians frequently ignore. The conservation of material flows is recognized at all stages of the System Dynamics analysis and will be seen in our model in other places which are not so explicitly indicated by theory.

There is much discussion on 'transmission mechanisms' through which policy actions influence system behavior. Classical Keynesians postulate that the money stock drives interest rates directly, while their opponents note additional pressures through inflation and impact on output which tend to counteract the initial pressure. Causal mechanisms of this kind are explicitly identified in System Dynamics models. There is no way to allow uncertainty as to variable dependency, as in econometrics. This same example reveals theory differences concerning the force of a variable's value vs. that value's rate of change. Keynesian (IS-LM) analysis indicates interest rate to be a function of the level of the money supply while monetarists note at least one additional influence (inflation) through its rate of change.

Another important point of contention provides insight into the opposing approaches to suggested government policy. Fiscalists feel that our economy is inherently unstable or at least oscillatory, and that government must respond with
frequent adjustments or 'fine tuning'. Friedman's followers posit a basically stable system that will tend to self-correction of most internal fluctuations if left alone. A System Dynamics model should reflect the stability of the system it models (through the output of a simulation run) both at equilibrium and in response to various excitations and parameter changes.

In terms of the work presented here (which excludes output analysis) stability or instability may be indicated by visual analysis of the major feedback loops in the model.

Much of the variance in the two theories involves the value and importance of delays in system structure, recognition and emphasis on long-term vs. short-term responses, and other dynamic effects. Monetarists, for instance, acknowledge the existence of the fiscal multiplier, but claim that it lasts for only a few quarters rather than years. They assert the dominance of money growth rate, not only on short term output, but on long-term prices and aggregate demand, where response time and magnitude depend on initial conditions. System Dynamics is particularly appropriate for representing such dynamic and non-linear effects.

Concise descriptions of the basic issues in the controversy are found in Anderson (1973) and Carlson (1974). Our treatment of them is left until Chapter 3 where they are
juxtaposed with our model formulations for them.

2.2 Approach to the Modelling Task

The model we describe here represents our attempt at a synthesis of prevailing monetary and fiscal theory. The emphasis on theory rather than reality is consistent with our goal of demonstrating the utility of System Dynamics in light of our contentions regarding the inadequacy of existing theoretical models described in Chapter 1. We have chosen to look at both theories rather than either one to gain some insight into the issues of the controversy with this analytic methodology. Our choice of one (eclectic) model to embody both theories is in line with recent developments in the debate (Carlson, 1974, p. 11). There is increasing recognition that both monetary and fiscal policy 'matter'. The current controversy centers more on the delays and magnitudes of effects than on structure and these differences can in general be represented by simple parameter changes in one model. In areas of conflicting theoretical structure we modelled the one we thought more reasonable. We made similar choices when individuals within either school differed. In addition, the model incorporates
constraints and approximations indicated by the System
Dynamics analytic methodology which are not explicitly
revealed in economic theory. Thus, for instance, most
delays are modelled as third order (exponential)
approximations and most averages are exponentially weighted.
Also, investment adjusts the level of capital which can be
depleted no faster than the rate of depreciation, and which
is a prime determinant of production. When neither theory
described necessary areas of system operation, we modelled
widely-accepted general macroeconomic theory. Parameter
values not obtainable from our research on theory or
historical data are our best-guess estimates.

Our choice of system boundary includes all domestic
economic activity and excludes time-dependent exogenous
influences other than certain economic policy inputs. Thus
the influences of technology and population growth are
ignored. Certain initial values were chosen to allow the
model to start at a stable equilibrium.

Since our model is highly non-linear, its behavior may
be heavily dependent on initial conditions. Therefore, we
thought it important to have certain variable values
Correspond to actual data for a typical year. Thus the
relative rates of investment, consumption, and government
expenditure and certain other values are loosely derived
from figures for 1962.
Our factor aggregation decisions were made to make the model as simple as possible and still incorporate sufficient detail to exhibit the necessary theoretical mechanisms and results. Capital and consumer goods are aggregated into one type of good. All money in the system is assumed to exist in the form of demand deposits. In a similar vein, we implement only the more common monetary and fiscal policy alternatives. Government may adjust spending and the tax rate. The Fed may only use open market transactions to change the money supply.
2.3 Formulation and Implementation Process

We began our work with a review of the economics literature with special attention to traditional models. After learning enough about the issues to be thoroughly confused, we turned to examination of some existing System Dynamics models of other economic problems. These included work by Gilbert W. Low and Nathaniel J. Mass of Samuelson's multiplier-accelerator theory (unpublished, preliminary, internal memo), a treatment of money and income by Low (unpublished, preliminary, internal memo, and a model of the economy by Ware D. Fuller, based on prior work by Alexander L. Pugh III (Fuller, 1972).

Our current model formulation evolved from very basic structures seen in these efforts and knowledge of some of the implementation problems faced by the authors. The arrangement of capital, inventory, depreciation, production, consumption, investment and government spending in the Expenditure Sector of our model (see Appendix I) was derived from Low and Mass. Low's work provided our first hints toward the ultimate use of marginal productivity for capital and labor adjustments and our current nominal interest rate function. The Pugh-Fuller model contributed the outline of our current demand deposit-credit sub-structures in the Government/Monetary Sector and the identification of some
variables in the Income/Profit Sector. The current model represents, in the greatest part, our original contributions to the formulation, as guided by these core ideas of monetary and fiscal concepts, and where necessary more general macroeconomic theory (Smith 1970).

The model was developed in stages, with new structure or additional theoretical concepts appended as confidence in the old was obtained through sub-system simulation runs. Simple parameter sensitivity analysis was performed throughout this process. Our research proceeded in parallel with model development and several alternative theories were examined via simulation as they were discovered.
3 MODEL DESCRIPTION

This chapter is a description of the model and the theoretical constructs it represents combining the language and descriptive symbols peculiar to System Dynamics with plain English. It assumes a knowledge of System Dynamics basic building blocks, level/rate sub-structures (and attendant exponential behavior), functions, and flow diagrams (see Forrester 1968 or Pugh 1973). It also assumes understanding of classical economic theory (Smith 1970) and exposure to basic monetary and fiscal policy issues (Anderson 1973 and Carlson 1974).

Some insight into the dynamic behavior of the model is provided by the use of causal flow graphs. These graphs indicate the flows which constitute the major feedback loops in the system. A cause and effect influence between two variables is indicated by an arrow from the causitive variable to the effected one. A sign (+ or −) is placed near the head of the arrow to signify that a positive change in the causitive variable induces a positive or negative change in the other. The algebraic product of signs around a loop determines the nature of the feedback loop -- positive or negative. The behavior of systems can only be inferred from these major feedback loops. For example, it is known that level-seeking systems usually operate
successfully because of a dominant negative feedback loop. It is the question of dominance that defeats intuitive assumptions based only on the causal flow graph. However, powerful insights into model behavior can be communicated by a study of model output and the causal loops.

In the description, emphasis is placed on the representations of monetary and fiscal theory constructs and their sources. Some classical economic theory embodied in the model is described and referenced. All other structure is, in general, derived from our interpretations of common classical theory and real world observations. Some delay and adjustment values are justified in this way. Others may be assumed to be subjective best guesses. Aggregation decisions are mentioned or are obvious.

The Appendices completely specify the model via a listing of the DYNAMO equations (Appendix II), variable definitions (Appendix III) and directory (Appendix IV) and DYNAMO flow diagrams (Appendix I). The flow diagrams omit certain delays and auxiliaries without physical significance for purposes of clarity. The model is divided into five sectors in the listing (by heading) and the flow diagrams (one sector per page) as well as in the descriptions below. The listing divisions were made according to functional association. The flow diagrams deviate somewhat from the listing to minimize the lines of
influence between sectors. The descriptions below follow the flows, and we assume the reader is referencing them while reading. Mnemonics for most variables are indicated in capital letters in the sector descriptions. Causal flow graphs are depicted for some sectors to reveal the loops which seem, by inspection and analysis, to have significant influence.
3.1 EXPENDITURE SECTOR

This sector includes the mechanisms governing the production and consumption of real goods (in goods-units, not dollars). Inventory (INVEN) is the intermediary between production and consumption flow rates whose existence is mandated by the System Dynamics prohibition against rates directly controlled by rates. The fact that such intermediaries almost always have physical significance is an analytically useful axiom of the technique. SALES, the sum of the inventory depletion rates, is averaged over one year (AS) and multiplied by a coverage factor (CF) to derive the amount of inventory desired (DINV) by manufacturers as a buffer against unforeseen fluctuations in demand. AS is an exponentially weighted average to reflect the increased impact of more recent activity on human perception. GNP is a close approximation to a true average of production over one year and is used only as a statistical indicator of economic activity. The level of capital (CAP) is a prime determinant of production. It is, therefore, important to note that it can be depleted only by depreciation (DEPR), which can not be affected by any other variable and which is a limitation the possible rate of disinvestment. The delay between desired and actual investment (INVEST) logically differentiates capital goods
from ordinary goods as being made-to-order and, therefore subject to order delays. Desired investment (DI) includes a component to offset depreciation, new investment (NEWINV) to adjust to desired capital stock, and a pipeline adjustment rate. This last factor represents industry's response to the knowledge that changes in the quantity of goods on order will continue to affect actual investment for some time after desired investment has stopped changing.

Desired consumption (DCONS) is based on consumers' long term (5 years), exponential average of nominal income (ANINC), in rough approximation to Friedman's permanent income hypothesis. The average propensity to consume (APC) is set equal to unity for reasons seen in the Government/Monetary Sector description. Actual consumption (CONS) is limited by the availability of goods represented by the availability multiplier (AM). As the ratio of the level of aggregate inventory to desired inventory goes below unity, we assume that an increasing number of individual manufacturer and distributor inventories are exhausted, thus frustrating desired consumption. (This assumes that consumer goods are not, in general, back-ordered.) Government spending (GS) is normally equal to its income from taxes, but may be varied exogenously according to intended fiscal policy. Indicated production (IPROD) is a classical Cobb-Douglas production function of labor and
capital:

\[
\text{PROD} = (A) (\text{CAP}) (\text{LABOR})
\]

AA and BB equal 1/4 and 3/4 respectively in rough approximation to accepted real economy values. Constant returns to scale is indicated by a sum of unity for these terms. The amount of capital desired (DCAP) is based on its profitability. That is, new capital goods units are desired until the last unit obtained costs just as much as the new revenue generated by its contribution to productivity. This point is expressed in classical theory as:

\[
\text{Marginal Productivity of Capital} = \text{Cost of Capital}
\]

or:

\[
\frac{d(I\text{PROD})}{d(\text{CAP})} = \text{COC}
\]

\[
\text{CAP} = \frac{3/4}{4/3} (1/4)(A)(\text{LABOR}) / (\text{COC})
\]

At current values of LABOR and COC, the solution for CAP in this equation is DCAP. Actual production (PROD) is IPROD delayed by 1/2 year to reflect a reasonable amount of manufacturing time for goods.
From descriptions above (and those for PRICE and COC given later) the causal loops illustrated below are identifiable by inspection. The potential for instability in this sector exists and depends upon the relative gains of the two loops.

Figure 3.1 Causal Flow Graph for Expenditure Sector
3.2 Wage/Price Sector

This sector deals with labor, the other factor of production, its wage, and the price determination. The LABOR level represents the number of labor units currently employed by industry. Another level, OTLAB, indicates the number of additional labor units which are attained by working overtime, as desired for increased production. This figure can never exceed more than 10% of existing LABOR.

The sum of LABCR and OTLAB is effective labor (ELAB) and is the quantity used (with capital) to determine production, as indicated in section 3.1 above. Labor starts off at 96% of total labor force (TLF), which is a value it cannot exceed.

The amount of LABOR desired is determined by its profitability. To make this calculation, a classical marginal productivity formulation is used, similar to that employed for desired capital (CAP):

Price \* Marginal Productivity of Labor = Wage

or:

\[
\text{Price} \times \frac{d(IPROD)}{d(LABOR)} = \text{Wage}
\]

\[
\text{LABOR} = \frac{(A(PLAB)(3/4)(A)(CAP)^{1/4})}{\text{WAGE}^{4}}
\]
At the current values of CAP and WAGE this equation is solved for LABOR to get DL. For this equation, PRICE is averaged over 1/8 year (APLAB) to reflect perception delay and a degree of caution in action. Industry may react to a new DL in two ways. It hires or fires labor over some delay time. Firing delay reflects caution and benevolence. Hiring delay embodies training time and personnel acquisition time. This latter factor is presumed to be a function of the current unemployment rate. If hiring is indicated (DL exceeds LABOR), industry compensates for the inherent delays by ordering overtime. This level (OTLAB) responds to the difference between DL and LABOR with a very short delay (one month) due to parts set-up, organization, etc.

WAGE is adjusted by inflation and unemployment effects. Perceived inflation (APDOT) is instantaneous inflation (price change rate divided by price) exponentially averaged over ten years. This quantity is then delayed by one year to reflect a 'negotiation delay' before affecting WAGE. Unemployment (UNRATE) may accelerate this change. An effective wage (EWAGE) is calculated as the average wage paid to each unit of ELAB, considering the overtime premium (OP) of .5 paid for each unit of OTLAB.

PRICE is an extremely important variable in the model for which we have tried several formulations. Our current
one is a unique (to our knowledge) System Dynamics representation and is an evolution from past trials and analysis. PRICE responds to the difference between an indicated price and itself over an adjustment time. This time is one half year if an increase is indicated and twice that otherwise. The indicated price (IPRICE) reflects the ability of the commercial world to sense, to a first approximation, the demand curves of spenders. This knowledge is indicated by the proliferation of salesmen, marketeers and intuitively savvy businessmen whose goal is to do just that. The imperfection of their knowledge is represented by the adjustment time for the indicated change and the second order effects of changing values of COC, CAP, LABOR and WAGE on the consumption factors. IPRICE is calculated as the price which will equilibrate DI, GS, CONS and an inventory adjustment rate (INVPRD) with current production (PRCD).

Our formulations in this sector involve at least one aspect of Keynesian theory, the inverse relationship of wage to unemployment. This, and a cost plus markup determination for price leads them to posit an inflation-unemployment trade-off for policy making. Monetarists believe that long-run unemployment will remain steady when constant price change is expected (Anderson 1973). The cost-plus-markup hypothesis is presented as a short run affect which we have
rejected as unsuitable for a good (long and short term) dynamic model. We represent expected price change explicitly (APDOT) as a prime determinant of WAGE and interest rate in the model (the averaging time for APDOT is ten years which seems in line with many Friedman hints).

The causal loop graph below identifies some of the major loops in this sector. Notice that the positive one describes the wage-price spiral embodied in the model.

Figure 3.2 Causal Flow Graph for Wage/Price Sector
3.3 Income/Profit Sector

This sector deals with the accounting processes of income, payments and taxes. This section is an auxiliary to the following one but is treated separately for clarity. Note that this sector converts the goods flows of the Expenditure Sector to dollar flows through multiplication by PRICE.

Consumer Nominal income (NINC) includes wages (WBILL) and dividends (DIV) minus taxes (CONSTX). DIV is all of industry after-tax PROFIT (CORPTX). This PROFIT derives from industry income (INCIND) from all spending -- government (GS), consumer (CONS) and investment (INVEST) -- minus costs and taxes. Note that depreciation charged against PROFIT (BKDEPR) is derived from book capital (BRCAP) which reflects the price of capital at the time of its acquisition. NINC is exponentially averaged over five years to derive average nominal income (ANINC). Government income (INCGOV) is the sum of corporate and consumer taxes which depend on tax rates -- CPTXRT and CNTXRT -- which may be varied exogenously according to government policy.
3.4 Government/Monetary Sector

This sector concerns the supply of and demand for money and the operations of the Fed (Federal Reserve Board). Money is given the Friedman definition of cash and demand and savings deposits. In the model, these forms are aggregated into demand deposits. We recognize that the lack of explicit consideration of cash and the public's desire to hold it rather than other forms of money may have significant effects on real and modelled economic systems. However, our formulation is consistent with monetary theory in this regard. The important effects we model here are the ramifications of a conserved supply of money in the face of varying demand.

The Fed regulates the money supply through its sales and purchases of Treasury Bills. The level of TB's outstanding (TBOUT) is determined by these actions and those of the government. The money received or relinquished by the Fed, which is presumed to sell only to the banks, directly adjusts the bank's reserve accounts (RES). The maximum money in the system (MMS) is RES/RR. The reserve requirement, RR, is set as a matter of Fed policy and is .1 in the model.

Inspection of the DYNAMO flow diagram for this sector (Appendix I) reveals three very similar sub-sections, one
for each major spending factor in the model -- government, consumers and industry. Each has a level and demand deposits (DDGOV, DDCONS, DDIND). These levels are adjusted by the rates of money income and expenditures. The demand for money is reflected in the desired demand deposits for each sub-section (DESDDG, DESDDC, DESDDI). Each of these desired levels is determined by a transaction coefficient times the amounts of expenditures less credit repayments (TCGOV, TCCONS, TCIND). When desired demand deposits exceed those in existence at a point in time, each sub-section finances the difference through its credit source (TBOUT, DEBT, LOAN). Thus, government is presumed to finance deficit spending this way. The total demand for credit effects the interest rate, as seen in the next sector.

Consumer money is increased by nominal income (NINC) and exhausted by its expenditures. These expenditures equal (APC*ANINC)/PRICE (see sections 3.1 and 3.2 above). The use of this type of consumption function is well-grounded in classical theory. The use of ANINC is consistent with Friedman's permanent income hypothesis in which consumers spend from an income level they assume to be permanent. Classical and statistical APC is usually estimated to be approximately 93%. We are using APC=1 as is necessary in a stable equilibrium, conserved money system. In the real world, growth due to technology and increasing population
and standard of living leads to a motivation for increasing investment financed by savings. For simplicity, we have chosen a stable vs. growth equilibrium, although inclusion of such growth effects is possible and is recommended in Chapter 5 as a direction for extension of the model. If income (NINC) changes over time, its long-term average (ANINC) will follow slowly and desired expenditures (DCONS) will vary from income so as to change DDCONS. When it exceeds the money required for transactions (TRDC), a quantity of money becomes available for savings. The disposition of this excess between money and consumer investment (in, for example, industry bonds) is a main area of disagreement between monetarists and fiscalists. The latter postulate an interest rate driven division of these funds with the amount retained called the 'speculative demand for money' (Smith 1970, pp. 222-226) or 'liquidity preference'. Friedman has accepted a version of this analysis, but some other monetarists (particularly Brunner and Meltzer) postulate an addition to the bonds-money substitution called the market for 'existing real capital'. We have chosen to represent the more common IS-LM model. (This model indicates static equilibrium values of interest rate and money supply at the point on the graph of one vs. the other where the investment-savings (IS) crosses the liquidity-money (LM) curve, (Smith 1970). Thus consumers
are said to allot a portion of their excess money to buying bonds, where this amount increases as the interest rate rises. This bond decision makes additional funds available to the credit market and thus affects interest rates. In order to capture this effect simply, the model allows debt to go negative to reflect bond purchases. We assume consumers save only when all real debt has been repaid. Savings is then an excessive 'debt repayment', and dissavings is increased 'debt repayment' with the difference between it and real debt indicated by the sign of DEBT. This rather unusual formulation has the desired effect on both the credit market and DDCONS. DESDDC is the sum of TRDC plus the amount of savings to be kept in demand deposits. The portion of the excess of DDCONS over TRDC (POTSAV) which is dept as money is a fraction varying with the interest rate like a downword sloping LM curve (Smith 1970, pp. 226-231) and equal to one half at the 'normal' rate (QPRINT) of 6%. The consumer is thought to associate risk with bonds and therefore does not devote all spare money to them.

More explanation of the credit market and some flows for this sector are given in the next section.
3.5 Bank Sector

The bank is the source of all credit for government, consumers and industry. It is modelled as the purchaser of all Treasury Bills sold by government and the Fed. It 'creates money', as limited by the Fed-adjusted level of reserves (RES) and the reserve requirement (RR), by making loans or buying TB's against which it credits demand deposits. The negative DEBT created by consumer savings may be thought of as industrial bonds bought by the bank and sold to consumers. The model has only one interest rate to represent cost of credit (or returns to savings). However, industry must add on equity premium (EP) to interest rate to get its cost of capital (COC). EP represents the premium paid to stock holders for equity financing, although in the model all funds come from loans. Interest payments are considered insignificant compared to other quantities and are not modelled. Nominal interest rate (NINT) is set by the bank and contains a factor to account for inflation (APDOT) and a factor reflecting the demand for credit (RINT). APDOT (see Section 3.2) is the actual inflation rate exponentially averaged over five years as indicated by Friedman's 'price expectation' effect.

We assume that RR embodies both legal and voluntary restrictions on the bank's desired earning assets and that
they wish to make all of these assets available as credit to
the three money demanders. Therefore, they adjust RINT so
as to clear the credit market. That is, so that EXCESS --
the difference between earning and actual assets -- equals
zero. Government's demand depends upon its deficit spending
policy decision and is assumed to be independent of interest
rate. Consumers' speculative demand for money is interest
rate (NINT) dependent. Industry invests when revenues from
additional capital exceed COC. Since the co-flows between
demand deposits and bank credit obey the accounting
identities, maintaining bank credit maintains the money
supply. In terms of the bank's balance sheet:

<table>
<thead>
<tr>
<th>ASSETS</th>
<th>LIABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESERVES</td>
<td>DDIND</td>
</tr>
<tr>
<td>LOAN</td>
<td>DDCONS</td>
</tr>
<tr>
<td>DEBT</td>
<td>DDGOV</td>
</tr>
<tr>
<td>TBOUT</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.3 Balance Sheet for the Bank

One corruption of the principal of conservation of money is
the possibility of borrowing money from the Fed (discounts)
to cover loans in excess of the amount allowed. This is
reflected in negative EXCESS and is limited in the model by
an extremely high upward pressure on RINT.

The bank sets RINT according to the value of EXCESS.
An indicated interest rate (IR) is determined from the value of EXCESS over allowable credit (MMS-RES). RINT is adjusted towards this IR over time, but the adjustment rate is modified by a multiplicative factor of the fraction of (EXCESS/(MMS-RES)) which is zero when EXCESS is zero, as desired.

This credit market influence on interest rate is widely acknowledged by both monetarists and fiscalists. A Fed expansion of the money supply, for instance, suddenly increases EXCESS by depleting TBOUT and increasing available credit much more which reduces RINT. Friedman points out that this short term effect is soon cancelled by increased production (due to lowered initial COC) requiring more LOAN and increased speculative demand for money and inflation pressure on NINT. This hypothesis is indicated among the following flows:
Figure 3.4 Causal Flow Graph for Bank Sector
In Chapter 1 we noted the influence of System Dynamics methodology constraints in guiding analysis and more logically appealing formulations of concepts. We found this aspect of the technique very useful in our work. The emphasis on feedback stimulates the search for such mechanisms in systems. We frequently made causal flow graphs of theoretical descriptions. As an example, the classical money-interest rate relationship can be viewed as shown below (in terms of our model variables):

![Diagram]

Figure 4.1 Classical Money-Interest Rate Hypothesis
No true System Dynamicist would look at such a graph without seeking a feedback path through other variables. This, of course, is what Friedman does (1968) and what led us to understand and accept his position. The System Dynamics representation of generally conserved money flows aided our identification of the rates which are necessary to control flows. The typical level and rate structure with rate depending on continuous adjustment to decrease differences within a specified time provided formulations for labor, real interest rate, and price with much intuitive appeal.

Derivation of a model as complex and ours in the time allotted would have been impossible by any other combination of techniques known to us. The simplicity and convenience of System Dynamics model building blocks were helpful to us at many points. The simple table equations enabled us to quickly represent influences (such as that of unemployment rate on hiring adjustment time) whose effect, but not precise magnitude, seemed important to us. Our decision to account for the capital goods pipeline in the investment decision was facilitated by the existence of the DELAYP function in DYNAMO which maintains the value of the pipeline in a delay as a variable in its argument list. The DYNAMO equations for key building blocks are trivial and allowed implementation of our model in much less time than any other higher level programming language known to us (see
Appendix III. DYNAMO flow diagrams were frequently more useful than words or mathematical expressions for the communication of ideas between us and integrating the results of our often individual research efforts. The diagrams for the sectors of our model are presented in Appendix I with links to other sector variables indicated by the names in parentheses. From them, the modularity of the model is clearly seen. The Expenditure, Wage/Price, and Government/Monetary Sectors were built (and briefly tested) separately and connected in a very short amount of time.

The robustness of System Dynamics for our application is best indicated by the Chapter 3 description of formulations. In the relatively short amount of time allotted for our work, we have derived a complete model of a complex system suitable, we think, for the initiation of simulation runs to investigate and analyze system behavior. In summary, we began our work with little formal knowledge of the theories we modelled and little real experience in System Dynamics or other complex modelling. We feel that System Dynamics has provided a very major contribution to our learning experience in both areas.
5 SUGGESTIONS FOR FURTHER WORK

As stated previously, one of the purposes of our work was to devise a sufficiently credible model to qualify as an appropriate starting point for completion of System Dynamics analysis and for further work. Although our analysis is not complete, our emphasis on thorough treatment of the stages of analysis attempted serves this purpose well. We suggest three general areas worthy of additional effort based on our research and modelling experience.

The theories modelled and our choices for formulations and parameter values suggest that the existing model should probably maintain a stable equilibrium without exogenous inputs. Equilibrium and exogenously induced behavior should be validated against explicit theoretical conclusions, or conclusions which logically follow a proper combination of the two general theories modelled. Failing this, an understanding of the model dynamics should be achieved to enable determination of consistency of simulation output with intended formulations. Without this, there can be little assurance that the model does not contain syntax or implementation errors. With a validated model, sensitivity analysis of key parameters such as adjustment times and smoothing delays should yield insight into theory validity.
Disaggregation in some areas in indicated to allow increased accuracy or confidence in model validity. A better, more explicit treatment of savings from consumer demand deposits is a prime candidate here. A Keynesian approach might be to model bonds explicitly. It is possible to add exogenous time-dependent influences like technology and population increase and, thus, explore the behavior of, and policies suitable to, a growth equilibrium system. Another, possibly important extension might be the inclusion of cash explicitly in the system. A common criticism of Friedman's theories is the contention that the Fed cannot adequately control the money supply through open market or reserve requirement changes, since the public can choose to deplete bank reserves at will via cash withdrawals. Some logical restrictions on investment can be explored by disaggregating inventory into consumer and capital goods, with perhaps different prices. An examination of Smith (1970) indicates other theoretical levels of disaggregation which may be appropriate.

Tests of new policy ideas might be the most interesting avenue of additional research. Applying monetary and fiscal policy simultaneously in opposite directions might reveal the relative strengths of the two forces. Strong shocks in either area might illustrate model instabilities. If the model proves somewhat unstable, policy adjustments at steady
rates should be explored. With the addition of some added structure, 'fine tuning' could be investigated by implementing policy response to a sensing of other model variable values. It is possible to implement monetary adjustments through changes in the reserve requirement. Friedman acknowledges the inflationary influence of government expenditures financed by new money creation. This could be tested in a model with explicit cash balances. Finally, in light of recent economic history, it might be desirable to explore the effects of other exogenous government influences, such as wage and price controls, on the system.
CONCLUSIONS

In this thesis, we have tried to outline the nature and limitations of some of the methods of description or models for economic theory in common use today. We have indicated the reasons for our preference for System Dynamics as an alternative and have tried to illustrate some of these reasons through an application to a problem.

We distinguish two general types of models seen in most of the current economic literature. Prose descriptions of cause and effect relationships which may embody dynamic, non-linear and/or feedback mechanisms often seem to provide a more thorough grasp of observed effects, but usually lack sufficient specification and rely on hypothesized, rather than analytically derived, behavior results. Other models are often expressed in simple mathematical expressions with specific, econometrically derived parameter values. Such models may offer analytic solutions as results of the theories they represent, but are usually incapable of incorporating more complex, but relevant, aspects of the systems they model. Monetarists frequently employ the former, more casual type of representation, presumably because it allows consideration of the long-term effects which seem to be of primary interest to them. Keynesians seem to prefer the second, more formal type. One result of
our work was a rough determination of the degree to which the respective limitations cause failure to account for factors necessary to derive a more comprehensive simulation model representing the theoreticians' ideas. Traditional modellers frequently invoke 'ceteris paribus' or parameter insensitivity assumptions to justify their limited models and resultant omissions. With regard to the monetary and fiscal policy debate, we find these assumptions largely untenable or, at least, as worthy of justification as the models themselves. For this reason we conclude that many of the more popular models are not as credible explanations of the economic system as they claim to be. The model presented here includes factors missing in both theories. Many of the omitted factors necessary for our model were derived from classical macroeconomic theory and best-guess reasoning. It is in these areas that the cause of any unexplained (by theory) behavior is expected to reside. If our formulations for explicit theory mechanisms are accurate, then one interpretation of unusual behavior in a completed version of our model would be that factors assumed insignificant to theory are not.

Judgment of any model on the basis of output of long-term time behavior of variable values alone implies a stricter test of validity than is even possible for the standard models we have described. The 'casual' models
usually include equally casual logical reasoning for justification. Simple mathematical models usually do not attempt to justify long-term results. In terms of logical formulation and integration of concepts, we believe that our model is quite sound. If so, this alone should make it a preferred alternative to the standard methods. Completion of the System Dynamics analysis (via validation and parameter sensitivity testing) should make the model a powerful tool. We feel that it provides a good example of the proper application and virtues of the System Dynamics methods reflected in its current form.

The major goal of this thesis is the motivation of greater consideration of System Dynamics methodology as an alternative to techniques currently popular in the economics field. In evaluating our (or any other) work in light of this goal, it is important to distinguish between the methodology and our application of it. The latter is certainly a reflection of the former but not necessarily a definitive determinant of its attributes. Any perceived deficiencies in our work are insignificant compared to the capability of the technique to allow corrections. We hope the reader will be able to see beyond any such weaknesses to the advantages and power of System Dynamics, and we trust that we have provided sufficient descriptions and explanations to make this possible.
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APPENDIX I

DYNAMO FLOW DIAGRAM OF MODEL
Figure I-1 Expenditure Sector
Figure I-3 Income/Profit Sector
Figure I-4  Government/Monetary Sector
Figure I-5 Bank Sector
APPENDIX II

LISTING OF MODEL EQUATIONS
* MONETARY AND FISCAL POLICY IN THE U. S. ECONOMY
* --- 5/13/74 ---
* ---- INITIAL EQUILIBRIUM SPECS ----
* C QAPC=1
C QPRICE=1
C QPROD=1000
C QCNTXR=.2
C QCPTXP=.5
C QKORAT=2
C QALC=25
C QPRINT=.06
C QALPHA=.25
N QBETA=1-QALPHA
C QKLAT=2
* ---- EXPENDITURE SECTOR ----
* L INVEN.K=INVEN.J+ (DT) (PROD.JK-ACINV.S.J-CONS.JK-GS.JK)
N INVEN=DINV
R PROD.KL=DELAY3 (IPROD.K,PRODAT)
N PROD=QPROD
A IPROD.K=EXP (LOGN(A) + AA*LOGN (CAP.K) + BB*LOGN (ELAB.K))
N AA=QALPHA
N BB=QBETA
C PRODAT=.5
* L CAP.K=CAP.J+ (DT) (INVEST.JK-DEPR.JK)
N CAP=QKORAT*PROD
R DEPR.KL=CAP.K/ALC
N ALC=QALC
* R INVEST.KL=DELAYP (ACINV.K,INVDEL,INVPIP.K)
A ACINV.K=AM.K*DI.K
A DI.K=MAX (0,DEPR.JK+NETINV.K)
A NETINV.K= ((DCAP.K+DINVSP.K)-(CAP.K+INVPIP.K))/CAPAT
N NETINV=0
A DCAP.K=EXP ((1/(AA-1))*LOGN (DC.K))
A DC.K=COC.K/(AA*A*EXP (BB*LOGN (LABOR.K)))
A DINVSP.K=(DCAP.K/ALC)*INVDEL
C INVDEL=1
C CAPAT=2
* R CONS.K=DCONS.K*AM.K
A DCONS.K=((QAPC*ANINC.K)/PRICE.K)
A AM.K=(1-(1-AMF.K)*CF)
A AMF.K=TABLE (AMPT,INVEN.K/DINV.K,0,1.1,0)
AMFT=0/2/5/7/8/9/92/94/96/98/1/1.02
DINV.K=AS.K*CP
CF=.2

AS.K=AS.J+(DT/SAT) (SALES.J-AS.J)
AS=SALES
SALES.K=ACINV.$K+CONS.JK+GS.JK
SALES=PROD
SAT=1

GSBL.K=GSBL.J+(DT) (DG$J-GE$J)
GSBL=0
GS.KL=AM.K*(DG$K+MAX(0,GSBL.K/GSBLAT))
GSBLAT=1

GSN=COR$TX*CONSTX
GSH=0
GST=4*PLTP1
GSTT=GST+1

GROWTH.K=GROWTH.J+(DT) (GR.JK)
GROWTH=1
GR.KL=GROWTH.K*GROWN.K
GROWN.K=SWITCH(GRP.K,-GRP.K,GRPS)
GRPS=0
GRP.K=SMOOTH(PDOT.K,.25)

GNP.K=GNP.J+(DT) (PROD.JK-SROUT.J)
GNP=PROD
SROUT.K=DELAY3(SROUT1.K,.5)
SROUT1.K=DELAY3(PROD.JK,.5)
SROUT1=PROD

WAGE.K=WAGE.J+(DT) (WCR.JK)
WAGE=BB*PROD*PRICE/LABOR
WCR.KL=(WDOT.K) (WAGE.K)
WDOT.K=DELAY3(APDOT.K,WDEL) * WDOTM.K
WDEL=1
WDOTM.K=TABBL (WDOTMT,UNRATE.K,1,8,1)
WDOTMT=2/1.5/1.25/1/95/.9/.05/.8

APDOT.K=SMOOTH(PDOT.K,PAT)
APDOT=0
PDOT.K=PCR.JK/PRICE.K
PAT=10
*  
L  LABOR.K=LABOR.J+(DT) (LCR.JK)  
N  LABOR=CAP/QKLRAT  
R  LCR.KL=(MIN(DL.K,TLF)-LABOE.K)/  
X  CLIP(EHAT.K,EFAT.K,DL.K,LABOR.K)  
A  DL.K=EXP((1/(BB-1))*LOGN(DL1.K))  
A  DL1.K=WAGE.K/(APLAB.K*BB*A*EXP(AA*LOGN(CAP.K)))  
N  TLF=LABOR/.96  
A  EHAT.K=TABHL(EHATT,UNRATE.K,0,6,1)  
T  EHATT=512/8/2/1.5/45.4  
A  UNRATE.K=(TLF-LABOR.K)*100/TLF  
A  EFAT.K=TABHL(EFATT,UNRATE.K,4,8,4)  
T  EFATT=1/1  
*  
L  APLAB.K=APLAE.J+(DT/PLAT) (PRICE.J-APLAB.J)  
N  APLAB=PRICE  
C  PLAT=.125  
*  
L  PRICE.K=PRICE.J+(DT) (PCR.JK)  
N  PRICE=QPRICE  
R  PCR.KL=(IPRICE.K-PRICE.K)/  
X  CLIP(FAUPL,PADN,IPRICE.K,PRICE.K)  
C  PADN=.5  
N  PADN=2*PDAU  
A  IPRICE.K=(CAPC*ANINC.K)/(PROD.JK-DGS.K-DL.K-INVPRD.K)  
A  INVPRD.K=(DINV.K-INVEN.K)/IAD  
C  IAD=1  
*  
A  EWAGE.K=WAGE.K*(1+OP*(ELAB.K-LABOR.K)/ELAB.K)  
A  ELAB.K=LABOR.K+OTLAB.K  
C  OP=.5  
*  
L  OTLAB.K=OTLAE.J+(DT/OTAT) (MAX(0, (MIN(DL.J,OP*  
X  LABOR.J)-LABOR.J))-OTLAB.J)  
N  OTLAB=0  
C  OTAT=.0833  
C  OP=1.1  
*  
---- INCOME/PROFIT SECTOR ----  
*  
L  BKCAP.K=BKCAE.J+(DT) (BKNV.JK-BKDEPR.JK)  
N  BKCAP=CAP*PRICE  
R  BKNV.KL=INVEST.JK*PRICE.K  
R  BKDEPR.KL=BKCAP.K/ALC  
*  
L  ANINC.K=ANINC.J+(DT/YAT) (NINC.J-ANINC.J)  
N  ANINC=NINC  
C  YAT=5  
*  
A  NINC.K=BTNINC.K*(1-CNTXT. K)
A B TNINC.K=WBILL.K+DIV.K
A WBILL.K=EWAGE.F.K*ELAB.K
A DIV.K=PROFIT.K*(1-CPTXRT.K)
A PROFIT.K=INCIND.K-WBILL.K-BKDEP.R.JK
A INCIND.K=(CONS.JK+GS.JK+INVEST.JK)*PRICE.K
N INCIND=PROD*PRICE
*
A CPTXRT.K=CPTXRN*(1+STEP(CPTXH,CPTXT)-STEP(CPTXH,CPTXTT))
N CPTXRN=0CPTXR
C CPTXH=0
N CPTXT=5*PLTE1
C CPTXTT=1001
*
A CNTXRT.K=CNTXRN*(1+STEP(CNTHX,CNTXT)-STEP(CNTHX,CNTHXT))
N CNTXRN=0CNTRX
C CNTHX=0
N CNTRX=5*PLTE1
C CNTHXT=1001
*
A INCGOV.K=CORPTX.K*CONSTX.K
A CORPTX.K=PROFIT.K*CPTXRT.K
A CONSTX.K=BTNINC.K*CNTXRT.K
*
* ----- GOVERNMENT/MONETARY SECTOR ----- *
* *
L DDCONS.K=DDCONS.J+(DT) (NINC.J-CONS.JK*PRICE.J+DEBTCF.JK-
X DBTDWN.JK)
N DDCONS=DESPDC
R DEBTCR.KL=CLIP(DEBTAC.K, BNDMAT.K, DEBT.K, 0)
A DEBTAC.K=MAX(0, DBTRPY.K+(DESDDC.K-DBCONS.K)/DDATC)
A DBTRPY.K=MAX(0, DEBT.K)/DEBTRT
C DEBTRT=2
A DESDDC.K=TRDC.K*DESSAV.K*SDMULT.K
A TRDC.K=CONS.JK*TCCONS*PRICE.K
N TCCONS=1/10
A DESSAV.K=MAX(0, DBCONS.K-TRDC.K-MIN(0, DEBT.K))
N DESSAV=0
A SDMULT.K=CLIP(SDMLO.K, SDMHI.K, CEXPIR.K, NINT.K)
N SDMULT=.5
A SDMLO.K=MINT(1, -(-(5/CEXPIR.K)*NINT.K)+1))
A CEXPIR.K=SWITCH(QPRINT, QPRINT+APDOT.K, SDSW)
C SDSW=0
A SDMHI.K=MAX(0, .5/((1-ZMF)*(CEXPIR.K)))*NINT.K+
X ((.5*ZMF)/(ZMF-1)))
C ZMF=4
C DDATC=.25
A BNDMAT.K=-(DEBT.K)/BNDMTM
C BNDMTM=2
R    DBTDWN.KL=CLIP(DBTRPY.K, BNDACQ.K, DEBT.K, 0)
A    BNDACQ.K = MAX(0, BNDMAT.K + (DDCONS.K - DESDDC.K) / BNDAT)
C    BNDAT = .125
*
L    DEBT.K = DEBT.J + (DT) (DEBTCR.JK - DBTDWN.JK)
N    DEBT = LOAN
*
* -- INDUSTRY FINANCE SUBSECTOR --
*
L    DDIND.K = DDINE.J + (DT) (INCIND.J + LOANCR.JK - EXPIND.J -
X    MAX(0, LOAN.J) / LOANRT)
N    DDIND = DESDDI
R    LOANCR.KL = MAX(0, DESLNR.K)
A    DESLNR.K = (MAX(0, LOAN.K) / LOANRT) + ((DESDDI.K - DDIND.K) /
X    DDATI)
A    DESDDI.K = EXPIND.K * TCIND
A    EXPIND.K = DIV.K + WBILL.K + CORPTX.K + INVEST.JK * PRICE.K
N    TCIND = 1/10
C    DDATI = .25
C    LOANRT = 10
*
L    LOAN.K = LOAN.J + (DT) (LOANCR.JK - MAX(0, LOAN.J) / LOANRT)
N    LOAN = (MMS-RES) / 3
*
* -- GOVERNMENT SUBSECTOR --
*
L    DDGOV.K = DDGOV.J + (DT) (INCGOV.J + GTBSR.JK - GS.JK * PRICE.J)
N    DDGOV = DESDDG
A    GTBSR1.K = (DESDDG.K - DDGOV.K) / DDATG
A    DESDDG.K = (GS.JK * TCGOV + SWGSBL * GSBL.K) * PRICE.K
C    SWGSBL = 1
N    TCGOV = 1/10
C    DDATG = .25
A    GTBSR2.K = MAX(0, GTBSR1.K)
*
L    RES.K = RES.J + (DT) (FEDSR.JK)
N    RES = DR
A    DR.K = DRN * (1 + STEP(DRH, DRT) - STEP(DRH, DRTT)) *
X    SWITCH(1, GROWTH.K, DRS)
N    DRN = (DDCONS + DDIND + DDGOV) * RR
C    DRH = 0
N    DRT = 4 * PLTE1
C    DRTT = 1001
C    DRS = 0
R    FEDSR.KL = (DR.K - RES.K) / FEDAT
C    FEDAT = .25
*
L    TBOUT.K = TBOUT.J + (DT) (GTBSR.JK + FEDSR.JK)
N    TBOUT = LOAN
* ---- BANK SECTOR ---- *
  L RINT.K=RINT.J+(DT/RINTAT) (RINTCP.JK)
  C RINT=IR
  RINTAT=1
  C RINTCR.KL=SWITCH(RCHOLD.K,RCHNEW.K,SWRCH)
  A RCHOLD.K=-XASRAT.K*MAX(IR.K-RINT.K,RINT.K-IR.K)
  A XASRAT.K=EXCESS.K/(MMS.K-RES.K)
  A RCHNEW.K=(-1.1*10*(XASRAT.K/(1+10*XASRAT.K)))
  X QPRINT
  A IR.K=TABHL(IRT,(EXCESS.K*100)/(MMS.K-RES.K),-20,0.30,10)
  A IRT=10/1/06/02/01/0
  A EXCESS.K=MMS.K-ASSETS.K-RES.K
  A EXCESS=0
  A MMS.K=RES.K/RR
  A RR=.1
  A ASSETS.K=LOAN.K+DEBT.K+TBOUT.K
  A COC.K=EP+NINT.K
  N COC=AA*PROD/CAP
  A NINT.K=MAX(0,RINT.K+APDOT.K)
  N EP=COC-QPRINT

SPEC DT=.03125/LENGTH=60
A PRTPER.K=PLTP1+STEP(PLTP2,PLTTM2)-STEP(PLTP3,PLTTM3)
C PLTP1=.5
C PLTP2=0
C PLTP3=0
C PLTTM2=1001
N PLTTM3=100
A PRTPER.K=STEP(.25,3)-STEP(.25,10)

PRINT WDOT,UNRATE
PLOT GNP=G,SALES=S,INCIND=$/PROFIT=P/UNRATE=U/CAP=K
PLOT PRICE=$/GNP=G/APDOT=A/UNRATE=U/GROWTH=W
PLOT PRICE=$/RINT=R,NINT=N,COC=C
PLOT TBOUT,LOAN,DEBT/ASSETS/EXCESS/RINT/INVEST

RUN RUN #1: EQUILIBRIUM (??)
CP SDSW=1
RUN RUN #2:  EQ. W/ CE Spend INFLAT.
C GSH=.05
RUN RUN #3: GS UP .05
C DRH=.05
RUN RUN #4: RES UP .05
C GSH=.05
C DPH=.05
RUN RUN #5:  BFS UP .05 - GS UP .05
QUIT
APPENDIX JII

DOCUMENTOR LISTING
QAPC=1
QPRICE=1
QPROD=1000
QCNTAXR=.2
QCPTXRT=.5
QKORAT=2
QALC=25
QPRINT=.06
QALPHA=.25
QBETA=1-QALPHA
QLKPAT=2
QAPC - EQUILIBRIUM APC (DX)
QPRICE - EQUILIBRIUM PRICE ($/UNIT)
QPROD - EQUILIBRIUM PROD (UNITS/YEAR)
QCNTAXR - EQUILIBRIUM CNTAXR (DX)
QCPTXRT - EQUILIBRIUM CPTXRT (DX)
QKORAT - EQUILIBRIUM CAPITAL-OUTPUT RATIO (YEARS)
QALC - EQUILIBRIUM ALC (YEARS)
QPRINT - EQUILIBRIUM REAL INTEREST RATE (DX)
QALPHA - EQUILIBRIUM CAPITAL-OUTPUT ELASTICITY (DX)
QBETA - EQUILIBRIUM LABOR-OUTPUT ELASTICITY (DX)
QLKPAT - EQUILIBRIUM CAPITAL-LABOR RATIO (DX)

INVEN=INVEN.*+(DT)*(PROD.JK-ACINV.J-J-CONS.JK-GS.JK)

INVEN - INVENTORY (UNITS)
PROD - PRODUCTION RATE (UNITS/YEAR)
ACINV - ACTUAL INVESTMENT (UNITS/YEAR)
CONS - CONSUMER SPENDING (UNITS/YEAR)
GS - GOVERNMENT SPENDING (UNITS/YEAR)
DINV - DESIRED INVENTORY (UNITS)

PROD.K=DELAY3(IPROD.K,PRODAT)

IPROD - INITIATED PRODUCTION RATE (UNITS/YEAR)
PRODAT - PRODUCTION DELAY (YEARS)
QPROD - EQUILIBRIUM PROD (UNITS/YEAR)

IPROD.K=EXP(LOGN(A)+AA*LOGN(CAP.K)+BB*LOGN(ELAB.K))
A=PROD/EXP(AA*LOGN(CAP)+BB*LOGN(LABOR))
AA=QALPHA
BB=QBETA
PRODAT=.5
IPROD - INITIATED PRODUCTION RATE (UNITS/YEAR)
A - PRODUCTION COEFFICIENT (1/YEAR)
AA - CAPITAL-OUTPUT ELASTICITY (DX)
CAP - CAPITAL UNITS
BB - LABOR-OUTPUT ELASTICITY (DX)
ELAB  - EFFECTIVE LABOR WITH OVERTIME (LABOR UNITS)
PROD  - PRODUCTION RATE (UNITS/YEAR)
LABOR - LABOR UNITS
QALPHA - EQUILIBRIUM CAPITAL-OUTPUT ELASTICITY (DX)
QBETA  - EQUILIBRIUM LABOR-OUTPUT ELASTICITY (DX)
PRODAT - PRODUCTION DELAY (YEARS)

\[
\text{CAP.K} = \text{CAP.J} \times (\text{DT}) \times (\text{INVEST.JK-DEPR.JK})
\]
\[
\text{CAP} = \text{QKORAT} \times \text{PROD}
\]

CAP  - CAPITAL UNITS
INVEST - INVESTMENT (UNITS/YEAR)
DEPR  - DEPRECIATION OF CAPITAL (UNITS/YEAR)
QKORAT - EQUILIBRIUM CAPITAL-OUTPUT RATIO (YEARS)
PROD  - PRODUCTION RATE (UNITS/YEAR)

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\[
\text{DEPR.KL} = \text{CAP.K} / \text{ALC}
\]
\[
\text{ALC} = \text{QALC}
\]

DEPR  - DEPRECIATION OF CAPITAL (UNITS/YEAR)
CAP  - CAPITAL UNITS
ALC  - AVERAGE LIFETIME OF CAPITAL (YEARS)
QALC - EQUILIBRIUM ALC (YEARS)

\[
\text{INVEST.KL} = \text{DELAYP} \times (\text{ACINVS.K, INVDEL, INVPIP.K})
\]

INVEST - INVESTMENT (UNITS/YEAR)
DELAYP - DELAY WITH PIPELINE (MACRO)
ACINVS - ACTUAL INVESTMENT (UNITS/YEAR)
INVDEL - INVESTMENT DELIVERY DELAY (YEARS)
INVPIP - CAPITAL UNITS IN INVESTMENT PIPELINE (UNITS)

\[
\text{ACINVS.K} = \text{AM.K} \times \text{DI.K}
\]

ACINVS - ACTUAL INVESTMENT (UNITS/YEAR)
AM  - AVAILABILITY MULTIPLIER (DX)
DI  - DESIRED INVESTMENT (UNITS/YEAR)

\[
\text{DI.K} = \max (0, \text{DEPR.JK+NETINV.K})
\]

DI  - DESIRED INVESTMENT (UNITS/YEAR)
DEPR - DEPRECIATION OF CAPITAL (UNITS/YEAR)
NETINV - INDICATED ADDITIONAL INVESTMENT (UNITS/YEAR)

\[
\text{NETINV.K} = (((\text{DCAP.K+DINVSP.K}) - (\text{CAP.K+INVPIP.K})) / \text{CAPAT})
\]

NETINV = 0

NETINV - INDICATED ADDITIONAL INVESTMENT (UNITS/YEAR)
DCAP  - DESIRED CAPITAL (CAPITAL UNITS)
DINVSP - DESIRED INVESTMENT IN PIPELINE (UNITS)
CAP   - CAPITAL UNITS
INVPIP - CAPITAL UNITS IN INVESTMENT PIPELINE  
(UNITS)
CAPAT  - CAPITAL ADJUSTMENT TIME (YEARS)

DCAP.K=EXP((1/(AA-1))*LOGN(DC.K))  12, A
DCAP  - DESIRED CAPITAL (CAPITAL UNITS)
AA  - CAPITAL-OUTPUT ELASTICITY (DX)
DC  - INTERMEDIATE IN DESIRED CAPITAL (DCAP)

DC.K=COC.K/(AA*A*EXP(BB*LOGN(LABOR.K)))  13, A
DC  - INTERMEDIATE IN DESIRED CAPITAL (DCAP)
COC  - COST OF CAPITAL ($/CAPITAL UNIT/YEAR)
AA  - CAPITAL-OUTPUT ELASTICITY (DX)
A  - PRODUCTION COEFFICIENT (1/YEAR)
BB  - LABOR-OUTPUT ELASTICITY (DX)
LABOR  - LABOR UNITS

DINVSP.K=(DCAP.K/ALC)*INVDEL  14, A
INVDEL=1  14.1, C
CAPAT=2  14.2, C

DINVSP  - DESIRED INVESTMENT IN PIPELINE (UNITS)
DCAP  - DESIRED CAPITAL (CAPITAL UNITS)
ALC  - AVERAGE LIFETIME OF CAPITAL (YEARS)
INVDEL  - INVESTMENT DELIVERY DELAY (YEARS)
CAPAT  - CAPITAL ADJUSTMENT TIME (YEARS)

CONS.KL=DCONS.K*AM.K  15, R
CONS  - CONSUMER SPENDING (UNITS/YEAR)
DCONS  - DESIRED CONSUMER SPENDING (UNITS/YEAR)
AM  - AVAILABILITY MULTIPLIER (DX)

DCONS.K=((QAPC*ANINC.K)/PRICE.K)  16, A
DCONS  - DESIRED CONSUMER SPENDING (UNITS/YEAR)
QAPC  - EQUILIBRIUM APC (DX)
ANINC  - AVERAGE NOMINAL INCOME--CONSUMERS ($/YEAR)
PRICE  - PRICE OF A GOODS UNIT ($/UNIT)

AM.K=(1-(1-AMF.K)*CF)  17, A
AM  - AVAILABILITY MULTIPLIER (DX)
AMF  - AVAILABILITY MULTIPLIER FACTOR (DX)
CF  - INVENTORY COVERAGE FACTOR (YEARS)

AMF.K=TABHL(AMFT,INVEN.K/DINV.K,0,1.1,1)  18, A
AMFT=0/.2/.5/.7/.8/.9/92/.94/.96/.98/1/1.02  18.1, T
AMF  - AVAILABILITY MULTIPLIER FACTOR (DX)
INVEN  - INVENTORY (UNITS)
DINV  - DESIRED INVENTORY (UNITS)

DINV.K=AS.K*CF  19, A
CF=.2  19.1, C
DINV - DESIRED INVENTORY (UNITS)
AS - AVERAGE SALES (UNITS/YEAR)
CP - INVENTORY COVERAGE FACTOR (YEARS)

AS = AS.J + (DT/SAT) (SALES.J - AS.J)

SALES = PROD

SAT = SALES AVERAGING TIME (YEARS)
SALES = SUM OF GS, CONS, ACINVS (UNITS/YEAR)

ACINVS = ACTUAL INVESTMENT (UNITS/YEAR)
CONS = CONSUMER SPENDING (UNITS/YEAR)
GS = GOVERNMENT SPENDING (UNITS/YEAR)
PROD = PRODUCTION RATE (UNITS/YEAR)
SAT = SALES AVERAGING TIME (YEARS)

GSBL = GOVERNMENT SPENDING BACKLOG (UNITS)
DGS = DESIRED GOVERNMENT SPENDING (UNITS/YEAR)
GS = GOVERNMENT SPENDING (UNITS/YEAR)

GS = GSBL + DGS - SAT

GSBLAT = GSBL - SAT

DGS = GSN * (1 + SWITCH (1, GROWTH, K, GSS))

GSN = CORPTX + CONSTX
GSH = 0
GST = 4 * PLTP1
GSTT = GST + 1
GSS = 0

GSS - DESIRED GOVERNMENT SPENDING (UNITS/YEAR)
GSS - GOVERNMENT SPENDING NORMAL (UNITS/YEAR)
GSH - PERCENT CHANGE IN GS (DX)
GST - TIME OF GS INCREASE (YEARS)
GSTT - TIME OF GS DECREASE (YEARS)
GROWTH - GROWTH FACTOR -- INFLATION RESPONSE (DX)
GSS - GS GROWTH SWITCH (DX)
CORPTX - CORPORATE TAX ($/YEAR)
CONSTX - CONSUMER TAX ($/YEAR)
PLTP1 - BEGINNING PLOT PERIOD (YEARS)

GROWTH.K = GROWTH.J* (DT) (GR.JK)  25, L
GROWTH = 1  25.1, N
GROWTH - GROWTH FACTOR -- INFLATION RESPONSE (DX)
GR - GROWTH CHANGE RATE (1/YEAR)

GR.KL = GROWTH.K * GROWN.K  26, R
GR - GROWTH CHANGE RATE (1/YEAR)
GROWTH - GROWTH FACTOR -- INFLATION RESPONSE (DX)
GROWN - INDICATED GROWTH RATE (1/YEAR)

GROWN.K = SWICH (GRP.K, -GRP.K, GRPS)  27, A
GRPS = 0  27.1, C
GROWN - INDICATED GROWTH RATE (1/YEAR)
GRP - GROWTH RATE OF PRICE (1/YEAR)
GRPS - GROWN SWITCH -- POSITIVE/NEGATIVE (DX)

GRP.K = SMOOTH (PDOT.K, .25)  28, A
GRP - GROWTH RATE OF PRICE (1/YEAR)
PDOT - PERCENT PRICE CHANGE RATE (1/YEAR)

GNP.K = GNP.J* (DT) (PROD.JK - SROUT.J)  29, L
GNP = PROD  29.1, N
GNP - GROSS NATIONAL PRODUCT -- REAL (UNITS/YEAR)
PROD - PRODUCTION RATE (UNITS/YEAR)
SROUT - PROD DELAYED ONE YEAR (UNITS/YEAR)

SROUT.K = DELAY3 (SROUT1.K, .5)  30, A
SROUT - PROD DELAYED ONE YEAR (UNITS/YEAR)
SROUT1 - INTERMEDIATE IN SROUT

SROUT1.K = DELAY3 (PROD.JK, .5)  31, A
SROUT1 = PROD  31.1, N
SROUT1 - INTERMEDIATE IN SROUT
PROD - PRODUCTION RATE (UNITS/YEAR)

WAGE.K = WAGE.J* (DT) (WCR.JK)  32, L
WAGE = BB*PROD*PRICE/LABOR  32.1, N
WAGE - WAGE TO LABOR ($/LABOR UNIT/YEAR)
WCR - WAGE CHANGE RATE ($/LABOR UNIT/YEAR/YEAR)
BB - LABOR-OUTPUT ELASTICITY (DX)
PROD - PRODUCTION RATE (UNITS/YEAR)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
LABOR - LABOR UNITS

WCR.KL = (WDOT.K) (WAGE.K)  33, R
WCR - WAGE CHANGE RATE ($/LABOR UNIT/YEAR/YEAR)
WDOT - PERCENT WAGE CHANGE RATE (1/YEAR)
WAGE - WAGE TO LABOR ($/LABOR UNIT/YEAR)
\[ \text{WDOT}.K = \text{DELAY3}(\text{APDOT}.K, \text{WDEL}) \times \text{WDOTM}.K \]

\[ \text{WDEL} = 1 \]

WDOT - PERCENT WAGE CHANGE RATE (1/YEAR)
APDOT - AVERAGE INFLATION (1/YEAR)
WDEL - DELAY IN WAGE RESPONSE TO INFLATION (YEARS)
WDOTM - UNEMPLOYMENT EFFECT ON WDOT (DX)

\[ \text{WDOTM}.K = \text{TABHL}(\text{WDOTMT}, \text{UNRATE}.K, 1, 8, 1) \]

WDOTMT = 2/1.5/1.25/1/0.95/0.9/0.85/0.8

WDOTM - UNEMPLOYMENT EFFECT ON WDOT (DX)
UNRATE - UNEMPLOYMENT RATE (DX)

\[ \text{APDOT}.K = \text{SMOOTH}(\text{PDOT}.K, \text{PAT}) \]

APDOT = 0
APDOT - AVERAGE INFLATION (1/YEAR)
PDOT - PERCENT PRICE CHANGE RATE (1/YEAR)
PAT - PDOT AVERAGING TIME (YEARS)

\[ \text{PDOT}.K = \text{PCR}.JK / \text{PRICE}.K \]

PAT = 10
PDOT - PERCENT PRICE CHANGE RATE (1/YEAR)
PCR - PRICE CHANGE RATE ($/UNIT/YEAR)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
PAT - PDOT AVERAGING TIME (YEARS)

\[ \text{LABOR}.K = \text{LABOR}.J + (\text{DT})(\text{LCR}.JK) \]

LABOR = CAP/OKLRAT
LABOR - LABOR UNITS
LCR - LABOR CHANGE RATE (LABOR UNITS/YEAR)
CAP - CAPITAL UNITS
OKLRAT - EQUILIBRIUM CAPITAL-LABOR RATIO (DX)

\[ \text{LCR}.KL = (\text{MIN}(\text{DL}.K, \text{TLF}) - \text{LABOR}.K) / \text{CLIP} (\text{EHAT}.K, \text{EFAT}.K, \text{DL}.K, \text{LABOR}.K) \]

LCR - LABOR CHANGE RATE (LABOR UNITS/YEAR)
DL - DESIRED LABOR (LABOR UNITS)
TLF - TOTAL LABOR FORCE (LABOR UNITS)
LABOR - LABOR UNITS
EHAT - HIRING DELAY (YEARS)
EFAT - FIRING DELAY (YEARS)

\[ \text{DL}.K = \exp((1/(\text{BE}-1)) \times \logn(\text{DL1}.K)) \]

DL - DESIRED LABOR (LABOR UNITS)
BE - LABOR-OUTPUT ELASTICITY (DX)
DL1 - INTERMEDIATE IN DESIRED LABOR (DL)

\[ \text{DL1}.K = \text{WAGE}.K / (\text{APLAB}.K \times \text{BB} \times \exp(\text{AA} \times \logn(\text{CAP}.K))) \]

TLF = LABOR/.96
DL1 - INTERMEDIATE IN DESIRED LABOR (DL)
WAGE - WAGE TO LABOR ($/LABOR UNIT/YEAR)
APLAB - AVERAGE PRICE FOR LABOR DECISION ($/UNIT)
BB - LABOR-OUTPUT ELASTICITY (DX)
A - PRODUCTION COEFFICIENT (1/YEAR)
AA - CAPITAL-OUTPUT ELASTICITY (DX)
CAP - CAPITAL UNITS
TLF - TOTAL LABOR FORCE (LABOR UNITS)
LABOR - LABOR UNITS

EHAT.K=TABLE(EHATT,UNRATE.K,0,6,1)  
EHATT=512/8/2/1/.5/.45/.4  
EHAT - HIRING DELAY (YEARS)
UNRATE - UNEMPLOYMENT RATE (DX)

UNRATE.K=(TLF-LABOR.K)*100/TLF  
UNRATE - UNEMPLOYMENT RATE (DX)
TLF - TOTAL LABOR FORCE (LABOR UNITS)
LABOR - LABOR UNITS

EFATT.K=TABLE(EFATT,UNRATE.K,4,8,4)  
EFATT=1/1  
EFAT - FIRING DELAY (YEARS)
UNRATE - UNEMPLOYMENT RATE (DX)

APLAB.K=APLAB.J+(DT/PLAT).K(PRICE.J-APLAB.J)  
APLAB=PRICE  
PLAT=.125  
APLAB - AVERAGE PRICE FOR LABOR DECISION ($/UNIT)
PLAT - APLAB AVERAGING TIME (YEARS)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)

PRICE.K=PRICE.J+(DT).K(PCR.JK)  
PRICE=QPRICE  
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
PCR - PRICE CHANGE RATE ($/UNIT/YEAR)
QPRICE - EQUILIBRIUM PRICE ($/UNIT)

PCR.KL=(IPRICE.K-PRICE.K)/CLIP(PADUP,PADDN,IPRICE.K,PRICE.K)  
PADUP=.5  
PADDN=2*PADUP  
PCR - PRICE CHANGE RATE ($/UNIT/YEAR)
IPRICE - INDICATED PRICE ($/UNIT)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
PADUP - PRICE ADJUSTMENT TIME--UP (YEARS)
PADDN - PRICE ADJUSTMENT TIME--DOWN (YEARS)

IPRICE.K=(QAPC*ANINC.K)/(PROD.JK-DGS.K-DI.K-INVPRD.K)  
IPRICE - INDICATED PRICE ($/UNIT)
QAPC - EQUILIBRIUM APC (DX)
ANINC - AVERAGE NOMINAL INCOME--CONSUMERS ($/YEAR)
PROD - PRODUCTION RATE (UNITS/YEAR)
DGS - DESIRED GOVERNMENT SPENDING (UNITS/YEAR)
DI - DESIRED INVESTMENT (UNITS/YEAR)
INVPDRD - PRODUCTION DEMAND FOR INVENTORY (UNITS/YEAR)

INVPDRD.K=(DINV.K-INVEN.K)/IAD
IAD=1

INVPDRD - PRODUCTION DEMAND FOR INVENTORY (UNITS/YEAR)
DINV - DESIRED INVENTORY (UNITS)
INVEN - INVENTORY (UNITS)
IAD - INVENTORY ADJUSTMENT TIME (YEARS)

EWAGE.K=WAGE.K*(1+OP*(ELAB.K-LABOR.K)/ELAB.K)
EWAGE - EFFECTIVE WAGE INCLUDING OVERTIME ($/LABOR UNIT/YEAR)
WAGE - WAGE TO LABOR ($/LABOR UNIT/YEAR)
OP - OVERTIME PREMIUM ($/LABOR UNIT/YEAR)
ELAB - EFFECTIVE LABOR WITH OVERTIME (LABOR UNITS)
LABOR - LABOR UNITS

ELAB.K=LABOR.K+OTLAB.K
OP=.5

ELAB - EFFECTIVE LABOR WITH OVERTIME (LABOR UNITS)
LABOR - LABOR UNITS
OTLAB - OVERTIME LABOR (LABOR UNITS)
OP - OVERTIME PREMIUM ($/LABOR UNIT/YEAR)

OTLAB.K=OTLAB.J+(DT/OTAT) *(MAX(0,(MIN(DL.J,OP*LABOR.J))-OTLAB.J))
OTLAB=0
OTAT=0.0833
OP=1.1

OTLAB - OVERTIME LABOR (LABOR UNITS)
OTAT - OTLAB ADJUSTMENT TIME (YEARS)
DL - DESIRED LABOR (LABOR UNITS)
OP - OVERTIME FACTOR--UPPER LIMIT (DX)
LABOR - LABOR UNITS

BKCAP.K=BKCAP.J+(DT) *(BKINV.JK-BKDEPR.JK)
BKCAP=CAP*PRICE

BKCAP - BOOK CAPITAL ($CAPITAL UNIT)
BKINV - BOOK INVESTMENT ($CAPITAL UNIT/YEAR)
BKDEPR - BOOK DEPRECIATION ($CAPITAL UNIT/YEAR)
CAP - CAPITAL UNITS
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
BKIINV.KL=INVEST.JK*PRICE.K
BKIINV  - BOOK INVESTMENT ($*CAPITAL UNIT/YEAR)
INVEST  - INVESTMENT (UNITS/YEAR)
PRICE   - PRICE OF A GOODS UNIT ($/UNIT)

BKDEPR.KL=BKCAP.K/ALC
BKDEPR  - BOOK DEPRECIATION ($*CAPITAL UNIT/YEAR)
BKCAP   - BOOK CAPITAL ($*CAPITAL UNIT)
ALC     - AVERAGE LIFETIME OF CAPITAL (YEARS)

ANINC.K=ANINC.J+(DT/YAT) (NINC.J-ANINC.J)
ANINC=NINC
YAT=5
ANINC  - AVERAGE NOMINAL INCOME--CONSUMERS ($/YEAR)
YAT    - INCOME AVERAGING TIME -- CONSUMERS (YEARS)
NINC   - NOMINAL INCOME AFTER TAX--CONSUMERS ($/ YEAR)

NINC.K=BTNINC.K*(1-CNTXRT.K)
NINC   - NOMINAL INCOME AFTER TAX--CONSUMERS ($/ YEAR)
BTNINC - BEFORE TAX INCOME--CONSUMERS ($/YEAR)
CNTXRT - CONSUMER TAX RATE (DX)

BTNINC.K=WBILL.K*DIV.K
BTNINC  - BEFORE TAX INCOME--CONSUMERS ($/YEAR)
WBILL  - WAGE BILL ($/YEAR)
DIV    - DIVIDENDS ($/YEAR)

WBILL.K=EWAGE.K*ELAB.K
WBILL  - WAGE BILL ($/YEAR)
EWAGE  - EFFECTIVE WAGE INCLUDING OVERTIME ($/LABOR UNIT/YEAR)
ELAB   - EFFECTIVE LABOR WITH OVERTIME (LABOR UNITS)

DIV.K=PROFIT.K*(1-CPTXRT.K)
DIV     - DIVIDENDS ($/YEAR)
PROFIT  - CORPORATE PROFIT--BEFORE TAX ($/YEAR)
CPTXRT  - CORPORATE TAX RATE (DX)

PROFIT.K=INCIND.K-WBILL.K-BKDEPR.JK
PROFIT  - CORPORATE PROFIT--BEFORE TAX ($/YEAR)
INCIND  - INCOME TO INDUSTRY ($/YEAR)
WBILL  - WAGE BILL ($/YEAR)
BKDEPR  - BOOK DEPRECIATION ($*CAPITAL UNIT/YEAR)

INCIND.K={(CONS.JK+GS.JK+INVEST.JK)*PRICE.K
INCIND  - INCOME TO INDUSTRY ($/YEAR)
CONS   - CONSUMER SPENDING (UNITS/YEAR)
GS - GOVERNMENT SPENDING (UNITS/YEAR)
INVEST - INVESTMENT (UNITS/YEAR)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
PROD - PRODUCTION RATE (UNITS/YEAR)

CPTXRT.K = CPTXRN* (1 + STEP(CPTXH, CPTXT) - STEP(CPTXH, CPTXTT))
CPTXRN = QCPTXR
CPTXH = 0
CPTXT = 5 * PLTP1
CPTXTT = 1001
CPTXRT - CORPORATE TAX RATE (DX)
CPTXRN - CORPORATE TAX RATE NORMAL (DX)
CPTXH - PERCENT INCREASE IN CPTXRT (DX)
CPTXT - TIME TO INCREASE CPTXRT (YEARS)
CPTXTT - TIME TO DECREASE CPTXRT (YEARS)
QCPTXR - EQUILIBRIUM CPTXRT (DX)
PLTP1 - BEGINNING PLOT PERIOD (YEARS)

CNTXRT.K = CNTXRN* (1 + STEP(CNTXH, CNTXT) - STEP(CNTXH, CNTXTT))
CNTXRN = QCNTXR
CNTXH = 0
CNTXT = 5 * PLTP1
CNTXTT = 1001
CNTXRT - CONSUMER TAX RATE (DX)
CNTXRN - CONSUMER TAX RATE NORMAL (DX)
CNTXH - PERCENT INCREASE IN CNTXRT (DX)
CNTXT - TIME TO INCREASE CNTXRT (YEARS)
CNTXTT - TIME TO DECREASE CNTXRT (YEARS)
QCNTXR - EQUILIBRIUM CNTXRT (DX)
PLTP1 - BEGINNING PLOT PERIOD (YEARS)

INC1GOV.K = CORPTX.K + CONSTX.K
INC1GOV - INCOME TO GOVERNMENT ($/YEAR)
CORPTX - CORPORATE TAX ($/YEAR)
CONSTX - CONSUMER TAX ($/YEAR)

CORPTX.K = PROFIT.K * CPTXRT.K
CORPTX - CORPORATE TAX ($/YEAR)
PROFIT - CORPORATE PROFIT--BEFORE TAX ($/YEAR)
CPTXRT - CORPORATE TAX RATE (DX)

CONSTX.K = BTNINC.K * CNTXRT.K
CONSTX - CONSUMER TAX ($/YEAR)
BTNINC - BEFORE TAX INCOME--CONSUMERS ($/YEAR)
CNTXRT - CONSUMER TAX RATE (DX)

DDCONS.K = DDCONS.J + (DT) * (NINC.J - CONS.JK * PRICE.J + DEBTCH.JK - DBTDWN.JK)
DDCONS = DESDDC

DDCONS = DEMAND DEPOSITS OF CONSUMERS ($)
NINC = NOMINAL INCOME AFTER TAX—CONSUMERS ($/YEAR)
CONS = CONSUMER SPENDING (UNITS/YEAR)
PRICE = PRICE OF A GOODS UNIT ($/UNIT)
DEBTCR = DEBT CHANGE RATE ($/YEAR)
DBTDLN = DEBT DOWN ($/YEAR)
DESDDC = DESIRED DDCONS ($)

DEBTCR. KL = CLIP (DEBTAC. K, BNDMAT. K, DEBT. K, 0)
DEBTCR = DEBT CHANGE RATE ($/YEAR)
DEBTAC = DEBT ACQUISITION ($/YEAR)
BNDMAT = BCND MATURATION ($/YEAR)
DEBT = BANK LOANS TO CONSUMERS ($)

DEBTAC. K = MAX (0, DBTRPY. K + (DESDDC. K - DDCONS. K) / DDATC)
DEBTAC = DEBT ACQUISITION ($/YEAR)
DBTRPY = DEBT REPAYMENT ($/YEAR)
DESDDC = DESIRED DDCONS ($)
DDCONS = DEMAND DEPOSITS OF CONSUMERS ($)
DDATC = DDCONS ADJUSTMENT TIME (YEARS)

DBTRPY. K = MAX (0, DEBT. K) / DEBTRT
DEBTRT = 2
DBTRPY = DEBT REPAYMENT ($/YEAR)
DEBT = BANK LOANS TO CONSUMERS ($)
DEBTRT = DEBT RETIREMENT TIME (YEARS)

DESDDC. K = TRDC. K * DESSAV. K * SDMULT. K
DESDDC = DESIRED DDCONS ($)
TRDC = TRANSACTIONS DEMAND — CONSUMER ($)
DESSAV = DESIRED POTENTIAL SAVINGS ($)
SDMULT = SPECULATIVE DEMAND MULTIPLIER (DX)

TRDC. K = CONS. JK * TCCONS * PRICE. K
TCCONS = 1/10
TRDC = TRANSACTIONS DEMAND — CONSUMER ($)
CONS = CONSUMER SPENDING (UNITS/YEAR)
TCCONS = TRANSACTIONS COEFFICIENT FOR CONSUMERS (YEARS)
PRICE = PRICE OF A GOODS UNIT ($/UNIT)

DESSAV. K = MAX (0, DDCONS. K - TRDC. K - MIN (0, DEBT. K))
DESSAV = 0
DESSAV = DESIRED POTENTIAL SAVINGS ($)
DDCONS = DEMAND DEPOSITS OF CONSUMERS ($)
TRDC = TRANSACTIONS DEMAND — CONSUMER ($)
DEBT = BANK LOANS TO CONSUMERS ($)
$SDMULT\cdot K = \text{CLIP}(SDMLO\cdot K, SDMHI\cdot K, CEXPIR\cdot K, NINT\cdot K)$

$SDMULT = 0.5$

$SDMULT$ - SPECULATIVE DEMAND MULTIPLIER (DX)

$SDMLO$ - SPECULATIVE DEMAND MULTIPLIER -- LOW (DX)

$SDMHI$ - SPECULATIVE DEMAND MULTIPLIER -- HIGH (DX)

$CEXPIR$ - CONSUMER EXPECTED NINT (1/Year)

$NINT$ - NOMINAL INTEREST RATE (1/Year)

$SDMLO\cdot K = \min(1, -((0.5/CEXPIR\cdot K)*NINT\cdot K)+1))$

$SDMLO$ - SPECULATIVE DEMAND MULTIPLIER -- LOW (DX)

$CEXPIR$ - CONSUMER EXPECTED NINT (1/Year)

$NINT$ - NOMINAL INTEREST RATE (1/Year)

$CEXPIR\cdot K = \text{SWITCH}(QPRINT, QPRINT+APDOTE.K, SDSW)$

$SDSW=0$

$CEXPIR$ - CONSUMER EXPECTED NINT (1/Year)

$QPRINT$ - EQUILIBRIUM FAIR REAL INTEREST RATE (DX)

$APDOTE$ - AVERAGE INFLATION (1/Year)

$SDMHI\cdot K = \max(0, (0.5/((1-ZMF)\cdot CEXPIR\cdot K))\cdot NINT\cdot K + (0.5*ZMF)/(ZMF-1)))$

$ZMF=4$

$DDATC=0.25$

$SDMHI$ - SPECULATIVE DEMAND MULTIPLIER -- HIGH (DX)

$ZMF$ - ZERO MULTIPLIER FACTOR (DX)

$CEXPIR$ - CONSUMER EXPECTED NINT (1/Year)

$NINT$ - NOMINAL INTEREST RATE (1/Year)

$DDATC$ - DDCONS ADJUSTMENT TIME (YEARS)

$BNDMAT\cdot K = -(DEBT\cdot K)/BNDMTM$

$BNDMTM=2$

$BNDMAT$ - BOND MATURATION ($/YEAR)

$DEBT$ - BANK LOANS TO CONSUMERS ($)

$BNDMTM$ - BOND MATURATION TIME (YEAR)

$DBTDWN\cdot KL = \text{CLIP}(DBTRPY\cdot K, BNDACQ\cdot K, DEBT\cdot K, 0)$

$DBTDWN$ - DEBT DOWN ($/YEAR)

$DBTRPY$ - DEBT REPAYMENT ($/YEAR)

$BNDACQ$ - BOND ACQUISITION ($/YEAR)

$DEBT$ - BANK LOANS TO CONSUMERS ($)

$BNDACQ\cdot K = \max(0, BNDMAT\cdot K+((DDCONS\cdot K-DESDDC\cdot K)/BNDAT))$

$BNDAT=0.125$

$BNDACQ$ - BOND ACQUISITION ($/YEAR)

$BNDMAT$ - BOND MATURATION ($/YEAR)

$DDCONS$ - DEMAND DEPOSITS OF CONSUMERS ($)

$DESDDC$ - DESIRED DDCONS ($)

$BNDAT$ - BOND ACQUISITION TIME (YEAR)

$DEBT\cdot K = DEBT\cdot J + (DT)(DEBТCR.JK-DBTDWN.JK)$
DEBT=LOAN
DEBT - BANK LOANS TO CONSUMERS ($)
DEBTCH - DEBT CHANGE RATE ($/YEAR)
DEBTDOWN - DEBT DOWN ($/YEAR)
LOAN - BANK LOANS TO INDUSTRY ($)

DDIND.K=DDIND.J*(DT)*(INCIND.J+LOANCR.JK-EXPIND.J-
MAX(0, LOAN.J)/LOANRT)

DDIND=DESDDI
DDIND - DEMAND DEPOSITS OF INDUSTRY ($)
INCIND - INCOME TO INDUSTRY ($/YEAR)
LOANCR - LCAN CHANGE RATE ($/YEAR)
EXPIND - EXPENDITURES OF INDUSTRY ($/YEAR)
LOAN - BANK LOANS TO INDUSTRY ($)
LOANRT - LCAN RETIREMENT TIME (YEARS)
DESDDI - DESIRED DDIND ($)

LOANCR.KL=MAX(0, DESLNR.K)
LOANCR - LCAN CHANGE RATE ($/YEAR)
DESLNR - INTERMEDIATE IN LOANCR

DESLNR.K=(MAX(0, LOAN.K)/LOANRT)*((DESDDI.K-DDIND.K)/DDATI)
DESLNR - INTERMEDIATE IN LOANCR
LOAN - BANK LOANS TO INDUSTRY ($)
LOANRT - LCAN RETIREMENT TIME (YEARS)
DESDDI - DESIRED DDIND ($)
DDIND - DEMAND DEPOSITS OF INDUSTRY ($)
DDATI - DDIND ADJUSTMENT TIME (YEARS)

DESDDI.K=EXPIND.K*TCIND
DESDDI - DESIRED DDIND ($)
EXPIND - EXPENDITURES OF INDUSTRY ($/YEAR)
TCIND - TRANSACTIONS COEFFICIENT FOR INDUSTRY (YEARS)

EXPIND.K=DIV.K*WBILL.K*CORPTX.K*INVEST.JK*PRICE.K
TCIND=1/10
DDATI=.25
LOANRT=10
EXPIND - EXPENDITURES OF INDUSTRY ($/YEAR)
DIV - DIVIDENDS ($/YEAR)
WBILL - WAGE BILL ($/YEAR)
CORPTX - CORPORATE TAX ($/YEAR)
INVEST - INVESTMENT (UNIT/YEAR)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
TCIND - TRANSACTIONS COEFFICIENT FOR INDUSTRY (YEARS)
DDATI - DDIND ADJUSTMENT TIME (YEARS)
LOANRT - LCAN RETIREMENT TIME (YEARS)
LOAN.K = LOAN.J + (DT) (LOANC.R.JK - MAX(0, LOAN.J)/LOANRT)
LOAN = (MMS - RES) / 3

LOAN - BANK LOANS TO INDUSTRY ($)
LOANC.R - LOAN CHANGE RATE ($/YEAR)
LOANRT - LOAN RETIREMENT TIME (YEARS)
MMS - MAXIMUM MONEY SUPPLY INCLUDING RESERVES ($)
RES - BANK RESERVES ($)

DDGOV.K = DDGOV.J + (DT) (INCGOV.J + GTBSR.JK - GS.JK * PRICE.J)

DDGOV = DESDDG

DDGOV - DEMAND DEPOSITS OF GOVERNMENT ($)
INCGOV - INCOME TO GOVERNMENT ($/YEAR)
GTBSR - TREASURY BILL SALES RATE--GOV ($/YEAR)
GS - GOVERNMENT SPENDING (UNITS/YEAR)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
DESDDG - DESIRED DDGOV ($)

GTBSR.KL = CLIP(GTBSR.KL, GTBSR2.K, 2*TBOUT.K, RES.K)

GTBSR - TREASURY BILL SALES RATE--GOV ($/YEAR)
GTBSR1 - INTERMEDIATE IN GTBSR
GTBSR2 - INTERMEDIATE IN GTBSR
TBOUT - TREASURY BILLS OUTSTANDING--BANK ($)
RES - BANK RESERVES ($)

GTBSR1.K = (DESDDG.K - DDGOV.K)/DDATG

GTBSR1 - INTERMEDIATE IN GTBSR
DESDDG - DESIRED DDGOV ($)
DDGOV - DEMAND DEPOSITS OF GOVERNMENT ($)
DDATG - DDGOV ADJUSTMENT TIME (YEARS)

DESDDG.K = (GS.JK * TCGOV * SWGSBL1 * GSBL.K) * PRICE.K

SWGSBL1 = 1
TCGOV = 1/10
DDATG = .25

DESDDG - DESIRED DDGOV ($)
GS - GOVERNMENT SPENDING (UNITS/YEAR)
TCGOV - TRANSACTIONS COEFFICIENT FOR GOVERNMENT (YEARS)
SWGSBL1 - GSBL SWITCH (DX)
GSBL - GOVERNMENT SPENDING BACKLOG (UNITS)
PRICE - PRICE OF A GOODS UNIT ($/UNIT)
DDATG - DDGOV ADJUSTMENT TIME (YEARS)

GTBSR2.K = MAX(0, GTBSR1.K)

GTBSR2 - INTERMEDIATE IN GTBSR
GTBSR1 - INTERMEDIATE IN GTBSR

RES.K = RES.J + (DT) (FEDSR.JK)
RES = DR
RES  - BANK RESERVES ($)
FEDSR  - TREASURY BILL SALES RATE--FED ($/YEAR)
DR  - DESIRED BANK RESERVES ($)

DR.K = DRN * (1 + STEP(DRH, DRT) - STEP(DRH, DRTT)) * SWITCH(1, 95, A
GROWTH.K, DRS)
DRN = (DDCONS + DDIND + DDGOV) * RR
DRH = 0
DRT = 4 * PLTP1
DRTT = 1001
DRS = 0

DR  - DESIRED BANK RESERVES ($)
DRN  - DESIRED BANK RESERVES NORMAL ($)
DRH  - PERCENT INCREASE IN DR (DX)
DRT  - TIME TO INCREASE DR (YEARS)
DRTT  - TIME TO DECREASE DR (YEARS)
GROWTH  - GROWTH FACTOR -- INFLATION RESPONSE (DX)
DRS  - DR GROWTH SWITCH (DX)
DDCONS  - DEMAND DEPOSITS OF CONSUMERS ($)
DDIND  - DEMAND DEPOSITS OF INDUSTRY ($)
DDGOV  - DEMAND DEPOSITS OF GOVERNMENT ($)
RR  - REQUIRED RESERVES RATIO (DX)
PLTP1  - BEGINNING PLOT PERIOD (YEARS)

FEDSR.KL = (DR.K - RES.K) / FEDAT
FEDAT = .25
FEDSR  - TREASURY BILL SALES RATE--FED ($/YEAR)
DR  - DESIRED BANK RESERVES ($)
RES  - BANK RESERVES ($)
FEDAT  - FED RESPONSE TIME (YEARS)

TROUT.K = TBOU.T.J + (DT) * (GTBSR.JK + FEDSR.JK)
TBOU = LOAN
TBOU  - TREASURY BILLS OUTSTANDING--BANK ($)
GTBSR  - TREASURY BILL SALES RATE--GOV ($/YEAR)
FEDSR  - TREASURY BILL SALES RATE--FED ($/YEAR)
LOAN  - BANK LOANS TO INDUSTRY ($)

RINT.K = RINT.J + (DT/RINTAT) * (RINTCR.JK)
RINT = IR
RINTAT = 1
RINT  - REAL INTEREST RATE (1/YEAR)
RINTAT  - RINT ADJUSTMENT TIME (YEARS)
RINTCR  - RINT CHANGE RATE (1/YEAR/YEAR)
IR  - INDICATED REAL INTEREST RATE (1/YEAR)

RINTCR.KL = SWITCH(RCHOLD.K, RCHNEW.K, SWRCH)
RINTCR  - RINT CHANGE RATE (1/YEAR/YEAR)
RCHOLD.K = -XASRAT.K*MAX(IR.K-PINT.K,RINT.K-IR.K)
  IR      - INDICATED REAL INTEREST RATE (1/YEAR)
  RINT    - REAL INTEREST RATE (1/YEAR)
  XASRAT  - EXCESS/ASSETS RATIO (DX)

XASRAT.K = EXCESS.K/(MMS.K-RES.K)
  XASRAT  - EXCESS/ASSETS RATIO (DX)
  EXCESS  - UNUSED BANK ASSETS ($) 
  MMS    - MAXIMUM MONEY SUPPLY INCLUDING RESERVES ($) 
  RES    - BANK RESERVES ($) 

RCHNEW.K = (-1*10*(XASRAT.K/(1+10*XASRAT.K)))*QPRINT
  XASRAT  - EXCESS/ASSETS RATIO (DX)
  QPRINT  - EQUILIBRIUM PAIR REAL INTEREST RATE (DX)

IR.K = TABHL(IRT,(EXCESS.K*100)/(MMS.K-RES.K),-20,
  +30,10) 
IRT=10/1/06/.02/.01/0
  IR      - INDICATED REAL INTEREST RATE (1/YEAR)
  EXCESS  - UNUSED BANK ASSETS ($) 
  MMS    - MAXIMUM MONEY SUPPLY INCLUDING RESERVES ($) 
  RES    - BANK RESERVES ($) 

EXCESS.K = MMS.K-ASSETS.K-RES.K
  EXCESS  - UNUSED BANK ASSETS ($) 
  MMS    - MAXIMUM MONEY SUPPLY INCLUDING RESERVES ($) 
  ASSETS  - BANK EARNING ASSETS ($) 
  RES    - BANK RESERVES ($) 

MMS.K = RES.K/RR
  RR= .1
  MMS    - MAXIMUM MONEY SUPPLY INCLUDING RESERVES ($) 
  RES    - BANK RESERVES ($) 
  PR     - REQUIRED RESERVES RATIO (DX)

ASSETS.K = LOAN.K+DEBT.K+TBOUT.K
  ASSETS  - BANK EARNING ASSETS ($) 
  LOAN   - BANK LOANS TO INDUSTRY ($) 
  DEBT   - BANK LOANS TO CONSUMERS ($) 
  TBOUT  - TREASURY BILLS OUTSTANDING--BANK ($) 

COC.K = EP+NINT.K
  COC     - COST OF CAPITAL ($/CAPITAL UNIT/YEAR)
  EP      - EQUITY PREMIUM (1/YEAR)
  NINT    - NOMINAL INTEREST RATE (1/YEAR)
  AA      - CAPITAL-OUTPUT ELASTICITY (DX)
  PROD    - PRODUCTION RATE (UNITS/YEAR)
  CAP     - CAPITAL UNITS
\[ N \text{INT.} \cdot K = \max(0, \text{RINT.} \cdot K + \text{APDOT.} \cdot K) \]
\[ \text{EP} = \text{COC} - \text{QINT} \]

\text{NINT} - \text{Nominal Interest Rate (1/year)}
\text{RINT} - \text{Real Interest Rate (1/year)}
\text{APDOT} - \text{Average Inflation (1/year)}
\text{EP} - \text{Equity Premium (1/year)}
\text{COC} - \text{Cost of Capital ($/Capital Unit/year)}
\text{QINT} - \text{Equilibrium Pair Real Interest Rate (DX)}

\[ \text{PLTPER.} \cdot K = \text{PLTP1} + \text{STEP} (\text{PLTP2}, \text{PLTTM2}) - \text{STEP} (\text{PLTP3, PLTTM3}) \]
\[ \text{PLTP1} = .5 \]
\[ \text{PLTP2} = 0 \]
\[ \text{PLTP3} = 0 \]
\[ \text{PLTTM2} = 1001 \]
\[ \text{PLTTM3} = 100 \]

\text{PLTPER} - \text{Plot Period (Years)}
\text{PLTP1} - \text{Beginning Plot Period (Years)}
\text{PLTP2} - \text{Change to Beginning Plot Period (Years)}
\text{PLTTM2} - \text{Time to Effect PLTP3 Change (Years)}
\text{PLTP3} - \text{Change to (PLTP1 + PLTP2) (Years)}

\[ \text{PRINTK} = \text{STEP} (.25, .3) - \text{STEP} (.25, 10) \]
\text{PRINTPER} - \text{Print Period (Years)}
APPENDIX IV

MODEL VARIABLE DIRECTORY
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<td>WDOT</td>
<td>PERCENT WAGE CHANGE RATE (1/YEAR)</td>
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<tr>
<td>WDOTM</td>
<td>UNEMPLOYMENT EFFECT ON WDOT (DX)</td>
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<td>WDOTMT</td>
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<td>XASRAT</td>
<td>EXCESS/ASSETS RATIO (DX)</td>
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<td>INCOME AVERAGING TIME -- CONSUMERS (YEARS)</td>
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<td>ZMF</td>
<td>ZERO MULTIPLIER FACTOR (DX)</td>
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APPENDIX V

MODEL OUTPUT PLOTS
### Equation

\[ GNP = G, \text{PRICE} = $, \text{UNRATE} = U \]

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### Figure V-1 Equilibrium
Although we constructed a complete model suitable for beginning exploration via simulation, the scope of this thesis work was insufficient to allow completion of the final stages of an overall System Dynamics analysis. We did make several simulation runs of the model, however, and analyzed output behavior; we finally produced the desired (stable) equilibrium behavior. The above plots are the result of this work; it is an example of the graphical output produced by DYNAMO.